should point out that the Phoenicians were equally successful at about the same time. Both, of course, eventually succumbed to Rome.

There are many other cases of ideas growing and becoming "institutionalized". We have no real explanation of why Christianity took over the Roman Empire. The spread of Islam is easier to explain because actually took place by military means. There is, however, the question of why the armies suddenly coming out of the deserts of Arabia won so many battles. There had never previously been much in the way of Arab victories. Indeed, this turned out to be merely temporary. It is now 1000 years since an Arab army under Arab command has won a battle against non-Arabs.

Thus, I have named this commentary "A Source of Conventions." I point to one factor, the existence of the communication facility, together with the necessity of the bulk of these communications to be true for that facility to have evolutionary value. Evolution would also produce falsehoods and methods of checking. I argue that this is one reason for both the development and slow change of conventions. It is clearly only one.

About the Author

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The Brain, Its Sensory Order, and the Evolutionary Concept of Mind: On Hayek's Contribution to Evolutionary Epistemology

Carsten Herrmann-Pillath

1. The Problem: What are the Formal Foundations of Evolutionary Epistemology?

Since K. R. Popper published his seminal evolutionary approach to *Objective Knowledge*, the Popperian tradition within philosophy of science, i.e., so-called "critical rationalism," has undergone a profound metamorphosis: formerly a comprehensive philosophy of scientific progress and the design of society, it now seems to have developed into an universal research program of the life sciences. Such an extension of domain became possible because Popper had conceived life as a process of accumulation of knowledge. Consequently, one could suppose the underlying formal structures of knowing in living organisms and in human science to be identical. Their essence lay in the fundamental tenets of evolutionary theory, which means, on the one hand, that the mechanism of blind variation and selective retention has to be regarded as an essential feature of the evolution of human knowledge and science, and on the other hand, that the logical structure of Darwinian selection is to be equated with the principle of the adaption of fallible hypotheses to reality by falsificatory criticism. The accumulation of knowledge in life as well as science thus results from the adaption of structures having knowledge of reality qua environment by means of selection. From that perspective, on a very fundamental level human science proves to be a simple continuation of the process leading to growing storage of knowledge about reality within the structures of life, and we should expect a fundamental commensurability between different types of knowledge stored in different types of such structures—for reality is a unified phenomenon.[1]

In the following study, the above claim of critical rationalism will be scrutinized critically. Note that only one school of thought within evolutionary epistemology is affected.[2] I shall not talk about the question of whether human cognitive abilities proper should be

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explained by means of evolutionary theory. For the constitution of our topic, the question of whether the evolutionary process itself is to be conceived as a unified and continuous one—which would mean that the evolution of scientific knowledge needs to be explained through materially similar selective mechanisms like those operating on living organisms in general (i.e., genetic evolution)—is irrelevant. Instead, our focus will be on the hypothesis that if the observed principles of the evolution of life are to be reduced to certain well-defined formal structures, these structures will be the same as those underlying the production of scientific knowledge (cf. Gombault, 1990). Note further that even within critical rationalism a clear distinction should be drawn between the generalized ideas of fallibilism and falsification in the logical and formal realm, and so-called "pancritical rationalism" as proposed by W. W. Bartley, because the latter seems to transcend questions of logic and to attain the status of an ethics of knowledge that cannot be reasonably discussed by means of pure logical arguments.[3] If analysis of the alleged identity between evolutionary and critical formalism does not confine itself to discussion of the equation between selection and falsification ("falsificationalism"[4]), there is a great danger of blurring the otherwise sharply defined semantics of the biological concept of "evolution." In the history of thought, evolutionary theory has far too often lost its content when transferred to applications outside biology. Our concentration on formal aspects is therefore necessary to preserve the comparability of evolutionary approaches referring to different ontological domains.

In most of its variants, evolutionary epistemology avoids the pitfalls of confused semantics. However, within the variant produced by critical rationalism, the formal equation between "falsification" and "natural selection" that starts from catchwords like "survival of the fittest"[5] is illusory, because on the formal level, the concept of "selection" is far more complex than the simple structure of modus tollens underlying falsification. This results not only from the very complicated theoretical and empirical problems that inhere, for example, in the biological concept of "adaption" (cf. Burian, 1983; Engels, 1989, pp.130–154), but becomes already obvious when the conceptual apparatus itself that is applied by Darwinism is scrutinized. For instance, how should important concepts like "species", "individual," and "population" be interpreted formally when talking about theories? Attempts to falsify theories by means of the confrontation of predictions with reality are said to weed out false hypotheses: does this imply that hypotheses are to be referred to formally as "individuals"? If so, what is to be made with the distinction between "phenotype" and "genotype"? Since "blind variation" only occurs on the level of the genotype, the assumption of a falsification of theories qua individuals would lead to the conclusion that the process of the accumulation of knowledge needs to be a probabilistic one where the many single instances of falsifications and corroborations of certain theories (its "phenotypical" expressions) add up to the ultimate success of the theory to such an extent that it is reduced to a certain "genotypical" core. This is of course in complete contradiction of the assumption of critical rationalism that single instances of falsification in principle are sufficient to reject a theory in any other case of application: from the viewpoint of truth, even if Newtonian mechanics can be applied in many circumstances successfully, it has been falsified and demonstrated to be wrong.

Such types of considerations have already been articulated by many followers and critics of evolutionary epistemology in general. In what follows, I will try to provide an extension of the argument that starts from the early contribution of F.A. von Hayek's *The Sensory Order*. I have three reasons for this choice. First, proponents of a critical-rationalist evolutionary epistemology claim Hayek to be one of their important precursors (e.g., Bartley, 1987a, p. 21). However, Hayek's attempt to build the foundations of epistemology on the biology of the brain leads to results that remain in stark contrast to the tenets of Popperian approaches. Second, since theories need to have a counterpart in neuronal processes simply because the human brain is what thinks, Hayek's proposal that global brain theories have important implications for epistemology seems fruitful. Such an approach has been somewhat neglected within the mainstream of evolutionary epistemology but is appropriate in a focus on alternative approaches, particularly the "radical constructivism" starting from Maturana's contributions. Third, brain theories provide the missing link between the analysis of the evolution of general cognitive abilities as scrutinized by one school of thought in evolutionary epistemology (e.g., Lorenz, Riedl, Vollmer) and the formal evolutionary analysis of human knowledge. They have important implications for a reintegration of diverging approaches in evolutionary epistemology.

This article proceeds as follows. Section 2 delivers a shorthand critique of Popper's concept of "World 3" on the basis of psychoneural monism that is one of the cornerstones of Hayek's elaboration of the enlightened materialist concept of mind. Psychoneural monism is shown to be a sufficient precondition for achieving an ontological integration of the formal application of evolutionary principles in different domains. Section 3 develops a non-falsificationalist (although fallibilist) view of evolution that can be distilled from the formal analysis of brain processes. Throughout our presentation, the relevance of Hayek's contribution from the perspective of modern brain sciences is demonstrated by a recurrent, albeit sketchy, comparison with the Darwinian global brain theory that has been recently proposed by Edelman (1987). The logical features of the sensory order as opposed to the physical properties of reality are scrutinized via analysis of its linguistic equivalents, i.e., the formation of concepts within the sensory order is viewed as mirrored in the use of concepts in a description of the sensory order. The logic of evolution in general appears to be a "naturalized version" of the "New Structuralism" in philosophy of science as proposed by Sneed, Stegmueller, and others. Section 4 links the formal (though not formalized) argument to the general view of evolution: the probabilistic nature of evolutionary processes is conceived to lay the foundation for a non-inductivist and non- falsificationalist epistemology. An attempt is made to respond to Popper's challenge to inductivism.

2. Psychoneural Monism and the Ontological Unity of Evolutionary Epistemology

From the perspective of the present, Hayek's book on *The Sensory Order* ought to be regarded as one of the most creative and innovative attempts to develop a biologically founded epistemology by means of establishing a direct linkage between a global brain theory and philosophy. More particularly, Hayek provided the starting points for a full-fledged evolutionary epistemology that simultaneously analyzes phylogenetic and ontogenetic aspects of human cognition present in the development of neuronal structures: epigenesis appears to be the link between the genetic basis of human cognition and its conceptual structure and change. Hayek thus proposed that the vicarious function of cognitive structures might be one of the main features of the process that leads to individual knowledge about the world by means of explorative trials and errors exposed to selection by the environment (1952/1963, pp. 102 ff., 127 ff.). Of course, many descriptions of the sensory order need to be revised in light of modern neuroscience, which might be relevant for the philosophical evaluation of global brain theories. Nevertheless, the formal essence seems as valid today as in 1952, if an appropriate level of abstraction is considered. This claim is especially justified as far as Hayek's central hypothesis is concerned:

> Human "mind" should be conceived as neuronal activity within a complex neuronal structure which is the product of phylogenetic evolution and ontogenetic development. Although the formation of that structure is due to physical contacts between body and world as channeled through neuronal receptors, it can by no means interpreted as some kind of a "accumulation of sensory data" because the primacy of internal structural determinants for the processing of sensory data rules out any possibility of a direct mapping between mental and physical events. The origin of the meaning of sensory data thus lies within the brain and not within the reality qua physical environment. Hence, the sensory order is a system of qualities that do not simply represent physical properties of the outer world: Even on the phylogenetically as well as physiologically most primitive level of neuronal processes, there are no sensory data independent from endogenously generated structural classifications of organismic reactions to body/world contacts.[8]

Thus, Hayek advocates psychoneural monism as opposed to the mind/body dichotomy of dualistic interactionism (e.g., Eccles, 1974). The position is to be distinguished from strict epistemological reductionism because Hayek assumes that complex hierarchical structures imply the emergence of new properties on higher levels of organization. Furthermore, on mere pragmatic grounds, the category "mind" needs to be preserved because there will never be possible a complete description of the neuronal system (1952/1963, p. 179). Acknowledgment that the essential properties of the sensory order cannot be identified by a mere analysis of linear causal relations between single neurons suffices for taking Hayek's stance, in which topological characteristics of sets of causal relations are the objects of the informational processing by the brain.[9]

Critical rationalism as evolutionary epistemology is now confronted with a serious clash between Hayek's psychoneural monism and Popper's dualistic interactionism, implied by the latter's famous concept of "World 3". Popper's distinction between "brain" and "mind" has led to the assumption that the products of mind should be considered as objectively existent, so that the formal isomorphy of the respective selective processes in "World 3" and "World 1" (the world of physical events) could be regarded as the cornerstone of the amalgamation of evolutionary theory and critical rationalism.[10] But what if the idea of "objective mind" is rejected in favor of Hayek's approach?[11]

Abandoning the ontological category "mind" has many advantages if one tries to construct a synthesis of evolutionary theory and epistemology. This is so because only monistically are we able to make sense of the terms "individual" and "variation," which are at the core of Darwinian theory and need to be transferred to any kind of naturalized epistemology. If theories came to be considered as objective entities, evolutionary epistemology would be obliged either to turn back to pre-Darwinian essentialism or make the mistake of transplanting the physical class-concept into the field of biology.[12] Within a formally rigid evolutionary approach, the classical Aristotelian delimitation of metaphysics from the "principium individuationis" needs to be valid (cf. Pieper, 1974). This means that the concept of "individual" cannot be reduced to the concept of a class of individuals denoted by some common property (and where single individuals are identified by their position in space and time), because precisely non-essential variations of individual properties (which by definition

cannot be denoted by class-terms) are the objects of selection and thus the stuff of which evolutionary change is made. Looking at theories as abstract entities would be formally equivalent to looking at species as entities. However, unless the concept of "theory" (or thought in general) is founded other than neurologically, there is no other way to make sense of it within an evolutionary approach.[13]

2.1 What is a Theory?

Such an evolutionary approach results in a surprising switch in the argument of evolutionary epistemology, because then the attribution of "objective existence" to theories is possible without recurrence to Platonic entities. What the observer regards to be a "theory" (for instance, the axioms of Newtonian mechanics) is in fact a complex denotation of a set of neuronal structures in the space of states of the objective entity "brain"—or more exactly, refers to structured neuronal processes resulting from the rule-governed interaction between the brain and an artifact called "theory". Books, formulas, etc. are nothing else but meaningless material artifacts, aside from the rules of application and interpretation stored in neuronal structures of individual brains and transmitted by socialization. The essentialist view of theories simply results from the fact that through socialization and recurrent communication between brains a certain constancy of the meaning of those artifacts for the individual brains is dynamically reproduced. However, the material similarity between different artifacts representing the same theory (e.g., different textbooks on Newtonian mechanics) does not justify the conclusion that there is something like a "theory" beyond the individual activities of communicatively interconnected brains.[14]

Hayek's psychoneural monism therefore does not succumb to the failures of behaviorism because it is indissolubly linked to the view of knowledge as an intrinsically social phenomenon.[15] Perhaps this is one of his most remarkable achievements rediscovered by modern neuroscience (Edelman 1987, pp. 308 ff.). Precisely because there is an epistemological gap between brain and world there are only two possible ways leading to a correspondence between both—that is to say either as a product of natural selection and phylogenesis, or through social communication during ontogenesis. The latter of course lays the foundation for the further evolution of theories through social interaction (for a related view see Kantorovitch, 1990). The important consequence for critical rationalism as a variant of evolutionary epistemology turns out to be that representationalist views of mind can be reconciled with hermeneutic approaches that, for example, try to link Peirce's concept of a community of investigators to the hermeneutic analysis of communicative acts within such a community (Apel, 1974). Traditionally, such a reconciliation was regarded as impossible (see, e.g., Munz, 1987; or Albert, 1975, 1989).

However, in contrast to hermeneutic approaches, psychoneural monism conceives the rules governing the handling of artifacts to be neuronal phenomena constituted by means of genetic inheritance, or by environment/gene interaction during epigenesis, or by social intercommunication during later stages of ontogenesis. One methodologically important example for such a complex interaction between different levels of explanation is the phenomenon of "reification"—i.e., the human proclivity to regard processes as things.[16] Our example is precisely the essentialist view of theories and the considerable cognitive inhibition for humans regarding adoption of an evolutionary, non-essentialist perspective on mind. However, psychoneural monism is able even to explain the evolutionary origin and function of reification: a reified theory (i.e., its essentialist conceptual construct) simply mirrors the fact that, within complex hierarchies of neuronal structures, internal selection occurs where higher levels (i.e., storing the theory) select blind variations of signal processing on lower levels, thereby internally stabilizing the brain/world-interaction.[17]

An important consequence of this view is that the original assumption of a formal homology between natural selection and scientific evolution on its part can be founded in evolutionary considerations. Gene/environment interaction during epigenesis leads to the development of selective hierarchies[18] where, for example, variations in neuronal structures and the respective processes are selected internally as well as externally during body/world interaction, and where internal selection proceeds through differential reproduction on different selective levels, implying different degrees of range of variations not selected against. Thus, in the example of reification, the neuronally stored rule of application of an artifact representing the theory selects variations in single applications. However, this process simultaneously is influenced by the much more general, genetically transmitted rule of reification of theories. Other intermediate levels include the rules governing social interaction during communication about single applications of a theory. On each level, the formal structure of evolutionary explanation can be applied after an appropriate interpretation of its theoretical terms has been achieved. Furthermore, the concept of selective hierarchies allows analysis of the interaction between these different levels of selection.

As has already been explained in Campbell's (1987b) early exposition, within such an overwhelmingly complex interactive system there is a rich source of individual variations of theories if they are reduced to their ontological essence, i.e., conceived as neuronal phenomena. For instance, variations result from genetical differences between researchers, errors or informational distortions during communication, or effects of general socialization on the handling of theories. Thus, psychoneural monism is a necessary precondition for the assumption of a formal homology between natural selection and the development of science. The non-essentialist concept of a theory interprets a theory as a complex, dynamical process in historical time wherein a chain of individual applications of certain reified rules guiding the interaction between brain and artifacts on its part is determined by more general rules governing socialization, social interaction, and communication within a set of individual brains. What is regarded as "theory" in the traditional sense is a mere shorthand for this process. (A related view in philosophy of science has been proposed by the so-called "New Structuralism"—Sneed, Stegmueller, and others—and in particular in an extension provided by Moulines, cf. Stegmueller, 1986, pp.109–127, that looks at theories as pragmatically enriched networks of applications of abstract cores within an historical community of individual applicators.)

2.2. *Analysis of Competition*

If the traditional concept of "theory" can be formally equated to an essentialist interpretation of the concept of "species," and if the concept developed here can be regarded as a shift to population thinking in evolutionary epistemology that differs, for example, from Toulmin's early proposal, then the next step of putting more flesh on the bones of the formal homology needs to be the analysis of competition. If there is a unlimited source of variation, what are the resources restricting an unlimited expansion of theories and thereby providing the causal foundation for selective processes? This question leads to the discovery of a further implication of psychoneural monism—one, however, that has not been developed by Hayek. In the critical rationalist view, selective pressure results from possible conflict between reality and hypothesis. As long as there is an immediate consequence of wrong theories for genetical reproduction, "reality" indeed reveals itself to be a set of possible resources for reproduction that needs to be discovered by the individuals competing with each other. But that approach is not valid regarding the question of formal homology between nature and theory. "Reality" does not seem to be a set of resources limiting the reproduction of theories unless the methodological rules of falsificationalism are already given; but this makes falsificationalism a necessary precondition for making sense of evolutionary thinking in philosophy of science, and of no necessary consequence for a transference of the evolutionary formalism into the realm of theories.

Now the important insight of a Hayekian approach is precisely that convincing attempts to provide a more substantial empirical interpretation of that transference constitute further theoretical linkages between the different levels of the formal homology in question, thereby opening up a new aspect of the ontological unity of evolutionary epistemology. There are different paths leading to such a synthesis. First, communities of individuals utilizing similar types of theories have to be conceived as a sub-group interacting within the much more complex division of labor in great societies. Since the adaptive consequences of the latter can be analyzed only on the societal level,[19] not on the individual level, we can find plausible the hypothesis that competition between individuals utilizing competing theories has consequences on differential reproduction, because the position obtained by individuals within the division of labor depends on the outcome of competition between theories. Now adaptive consequences arise in at least two ways. The economic and/or power status of individuals in society depends indirectly on the outcome of competition between the respective theories, and the result of that competition determines societal adaptive performance contributing to individual adaptation as well. Although asking for the adaptive consequences, say, of a new scientific theory for the individual researcher does not make sense, this does not imply that the whole process determining the evolution of the theory viewed as a population phenomenon does not produce such adaptive consequences. How these consequences occur can be understood when a second possible path to an ontological synthesis of formal homologies in evolutionary epistemology is considered.

Fairly obviously, the expansion of theories is first limited by economic restrictions (see Rescher, 1984; Ghiselin, 1987; Radnitzky, 1987b) that work simultaneously on the lives of the human beings who create and apply these theories. Therefore we can expect that the comparative capacity of theories to mirror reality indeed influences their competitive success only through intermediation of their effects on the amount of societal resources invested in their propagation. By implication, then, the particular social organization of that investment process (monopolized or not, cultural proclivity to innovation, etc.) determines the outcome of the evolution of theories. Although a better-informed outside observer might be able to assess that outcome in terms of realism (as, e.g., in the case of an observation of traditional societies through the eyes of a modern scientist), the actual state of knowledge at the frontiers of its evolution cannot be assessed independently. And this in turn means that the question can be answered only *ex post facto* of whether there is an equality of outcome between the effects of economic resource restrictions on the performance of theories on the one hand, and of a hypothetical state of knowledge on the other where only theoretical and empirical methodologies internal to science determine the evolution of theories irrespective of its costs.

The argument could be extended in much more detail if the relevant selective hierarchies are elaborated on. Within a model starting from the fundamental tenets of dual inheritance theory (Boyd and Richerson, 1985) and of an economic theory of knowledge, different levels of selective processes could be identified where the processes on each levels are describable by means of an evolutionary formalism. For instance:

- theories are supposed to compete for individuals as a resource basis needed for the propagation of theories; or, more exactly, neuronal processes representing theories compete with each other to "enslave" individual brain dynamics in the relevant field;
- individuals utilizing theories compete for economic resources within the societal division of labor, and the outcome of that competition partially determines individual reproductive success as well as the outcome of the competition between theories;
- societies compete for economic resources as well, and the outcome of that competition is partially determined by the contribution of theories to competitive success;
- the adaptive performance of societies contributes to individual reproductive success;
- individual reproductive success partially determines the degree in which epigenetic rules are inherited guiding the evolution of science as a social phenomenon.

Within such a general context, any kind of a global brain theory endorsing psychoneural monism serves to provide the essential ontological link between the first and the second level. (Other theories—e.g., economics—are needed to provide the links between the other levels, but are not considered in this article.)

However, if we again restrict our perspective to the analysis of theories proper, the restoration of an ontological synthesis in evolutionary epistemology does not resolve every problem involved in the assumption of formal homologies between different selective levels. We still have not clarified theoretical terms central for population thinking in epistemology. When should we talk about a "theory" as "reproductively isolated" in relation to other theories, thereby constituting a "species"?[20] Additionally, we still found no conclusive answer to the question of whether in principle "selection" amounts to "falsification" in Popper's sense, and ultimately the distinction between genotype and phenotype and the corresponding interpretation of the "one-way-principle" governing the interaction between geno- and phenotype have not been redrawn along formal lines independent of their original ontological substance.

If we accept that a theory species needs to be reduced to the concepts of "common descent" and "reproductive isolation" when the formal homology turns out to be conclusive, then the first term seemingly does not make many difficulties. Obviously the above mentioned chain of applications of a theory in historical time and within an historical community of brains starts from an ancestor that is common to all later amplifications of domain or variations of theoretical content. Within the formalism of the Moulines-approach mentioned above, there is even the possibility of linking the concept of "common ancestor" to the geno/phenotype distinction: the common ancestor needs to be described as (a) an ordered set of a theoretical core ("genotype") and (b) the conditions of its application within a given social and physical environment including the respective additional assumptions that generate empirical implications ("phenotype").

Real difficulty, however, resides in the concepts of "reproductive isolation" and the one-way dogma. For instance, from the perspective of the above sketched hierarchy of selective levels, "reproductive isolation" would mean that there is a formal many-to-one mapping between "theories" and "individuals" that is governed by the implicit rule that individuals bearing different theories will not be able to construct a synthesis of the theories if a theory is supposed to be the formal analogue to a "species." This is possible only if the theories either are related to different aspects or domains of reality, or if they are mutually contradictory. In the latter case, if during social interaction an individual is bound to be confronted with two mutually contradictory theories on the same domain, she or he is compelled to choose between both theories. That means the individual at least implicitly needs a decision rule of the type discussed in standard philosophy of science. Of course, this could be the principle of falsification. As regards the one-way dogma, this problem becomes even more acute, because the formal equation between "genotype" and "phenotype" amounts to an outright rejection of the possibility of falsification as far as theoretical cores representing the status of a theory species are concerned. Precisely in the sense of the already mentioned probabilistic implications of an evolutionary approach to epistemology, there is of course differential competitive success of theories, but a single case of falsification on the "phenotypical" level has no immediate and purely logical implications for the status of the theory.[21]

Thus the issue of falsification needs to be tackled. There are two possible paths for discussion. The first approach, already chosen here, restricts itself to the selective level of theories and the respective neuronal structures: What implications have global brain theories for epistemological issues? The second path should at least be mentioned, and starts from a comprehensive evolutionary perspective. For instance, within the above sketched model of selective hierarchies, the case for falsification need not be made on a purely logical or methodological level, but under consideration of the possible observation that societies where the evolution of science is guided by falsificationism are more successful in the long run than other societies and therefore are able to provide more resources for individuals for further development of science (cf. Radnitzky, 1987c, and Albert, 1988). However, such an approach still needs to explain the differential adaptive success of these societies. The traditional argument, of course, assumes that falsificationism is the most powerful tool for gaining knowledge about reality. Therefore, the epistemological problem in the narrow sense still needs to be considered.[22]

3. The Non-Falsificationist Logic of the Evolution of Knowledge

Hayek draws very strong epistemological conclusions from his global brain theory, because he argues that the evolution of knowledge proceeds through a gradual isolation of conceptual structures from disturbances resulting from environmental influences and transmitted through neuronal processes. Such an isolation ultimately is supposed to lead to a completely tautological system of knowledge. To quote Hayek (1963, sec. 171):

> Science thus tends necessarily towards an ultimate state in which all knowledge is embodied in the definitions of the objects with which it is concerned; and in which all true statements about these objects therefore are analytical or tautological and could not be disproved by any experience. The observation that any object did not behave as it should could then only mean that it

> was not an object of the kind it was thought to be. With the disappearance of all sensory data from the system, laws (or theories) would no longer exist in it apart from the definitions of the objects to which they applied, and for that reason could never disproved.

This is indeed a very astonishing assessment, and amounts to a full-fledged contradiction of the fundamental tenet of Popperian philosophy of science that by means of conjectures and refutations science will be able to grasp more and more parts and aspects of reality; in contrast, Hayek says that science tends to evolve to a state immune from empirical refutation. Such a bifurcation is the more remarkable as both the Hayekian and the Popperian approaches start from very similar assumptions, in particular as regards the growth of knowledge in living organisms. In accord with modern global brain theories (Edelman, 1987, pp. 291–311), Hayek argues that learning occurs within neuronal structures because the already developed mappings between environment and the neuronal system guide behavior by the implied expectations of what the environment looks like even in the most immediate future (Hayek, 1962, pp. 120 ff.). If these implicit expectations are proved to be false, the organism learns through adaptation of the mappings. Of course, this is precisely a variant of a supposed selective mechanism in the evolution of knowledge as conceived by critical rationalism. The crucial divergence lies in Hayek's belief that the higher the level of complexity of knowledge processing, the more immune the organism from disturbances generated by the environment—that is to say, although falsification and selection might be formally homologous in the case of lower organisms, this is no longer valid especially with regard to theorizing animals, i.e., us.

Of course, Hayek's idea of "tautologization" does not strictly imply that there can no longer emerge any new knowledge resulting from interaction with the environment. If an object does not fit into already given theories, a new conceptualization needs to be developed. Thus, learning and surprise continue to be causal force of the evolution of knowledge even if its "ultimate state" is near. The crucial point made by Hayek is that the formal structure of brain-environment interaction is not that of falsification, because theories are the foundation of the cognitive categorization of the world into objects, i.e., they define an ontology which needs to be the foundation of every type of statement including possibly falsificatory ones. Formally such a view of theories is quite similar to Hilbert's classical attempt to reduce mathematical objects to implicit, axiomatized definitions. Let us look a little bit closer at how Hayek generates such a conclusion from a global brain theory.

3.1. *Classification and Psychoneural Structures*

The cornerstones of Hayek's analysis of the neuronal system are the concepts of "classification" and "structure." From the logical point of view, "classification" simply means "predication," i.e., the description of objects by general terms (predicates), and "structure" means a set of relations between objects. The whole argument leading to the above quoted thesis rests upon the assumption that within the neuronal system classification is only possible by means of structures built of neurons: not only the classes are identical to structural properties of the neuronal system, but also the objects of classification (i.e., the subjects of the formal predication) are neuronal structures, because the environment is only given through intermediation of its influence on neuronal structures. Obviously, there is a closed loop in the resulting dynamics of brain-environment interaction whose analysis actually might lead to substantial epistemological conclusions (cf. Roth, 1987).[23]

Hayek is interested foremost in answering the principal epistemological question: Why does the effect of physical events at the body/environment interface consist in the evolution of a sensory order which shows distinctions between just these events without any direct physical cause? Why is there any divergence between the sensory and the physical order? The answer elaborates on the observation that already the seemingly simple case of sensory perception shows the complex logical structure of an classificatory (predicative) act (cf. Waldenfels, 1974; Bunge, 1984, pp. 128 ff.). The physical events at the receptors of the neuronal system ("stimuli") cause neuronal events which do not display any qualitative difference because (according to Hayek's state of neurophysiological knowledge) single neurons could not be distinguished qualitatively from each other. However, even if we acknowledge that there is a multitude of physiologically different neurons ultimately connected to particular zones in the brain, Hayek's argument remains to valid because there is no substantial qualitative difference between the electro-chemical signals proper that are processed by the neuronal system. Thus, in principle the whole potential range of qualitatively different sensory inputs from the environment is reduced to only one qualitative type of a neuronal signal (Roth, 1987, p. 232). Rather than different neuronal signals, specific neuronal structures activated during the transmission of an impulse are the *criterium comparationis* of the qualitative identification of stimuli: within the neuronal system, "qualities" are defined by causally connected topological structures within the neuronal system. In turn, topological structures activated by stimuli are classified and identified by means of neuronal structures on "higher" levels (the term "high" has to be understood in no strictly hierarchical sense because the whole network is very complex and often circular). For instance, even if a certain object in the environment is translated in a structurally similar topology of a part of the neuronal system, during its further processing by the brain that topology needs to be referred to by other topological structures because it is not connected to a qualitatively distinct and unique neuron representing that structure. Figure 1 tries to visualize one abstract element of such a kind of system which, of course, does not reflect the modern state of knowledge about the concrete structure of the brain.

The assumption of a formally closed system does not lead us into a solipsistic paradox if an evolutionary perspective is adopted. Hayek does not assume that a particular brain coming into existence represents a "tabula rasa" containing no pre-sensory experience that might be a foundation for the classification of stimuli. In the course of phylogeny, natural selection shapes certain genetically inherited, fundamental structural constraints of the development of the neuronal system that Hayek calls "linkages" between neurons.[24] Linkages develop without any sensory experience in the strict sense but nevertheless represent the backbone for the further developing sensory order because linkages leading to nonadaptive behavior by misguiding organismic expectations are weeded out by natural selection. Obviously, linkages are the conceptual equivalent of the reinterpretation of Kantian a priori categories as proposed by one school of evolutionary epistemology established by Lorenz (for an overview, see Engels, 1989).

However, linkages are far from representing the full-fledged sensory order. The organism unfolds the whole neuronal network according to the relative frequencies of co-occurrences of different sequences of neuronal impulses (which Hayek calls "followings")—which means that although Hayek was not able to identify the neurophysiological mechanisms, he assumes that neuronal processes are reflected in structural changes embodying the resulting experience. He furthermore does not presume that these structures are immutable afterwards, because their stability is supposed to depend on the relative frequencies of

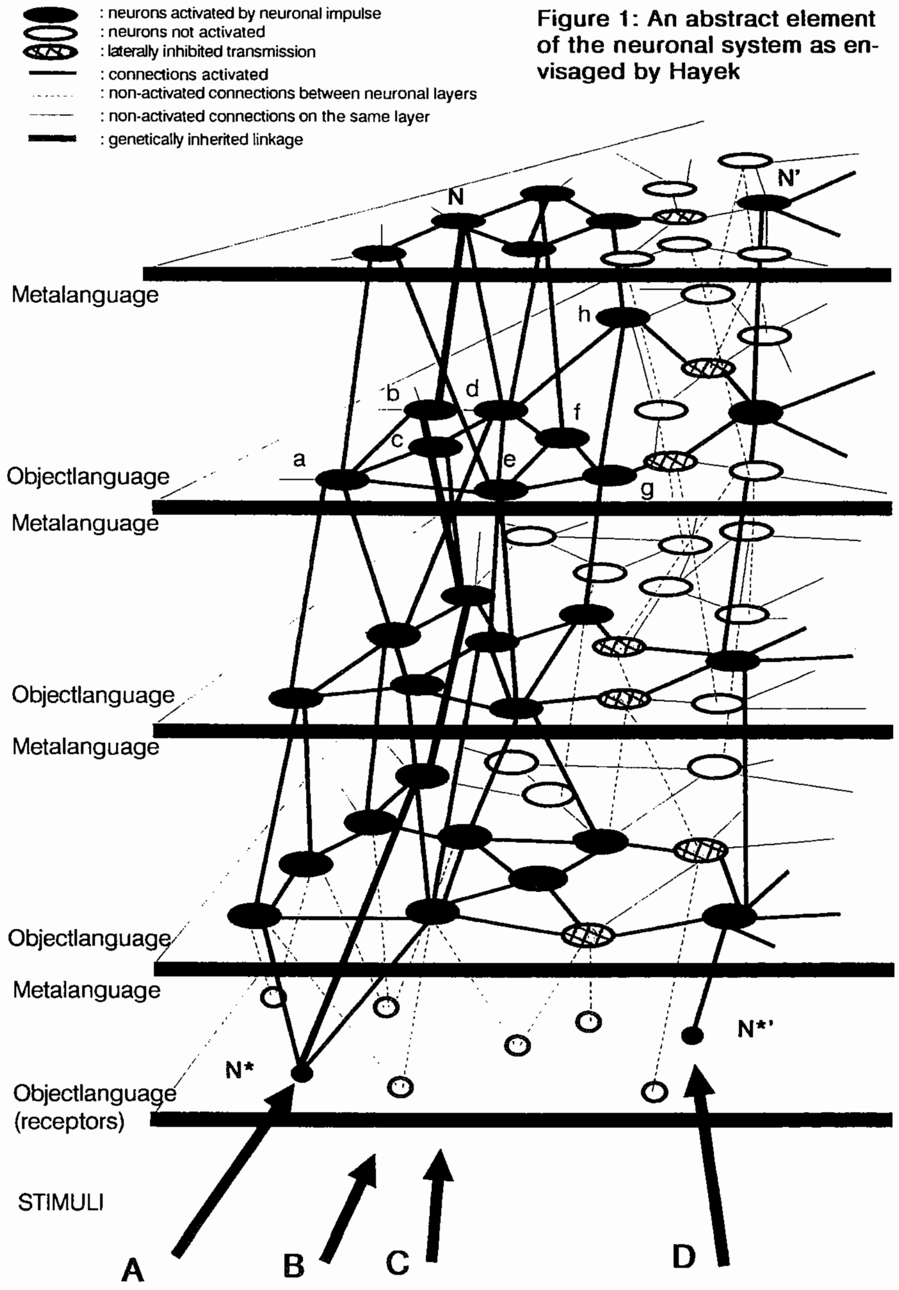

Figure 1. An abstract element of the neuronal system as envisaged by Hayek.

followings after the initial constitution of the sensory order. The system learns by means of restructuring malleable neuronal connections.

In principle, this view corresponds to the modern variant of "neural Darwinism" as proposed by Edelman, albeit without elaborating in detail on the dynamic aspects. This is especially valid with regard to the assumption that topological sets of neurons are the units of information processing (and not single neuronal connections), and that these show "fuzzy" boundaries to other sets because the construction and destruction of connections is essentially a statistical phenomenon. Little needs to be changed in the Hayekian picture to reach the view that there is a competitive interaction between a multitude of neuronal connections to be activated potentially ("degenerated networks" according to Edelman), ultimately leading to the selection of certain ordered sets of groups. Thus, Hayek's epistemological problem remains unchanged prima facie: within the completely developed network of neuronal structures there is no way of identifying single impulse-events other than by the topological features of their "following." Since there is no outside observer[25] who could use Cartesian coordinate systems to identify the position of single neurons, there is only the possibility of identification by means of an ultimately circular remapping of structures. Nonetheless, the system as a whole still needs to be known in order to identify the function of particular structures. Thus, even the mere sketch of some fundamentals of the sensory order leads to the consequence of epistemological holism (Hayek, 1963, p. 22).

Before turning to a possible modification or even solution of that problem within a modern approach, let us take the few steps needed to reveal the reasons why Hayek deduces a non-falsificationalist philosophy of science from his analysis of classification by the brain.[26] Take two different stimuli A and D belonging to different objects (one represented by stimuli A-C, see Figure 1). If a Cartesian coordinate system was given, the stimuli could be differentiated qualitatively by any singular neuron within their divergent followings n( ), i.e., a neuron N = n(A) is not the same as N′ = n(D). However, since there is no such a system and the neuronal impulses going through neurons are qualitatively identical, there is only a numerical difference between N and N′, and this cannot be processed as such by the neuronal system. The invalidity of N = N′ can be proved only by means of a differentiation between the topological features of the neuronal structures connected with both neurons. This means that the neuronal systems need to refer to a property on a higher logical level than a property of a neuron, i.e., properties of relations between neurons. This observation can be rephrased by saying that because the extension of every equally large set of neurons is the same one (i.e., a quantity of qualitatively identical neuronal impulses) the invalidity of N = N′ can only be proved intensionally in the narrow sense of the word, i.e., by reference to the structural context. Different neuronal structures might be numerically different, but such a criterion would leave a large set of equally large sets of neurons indistinguishable. Reference to qualitative differences between properties of relations between neurons is needed to identify single neurons of a "following." For instance, N and and N′ are not identical, because only N can be described as N = n(s{A − H}), s{ } meaning the topological configuration of the neurons a - e.

Quite naturally, the epistemological problem has only been shifted because the difference between two qualitatively identical s{ } and s′{ } has no ontological quality given the qualitative identity of neuronal impulses. On a second look this is also valid for qualitatively different s{ }'s, because that difference also has no ontological status, and therefore needs to be mirrored in some other property of the neuronal system. That property of course lies in the diverging "followings" within the wider context of the neuronal system, which means that a difference between some s{ }'s needs to be mapped into some other s{ }'s, so that s*{S{ }} is not identical to s*'{S{ }}. Thus, the process of identification of single stimuli runs through an encompassing set of nested neuronal structures identifying topological features of neuronal structures by means of topological features of other structures. The neuronal system might therefore be defined as a "processually ordered recursive relation of inclusive structural intensions." In Figure 1 that means that the identification of N depends on the structural properties of the different neuronal groups of the "following" linking N to the receptor N*. The process is not open-ended in the strict sense. Since the neuronal impulse of N* is qualitatively identical to any other N, N* can be identified only by the "following" including the "following" connecting N* and N. This structural circularity of the neuronal system indeed represents a tautology from the logical point of view.[27] Although in the first step the reference to intensionality (i.e., topological characteristics) seemed to resolve the epistemological dilemma, the identification of just these features remains underdetermined. Unless an exogenous system of reference or qualitative identification is provided, the circularity of the neuronal system makes any proposition about a partial structural characteristic of it true since that characteristic can be identified only by means of the identification of the whole system which in turn amounts to the proposition that "the system is the system"—a tautology.

Fortunately the analysis does not stop here. As we have already seen, a system of such a kind can be adapted to its environment by means of natural selection. With regard to higher cognitive functions, we have already seen (in footnote 7) that the self-referring circularity of the neuronal system might be abolished if the brain itself provides an external system of reference, as, for example, in the case of a division of functions between the hemispheres (cf. Levinson, 1982). There is no need for dualistic interactionism or mind/brain dualism if there are sufficiently independent subsystems of the brain. Within the precepts of psychoneural monism that assumption resolves some of the analytical difficulties described. Edelman therefore argues that the identification of topological features is realized through recurrent remapping ("reentry") between different systems—for example, of categorization of sensory inputs (also cf. Roth, 1987). Especially if attention is paid to the fact that such processes need to be described as non-linear ones, a stable end-point with unique topological characteristics can emerge out of an structurally indeterminate starting configuration.[29] This is particularly important for the interpretation of concepts like a perceptual "prototype" (see Holenstein, 1980) in terms of psychoneural monism.

On the other hand, such approaches seem unable to resolve the issue at stake completely. For instance, even if—in the most simple case—the hemispheres provide mutual systems of reference, another framework of reference is needed to specify the singular mappings.[30] Therefore, as in the case of elementary linkages, an evolutionary approach still is needed. The epistemological dilemma of psychoneural monism necessarily compels us to adopt the perspective of evolutionary epistemology because no other epistemological approach is able to provide a solution to the problem of how "true" or approximately true knowledge is possible within a self-referentially closed neuronal system.[31]

The problem has three aspects. The first refers to the observation that Hayek already puts forward the hypothesis that classification and cognition are not independent from the active behavior of an organism (1963, pp. 90 ff.). Cognition is a sensorimotoric phenomenon—that is to say, mutual mappings between the sensory and the motor system provide the most reliable (since qualitatively most different) internal system of reference. In classifying the outer world, the organism classifies whole sets of its own behavior towards that world. Indeed Edelman (1987, pp. 209–239) assumes that only the "global mapping"—between the sensory and the motor systems in particular—lays the foundation for minimal units of perception. Given that, the evolutionary approach gains in plausibility because the idea of a "vicarious" function of thought is reflected in the sensorimotoric essence of cognition.[32]

Nevertheless, the question remains to be answered of how the malleable part of the neuronal system reacts to the disappointment of expectations. Thus, consideration of the motor system is not able to answer the question regarding the formal mechanism guiding the process of classification of "global mappings" in relation to the outer world. Edelman (1987) resolves the issue with the assumption that, only within communicative interaction between different brains, global mappings turn into information about the outer world in the strict sense. This is the second relevant aspect of the problem, which quite immediately guides the discussion into the whole gamut of problems related to the question of whether or not the communicative context can be modelled according to the falsificationalist formalism (e.g., the classical Kuhn/Popper-controversy). With regard to our epistemological problem, the second aspect is not very important because obviously falsification during communication depends on the possibility of actually realizing falsificatory statements within the individual brain. This might be the reason why to Hayek communicative behavior does not seem to be relevant to his epistemological analysis although he explicitly regards the sensory order as a social phenomenon.

Thus we continue with the third aspect, i.e., the question of whether approximately true knowledge is possible because there is a selection of neuronal structures according to the formal principle of falsification. Although the system itself cannot bridge the gulf between its self-referentiality and the environment, it can be supposed to generate "blind variations" which are then selected against by environmental feedbacks resulting from organismic action. Hayek adopted a completely different point of view, however, because he believed that progress of knowledge results in a growing independence from such environmental feedbacks. Let us try to understand the reason.

A neuronal mapping of the outer world is a semantic process in the strict sense. That means the neuronal system needs to provide a mechanism for reference to objects outside the brain. As we have already seen, a mapping from a physical input into a receptor N* is not sufficient to provide unequivocal reference because the qualitative differences between physical events cannot be mirrored in qualitative differences between neuronal signals. Nevertheless there is a referential relation between stimulus A and receptor N*. The crucial point now consists in the observation that this semantic relation is defined on the next higher level of the neuronal structure involved in the "following" of N*. That N* "means" A and not D can only be asserted by referring to the topological features of its "following." Thus, with regard to the mapping A/N*, the first level of the neuronal structure takes the position of an internal "metalanguage" in the sense of a set of rules defining the semantics of the object language, i.e., the set of receptors. On its part the mapping N*/n(s{ }) cannot be defined without the help of an identifying structure on the next higher level in the neuronal system, i.e., n(s'{N(S{ })}): that means the mapping from N* into the next higher level now is to be considered as a semantic relation too, since the relevant structure "means" N*. This leads to the functional conversion of the first-level neuronal structures from the status of a metalanguage concerning the sets of mappings stimuli/receptors to the status of an object-language related to the set of receptors. Consequently, the second level neuronal structures attain the status of a metalanguage as far as the first level structures and their mapping relation to the receptors are concerned.

We are now able to draw an important epistemological conclusion: The hierarchically ordered neuronal structures are formally equivalent to an iteration of object–and metal-anguages that are mutually related and change their relative position in turn. This situation differs fundamentally from the situation where an outside observer ("mind") provides the metalanguage immediately defining the semantics of the receptors (e.g., measuring the interaction between exactly located receptors and physical events). It also differs in principle from the position of naive empiricism or positivism, where sensory data were supposed to be semantically complete already on the level of the receptors, which means that the rest of the neuronal system was separated off analytically. Instead, the elementary semantics of the receptors is now conceived as defined only within the nested hierarchy of the whole interactive system of meta–and object- languages in the brain.

However, such an insight is still without immediate consequence for our question of truth. This is particularly disturbing because the psychoneural monist has to be a metaphysical realist by definition: materialism cannot question the existence of physical reality without becoming self-contradictory. We have now to ask what consequences result from the semantic nature of the sensory order for the issue of falsification. This is precisely what Hayek's epistemological stance implies because he seems to regard theories as semantic phenomena, i.e., concepts that serve the purpose of referring to objects by means of describing their properties. What are the implications of such semantic aspects for the problem of true knowledge?

3.2. *The Evolution of Concepts and the Necessary Conditions of the Possibility of Truth*

Popperian evolutionary epistemology contends that although absolute truth will never be attained, the falsificationalist logic of evolution makes an approximation to truth possible because cognitive structures that misrepresent reality are selected against. Consider the case of an simple organism operating according to Figure 1. If the organism confuses the stimuli A and D because lateral transmission of impulses is not repressed between their followings, and if that confusion causes an error about features of the world that are important for survival, than the carrier of the "wrong theory" will be sorted out, at least probabilistically, by natural selection. In principle, although individual knowledge might never be true, the knowledge generated by the evolutionary process thus will be true approximately, and furthermore will be consistent across different stages of evolutionary change—i.e., organisms evolve as if in response to a single (though multi-faceted) reality (Bartley, 1987a).

I do not want to go into the details of the question of whether such an adaption of the neuronal system to the environment can be interpreted as a process leading to knowledge in the epistemological sense, because this has already been done by Engels (1989) in considerable detail. Suffice to note that from the biological viewpoint natural selection operates not like a simple filtering process, nor does it result in a simple adaptation of the organism to its environment.[33] This point becomes obvious already if the "falsification" of an individual phenotype is considered. In the strict sense, individual variations do not contain any knowledge at all. If such variations are selected against in one situation and not in another, the genetic heritage changes slowly and embodies the whole history of contingent selective events. A single individual variation could only be regarded as falsified if this variation is a feature of the whole population in question and if the whole population would not be able to survive under any type of actually working selective pressure. So long as a "wrong" theory is good enough to allow a population to reproduce itself within a certain ecological niche, it does not make sense to talk of "falsification" when a member of the population perishes after leaving that niche. As has already been pointed out, there is a fundamental difference between the logic of evolution and the logic of falsificationalism: the reproductive success of members of a population with a common gene pool that represents evolutionary accumulated "knowledge" is the result of a very simple arithmetic adding the positive values of past individual "corroborations" and the negative values of past individual "falsifications." In evolutionary terms, "approximation to truth" is simply the relative propensity of differential reproductive success, i.e., a probabilistic term. That means "truth" might prove wrong in a single case, and furthermore, under certain circumstances, wrong theories can foster reproductive success.[34]

If, furthermore, the whole discussion about "internal selection," the role of "epigenesis," and so on is accorded attention (cf. Wuketits, 1987, or Burstein, 1991), then even on the level of more primitive organisms there obviously is no formal equivalence between natural selection and falsification because the environment qua reality is by no means the single instance deciding evolutionary success. Thus we need to ask whether falsification comes to the fore when higher levels of organismic complexity are scrutinized—where within a population, theories are inherited by communicative acts, i.e., where brains interact on the phenotypical level as reflected in the perspective of "dual inheritance theory" (Boyd/Richerson, 1985; Edelman, 1987). Precisely such a hypothesis has been explicitly rejected by Hayek.

The reason becomes evident when the conceptual structure of the neuronal system is revealed. By "conceptual structure" we mean: first, the concepts generated by the process of classification on higher levels of the neuronal network, and second, the logical relation between concepts used in a linguistic description of just that network. Both aspects are closely related because of course the descriptor itself is a neuronal system. From a Hayekian point of view every analysis of the logical structure of the neuronal system has immediate implications for the logical structure of concepts, theories, and so on[35] because psychoneural monism assumes that there is no ontologically separated world of "ideas" governed by rules other than the brain's.

A condensed argument against the possibility of falsification therefore runs as follows:

> Falsification of theories in the strict sense is impossible, because the neuronal system has the logical structure of a nested hierarchy of implicit definitions (in the sense of Hilbert's, cf. Kambartel, 1974). On every specific level of the hierarchy, singular terms (i.e., the conceptual equivalents to unique neurons or neuronal structures that can be identified unequivocally as individuals) are eliminated by existential quantification leading to a definite description by means of predication. Therefore the hierarchy is to be conceived as an ordered sequence of inclusive intensional classes which can be analyzed in more detail as a sequence of meta-and object- languages if the interrelation of intensional classes on the same hierarchical level is considered. These meta-and object-languages undergo a step-by-step functional conversion from meta-into object-languages as the sequence proceeds. In such a kind of structure, "truth" can neither be defined nor assessed independently from the structure itself because reference is defined within the system and not from without. Since reference is formally prior to the formulation of possibly true statements and falsificatory ones, falsification of single statements cannot reach through to the rules determining the referential functions of the system.[36]

Let me try to clarify these assertions. Popper (1984, pp. 35 ff.) needs the essential and operative distinction between singular and general terms as a precondition of the formal possibility of falsification because reference to single events is needed to construct an unambiguous semantic relation to reality.[37] The application of *modus tollens* which is the underlying logical structure of the falsification of hypothetico-deductive systems presupposes that the singular term of the *consequens* denotes the same object as the singular term of the falsificatory statement. This is by no means a trivial condition since the reference of singular terms belongs to the most complex problems in the analysis of language. Hayek's description of the sensory order and its neuronal base does eliminate the concept of singular terms in the operative field since the sensory order is conceived as an exclusively predicative structure in the sense of being processed by means of general terms alone, recurrently eliminating singular terms.[38] Singular objects in the environment are identified not by singular terms but by general terms denoting certain structural properties of the neuronal effects of certain structural properties of the objects.

Consider our example of the receptor N*. Within the linguistic equivalent of the neuronal structure, if N* is identified by the singular term "N*", on the level of the object-language this term is eliminated by the identification of N* on the next higher level by means of a n(s{ }), the latter being interpreted linguistically as general term "n(s{ })" which denotes the topological structure of the "following" of N*. That general term might be functionally conversed into an operative singular term if now N* could be identified unambiguously. However, since n(s{ }) can not be identified other than by n(s{n(s{ })}), within the linguistic equivalent a new definite description with the general term "n(s{n(s{ })})" needs to be introduced. Thus a singular term on the level of an object-language is eliminated by means of referring to a general term when shifting to the level of the next higher metalanguage. On that level the general term shifts into the position of the subject of metalanguage propositions, thereby turning into a singular term and transforming the metalanguage proposition into an object-language one. Again, such a singular term is eliminated if the existence of a neuronal structure is asserted which has these properties described by the general term which denotes the relevant neuronal structure on the level of the second metalanguage. Therefore the functional transformation of general terms into singular terms which are then eliminated is always accompanied by a shift from meta- to object-language and vice versa.[39]

To take a concrete example: if there were a neuron for "red," the singular term "red" would be first processed into the general term "is red." What "is red" means to the neuronal system, given the qualitative identity of neuronal impulses, can be assessed only by a new statement ""is red" is "(. . .)""—where "(. . .)" could be a new singular term if there was not again qualitative identity of neuronal impulses. Therefore a new proposition in terms of neuronal structures has to be formulated of the type """"is red" is "(. . .) is [. . .]"""". In general such an iterative process of elimination of singular terms can be described by the recursively encapsulated proposition (compare Foerster, 1987) $Vx\ (x = s \land s = (Vx'(x' = s' \land s' = (Vx''(\ldots))))$, where "s" stands for a general term denoting a structural property of the neuronal system. Note that the whole topic hinges upon the semantically complex interpretation of the simple equation $x = s$ (cf. Tugendhat and Wolf, 1986, pp. 168 ff.). Only the assumption of a recursive semantic relationship is able to preclude the immediate setting of a Platonic ontology.[40] This has one serious implication leading immediately to Hayek's above quoted hypothesis on science: within the brain there are only existential statements operative on the existence of objects which logically can only be verified not falsified. If an existential statement has to be rejected, the only conclusion to be drawn is "that it was not an object of the kind it was thought to be." A posteriori there is the possibility of summing up the set of successful verifications, i.e., giving the extension of the predicate of the existential statement—the general term in its predicate. A failure to apply the general term does not justify its wholesale rejection. With this kind of cognitive dynamics, an organism indeed learns by trial and error: successful applications of predicates (or, on the neuronal level, of the related neuronal structures) will be stored by stabilizing certain subsets of connections within the neuronal system, whereas failures simply are to be regarded as misplaced applications eventually leading to a "degeneracy" of the related neuronal connections. Given the utmost importance of the notion of "degeneracy" in Edelman's global brain theory (1987, pp. 46–57, 162f.)—meaning the overabundance of potentially usable neuronal connections as compared to the actually stabilized—we have to assume that the brain contains a whole set of possible worlds as reflected in possible theories in which a subset is carved out by interaction with the environment without making the other connections invalid. A simple proof is the fact that the brain is able to imagine realities completely different from the one actually regarded as existent. A certain general term/neuronal structure is evolutionarily stable if its extension (the set of successful applications) grows larger in the course of time.

What are the implications of such an analysis for the concept of truth? If the brain is supposed to be able to produce "true" statements (or "true" neuronal mirrors of the outer world), its internal logical structure needs to be homologous to Tarski's formal analysis of the possibility of a definition of truth that is not paradoxical—the mappings from world to mind must fulfill the preconditions of the correspondence theory of truth without falling into the traps of self-reference.[41] As we have seen, Hayek describes a neuronal system that precisely shows the hierarchy of meta-and object-languages that Tarski demonstrated to be a necessary condition for a formulation of a non-paradoxical definition of truth. This is also true for the recursive transference of general terms into singular terms on the different language levels. However, this implies that within the sensory order formally consistent "true" statements will only be possible under the condition that a concept of truth boils down to the concept of "fulfillment," i.e. if the recursive process leads to an end state in which the variables of a description of a neuronal structure (its implicit definition) can be replaced definitively by singular terms ("*Namen*") such that the description consists of true statements. That condition is not valid in the case of the sensory order, as we have seen.

Therefore, the structure of the brain seems to be homologous with the semantics of languages of an infinite order (admitting types of an infinite order) which have been scrutinized by Tarski (1935/1983, pp. 518–546) as a much more complicated case for constructing a formally adequate definition of truth. Accordingly, if for any object-language proposition an metalinguistic translation can be provided, on that level a definition of truth could be found. However, in order to talk about that definition, a metalanguage of a higher order needs to be constructed. Thus, the concept of truth is either embedded in the possibly infinite nested hierarchy of metalanguages or it is introduced by means of axioms claiming evidence of truth. In both cases, the question of truth is no longer separable from the problem of reference, since there is no set of simple singular terms given which immediately represents reality (i.e., sensory data in the positivist sense).

This point receives an immediate illustration in the case of falsification. In any instance of attempted falsification, the falsificatory statement needs to be true in the sense of correspondence theory if *modus tollens* is to be valid. Completely independent from the issue of an adequate empirical criterion for assessing the truth of the statement, a metalanguage needs to be introduced to check on a formally adequate use of the term "true." However, this seemingly simple step leads us into severe logical difficulties because we still cannot decide whether the definition of truth which is formulated in the metalanguage of the falsificator is the same definition as in the metalanguage of the statement which is to be falsified—viz., of the respective theory. This means that unless a unifying metametalanguage has been introduced which definitively reduces the potential diversity of definitions of truth of different metalanguages (object-languages in relation to the former), we have no way out of the dilemma that the falsificator and the statement to be falsified are not commensurable. Precisely this possible incommensurability has already been revealed by Tarski (1935/1983, pp. 534 ff.) (cf. Stegmueller, 1968, pp. 38 ff.) who concluded that the concept of truth cannot be operationalized except by reference to a specific language system.

What is the practical meaning of such an abstract reasoning? Quite obviously, the problem of a unified metalinguistic framework is the formal mirror of the problem of how to provide a unified framework for reference. This is a classic topic in philosophy of science, starting from Hempel's (1951) assertion that any empirical proposition presupposes a linguistic framework arranging certain elementary semantic relations, and leading to Quine's (1969) problem of "ontological relativity" that results from the fact that the reference of a certain language cannot be determined other than within a framework language.[42] However, the semantic nature of reference within a certain language is related to the problem of truth since different ways of reference do not leave definitions of truth unchanged. As regards falsification, there are two implications. First, the application of *modus tollens* requires a prior decision about which theory—the theory applied in the falsificator or the theory to be falsified—is "more true." This was expected to be decided upon by means of falsification. Therefore falsification wins logical priority only if the theory underlying the explanans and the explanandum, or the falsificator respectively, is the same one. But then the possibility of falsification simply demonstrates that the theory has been wrongly applied in one case. This situation is the simple reason why only a new theory is able to falsify a given theory. This means that for a comparison between two different theories, a criterion of truth is needed a priori in the first case. On a more fundamental level there is a need to define the relevant metalanguages of the theories in question because the commensurability of their otherwise implicit definitions of truth is not guaranteed. If the semantics of the theories prove to be different, a meta-metalanguage needs to be introduced providing the framework for an encompassing definition of truth. Consequently, if there is an infinite number of possible theories with different metalanguages and ways of reference, there will be no ultimately converging, general definition of truth—which means there is no truth independent of certain given theories. Semantics has substantial implications for truth.

Examples for this somewhat disturbing result are ready at hand when we talk about evolutionary approaches. The problems of standard falsificationalism with Darwinism (cf. Popper, 1987) result from the fact that a physicalist concept of a theory is transferred into another conceptual realm. After a closer look, we can clearly see that Darwinism and at least classical physics differ considerably in their semantic structure. Laws in physics never refer to individuals but to classes of individuals which are specified intensionally, meaning that there is a mapping between a set of individual objects which can be located in space and time into the class of sets of objects with the same value measured. In stark contrast, once the essentialist concept of a species was rejected by evolutionary theory, its semantic structure departed fundamentally from that of physics because individuals are referred to only as not belonging to a class. Although in modern biology there are equivalents to the physicalist concept of a law (e.g., in behavioral ecology), such laws refer only to a narrow aspect of individual behavior (and therefore are explanatorily incomplete) and, more important, their validity in turn needs to be explained by evolutionary theory. The completely different status of the individual in both theories has profound implications for criteria of truth and even the definition of truth (cf. Hayek, 1972), because central concepts of evolutionary explanations like adaptation show fundamental problems in empirical operationalization leading to completely different yardsticks of what a "true statement" is supposed to be (see Kueppers, 1986).

The above example shows that Hayek's analysis of the neuronal order has somewhat surprising, immediate consequences for philosophy of science, thereby providing the missing link between two hitherto disconnected domains of evolutionary epistemology. Hayek shows that the reference of the neuronal object-language is defined by a mapping which relates object-language to a neuronal structure on the metalinguistic level. If now we make the simplifying assumption that theories are a subset of neuronal structures on a high level of complex organization, theories are not to be conceived as a set of statements but as a formal equivalent to general terms (defined implicitly by the laws of the theory). On mere formal grounds these general terms (which in sophisticated approaches of philosophy of science are analyzed as set-theoretic predicates) cannot be falsified. On a deeper level of analysis, we can see that theories cannot be strictly falsified because although they are used in the formulation of statements about reality they have not only a propositional function but a semantic one. Theories define the semantics of their respective object-language statements, e.g., in delimiting the range of admissible objects or describing the general characteristics of the possible domain of the theory in question. But then the theory belongs to the necessary preconditions of the possibility of truth (even definitions of truth) on the level of the object-language where the relative truth of statements and falsificators needs to be assessed. Theories have meta-linguistic status in the strict sense of defining (partially, at least) the semantics of an object-language. Moreover, in Tarski's sense, reference of the object-language is no longer given by means of an exogenously given mapping from objects to singular terms: instead this mapping is reduced onto the "morphology" of the theory as a metalanguage. Within Hayek's description of the neuronal system, this is explicit in the fact that we can speak about the semantic relation between stimulus A and receptor N* only if the singular term "N*" has been eliminated by a definite structural description on the metalinguistic level; at the same time, this linguistic process is the only way in which the physical relation between A and N* can be identified within the neuronal system. This means that the mapping A/N* is reduced to morphological features on the next higher level of the neuronal system. If the neuronal system errs and produces the hypothesis D/N*, this hypothesis can be falsified only if the system is able to distinguish between structural features of the "followings."

This situation is formally homologous to the analysis of the problem of measurement by the so called "new structuralism" in philosophy of science (Stegmueller, 1986). Typically, fully developed scientific theories show a formal dependence on certain related measurement procedures on the theory itself, which means that an important part of the object-language can be applied only for reference if the theory is already regarded as valid. In Figure 2 this aspect is scrutinized for the classical case of Newtonian mechanics, in which some measurable quantities like velocity do not depend on the theory and might be regarded as "observational languages" in relation to Newtonian mechanics (that relation is labelled "non-t-theoretical"), but in which the crucial concept of "mass" can be measured only by utilization of precisely the laws of Newtonian mechanics (governing, e.g., the behavior of scales). Such a priority of the theory for measurement can be interpreted in the sense that the theory is not only applied in statements about reality but has important semantic functions in delimiting the range of admissible objects, thereby partitioning the world into objects that can be referred to by the linguistic means of the theory. The class of objects which are considered as measurable or simply as being apt to be handled by means of a certain object-language can be defined only intensionally, i.e., by verifying the existence of properties which are denoted by the general term of the theory (e.g., " . . . is a model of Newtonian mechanics"). Thus the extension of the class of measurable objects is the a posteriori result of the application of the theory in the course of time. This is precisely the reason why Hayek believes that there will be a tautologization of science—although he was not clear enough about the distinction between semantics and statements. Obviously, the term "tautology" is somewhat misplaced in labelling what Stegmueller calls an "epistemic circle," albeit not a logical one.[43]

In Figure 2, the way in which a theory can be interpreted as a nested hierarchy of functionally conversed meta- and object-languages is scrutinized in detail. We can obviously see that not only is there no single theory, but on every level an autonomous subset of a theory ultimately presents itself as the implicit definition of the predicate "Newtonian mechanics." The decisive point is that on every level general terms are transformed into singular terms, making reference possible that then needs to be constructed on the next higher level. Thus, in general, theories are to be conceived not as talking about real-world phenomena in the strict sense of the correspondence-theory of truth, but as semantic relations between the respective object-languages and their objects, the objects as such never being conceivable independent of a certain theory. In that sense, we have no possibility of talking about the truth of a theory unless a theory on a higher level is utilized that can talk about, or be utilized within, an appropriate definition of truth—and so forth. As can be learned from Figure Two, this infinite process indeed can be chopped off by means of an axiomatization of a theory—also envisioned by Tarski when talking about the metalinguistic foundations of truth within languages of an infinite order. The axiomatization and thereby partial immunization of theories serves to provide an anchor for reference. Axiomatization in this sense does not mean that theories are to be regarded as true by evidence; rather, axiomatization is merely a way of defining the general term (set-theoretic predicate) of the theory. The traditional concept of "evidence of axioms" simply mirrors the more fundamental metalinguistic aspects of theories, and provides the necessary preconditions for a consistent definition of truth on the object-language level. We are not able to start from correspondence theory of truth and deduce a general definition of truth as well as a criterion of truth that can serve as an external standard for an evaluation of the descriptive power of theories, because the theories themselves provide the semantic means by which the concept of truth inhering in the correspondence theory of truth can become operational.

This process can be scrutinized in more detail when theories are compared. For instance, an analysis of Einsteinian mechanics along the lines of Figure Two would show that the delineation between non-t-theoretical and t-theoretical terms is shifted towards the level of individuals, including now the specification of the coordinate system. The decisive point regarding falsification is that Einsteinian mechanics provide the conditions wherein the laws of Newtonian mechanics can prove to be valid. This means the intension of the set-theoretic

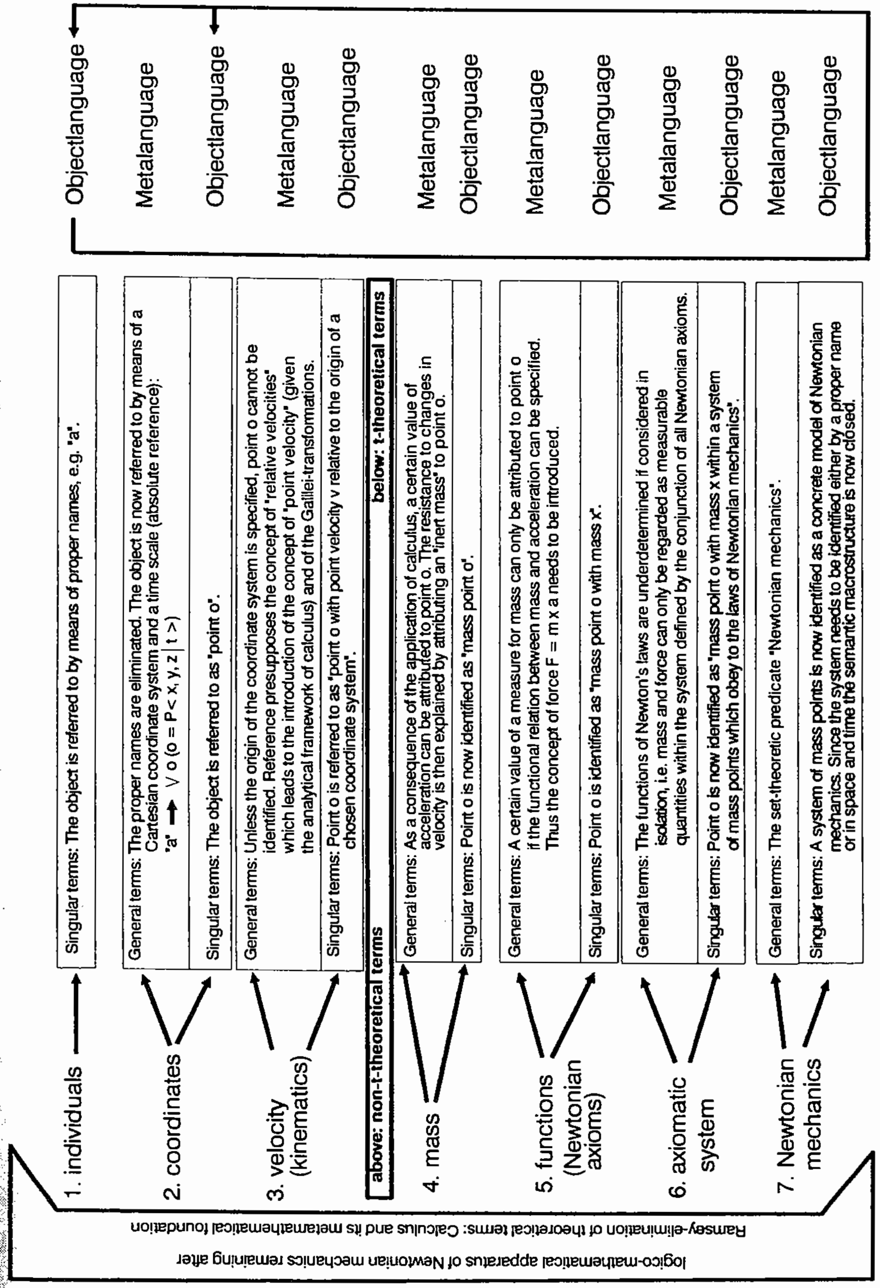

Figure 2. The semantic macrostructure of Newtonian Mechanics.

predicate "Newtonian mechanics" is a subset of the set-theoretic predicate "Einsteinian mechanics," and the extension of the former is simply smaller than that of the latter. The crucial factor is that the system of reference that determines the identification of objects presumed to behave only in accordance to the rules inhering in the process of reference has become much more complex. This is not simply a question of whether Einsteinian mechanics is a "more true" statement about reality.

This important result notwithstanding, what is of more interest in our context of discussing Hayek is the question of whether we are justified in transferring results from the analysis of neuronal structures to philosophy of science. Most readers will doubt this—given, for example, classic critiques such as Husserl's (1975) (cf. Sukale, 1986) of such a procedure. In concluding this section I therefore want to provide a powerful empirical proof of that "transfer" hypothesis. If global brain theories are right in assuming that the conceptual structure of cognition evolves during epigenesis and growth into social communication, then the formal features of the still more-or-less unobservable in detail—viz., non-interpretable—structural changes of the neuronal system can be supposed to be mirrored in the conceptual development of the child. Indeed, Piaget's "genetic epistemology" can be shown to fit very well into the framework of the Hayekian analysis of the sensory order, as well as the New Structuralism.[44]

A condensed summary of this argument as well as its empirical support is presented in Figure Three. As indicated, the cognitive development of the child indeed proceeds through different stages in which new general terms are discovered (abstraction réfléchissante) and then functionally transformed into singular terms (abstraction réfléchie). As is precisely envisaged by Hayek, the growing complexity of the cognitive system leads to the construction of conceptual structures that become more and more independent from environmental disturbances by means of adaption. Ultimately, the process itself generates conceptual innovations[45] that determine the ways in which the organism handles the environment. When the system is "closed" ("fermeture"), there is no longer any possibility of falsification in the strict sense because the organism is able to compensate for external disturbances (Piaget, 1975, pp. 71–77). However, this does not imply that the organism would not be able to cope with completely new phenomena in the environment. To the contrary: since the capacities for internal stabilization of cognitive structures are fully developed, reality is now reflected in a reliable mirror in which expectations in general prove to be correct. If not, the need is not to destroy already present structures but to create new, more complex ones.

Thus a full fledged restatement of a Hayekian Evolutionary Epistemology from the vantage point of the present will include:

- first, a Darwinian theory explaining the evolution of the genetic backbone of the brain and the related, generic conceptual fundamentals;
- second, a global brain theory in a modern version like Edelman's explaining epigenetical neuronal development as a basis for the formation of concepts;
- third, a Piagetian genetic epistemology explaining the ontogenesis of concepts and providing the empirical linkage between neuroscience and psychology;
- fourth, a philosophy of science along the lines of the New Structuralism that is able to analyze semantic aspects of theories as a means of reference, and that conceives single theories as embedded in networks and hierarchies of theories.[46]

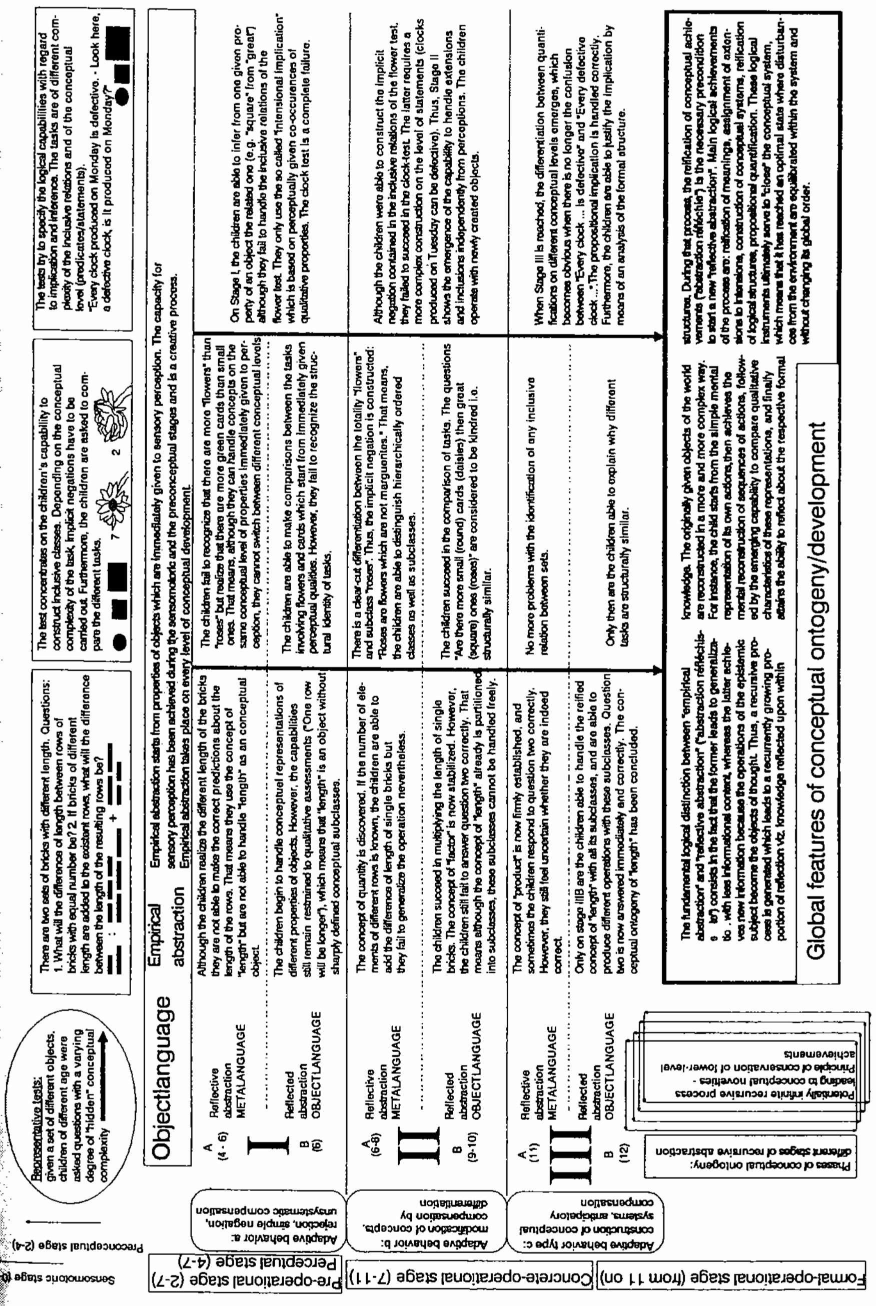

Figure 3. The conceptual ontogeny of the psychoneural system in a Piagetian perspective: the case of abstraction. Source: Piaget (1977), pp. 9–30, 81–114, 303–324.

Within such a large-scale approach to evolutionary epistemology the logic of evolution turns out to be non-falsificationalist, albeit fallibilist, and the same on every level of the selective hierarchy of life. Furthermore, psychoneural monism provides an ontological link among all levels without reducing the evolution of concepts on differential reproductive success in the Darwinian sense.

Two additional notes seem to be appropriate in conclusion of this section. First, the general argument appears to be correct in the case of falsificationalism proper if it were to be understood as an empirical theory about science and not as a normative ethics of knowledge.[47] Falsificationalism cannot be falsified because it provides the criterion for the decision about whether a mental construct can be regarded as a theory. If it is falsified—and there seem to be important examples in the history of science - this is without any consequence for its theoretical status, precisely as predicted in our perspective. Of course, this is an contradiction within the fundamentals of falsificationalism—which therefore breaks down in such a case of self-reference. Furthermore, any concept of falsification presupposes fundamental assumptions about the relation between theory and reality, and in particular about whether there is at least one true theory in the set of all possible theories towards which knowledge approximates, or whether there is no such theory so that for every theory there is at least one falsificator. These assumptions themselves cannot be falsified in principle, the first being an existential statement and the second a mixed universal-existential one. Thus, given the standards of falsificationalism, it is no theory but a metaphysical research program at best, like Popper's metaphysical realism.[48]

The second note concerns the topic of transference of Darwinian concepts into epistemology, especially the question of whether the non-essentialist and populationalist view of theories can be linked to the concept of "reproductive isolation." Fairly obviously, if a theory is axiomatized and if definitions and criteria of truth depend on the theories in question, there can be neither cross-breeding between theories nor can theories be essentially contradictory to each other. In that case, we might talk about "reproductive isolation": theories can live together sympatrically without any interbreeding.

Our results seem to be satisfying. However, a difficult question still needs to be tackled. If the evolutionary concept of mind includes a probabilistic interpretation of relative success of theories, does this not imply an inductivist philosophy of science? What about the concept of "probability" in evolutionary epistemology?

4. Evolution and Probability

The logic of evolution is neither falsificationalist nor inductivist. Of course, in Hayek's account of the sensory order the concept of frequency plays an important role. This is also valid for modern global brain theories (cf. Bunge, 1984, pp. 74 ff.). The development of the neuronal system is supposed to depend on the relative frequencies of the common occurrence of impulse sequences leading to a stabilization of certain neuronal structures. Furthermore there is the epistemologically important assumption that the mental construction of models of reality is based on the processing of the relative frequencies and densities of neuronal "followings" and their simultaneous occurrence, respectively. Models become determined when they are stabilized by the ex post facto confirmation of expectations that have been derived during their application: on the linguistic level, a model is confirmed if the application of its intensionally defined terms leads to the inclusion of new successful applications in the set of its extensions a posteriori.[49]

As in Darwinism in general, the evolutionary success of models is supposed to depend on verifications and falsifications as well. Nevertheless Hayek is no inductivist, because there is still a deep logical gap between the sequences of world/body contacts—physical events in the outer world and the neuronal structures of the sensory order. Hayek's concept of frequency does not refer to relative frequencies of the former but exclusively to relative frequencies of neuronal phenomena. The only possible extension of the argument would refer to the differential reproductive success of applicators of theories within a Darwinian framework, since Hayek explicitly assumes that the application of models has a vicarious function during the exploration of the environment by an organism (1963, ch. 5). Neither approach has anything in common with the traditional understanding of inductivism. Indeed, within Hayek's assumptions the hypothesis is implicit that first a set of possible connections between neurons needs to be present (representing competing hypotheses), and this is then exposed to selection operating probabilistically. Therefore, if in the real world there are phenomena occurring even very frequently but whose effects on the body cannot be included in the set of possible neuronal structures, these frequencies are completely irrelevant to the evolution of the neuronal system.[50] Thus we have to look for a synthesis of a non-inductivist realism and a frequentist global brain theory.[51]

The analytical problems inhering in such an endeavor are already salient if we scrutinize the elementary assumption of a simple version of evolutionary epistemology that the degree of truth of a certain genetically stored hypothesis about reality is reflected in the differential reproductive success of the respective individual. Quite obviously (Burian, 1983; Engels, 1989) this assumption is non-tautological only if actual reproductive success as a probabilistic phenomenon can be differentiated analytically as well as empirically from the objective propensity to reproduce that can be deduced by the observer from an investigation into the degree of truth of the hypotheses that are stored genetically. In that context, the propensity to reproduce could serve as a substitute for a measure for the degree of truth. If actual reproductive success could be demonstrated to reflect these propensities, evolutionary epistemology as an empirical theory would be corroborated.

Already this observation is remarkable because it would introduce Popper's (1983, pp. 347–401) understanding of "propensities" as non-statistical, objective probabilities into evolutionary epistemology. Actual reproductive success as a frequency phenomenon is to be distinguished from the propensity to reproduce—which means that theories have to be conceived independently of frequentist interpretations (although corroboration of theories might proceed in a frequentist manner). On the other hand, theories are to be construed as having objective probability in the sense of propensity—and this would be a non-inductivist but nevertheless probabilistic interpretation of "relative truth" even within Popperian concepts. Popper's challenge to inductivism thus might be resolved by a surprising switch of the argument.

However, these considerations are valid only with regard to genetically stored knowledge. The issue at stake is whether such a propensity-interpretation of theories makes sense within a global brain theory, although even the simple argument is already sufficient to provide a big blow to Popper's rejection of probabilistic measures of truth.

Let us start with the implications of Section 3 for the problem of probability. The most simple point to be made is that if theories are regarded as set-theoretic predicates or general terms, talking of probabilities in the frequentist meaning does not make sense. However, within a non-essentialist concept of theories, the psychoneural monist might connect the concept of propensity of theories with the time path of the changing extension of successful applications. But before this idea can be elaborated on, two arguments that are commonly made in favor of a general zero-probability of theories must be shown to be invalid. (Remember that zero-probability makes any inductivist argument invalid a priori.) The arguments are: first, since the evolution of theories consists of infinite sequences of pairs of disjoint theories, the probability of any single theory is equal to zero; second, the probability measure of a universal theory is the product of probability measures for singular statements about events in an infinite universe and hence arbitrarily close to zero (see Popper, 1983, pp. 252 ff.; 1984, pp. 431 ff.).

The first argument is valid only if the theories contradict each other (or have a non-overlapping domain). However, if theories (as we have seen) give us a criterion of their own range of admissible objects, thereby realizing a semantic function, they cannot stay in logical contradiction with each other. General terms cannot contradict each other unless they refer to the same singular term (viz., the object denoted by that term) within a certain statement, and moreover unless they have the same conceptual descent within a given predicative hierarchy (e.g., both referring to colors) (see Husserl, 1984, pp. 635 ff.). For instance, physical theories like Newtonian and Einsteinian mechanics do not immediately refer to observable objects that we encounter in everyday reality but to classes of objects that are identified by measurement and defined intensionally. This means the theories themselves provide the criterion of whether an object belongs to the class of the classes of measurement, i.e., the class of admissible objects. With regard to the topic of zero-probability this has profound implications. First, different theories in principle (the implicit definitions define different intensions) do not refer to the same classes qua intensions and thus cannot be mutually contradictory (there are no pairs of disjoint theories). Second, if the extensions of the sets of successful applications contain identical objects, there is no possibility of contradiction because the predicative hierarchies either diverge completely or are nested. As we have seen, in the case of Newtonian and Einsteinian mechanics the latter defines a part of such a nested hierarchy which contains the intension of the former, as well as where the respective extensions of the latter contain the subset of extensions of the former (see Stegmueller, 1970, pp. 110 ff.). In each of the cases there is no contradiction, and other cases are not possible. The case for zero-probability is thus refuted.

As regards the second argument, we suffice to indicate that neither the set-theoretic predicate nor the existential statements delimiting its extension can be conceived as products of singular statements. The extension is a set of existential statements that have been verified obtaining therefore probability one. A probability measure of the theory proper would exist only if two-valued logic is abandoned and degrees of truth are ascribed to the existential statements, thereby implying that the successful verification of the theory is only of degree. Thus, to speak of zero-probability does not make sense. To put this simply, one may conclude that general terms, being no statements, cannot be assigned to a probability measure at all. Although Popper (1983, pp. 223 ff.) maintains that his "degree of corroboration" (which needs to be constructed for the comparison between theories and falsificators) is no probability, the concept of probability is needed in construction of "degree of corroboration" (pp. 240, 251) because conditional probabilities of the type "probability of a hypothesis, given an event or a set of background knowledge statements" or "probability of an event, given a hypothesis" are utilized. This means that even if a hypothesis is supposed to have probability zero, this remains after all a probability in the classical statistical sense. However in the strict sense of such a probability statement, this would be admissible only if a statistical hypothesis had been constructed that clearly defines that set of possible events. The set of possible events would not be the set of observable events but the set of all possible hypotheses. Only then could a probability of zero be assigned to a single hypothesis. But then we are back to Popper's first argument because a probability measure of that type presupposes sets of pairs of disjoint hypotheses.

As we have seen, serious doubts have to be raised concerning the validity of Popper's assumption that theories have zero probability by necessity. Therefore taking a different point of departure seems advisable. Within the framework of the psychoneural-monistic, non-essentialist concept of a theory, the concept of "propensity" might become a substitute for the frequentist concept of probability. On the first step of analysis, such a propensity does not turn out to be an objective probability as regards the statements about the world that can be deduced from a theory, but a probability of propagation of a theory within an intercommunicating community of applicators acting within a certain natural environment and within historical time. This assertion is independent from the question of how theories are transmitted from applicator to applicator—for example, genetically or through social interaction. On the formal level of the logic of evolution, in essence the propensity of a theory is an objective probability to expand its extension of successful applications within a concrete setting in space and time. This view is completely congruent with the usage of the term in Darwinism, and corresponds as well to Hayek's analysis of the sensory order. The consequence is that although a probabilistic aspect of theories can be conceived, the approach does not result in inductivism, since the probabilities do not refer to sequences of phenomena observed by the community of applicators.

Indeed, as regards Hayek's account of the brain and in particular of the conceptual level of the sensory order—that is, "consciousness"—there is no reason to reject the assumption that certain regularities in the picture of the world transmitted by lower levels of the neuronal system lead to the tentative formulation of new "conceptual qualities" (predicates, general terms) (see Simon, 1979, pp. 25 ff.). Although relative frequencies of neuronal phenomena within the brain determine the development of concepts, this is by no means an inductivistic procedure, because only after new concepts have been "invented" or appear by chance can these frequencies be supposed to stabilize these new structures. This view closely corresponds with the standard assumptions of evolutionary epistemology (cf. Campbell, 1987a). The application of a new term is logically different from the act of its invention such that the gap cannot be bridged by means of inductivistic reasoning.

Let us look at the behavior of an applicator of a theory. The applicator evaluates the utility of a new term (i.e., hypothesis) according to the development of its extension (the set of successful applications) in the course of time: if successful applications occur significantly more frequently than failures, and if we can reasonably assume that in the future the set of failures will also be much smaller than the successes, we will conclude that the term is useful. This is nothing but a reasonable estimation based on subjective probabilities assigned to a set of potential future applications of a theory (i.e., not to the theory proper), and constructed out of the past observed frequencies of success and failure (cf. Stegmueller, 1973b, pp. 80, 191 ff.). However, such subjective probabilities cannot be used to support a hypothesis concerning objective probabilities of hypotheses. First, inference from an observed sequence of applications of a general term to its representativeness in the course of the whole infinite sequence of future applications is not possible - this argument simply is the analogue to the classical rejection of the frequency theory of probability. Second, obviously there must be a sort of a preselection of possible applications—viz., situations of applications—because otherwise every theory will show a far greater number of failures than successful applications.

The second point is the more important for our discussion because it reveals new implications of the analysis of Section Three. As we have seen, because of the semantic function of theories,the general term of the theory itself is the criterion for delimitation of the range of admissible situations of application—for example, experimental settings, limits on the space of possible events, definitions of samples, and so on. Therefore, the series of situations of application does not have the formal properties necessary for formulation of statistical hypotheses on objective probabilities in the frequentist sense. Different instances of an imagined statistical test of a theory are not independent from each other. Take, for instance, a class of objects that have been excluded from the class of admissible objects because the application of the theory failed recurrently (e.g., attempts to apply mechanics to electromagnetic phenomena). The formation of such an excluded class depends on frequency considerations too. However, the observed distribution of successes and failures of a theory changes after it has been formed: the envisioned "random experiment" of testing the theory statistically is altered ex post facto. Thus, there is no independence of single instances of applications on the level of linguistic description.

This problem makes obvious an essential difference between the theory that is denoted by the general term used in the series of existential statements on instances of successful application on the one hand, and the imagined statistical hypothesis which might be formulated by an applicator to describe the observed frequency on the other hand. In fact, observed frequencies of success and failure in theory applications do not belong to the class of data that are relevant to the theory: instead, they can be referred to only as a statistical hypothesis on a conceptual level higher than the theory in question. Such a superordinate statistical hypothesis would refer to a probability space of possible classes of events related to the whole set of applications of every possible theory in every point in space and time. Quite understandably, such kind of statistical hypothesis did not show up in the history of human thought.

Formally, this relation between an imagined superordinate statistical hypothesis and a theory is homologous to the relation between a theory and the statistical hypothesis that underlies any convention regarding the identification of "true values of measurement" on the level of the object-language. In any process of measurement, one needs to specify a range of admissible variations of results that draws a limit between "normal" inaccuracies of measurement and genuine failures of application of the theory. The underlying statistical hypothesis can be specified by means of a likelihood-analysis (Stegmueller, 1973b, pp. 84, 115, 167 ff.). This means, given the set of data concerning supposed random variations of results of measurement, that the statistical hypothesis is chosen whose parameters lead to the highest probability of the data. Such a maximization of likelihood does not result in an hypothesis on the probability of the statistical hypothesis because likelihoods simply are not probabilities, i.e., they do not obey the Kolmogoroff-axioms.

Notice immediately that the argument concerning measurement can be transferred directly to Hayek's understanding of the role of relative frequencies within the development of the sensory order, because the brain also needs to select implicitly among different statistical

hypotheses, drawing limits between admissible variations in neuronal impulse sequences and the respective mappings between different levels of the neuronal structure. Since the semantics of the brain is closed, it needs to work on the basis of presumed frequencies of errors. This means the selection of randomly produced neuronal connections could be described as if the brain operated through likelihood-maximization on every level. For instance, for the more higher levels of the sensory order at least, we can presume that there are phylogenetically evolved rules for behavior under uncertainty that become operational during epigenesis (Lumsden/Wilson, 1981, pp. 86 ff.). But this is only a special case of our problem.

On the most general level, we must recognize that likelihoods referring to statistical hypotheses utilized on the level of the object-language (measurement) related to the theory are completely irrelevant for the theory, because the theory sets the necessary precondition of applying the statistical hypotheses by defining the "prototypic," ideal values of measurement.[52] One may speak about the probability to achieve the prototypic value of measurement, given certain experimental conditions and given the statistical hypothesis that resulted from likelihood-analysis. But talk about the probability of a theory (be it zero-probability) is still nonsensical. The necessary precondition for assigning probabilities to theories is that the theories themselves function on the object-language level.

As we have already realized, this would presuppose that a statistical hypothesis could be formulated on the whole set of possible applications of all possible theories at all possible points in space and time. In that case, one could assign probabilities to any single instance of the application of one possible theory in one point in space and time, albeit again not to the theory proper. The superordinate statistical hypothesis would turn out to be an hypothesis on stochastic aspects of the ontological structure of the universe, describing the probability of certain phenomena occurring at different points in space and time, the phenomena being identified typologically by the possible theories that serve to define possible objects in the world that can be referred to in principle. What that hypothesis would look like could be specified by means of likelihood analysis. After successful specification, we could assign probabilities to theories in the sense of a propensity of the universe to show certain phenomena at certain points in space and time referred to by the theories. Furthermore, the most probable "prototypic" theory could be identified. This theory would be a metatheory in relation to the other theories in the same sense that a theory defines the prototypic value for measurements. Such a theory could be thought of as a principal theory about the most fundamental ontological structure of physical reality.

What has been described until now is science fiction in the true meaning of the word. Nevertheless, these considerations serve to yield an important insight for our discussion of "truth." We have already talked about the propensity of theories in the sense of psychoneural monism—meaning the propensity of a theory to expand its extension during application by individuals in historical time. How are both hitherto developed concepts of propensity related to each other? Obviously, the propensities of the universe to show certain phenomena cannot be known until all possible knowledge has been achieved. Therefore, at a given state of knowledge there is no possibility other than to assume that the evolutionary propensities of theories determining changes of their extension mirror the propensities of the universe, given that there is recurrent interaction between the universe and applicators of theories. In that sense, evolutionary epistemology reaches a new definition of the correspondence theory of truth in assuming that evolutionary propensities of theories in the long run mirror propensities of the universe. The fundamental epistemological problem then turns out to be that unless the propensities of the universe are known, the correspondence theory of truth cannot be proven, and remains a metaphysical assumption similar to the assumption of the metaphysical realist that there is only one reality. In precisely that sense, the problem of induction can be resolved into a non-inductivist approach without abandoning the usage of probabilistic concepts in the evaluation of theories. Evolutionary propensities of theories (hypotheses, general terms) objectively determine the path on which knowledge grows.

Within that broad perspective, two fundamental epistemological problems remain. The first one has been pointed out by Popper (1982, p. 46 ff.), who suggested that the universe might be unique in the sense of an individual phenomenon that in principle cannot be grasped by universal laws, i.e., by theories. In that case, we would be condemned to construct new theories in a never ending sequence because (following a theorem proved by Chaitin) (cf. Kueppers, 1986, pp. 139–151) we cannot prove that the structure of the universe is unique and hence random in principle, unless a theoretical system is available which is of greater complexity than the universe. Thus, there is no way to achieve reliable knowledge other than trying to demonstrate that certain phenomena are not unique but can be covered by laws. However, we could be constantly wrong in the long run without ever being able to reach a definite conclusion. And even more fundamentally, since we cannot take the position of an outside observer who knows the propensities of the universe, we will never be able to know even the meaning (not to speak of the truth) of our own theories—that is to say, the real semantics of theories cannot be an object of thought.[53]

The first epistemological problem is related to the second in an essential manner. Why should evolution lead to the establishment of theories at all if the universe could be unique? Be the universe unique or not, the reason why this is the case lies in the positive effects of law-guided behavior on the internal stabilization of an organism. Indeed, there is a general tendency in evolution to make organisms more and more independent from disturbances coming from the environment, a tendency which persists in the conceptual realm, as especially Piagetian epistemology has shown. Formally, this can be explained by the underlying non-linear dynamics of the neural system (Barham, 1990). But this leads to the conclusion that the effects of theories on the emergence of internal order might by far dominate the selective factors resulting from the environment. This is particularly true were the universe in fact unique. The Hayekian analysis of the brain supports such a perspective, given that the gap between environment and brain cannot be bridged in principle.

But then a new epistemological problem emerges. The interaction between the brain and the world could only be analyzed, the hypothesis on the relation between both types of propensities of the universe and of theories could only be investigated more deeply, and the degree of independence of neuronal processes and the resulting concepts from the world could only be further scrutinized and the related assumptions ultimately proven or rejected, if we knew more about the working of the brain. However, as regards this, read Hayek's challenge to evolutionary epistemology:

> 8.96. A definitive co-ordination of the model of the physical world thus constructed with the picture of the phenomenal world which our senses give us would require that we should be able to complete the task of the physical sciences by an operation which is the converse of their characteristic procedure (1.21): we should have to be able to show in what manner the different parts of our model of the physical world will be classified by our mind. In other words, a complete examination of even the external world as we know it would presuppose a complete explanation of the working of our senses and of our mind. If the latter is impossible, we shall also be unable to provide a full explanation of the phenomenal world.
>
> 8.97. Such a completion of the task of science, which would place us in a position to explain in detail the manner in which our sensory picture of the external world represents relations existing between the parts of this world, would mean that this reproduction of the world would have to include a reproduction of that reproduction (or a model of the model-object relation) which would have to include a reproduction of that reproduction of that reproduction, and so on ad infinitum. The impossibility of fully explaining any picture which our mind forms of the external world therefore also means that it is impossible ever fully to explain the "phenomenal" external world. The very conception of such a completion of the task of science is a contradiction in terms. The quest of science is, therefore, by its nature a never-ending task in which every step ahead with necessity creates new problems.
>
> 8.98. Our conclusion, therefore, must be that to us mind must remain forever a realm of its own which we can know only through directly experiencing it, but which we shall never be able fully to explain or to "reduce" to something else. Even though we may know that the mental events of the kind which we experience can be produced by the same forces which operate in the rest of nature, we shall never be able to say which are the particular physical events which "correspond" to a particular mental event.

Hayek's challenge in essence drives us out of the realm of formal analysis of evolutionary epistemology and indeed into the realm of "ethics of knowledge." The human knower is Sisyphus constantly moving the rock, or Tantalus longing for water and food but never achieving his aim even in the short run. This means, in the sense of Camus (1942), that science is constantly in danger of falling into the deep trap of the existential feeling of absurdity. Belief in the progress of knowledge and the human ability to grasp reality is an ethical a priori to shelter the knower from this trap. This observation indeed is the foundation of the ontological unity of evolutionary epistemology: only an organism whose behavior is not led by a feeling of the absurdity of its existence will be able to survive and reproduce.

Notes

1. A paradigmatic study in that line of thought is Waechtershauser (1987), especially if evaluated along the lines of Bartley (1987a). Campbell (1974, pp. 145 ff.) very early advocated a further extension of evolutionary theory into the realm of lifeless matter. His example was the explanation of the formation of a snow flake. This view has been corroborated by more recent attempts to explain the origin of life, see Kueppers (1986). In that sense, even non-living material might be supposed to contain knowledge.

2. On the following, compare the extensive evaluation by Engels (1989, pp. 34–62).

3. This point is very important because the difference between the characterization of people as rational and the rationality of propositions is often dismissed. Bartley (1987b, pp. 329 ff.) therefore is right when he adopts the position that narrow logical approaches cannot conclusively lead to the rejection of pancritical rationalism. This is plausible because pancritical rationalism even believes the precepts of logic to be criticizable, see Radnitzky (1987, p. 305). However, as we shall see below, if comprehensive criticism is introduced in just that narrow field of the logic of science (cf. Popper, 1983, pp. 18 ff.), a boomerang effect becomes possible which destroys the very logical fundamentals of falsification in general and especially the correspondence theory of truth. Then, pancritical rationalism turns out to be a research program in "ethics of knowledge," see our concluding remarks.

4. The word-monster "falsificationalism" is needed to make the differentiation from the more general "fallibilism." A person may be convinced of the fallibility of all knowledge but reject the strong presupposition of the possibility of strict falsification.

5. See, e.g., expressis verbis Campbell (1987a, p. 49) or Munz (1987, pp. 375, 386).

6. The remarkable achievement of that insight becomes obvious when we realize that within global evolutionary theories the mediating role of development between genotype and phenotype only recently has returned to the center of attention, as, e.g., in Bonner (1988). Within the neo-Darwinian synthesis, development fell out of focus because of the assumption of a one-way route between genotype and phenotype, so that developmental processes were supposed to be without any effect on evolutionary changes because only predevelopmental variations of the genotype could be inherited. On the need for a general reconsideration of epigenesis within global evolutionary theory, see Burstein (1991).

7. Compare, for instance, Hayek's psychoneural holism (1963, pp. 147 ff.) with Mario Bunge's (1984, pp. 53 ff.) systemism, or Hayek's (pp.12, 163 ff.) assumption that there are no physiological differences between neurons as compared to the focus on those differences in Bunge (1984, pp. 67 ff.). Philosophically, if systemism is understood along the lines of Edelman's (1987) idea of recurrent "reentry" of neuronal impulses between different, comparatively independent subsystems of the brain, then Hayek's impossibility theorem on the progress of knowledge might no longer be valid. This point has already been made by Levinson (1982, pp. 488 ff.), starting from the differentiation between the two hemispheres of the brain. On the other hand, the issue of neurophysiological differences between neurons does not seem as important because the electrochemical mechanism of transmission of impulses is basically the same for different neurons—that is to say, for example, that chemical differences between synaptic transmitter substances are without relevance for the "meaning" of neuronal impulses (for a survey see Schmidt, 1987, pp. 20–104). As von Foerster (1987) has put this: The brain has only one language and one word, "Click-Click."

8. This is precisely the fundamental tenet of a "radical constructivist" view on the brain sciences as proposed by Roth (1990). Hayek's seems to be the neuroscience analog to the arguments of his philosophical contemporaries Ryle (1949) and Austin (1962).

9. One might contend that Hayek already took important steps into the direction of a theory of neuronal group selection because, first, he focuses on groups of more or less densely connected neurons as the material substrate for conceptual categorization, and second, he assumes that the function of a neuron or neuronal group is determined by its position in the whole neuronal structure and its more particular neighborhood, which means that he implicitly refers to what Edelman (1987, pp. 195–206) calls "population effects." Nonetheless, given the state of neurophysiological knowledge of his day, Hayek could not provide an analysis of the dynamics of selective processes. A similar argument can be made as regards the "Poincaréan," i.e., non-linear, epistemology proposed by Barham (1990). The system described by Hayek needs to be non-linear if there are population effects and interactions between whole and part.

10. However, there is a way to reconcile Hayek and Popper philosophically. Hayek's treatment of "emergence" (1963, e.g., p. 47) starts from the observation that the logical distinction between the elements of a relation and the relation proper should be drawn neatly. If a relation is object of thought, the ontological quality of its elements is completely irrelevant. Now, precisely within Hayek's conceptual framework, we must recognize that within hierarchically complex neuronal structures there is a recurrent mapping from relations of elements into elements constituting other relations, so that the ontological and the epistemological domain are densely intertwined. In principle, every relation is mapped into at least one element, so we seem to be prima facie correct to assert that there is only one ontological substrate. However, such a reduction would be formally identical to the "Ramsey-elimination" of theoretical terms denoting abstract relations in theories describing the brain. But then the implication turns out to be a Platonism because the elimination results in existential quantification over a set of abstract relations (see, in general, the evaluation in Stegmueller, 1970, pp. 400 ff.). This is precisely equivalent to a Popperian "World 3" of "objective mind." (The issue of emergence contains very difficult problems that cannot be simply resolved by any straightforward distinction between "epistemology" and "ontology." However, Husserl's phenomenology shows a way out of the dilemma, as I have tried to discuss within another context, Herrmann-Pillath, 1991a.)

11. For an elaboration on the triad of "worlds" see Popper (1972), chapters III and IV. The neuroscience equivalent has quickly been provided by Eccles (1974). For critiques similar to and more extensive than mine, see Bunge (1984, pp. 213 ff.), Kueppers (1986, pp. 165 ff.), or Levinson (1988, pp. 76–80).

12. Compare the detailed treatment of the problems by Mayr (1982, pp. 46 ff.) or Hoffman (1983). Epistemology has considerable difficulties in accepting a non-essentialist view on theories because its Cartesian tradition is very strong. The tension implied in the Cartesian approach has never been resolved—i.e., the close interaction between individualized existentialist thinking and metaphysical reasoning (cf. Rescher, 1973, pp. 331 ff.).

13. Most people hesitate to accept any straightforward equation between "theories" and "neuronal structures." The same problem arose with Dawkin's (1989) assumption of the existence of "memes" as mental and cultural equivalents of genes. Actually Delius (1989) made the proposal to look at memes as structurally stable neuronal activities.

14. On the role of "artifacts" for evolutionary epistemology see Levinson (1988), and from a more general point of view Miller (1978, pp. 33 ff., 78).

15. Hayek (1963, pp. 23, 106) expressis verbis argues that the sensory order is an interpersonal phenomenon. That approach has been further developed in Hayek (1973, pp. 8 ff., and 1979, epilogue) and can be characterized as the concept of the "rule-governed mind" where rules are conceived as culturally transmitted and therefore as not reducible to individual thought. Hayek believes that only rules provide the foundation of individual rationality and thought. Compare Morris' (1981) classical critique of behaviorism. Wittgenstein's (1980) point against the possibility of a "private language" as well as his rejection of the traditional concept of meaning is another related problem. For instance, Hayek's focus on the primacy of internal structural determinants for the brain/world interaction amounts to a rejection of the traditional view of meaning as representation, i.e., sign/object relation.

16. On the linguistic analysis of "reification" or "hypostasis," see Leisi (1975). For a Darwinian analysis see Lumsden/Wilson (1981, pp. 93, 107, 317). The problem has been discussed within Maturana's epistemological approach as well and sometimes linked to Whitehead's view on processes, see Götschl (1990).

17. See already Campbell (1974b) on "structural selectors." On the further conceptual development of the concept of internal selection, see, e.g., Wuketits (1987).

18. More exactly, heterarchies, as argued in Lumsden/Wilson (1981). On this point of my argument this distinction need not to be made.

19. I have elaborated on the respective theoretical arguments in Herrmann-Pillath (1991b). Note that such a perspective does not imply a naive version of "group selection" which actually has been advocated by Hayek, see Radnitzky (1987c). However, for the construction of more convincing versions of evolutionary theories with quite similar empirical implications, the assumption is sufficient that individual adaptive behavior within human societies is dependent on socially stored and transmitted symbolic systems, see Boyd/Richerson (1985). Of course, if this is taken for granted, global brain theories might serve again as an important element of a general evolutionary perspective on humans, as is in fact demonstrated by Edelman (1987).

20. On the crucial importance of that concept for modern Darwinian theory see Mayr (1982).

21. The only, albeit powerful, argument that could establish a probabilistic foundation for falsification is the following one: The observed single case of falsification implies that there is an infinite set of similar cases whose characteristics can be deduced logically from the characteristics of the observed case, whereas the set of similarly defined verifications needs to be finite. However, such a criterion is not helpful if both sets are infinite. This explains why Newtonian mechanics continues to be

used in certain fields of application although it has been falsified according to the tenets of critical rationalism.

22. For a more general discussion of the relation between adaptive success and the epistemological performance of theories, see Engels (1989, pp. 205–210, 314–321), who also comes to the conclusion that on mere formal grounds the problem of assessing the truth or degree of truth of theories or general knowledge needs to be distinguished from the adaptiveness of knowledge because only then the fallacy of a possible tautology of the evolutionary argument can be avoided. That means epistemology needs to provide the external standard of measurement for evolutionary theory. But then there is no contradiction between "evolutionary" and other types of epistemologies. Quite the contrary, we must decide what kind of epistemology—or more narrowly, philosophy—provides the appropriate external standard for evolutionary epistemology. Traditional philosophic problems retain their autonomy within the encompassing evolutionary framework.

23. We should note that Wittgenstein (1919) tried to analyze the same problem, but with a completely different terminology. This is especially valid for his equation of "solipsism" with "realism" (sec. 5.6.). However, Wittgenstein refrained from explaining the relation between world and mind from a dynamic perspective. In a certain sense, this static approach corresponds to the impossibility theorem on complete explanation of knowledge that has been proposed by Hayek.

24. This idea is similar to Edelman's (1987, pp. 73–104) concept of "primary repertoires" established during epigenesis. The main difference lies in the more dynamic perspective on the development of "linkages"—i.e., Edelman rejects the simplistic notion that such repertoires are directly genetically determined. However, since Hayek also assumes that such a pre- sensory experience of a species is constantly elaborated on and increasingly specified during ontogenesis, there is no contradiction in principle to a modern view.

25. Edelman (1987, p.41) calls him "homunculus." Homunculi in the brain are needed to resolve the epistemological problem, mostly along the lines of a brain/mind dualism á là Eccles and Popper. In that case the mind could be supposed to observe the brain.

26. On the subsequent argument compare Strawson (1959, ch. 1).

27. Without being able to go in details, we must realize that such a simple analysis finds its counterparts in the much more sophisticated philosophical analysis of reference in Tugendhat (1976).

28. Let me hint already briefly at the utilization of the term "tautology" in Bateson (1979) who, similarly to Hayek, tries to link the term to creative processes in the mind.

29. This is Barham's (1990) topic, cf. von Foerster (1987).

30. Of course, this is Quine's (1969) problem of a frame of reference.

31. I believe that in essence "radical constructivism" following Maturana is another possible realization of the general program of evolutionary epistemology. Unfortunately, even comprehensive overviews like Engels' (1989) only hint at the possible relationship between both approaches. There is indeed a need for an attempt to reunify diverging strands of thought.

32. We should note that Jakobson early proposed to interpret thought in terms of motoric reflects. This is not the same assumption as Vygotsky's "inner speech" because the whole motor system is supposed to be an constitutive element of thought.

33. On this point, see already the conclusive arguments put forward by Dobzhansky (1974). A comprehensive critique of a simple-minded transference of the concept of adaptation into non-generic contexts is provided by Bargatzky (1984). Of interest is a comparison to Popper's (1983, pp. 39 ff.) discussion of learning. The whole issue is closely related to the issue of "progress." Although under certain preconditions biology is able to talk about "progress" in evolution (cf. Kämpfe et al., 1985, pp. 132 ff.), the concept lacks the strong unidirectional flavor of Popper's ideas concerning growing "verisimilitude" (see, e.g. 1984, pp. 428 ff.)—see Ayala (1974).

34. On the latter point from an even more radical perspective see Levinson (1988, pp. 50–56), who argues that error is even the necessary precondition for evolutionary progress. Of relevance is also Levinson's (1982) argument on the role of preadaptation, and Rappaport's (1979) distinction between the degree of truth of cognitive maps and their actual success in terms of adaptive behavior.

35. Unfortunately, there is no space for a discussion of Husserl's (1975) classical argument against such a conclusion.

36. A formally similar argument has been proposed by the so-called "radical constructivism" following Maturana (1978)—see, e.g., Roth (1987). However, Maturana provides no explicit discussion of competing approaches in epistemology that do not argue from the angle of psychoneural monism. A kindred argument has been proposed by Bateson (1979), starting from Russell's concept of types. In principle, his argument inheres in the reference to Tarski that is made below.

37. On the first view, a coordinate system in space and time seems to be sufficient to refer to single events. But then there is the problem of how the system is to be identified in turn as a singularity—cf. Tugendhat's (1976) discussion of Strawson. Remarkably, Edelman (1987, pp. 233 ff.) presumes that the brain processes different coordinate systems without any unique point of origin. Again the mutual remapping between such systems is supposed to construct reference. (See also Figure 2 in the present article.)

38. These could be, for instance, the different coordinate systems referred to in Note 37.

39. On the elimination of singular terms see Quine (1964, pp. 36, 37) and Wittgenstein (1919, secs. 5.52 ff.). Russell's concept of definite descriptions is implicit in Hayek's approach.

40. Again, this point is related to the problem of theoretical terms and the solution by means of Ramsey-elimination. If the equation is not interpreted as a direct ontological statement that attributes existence to the general term, then only a functional solution makes sense, i.e., s = n(x). However, given the Hayekian hypothesis on the embedding of concepts in neuronal structures, we seem reasonable to regard n( ) as a theoretical term within a global brain theory. Thus we are indeed back to Ramsey's problem and of course to the implied Platonistic ontology. Within a global brain theory this would imply that the brain or a part of it is supposed to be an observer of its own neuronal processes, i.e., the assumption of the existence of a homunculus could be deduced on purely logical grounds.

41. Tarski is of immense importance for our discussion because Popper (1972) as well as Bartley (1987b) claim him for critical rationalism as the person who demonstrated the correspondence theory of truth to be valid. However, Popper (1972, chs. VIII, IX) draws epistemological conclusions from Tarski's analysis that Tarski (1944, sec. 18) himself declared inadmissible. Tarski (1935/1983) provided neither an empirical criterion for truth in the sense of the correspondence theory (which, of course is needed for a operational epistemological interpretation) nor even a specific definition of truth. He tried only to establish very general criteria to evaluate the adequacy of any concrete definition of truth—see the discussion of these distinctions in Rescher (1973, pp. 1 ff.). (Note that paradoxes of self-reference as such are no longer destructive if the correspondence theory is rejected—quite the other way round as, e.g., Bateson, 1979, has demonstrated. In the approach of Maturana and his followers, self-reference is precisely the precondition for creative processes within the semantically closed brain.

42. Popper (1984, pp. 60 ff.) avoids the problem by committing a conventionalist sin when he introduced a set of basic statements for the formulation of empirical propositions, albeit referring later to a "rolling basis." Given that he regarded basic statements as "hypotheses, nearly similar to general statements" (p. 76) one wonders why he did not bother about the problem of reference but only about the problem of truth of statements.

43. On the much more complex argument of new structuralism see Stegmueller (1973a, 1986), who also argues that the formal dependence of measurement on the theory is not a circularity in the narrow sense. This seems to be a "virtuous circle" in the sense of Vollmer (1987). Between the new structuralism and critical rationalism, there was a controversy over the question of whether the former is instrumentalism—see Radnitzky (1987a, p. 287) and Stegmueller (1986, pp. 314 ff.). As we have seen, this results from a misperception of the semantic functions of theories. Nevertheless note that unlike Popper (1983, pp. 111–131), Campbell (1987a, pp. 85 ff.) speaks of a close affinity between instrumentalism and evolutionary epistemology!

44. Another attempt to integrate Piaget into the framework of evolutionary epistemology has been made by Engels (1989). On the relationship between general evolutionary approaches and genetic epistemology see Céllerier (1987), and on the meaning of the latter for an analysis of history of science

see Garcia (1987). My approach differs from Engel's in that I focus not on the general issues of evolution but on the details of Piaget's work as related to global brain theories.

45. This is the reason why "radical constructivism" also claims Piaget as one of its precursors, see Schmidt (1987).

46. As regards the latter, there are other approaches available as well, in particular Rescher (1978).

47. Popper is not very clear on this point—see Popper (1983, pp. 25 f.) and cf. Paehler (1986, pp. 86 ff.). Critical rationalists argue that their position is a normative one but nonetheless try to prove it by examples from the history of science. Obviously this behavior does not conform to the precepts of critical rationalism because it is simply an attempt at verification. The real issue at stake is whether falsificationalism produces statements which could be falsified.

48. If a reference point for the "verisimilitude" of theories cannot be found, the relative truth of hypotheses and falsificators cannot be determined conclusively. This corresponds to Engels' (1989) analysis of the failure of the concept of progress in evolutionary epistemology.

49. On a similar view compare Quine's (1969) concept of natural types.

50. This is the reason why technology ("translating" non-perceivable into perceivable phenomena) is of utmost importance within evolutionary epistemology, as has been demonstrated conclusively by Levinson (1988).

51. By the way, the problem inheres in the traditional falsificationalist interpretation of evolutionary epistemology as well. In order to apply modus tollens one needs to assume the existence of a certain class of basic statements which plays the role of an observational language though being fallible essentially. At least in the moment of falsification, the falsificator and the antecedent conditions of the theory need to be true in the sense of classical two-valued logic. Otherwise the retransference of the falsity of the consequence onto the premises (viz. the general statement of the theory) is not possible. This precondition remains a methodological ad-hoc assumption unless the metalanguage can provide criteria that serve the purpose of judging the theory applied in the falsificator to be "more true" than the theory in question. This criterion is non-trivial for our problem because it implies the transition to a many-valued logic. However, modus tollens turns out to be inapplicable. Thus, again falsificationalism proves to be self-contradictory. The only way out would be a methodology as proposed by Rescher (1973) which tries to measure something like "relative truth" of theories but achieves this by rejecting the correspondence theory of truth in favor of the coherence theory. According to Rescher, only the end-state of science will be characterized by a two-valued logic. Note that Popper (1972, pp. 69, 336 ff.) rejects many-valued logic as a foundation of evolutionary epistemology. On the other hand, falsificationalism presupposes the construction of a measure of truth and of certain arithmetic procedures which allow the calculation of some kind of a "degree of relative truth of a falsificator." If this construction leads us to consider instances of verification of a theory, again the basic precepts of strict falsificationalism are bound to be violated. The subsequent considerations in the present article are an attempt to respond Popper's challenge (1983, p. 256).

52. To be a little bit more explicit: Consider that the set-theoretic predicate of a theory already has to be conceived as a "prototype" that by definition cannot show a range of random variations. Thus, the arguments of Section Three are valid for the problem of likelihood-analysis during measurement too, because the delimitation of the extension of the theoretical prototype is only possible if prototypic predicates for measurement (e.g., defining the mean values) are already available. Evidently, these prototypes can only be defined if the theory qua prototye is presupposed, which means that its mathematical structure (implicitly defining its intension) is a precondition of the application of the statistical hypotheses delimiting the "borders" of its extension. Thus, one assigns a range of variations to admissible values of measurement, given a mathematically exact identification of the prototype. If the functional relations underlying the latter were also "fuzzy," then the fundamental problem would result that two different statistical hypotheses on the same expected values would have to be tested by a single set of events.

53. This repeats Wittgensteins's (1919) conclusion in a dynamic setting and corresponds to the general problems of evolutionary semantics as discussed by Kueppers (1986).

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The Evolution of Expressive Culture

David G. Hays

ABSTRACT

The capacity for integration of personality and formation of character changes in cultural evolution. Mechanisms of ego defense arise with literacy, and mechanisms of reorganization arise in and after the Renaissance). Expressive culture, consisting of religions, magics, arts, and entertainments, etc., differentiate correspondingly. At present, levels of art, entertainment, and diversion can be distinguished by the demands they make on their audiences, and by their effects. Neurologically, the human problem may be to bring cortical goals, such as the need for beauty, truth, love, and justice into concordance with animal goals, such as the need for security, sustenance, sex, and sociality. The difficulty of this problem is reflected in the prevalence of perversions.

Background

> . . . their variety in animation exhilarates; you are interested without knowing how to label the emotion. . . . I think that this direct enjoyment of dancing as an activity is the central aspect of ballet style that Balanchine has rediscovered" [Denby, 1949, p. 116].

We have no call to be surprised if the philosophers, historians, and psychologists of the modern world neglect our emotional life, nor even to be much amazed by Freud's extraordinary assertion that psychoanalysis has little to say about the emotions. For indeed the central fact about the emotional life of the West is neglect, disregard, and systemic suppression.

When our remote ancestors began to experience awareness, they must quickly have realized that they had to deal with an enormous problem that originated within themselves. Their impulses to rape, murder, dominate—take what appealed from whoever possessed it—were unpredictable, uncontrollable, inexplicable, a torment to the conscious soul. And they were likewise destructive to social life. A community of such persons cannot long endure, and in community there is strength. For fifty thousand years, more or less, our ancestors have done the best they could to pull themselves together—to integrate the impulsive life of the animal with the contemplative life of the angelic higher self. To that end they have created art and entertainment, ritual and religion, philosophy, and psychology. They have also fallen, many times and in spite of their efforts, into perversions.

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