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Societal Computation and the Emergence Of Mind

Abstract

Materialism floundered trying to reduce mind to brain. A paradigm borrowed from systems theory and cognitive science, however, may account for mind using natural patterns of self-organization. This hypothesis changes the domain in which the search for mind takes place, defining it as an emergent attribute of complex social, not biological, systems. While still dependent on brain, mind can no longer be reduced to it but becomes the experience of brains in social networks 'computing' environmental flows released by cooperative actions. Human self-consciousness also appears as an effect of evolved social complexity, for, as societies learn to solve more problems cooperatively, environmental exploitation becomes more intense, societal recalibrations more frequent, and role-transforming interactions in which individuals become aware of themselves more regular.

Key words

Complexity, computation, consciousness, mind, self

Mind—thinking with others and thinking about the self—may be the most elusive phenomena science seeks to comprehend. Because mind is directly experienced by us, brain scientists, and some philosophers, assumed it is an individual attribute, a thing as personal as arms or legs. Since the later nineteenth century, they have also considered mind a material object, an organ T. H. HUXLEY thought would be explained by calculating its mechanical equivalent. More recent theorists have assumed mind must be located in some particular part of the brain where the longsought central processing unit or "papal neuron" observes and controls behavior. Failure to locate this critical module of the brain has led others to suppose mind is a consequence of the distributed nature of brain behavior (DENNETT 1991), as if naming a phenomenon explained it. All these efforts claim the mantle of science because they presuppose a materialistic explanation by identifying mind with brain and because they define mind as a consequence of the brain's evolved capacity to generate, store, and process vast amounts of information.

This paper argues that previous explanations have yet to exploit the breathtaking audacity of contemporary evolutionary paradigms and reconceptualize the problem of mind. Substituting systems for parts, structural relationships for material objects, and randomness for determinism (PRIGOGINE/STENGERS 1988), many contemporary scientists think evolution takes place through symmetry breaks in which the continuity of development is "punctuated" (ELDREDGE and GOULD 1972) and new information is created when systems selforganize. New levels of reality may thus emerge in which the relationships between components redefine their attributes. Selforganized systems depend on their pasts, but their actual forms are underdetermined by their histories. Something is present when a selforganized system emerges that was not implied by previous developments (PRIGOGINE 1984).

An emergent self-organized system, therefore, may represent a reality that can only be described using qualitatively new kinds of information. An emergent system, in other words, creates itself and must be understood in terms of the constraints, laws, and phenomena it generates. Catalyzing the phenomena and behaviors that account for their emergence (ROQUE 1985), selforganized systems exemplify the limitations inherent in traditional causal explanations. Their attributes cannot be reduced to the sums of their component parts or be described in the languages appropriate to previous evolutionary levels. Thus, attempts to locate the elusive, intangible qualities of mind by calculating incremental increases in the computational power of brains is as wrong as the scientific fear of 'dualism' now appears misguided. Rather, the new paradigm suggests mind is as real as matter but that, as some philosophers and social scientists have already suggested (CRAIK 1943; RYLE 1949; MCCLAMROCK 1995), mind is a qualitatively new reality which appeared as a consequence of a selforganized system of brains (BRICKERTON 1990; WERTSCH 1991). Bateson anticipated much of this thinking when he went beyond the argument that "the mental characteristics of the system are immanent not in the part, but in the whole" and made mind "man plus environment", the "coupling of organism, society and ecosphere" (BATESON 1972: 316, 317, 440). Roland FISCHER summarized this position succinctly by saying "the mind is not in the brain" (FISCHER 1989).

This paper construes mind as a phenomenon that emerges when nature transcends biology and a social level of reality selforganizes. Mind, it claims, is individually experienced but socially engendered, and the emergence of mind typifies the patterned processes by which nature creates information through interaction. Thus, although the emergence of mind from brain may be a symmetrybreaking discontinuity there is nothing unnatural about it, since societies are parts of a process by which once independent components join together to work collectively and dissipate energy at higher rates. Nature evolves in this manner every where, for it conforms to the Second Law of Thermodynamics. The emergence of sociology from biology is thus analogous to the emergence of biology from chemistry and physics (PEACOCKE 1984). Through selforganization the world in which brains operate is transformed, and new attributes, such as 'mind,' emerge along with the new environment.

Emergence

Obviously, materialists and atomists still find the brain the most beguiling candidate for explaining mind (CHANGEUX 1985). They try to trace an incremental process by which various brain structures developed over the millennia, supposing 'mind' is an epiphenomenon of all those components acting together. This approach suffers from at least two major limitations. First there is the classic problem confronting all conventionally DARWINIAN approaches, namely explaining how small changes in the brain with no apparent selective advantage were tolerated for millions of years until mind appeared and made them valuable. Second, there is the problem of imagining just what the environment selecting for mind was. One might add the third problem of explaining why mind is so late a discovery, not apparently discernable in the Western world until about the time of ANAXAGORAS and PLATO (SNELL 1953)—tens of thousands of years after human brains appeared.

A societal model of mind cannot, to be sure, deny the importance of brain—there would no more be mind without brains than there could be dances without dancers. But if an observer excised dancers from the dance, it would be people (or Bees) not 'dancers' that were observed—knowledge of the dance would be lost by the act of analyzing it. Mind, or 'consciousness,' is like the dance, and a social system theory suggests mind is the transmutation occurring when system selforganization embeds brains in social contexts, integrating them into cooperative networks acting upon their environments as whole systems. Mind, therefore, emerges in the process of computing information generated by and stored in interacting brains. Interaction between brains has effects comparable to observations in quantum theory: It creates information embedded in an observer (HANSON 1970). But with human brains the observed is also an observer, and embedded effects feedback through interaction to change other observers. Thus, brains which organize themselves into social systems are mutually captured and capturing, in the process of which new attributes emerge. Mind is one such attribute: It is not what brains are but what think when they observe one another.

Observations become mutual, and therefore transforming, when humans act together to sustain a network perturbed by environmental flows. Sequences of orchestrated actions that preserve the cooperative network by stabilizing the environmental flows are 'computations'. 'Computation' follows scripted sets of mutually reinforcing behaviors able to sustain a social system, for a society is the output of its own orchestrated behaviors. Uncertainty about collective out-comes is reduced by 'information,' any flow across a frontier that 'makes a difference.' Societies store information catalyzing the behaviors replicating themselves in their own structures (WICKEN 1987). Storage media may be concrete, like biological tissue, abstract, like linguistic symbols, or, intermediate, like rituals and institutions. The flow of information through the brains of the human beings constituting social systems is 'mind.' Mind, as thinking with others, is feedback from environments to social systems, and, as thinking about the Self, is feedback from social systems to individual brains.

A societal theory of mind does not try to reduce an incorporeal reality to a biological organ. That is not, of course, to say that mind is divine in either origin or essence. Rather it supposes mind appeared when evolutionary "tinkering" (JACOB 1982) made use of an available organ for purposes not implied in its earlier development. The developments constituting brain that had previously proceded in pursuit of biological agendas are not problems for a social system theory of mind, since they contributed to increase the ability of hominids to store and process information useful to individual organisms. As computational devices, brains solve problems for individual organisms. Brains process sense data by chemical flows, which are experienced as 'emotions'. Emotions are the language of organic computation (WIMMER 1995), for they stimulate physical actions preserving complex organisms using environmentally selected 'wetware'.

But brain capacities which did not develop for the purpose of inventing mind should not be expected to explain it fully. Brains developed to meet the challenges of nature, but mind transcended brain because, by the linking of brains in societies (LIEBERMAN 1991), an emergent level of reality breaking symmetry with biological evolution was created. This emergent level of reality, in turn, created a new selective environment that, in a few tens of thousands of years, changed the evolutionary rules. Since the attributes of their biological components change when social systems selforganize, people may be, as Konrad LORENZ had it, "an ephemeral link in the chain of the live and the living ... a developmental phase on the way to becoming a truly human being" (LORENZ 1987, p 283).

The consequences of social selforganization thus parallel the emergence of sexual selection in biology. Both create levels of reality characterized by information not implied in previous stages of development. Mind is not the determined consequence of the existence of brain, nor would an expert observer of asexual reproduction predict sexual selection. Yet sexual reproduction permits evolution to accelerate because organic attributes can be mixed and shifted, allowing environmental hypotheses to be tested quickly. The complexity which emerges, meanwhile, introduces new kinds of problems. Sexually reproducing organisms must discover ways to interact: They must be drawn to one another by feelings of mutual attraction.

Attraction is a new kind of information, which is partly decoupled from the environment: Beauty is in the eye of the sexual, not the environmental, beholder. Natural environments only determine which children of a union have attributes moreorless beneficial to survival after they are born. Nature selects from among the offspring of a union; sex selects from among the attributes of the possible partners. Natural selection measures efficiency in accessing resources and avoiding predators long enough to reproduce. But sexual selection may be based on environmentally dangerous criteria—love, after all, is blind. Yet attractiveness is a critical determinant in sexual reproduction, and once the latter exists the rules for its operation exist as well. In the case of fully individualized humans, LUHMANN (LUHMANN 1986) has shown how rituals, codes, and institutions were invented to articulate and direct behaviors subordinating private needs and appetites to shared interests. The emergence of mind, it will be argued, depended upon comparable protocols being established for interacting brains.

To account for the emergence of mind in human social systems, a plethora of characteristics needs to have appeared moreorless simultaneously. Taking only language, the medium permitting brains to work together, biological changes in the architecture of human mouths, tongues, and air passages were as necessary as developments in the brain. Several of these developments were as disadvantageous from the point of view of direct environmental selection as some of the attributes evolved for attracting breeding partners. But in a social level of reality where rules not determined by the natural environment operate, environmental liabilities may suddenly become valuable. Communicating brains, having, perhaps accidentally, created a social system that affected nature on a collective level, gained resources by sustaining their social systems. Thus, the rules of the game changed and the ability to communicate information through language would henceforth be socially selected. Any offspring that was even modestly better at communicating linguistically would have socially selective advantage—despite, e. g., physiological liabilities like shortness of breath. Increasing the population of linguistic communicators made the selforganization of social systems more probable, while the social systems which were more effective in correlating behavior were more competitive in the emergent environment they created.

Language binds human beings together in ways that are qualitatively different from, say, flocks or herds. Brain permits members of flocks or herds to react to what their neighbors are doing. Nevertheless, although herds and flocks solve problems individuals cannot solve for themselves, the individuals are not intentionally acting in concert with the whole. Each is responding to local events in terms of its immediate needs and according to genetically wired instructions. But language permits people to think about how local responses affect other members of human groups globally, thus increasing the amount of information being communicated and altering the kinds of information being exchanged. Linguistically communicated information no longer belongs to an aggregate of 'yous' and 'mes' the way information passed to members of a flock or herd does. Linguistically communicated information belongs to a collective produced by the correlated behaviors of an integrated 'us'.

Reasoning about collective experience, cognition cannot be exclusively located in particular brains. Linguistically communicating people actually think in one another's brains. Linguistically communicated information has a public dimension; it requires using sets of symbols whose meanings are mutually agreed upon. And it is about the reality created by correlating human behaviors that fully developed human languages speak. Thinking in terms of the rules sustaining social systems, people, said Wilhelm DILTHEY, live in a "mindeffected world" (RICKMAN 1962) where social feedbacks help individuals who understand the reasons behind one another's behaviors select between possible actions.

The origin of life as a consequence of randomly generated links between various chemical molecules also exemplifies emergence. Of course, connections between molecules are physical. They are produced by the exchange of protons or electrons when elementary particles are brought close to one another. Yet when molecules emerge the attributes of their component atoms may change quite radically (MARGULIS and SAGAN 1986). The connections between biological brains forming a society, however, are not exclusively material exchanges, and the linked brains need not be in close proximity. Physical media and biological organs are, obviously, necessary to linguistic communication. Yet the symbols exchanged communicate new kinds of information. Consequently, the structures whose selforganization symbols permit are different in kind from molecules or cells. But just as biological cells can organize through chemical interactions, linguistic exchanges permit societies to selforganize. The results, however, defy reductionistic explanation, for attributes like mind may emerge that vary from society to society because they are not determined by the biology of their parts.

Society As Computation

Current theory (KAUFFMAN 1993) suggests a critical number of brains had to be linguistically connected before a phase transition to mind took place. Coordinating activities, brains joined together into mind displayed increased cleverness, which is why societies have greater environmental impacts than do aggregates of individuals. The natural world was transformed in ways that vastly increased the flow of information, energy, and matter into social systems. Storing, replicating, and processing information about environmental resources collected over vast expanses of time and space, human societies also increased the rate at which energy is dissipated and external entropy is produced. Increased cleverness reflects the evolutionary implications of thermodynamics, for linking brains together enables the operations of mind to reduce the gradient of energy flowing through the earth's biosphere more quickly. Linguistically linked farmers, soldiers, toolmakers, and scribes process flows of such magnitude that their effects no longer only determine the survival of biological individuals. From now on intentional or accidental cooperative action could global effects by altering the environment acting on the group as a whole. Thereafter, group survival would favor selecting roles and skills which were advantageous on the basis of social criteria.

It may seem likely that such a symmetrybreak in human experience would be lost in history. But the archaeologist Denise SCHMANDT-BESSERAT thinks she has actually located it in the emergence of the earliest Middle Eastern 'cities' about 10,000 years ago (SCHMANDT-BESSERAT 1986). These 'cities' were made up almost entirely of small, round houses. These houses were gathered around single large, rectangular structures, which were probably warehouses. The phase transition occurred when populations reached about 350 people, for a population this size required considerable cooperation to correlate actions widely separated in time and space. People harvesting fields in the autumn had to know their seeds would be saved until spring, while the first specialists manufacturing tools had to know food was available for them. To ensure functional distribution, resources were centrally collected, which in turn, required keeping records. Writing emerged, about 3500 B. C., from rudimentary efforts to communicate information from fields and workbenches to warehouse and hearths.

Once writing emerged information clearly flowed independently of the individuals communicating. A network—written communication—has partly decoupled from its environment—the sedentary, urbanized society—in much the same way that sexual selection operates selfreferentially. A boundary has been created that is partly impervious to external flows. Once people found themselves living in such an environment, they learned things which they had never directly experienced. Their society was acting as a 'sixth sense', supplying information about collective experiences that are independent of sight, sound, taste, smell, and touch.

Communicating symbolically, organized societies, says Mary DOUGLAS (DOUGLAS 1986), "think" as rule-regulated changes alter relationships defining their human components in response to environmental stimuli. When, to use the Roman legend of CINCINNATUS as an example, farmers could be counted on to lay down their plows, take up their swords, and fight attackers for the common defense, linguistically based information flows were obligating biological individuals to respond to collective challenges. In situations where threats become frequent, time does not permit the same men to ritualistically transform themselves from farmers to fighters. Societies then "makeup new people" (HACKING 1985), modeling altered environmental conditions by redefining roles with specialized functions. With the emergence of specialists, societies increase the number of types of people present and become more complex.

But with specialization complex societies selforganize whole systems that take priority over individuals. Making fighting 'rational,' they invent war and convert 'warriors' into 'soldiers.' Soldiers incarnate social roles that sacrifice themselves, their immediate needs, and even their reproductive potential to the longrun goals of the collective, despite their probably having only a limited interest in a particular act of violence, for social roles constrain individuals to transcend their local biological interests in favor of collective global needs. But since social roles store information about societal environments, 'new people' mean society is a learning system, and ever more specialized skills capture information about new aspects of the social environment.

Because no two human social systems organize in exactly the same way, natural selection introduces environmental criteria eventually capable of distinguishing between different kinds and degrees of social organization. Societies would be organized according to their internally selected relationships, but variations among a population of societies would now provide an opportunity for nature to select between competing modes of social organization. Any advantage in how a society was organized could, over time, be amplified. Thus, societies with symbol systems that were marginally better at storing, communicating, and processing information between members would find their complexity evolving. Nonlinear feedbacks exciting ever greater numbers of connections between individuals and ever more effective information flows would allow them to operate in wider ranges of flows. In simple societies flows can be processed by commanding people to do specific tasks, for central authorities have time to select appropriate responses from a limited repertoire of practiced behaviors and make decisions. In complex societies solutions to unexpected problems in new environments must be improvised rapidly. Symbols that individuals can manipulate facilitate adaptation.

In other words, societies and linguistically communicated symbols coevolve. Moreover, societies which created efficient ways to communicate information correlating the behaviors of larger numbers of people over greater distances of space and longer periods of time would multiply the populations of behaviors and artifacts distinguishing them from other groups (HILLIS 1988). Social systems had emerged that defined component parts topdown, creating an internal set of relations with selective advantage environmentally. A level of reality had emerged, 'mind', where how brains act is not determined by the needs of isolated biological organisms but depends on the context of social system.

A new way to record information about this emergent level of reality was necessary, for until the emergence of human social systems matter wrote time into nature. But rituals and symbols record information in the social level of reality, and the symmetrybreaking switch from material to ritualistic and symbolic storage systems tracks the transition from biology to sociology. The new language of rituals and symbols rather than organs and genes is necessary, for the information being stored is no longer about the experiences of concrete individuals—which brains could record. The information now being stored is about the experiences of human beings acting cooperatively in an emergent level of reality.

Mapping Social Reality

Mind as an emergent system is no less real than any other, but accounting for its attributes is so difficult materialist philosophers and scientists sometimes deny its existence. Frustration arises because individual philosophers and brain scientists are parts trying to observe the system wholes to which they belong, and it is one of the cherished axioms of systems theory that, while wholes do observe their parts, parts cannot observe wholes. Moreover, individual philosophers and scientists are trying to understand with their biological brains a next hierarchical level, the level of reality created by linking brains together. Separate brains aspiring to observe their own minds—even when those brains belong to cognitive scientists and famous philosophers—are as ineffective as neurons involved in a great idea would be if they, the neurons, speculated about their activity. If wholes really are greater than the sums of their parts, explaining the highest level in terms of lower ones is the kind of reductionism systems theory was designed to avoid.

People do have sensory knowledge of the social systems in which brains are embedded. They can, for instance, be 'touched' by the long arm of the law or excited by a culturally conditioned reflex. Yet neither the law nor the reflex is material, and intangible societal realities have other remarkable attributes. Being older than their members and continuing after their deaths, societies transcend people in time. They are stronger than individuals; they know things individuals do not know; and, in solving problems individuals cannot solve for themselves, societies make decisions for their members. As PHILO pointed out nearly two thousand years ago, naming so unusual a reality is difficult, and the early poets misspoke themselves by calling society God (discussed in TOULMIN and GOODFIELD 1965). Later philosophers would call the same reality 'mind', and the argument here is that it emerges when shared concerns for longrange globallevel processes guide decisionmaking by individuals at the locallevel.

Stepping out of biological nature into the realm of society was traumatic for our ancestors because, as with other symmetrybreaking phase changes, the transition from one stage to another passed through a turbulent entropy burst. If the model offered here is right, the people who made the transition were not yet fully able to articulate the experience. They were in the very process of acquiring the attributes—language and consciousness—whose emergence they were trying to record. Describing emergent social realities led to the invention of myth, the use of natural language to provide "a technique for handling the unknown" (COOK 1980) higher level reality that breaks symmetry with communication in nature. Myth records the emergence of mind, for myth results when the languages used to link brains together attempt to describe the meanings of the information created and stored by connecting brains. Language is being asked to describe the world it creates, and only myth does that adequately.

Myth emerges from the human dialogue with itself, just as the new science emerges, in PRIGOGINE'S terms, from our dialogue with nature. Science is thus what nature knows about itself, and myth is what social systems know about themselves. In neither case is the knowledge perfect or Godlike, although modern science aspired to such cosmic objectivity. In fact, of course, scientists are part of the nature they describe, and every effort to collect knowledge creates new information (ARTIGIANI 1993). Similarly, myth describes social realities from inside, and every attempt to escape from myth and achieve perfect rationality simply adds a new hierarchical level whose meaning has yet to be determined. An ideal perspective from which to observe a social whole beyond its cloud of mythical words would miss the point of what it means to live in that society.

The ultimate meaning of myth lies not in its objective retelling by outside observers using an academic language. Myth is how people interacting with each other and, collectively, with the environment, attempt to map flows of information across the internally selected pathways of a new level of reality. Myth measures how collective action affects the environment, on the system level, and how personal choices and actions affect the collective network, on the individual level. But now the semantic loop closes, for symbolically stimulated actions pass through an environment and release the resources necessary to preserve both the lives of the human components of a social network and the behaviors defining it. Their effects upon embedded networks are what individual choices and actions mean.

A glimmer of insight into the symmetrybreaking experience creating societies is visible through some ancient myths. The Garden of Eden story in the JudeoChristian testament, as an example, tells how the first (sic!) people became aware of themselves by eating from the tree of knowledge. The tree of knowledge symbolizes the experience of new information, created by the linking of brains into a society, while the expulsion from the Garden represents the sense of permanent estrangement from nature inherent in the fact that people now lived "suspended in language" (Niels BOHR quoted in PETERSEN 1963). Moreover, it was knowledge of Good and Evil that Eve and Adam tasted, and which they did not know previously. The myth recognizes that moral knowledge, like information regarding sexual selection, is not environmental. Moral knowledge is information about how individuals are held away from the equiprobable choices and actions available in nature and constrained by value symbols, and/or police powers, to behave in ways favoring network survival. Moral knowledge must, therefore, be stored in social systems.

Choices are moral or immoral because of their systemlevel meanings. When individual actions affect other people through a network, moral information represents the relationships correlating behaviors between individuals upon which all are mutually dependent. Local individual actions which have globallevel effects transcend the limits of biology. They cannot be evaluated in terms of the pleasure or pain sensed by individuals. Nervous tissue cannot decide whether an action is good or bad. Nor can genetically inherited 'instincts' select between behaviors appropriate to different kinds of societies. Of course, individual people still compute responses through their biologically evolved emotions. Pleasure and pain help individuals learn to moderate private pleasures as they avoid physical pains by anticipating collective reactions.

But by catalyzing individually experienced emotions with moral symbols representing global priorities, cultural evolution harnesses the products of eons of biological evolution and puts them to new uses.

Societies organize behaviors processing flows in ways that preserve themselves by values, legends, and myths. Values are societal analogs to emotions: they organize behaviors by catalyzing actions. But the actions must be constrained if behaviors are to be correlated at the societal level, and legends script the roles societies value as myths moralize the relationships replicating those roles. Thus, values, legends, and myths refer to realities which are socially constructed, and which will replicate and survive only so long as biological people are effectively assimilated to systemically legitimated perceptions, roles, and relations. People are inclined to assimilate roles and replicate relationships because societies acting as wholes compute solutions to the previously experienced flows released by collective action.

Operating Systems

Through language and the morally charged symbols its reflexivity creates, people gathered into societies store, reproduce, and process information in what are sometimes called "external symbolic storage systems" or "external memory fields" (DONALD 1991). Of course, social information can be recorded materially, as well. Technologies, works of art, or written documents all store information in concrete objects. But external storage systems need not be tangible. HOMER's beautiful poems stored all sorts of information about the environment experienced by Greek societies and the behaviors appropriate to those environments. But HOMERS's poems originally existed only as songs, which were not written down until several centuries after his death. In the words of Gianbattista VICO, the eighteenth century philosopher who first discussed the possibility that mind developed historically over time and through selfgenerated experiences, HOMER's poems were "all of Greece singing". Many of these storage media have the added benefit of providing paradigmatic models for how to think (TAMBIAH 1985). But material or symbolic, none of these storage systems are biological—they are all outside the brain.

Following different paradigms which altered how a morally symbolized society can change the ways human brains compute, VICO conceived mind in evolutionary terms and appreciated coevolution. He realized, to use more contemporary images, that myth and its value symbols are the software operating societal computers. Despite their importance, however, external symbolic storage systems have no privileged form. All people may speak languages, for example, but they can speak languages as different as Chinese, Magyar, or English. This implies linguistic knowledge is not stored in hardwired brain tissue. Brains have the capacity to learn all sorts of languages, and the social setting in which children are raised will select for one rather than others through the process of "neuronal group selection" (EDELMAN 1987). But the consequence of this simple fact are of fundamental importance, for the ability of brains to adapt to various language systems suggests that how we think is a function of the language we speak (WHORF 1956). DURKHEIM (DURKHEIM 1912/54) reached similar conclusions when, as GELLNER says, he argued "concepts ... are only possible in a social context", "are essentially social", and "society endows us with them and imposes their hold over us" through religion (GELLNER 1970, p22,49).

In other words, what goes on in our individual brains is conditioned by the operating instructions of the cultural system in which they are embedded. The information stored externally, and the cultural rules for processing that information, select for the contingently generated neuronal links inside our various heads. How we end up perceiving the world and how we manipulate those perceptions is the extraphysiological network—the 'mind'—whose rules of reasoning shape the behaviors of biological brains (DOUGLAS 1975). Embedded in linguistically created, morally saturated social networks, the workings of each interacting brain are adapted to the others, which means mind cannot be identical with any brain. Rather, a whole has emerged which is, literally, greater than the sum of its parts, for the societal operating system informing cognition is a collective property redefining the attributes of the brains composing it.

Storing information about a collective environment symbolically and writing the rules for how to process it, societies which survive by computing flows through the recognizably repeatable actions of their human members are the first examples of artificial intelligence. The myths guiding human choices for computing environmental flows are analogous to algorithms. Myths compress information essential to collective survival by symbolizing it, and myths catalyze appropriate actions by directions encoded in emotionally affective 'values'. Derived, as WHITEHEAD said, from rituals (WHITEHEAD 1926/54), themselves algorithmic representations of collective experiences, myths are shorthand descriptions of, among other things, behavior. But it is no more proper to reduce a society to myths then to treat brain as a TURING machine, as GÖDEL pointed out in his famous "1951" essay. The brain, GÖDEL said, could never formulate a precise set of rules which would be able to predict what new rules the brain would write. That is why revolutionary mathematical discoveries are as surprising to practitioners of an established paradigm as rare moments of revolutionary cultural change. Any rigorously specified set of computational instructions must, inevitably, encounter questions that simply cannot be dealt with. Thus, no brain can articulate a program for describing its own operations and their results, especially when those operations and results embed the brain in a larger external world. Myth describes the reality of brain in social worlds as the experience of what cannot be fully articulated. This is all just another way of saying that, being 'wholes', societies are 'incompressible information', the shortest computable solutions to the problems of processing environmental flows released by their components.

Thinking With Others

Preserving networks by communicating meanings that orchestrate individual propensities to process flows in repeatable patterns is how a society preserves itself. Success in practice, of course, reinforces collective commitments to mythical instructions, binding people to behaviors, relationships, and social roles through emotive values. Mythically moralized solutions equate algorithmic behavioral guides with "rightness", "righteousness" (COHN 1993), or, eventually, orthodox "straightthinking" (PAGELS 1979). But there is no way for the creators of social myths to predict what human and environmental resources will be available in the future. Thus, societies that attempt to specify exactly what roles, relations, and organized behaviors will be used in every circumstance will lose selective advantage in competition with more flexibly organized societies. In fact, by using symbol systems that partly decouple the society represented from nature, algorithmic limits show successful civilizations respect the need to occasionally improvise. Individual human brains are not rigidly controlled by myths but constrained by the logic of their operating systems—'mind'—to perceive and react within a range of propensities preserving order but permitting initiative.

If how we think, i. e., use our biological brains, partly depends on the external symbolic storage system in which we are embedded, then changes in the symbol system will change how we think. It is not, therefore, surprising that changes in our cognitive capacities have appeared without concomitant changes in biology. The brain does not have to change to stop thinking mythopoetically and start thinking scientifically, or to move from the frozen images of EUCLIDEAN geometry to the fluxions of NEWTONIAN calculus. There are no differences between the brains of prehistoric and postmodern humans, or between ancient Greeks and seventeenth century Englishmen. What has changed are the kinds of symbols used to record information and the rules for manipulating those symbols.

But changes in the networks determining how people think can lead to drastic changes in what is thought about and the conclusions reached. Moreover, some symbols—e. g., NEWTON's "mass"—can apply to a broader range of phenomena than others, e. g., a culturally specific 'ArchitectureGod'. The ability to map multiple environments increases the rate at which societies produce external entropy or reduce gradients, and societies mapped by scientific symbols will be able to do the work necessary to think themselves through more perturbations and access more resources. So the transformation of symbols used to prescribe behaviors tracks the evolution of social complexity.

Because symmetrybreaking changes in how people think and act violate the values emotionally binding agents to proven behaviors, they are painful to accomplish even though the connections linking brains are less crystalline than the forces binding atoms in molecules. It is easier, nevertheless, to change culture than biology. Despite the inherent conservatism of social systems, words are cheaper than genes. It takes less time to propose a new symbolic representation and test it selectively against its social environment than to produce a new organism, nurture and protect it, and then loose it on the world to measure how fit the organism is by counting its offspring. An argument can be explored and dismissed relatively quickly, while replacing a biological mistake can take years.

Rapid changes in thought patterns produced by radically altering the symbolic webs relating brains together are rare, and LAMARCKIAN factors are not necessary to explain cultural evolution. There is a LAMARCKIAN element present when children acquire skills from their parents, of course. But usually children born into a culture only learn how to carry out established tasks marginally better than previous generations. They learn from their parents how to think, or act, more efficiently within the confines of a socially selected symbol system. This may be important, but it is development, not evolution, for learning to improve how things are done merely unpacks the implications buried in a set of symbols, to which system stability has wedded a community. By contrast, cultural evolution means doing new things. Cultural evolution occurs with the emergence of new external symbolic storage systems or memory fields.

Societal systems can evolve because collective actions are guided by symbolic representations and no map is its territory. The looseness of fit between representation and reality makes mythical maps, like scientific laws for EINSTEIN, "free creations of the human mind": They are never determined by the realities they represent. In fact, there is a double ambiguity about social systems, which is another reason why society can evolve relatively fast. In societies not only are symbolic systems partly decoupled from the structural realities they represent, societies themselves are partly decoupled from the natural realities they model. Symbols are the language mapping social systems, while social roles and behaviors are the language modeling nature. As with any other translation, information is lost moving from nature to social systems and from social systems to mythical symbols. Symbol systems supervene on societies, just as social roles and relationships supervene on environmental states.

Consequently, although human "society is the most complex of all living systems on earth" (LORENZ 1977,p 245), external symbolic storage systems remain subject to GODELEAN limits: no mythic representation can perfectly predict the consequences of all collective actions or completely account for its own existence. Cultural operating systems, as systems, are bounded: their rules and symbols map learned experiences and familiar environments. Without being contradictory they cannot represent all possible realities or program all possible reactions. Thus, a social system may encounter environmental energy, matter or information flows it cannot process using established behaviors and roles. Alternatively, attempting to unpack every possibility implied by its symbol system may lead a society to fluctuate itself by embracing behaviors contradicting its axiomatic norms. Thus, perturbations or fluctuations of social systems may destabilize them and lead to their demise or evolution.

Ambiguity permits computational errors to occur, when some symbol is mistakenly equated with an inappropriate environmental element, for instance, or when the internal logic of a mythical symbology 'runs away' from its grounding in reality. Errors, in turn, mean that breakdowns in the collective processing of flows may occur, and the system as a whole will thereby be 'fluctuated'. With fluctuations, a system can be open to new or unexpected flows, which will destabilize it. Yet all systems are teleonomic—they aspire to survive. Destabilization thus turns out to be advantageous, for with it a system's capacity to keep out 'noise', or unprocessable environmental flows, is momentarily lost. Acting to regain stability, a system at this kind of bifurcation point may do more than unpack its ancestral wisdom and become better skilled at performing its old tricks. At instabilities systems can turn noise into information (ATLAN 1974), learn new tricks, and become more complex because they have recorded in new social roles information about processing flows from a greater number of environmental states.

This is why complexity rather than fitness evolves. Tending toward the maximization of universal entropy, social realities constantly probe nature for more efficient ways to dissipate energy. New kinds of social systems emerge when roles are altered and old moral relationships abandoned because cooperating people have had to compute new solutions to the flows of environmental energy, matter, and information across social boundaries. Of course, societies always oscillate between accessible states, even during dynamically stable periods. This is the thermodynamic dimension of societal computation, for each oscillation bounces and jiggles its members in a programmed dance degrading energy flows. Any change in the dance that models new circumstances, however, alters the relationships defining the dancers, attributing to people characteristics, like 'mind', that no longer have exact biological references. Mind is the brain-in-context, the feedback communicating brain's environmental effects. But human consciousness is more than the interaction of a biological individual and the material world, and the especially rich, qualitatively unique attributes of human consciousness follow from the fact that the environment contextualizing our brains is a human society.

Self-Consciousness

Mind as 'consciousness' or thinking with others follows from nesting a cooperating network of linked brains in environmental flows. According to David

BOHM (BOHM 1994), it thus becomes impossible to distinguish what is usually considered 'my thought' from information being exchanged socially. Individuals, he says, might best be regarded as points where information is recorded or experienced. But if thinking with others can be accounted for as a function of societal computation, to approximate completeness the other obdurately obscure aspect of mind, the sense of Self, should also be theoretically derivable. Selfconsciousness seems especially susceptible to a reductionist analysis based on brain (JAYNES 1977), but the logic of a model based on evolving social complexity can show selfconsciousness is related to interactions generated by symbolically linking brains collectively computing flows. The Self which mysteriously looks in at itself and out at its world becomes a relationship, the context of a human brain entangled in social feedbacks. The ground work was laid by the psychologist Karl PRIBRAM (PRIBRAM 1976) and the anthropologist Victor TURNER (TURNER 1986).

PRIBRAM points out that people become selfaware transitioning between states. In simple societies, TURNER showed, transitions are relatively rare, and ritual makes them almost seamless. A society moving from peaceful to conflictual relations with a neighbor, for instance, thinks its members from one state to another through the ritual medium of the war dance. Regular, rhythmic movements repeated over and over again, said Joseph CAMPBELL (CAMPBELL 1983), induce an ecstatic state from which participants emerge with a new identity appropriate to whatever collective challenge is being faced. Archaic societies communicating by ritual can compute solutions to only a restricted number of flows, and it is not difficult to imagine the several rituals suitable for transitioning regularly from one such state to another.

But complex societies are embedded in environments so dynamic that the societies constantly change from state to state, and there are no established rituals by which to smooth transitions of their human members from one identity to another. They survive in dynamical states because they have compressed symbols to such abstract forms they can be meaningful in an immense range of circumstances. Thus individual initiatives can be freed to seek new resources and cooperative behaviors orchestrated to process them. To facilitate initiative, the brains of biological individuals learn to process information according to shared programs that are collectively determined. Because each brain uses the same program, and each member of the society perceives and reacts to information similarly, social complexity links brains into massively parallel computers. Adapting spontaneously to unpredictable surprises, complex societies survive at "the edge of chaos" (LANGTON 1990), where the ability to continue evolving is preserved. Since every individual brain can thus tell itself what to do, self-consciousness appears as a somewhat ironic consequence of increased social complexity.

The price of collective survival at the edge of chaos is increased ambiguity in the match between symbolic representations and individual choices and actions in specific circumstances. Since no one can predict with certainty which choices will be rewarded, societies constantly monitor the behavior of their human parts as the relationships defining the identities of their human components change. Complex societies continuously observe, correct, and reward the ways individuals perceive, react to, and communicate information in order to ensure the cooperative behavior needed to process vastly increased information flows. Although selfconsciousness seems to be an entirely private, personal, and internally experienced, frequent shifts in defining relationships combined with regular scrutiny from the collective system means individuals in complex societies are made aware of themselves often as they make frequent transitions between roles. Topdown social actions create self-awareness by embedding societal members in the apparatus of collective feedbacks.

If selfawareness is a social construction, there is no Self inside the brain making observations. Although the brain must be developed enough to model the Self, it now seems likely that the human mind acquires its sense of Self as a function of the webs of relationship defining members of complex social systems (ARTIGIANI 1995). Rather than being an observer found inside the brain, the Self is 'semiotic'. It stores information about what the actions of an interdependent member of a social system mean in terms of other members' survival. The Self is an interface between individuals and social systems, exchanging information between levels of reality. Mutually interpreting individual and society, the Self is the 'difference' between biological organisms and the social roles (MEAD 1934/62) played in the process of societal computation. Permitting biological individuals to choose locally in terms of what is likely to be selected globally, the Self measures an individual's social effectiveness as an internalized moral identity.

The Self seems permanent and spiritual, for the consequences of its actions may affect future generations and it maps social relations rather than biological organisms. Yet the Self is neither permanent nor spiritual in a conventional sense. It is the 'meaning' being registered at a nodal point where social processes interact, and as different societal computations are successively carried out, the attributes of Self change. To anticipate (ROSEN 1985) future states, individual members of complex societies use models of themselves. The model is reified as 'the Self', because it is a vital part of decisionmaking processes. But such models are not purely internal in origin. They include information about the individuals doing the modeling, of course. But because these models incorporate information about previous global reactions, they necessarily transcend the modeler. Thus, if we try to locate the Self by isolating it, the Self excised out of the network dissolves like dancers cut out of a dance. A function of transitions from one state to another, the Self cannot be tied to the individual experiencing it or frozen in a fixed form. Becoming by definition, the Self is no "Ding an sich" but is disconcertingly mercurial.

The language used to record complex social interactions, however, creates the illusion of a fixed identity. Linguistic descriptions capture moments in time and are recorded in individual brains. But language records what is shared with others and influenced by the collectively owned operating program. So a linguistic description of who we are is really not personal or private, yet to be aware that we are aware requires linguistic description. To be aware that we are aware, people must be able to talk about themselves, and public linguistic communication records how the actions chosen by members of societies are interpreted collectively.

The Self appeared in antiquity, when moral judgments were used to influence behavior in Egypt and Babylon. In the Middle East, moral judgments were expressed in condemnations of people who victimized the poor and weak, widowed and orphaned, old and sick. These complaints were pleas for social justice. But social justice did not mean 'equality'. The ancients condemned people who failed to act 'rightly', which were actions in accord with the rules operating societal networks. But systemic rules discriminate; they cannot treat everyone equally and define distinguishable entities simultaneously. For there to be a social system it must be possible for roles and relations to distinguish people from nature and members of other systems. A rulebased social system, unavoidably, injures some and favors others.

Thus, condemning injustice in antiquity did not mean condemning hierarchy or variations in power and wealth. Rather, morality denounced persons who took excessive private advantage of public positions, who used privileged social roles to egregiously leverage personal, biological benefits. These behaviors were identified as 'bad' because they distorted flows between members of societies and destabilized systems. Since, as VICO and NIETZSCHE have both noted, the poor and weak could not force compliance with rules based on the good of the whole, moral identities were systemically useful because they encouraged individuals to police themselves. In the process people became aware of an 'alter ego', an intangible presence accompanying them through life.

Because this judgmental spiritual presence was unsettling, religion inspired the ancients to perform social roles so well the individual merged with them and selfawareness evaporated. But few indeed were the righteous whose social roles supervened perfectly on their biological identities, so, as with the myths and genes mapping societies and organisms, ambiguity made errors possible. Some errors, i. e., variant ways of behaving which altered flows of exchanged resources, proved more efficient than others, and through them social complexity evolved. In ever more complex societies, where roles and relations constantly shift, identity can no longer be equated with enduring insignia, like rank, status, or property, all of which may change unexpectedly. But a moral identity separable from the organism and its accoutrements endures, even in a process obliging individuals to navigate transitions constantly. Selfawareness proves valuable, since a Self modeling a person's relations with the world permits outcomes to be projected even when roles are new. But to project such outcomes individuals categorize (MAUSS 1934/85) themselves as conscious agents, choosing and acting in full awareness.

The Self became inescapable in complex societies, because, as multiple environments are modeled, societies recalibrate rapidly, roles change constantly, and a sense of selfawareness is recorded almost continuously. The social roles acquired as members of social systems, like the characteristics of components in complex chemical reactions, are not replicated by individual biological organisms. Social roles are replicated in autocatalytic processes distributed throughout social systems acting as wholes. Social roles are what result from the systemlevel processing of information generated by collective action. Thus as societies compute information from dynamic environments, the roles we play and the measures of our successes—the meanings of our lives—are determined elsewhere in the system. We should not be misled into believing either that a Self can be understood materialistically or that, as individuals, we make ourselves out of whole cloth.

Of course, most of us say we feel good or bad, happy or unhappy, because of what we are thinking, internally, about ourselves. We resent being thought of as cultural artifacts, as shifting, ethereal clouds of meaning entangled in other people's observations. But that very sensation, which seems so obviously internal in origin, may be a clue to the external origins of the self. For to feel anything, we must have an informational input; there must be a flow across the boundary of our person that changes our identity. If that flow is from the society, the web of symbolic knowledge and communication which affects how we perceive and think about the external world, then once again 'mind' becomes the cascade of interconnected relations that trigger mutual definition in all the selves constituting a social whole. That is, if who we are reflects what others think, similarly what they think depends on how our actions have affected their social positions. This is why, ironic though it may seem, self-awareness appears to be a consequence of increased social complexity. The Greeks, it seems, were right to delay judging whether a person's life had been happy until its end.

Toward The Postmodern Mind

Seeing the Self as a semiotic construct, a locus of meaning contextualized by external inputs and processing rules, makes sense of several otherwise annoying problems. We no longer, for instance, have to determine who is observing what when selfawareness is experienced. It would be obvious that the issue is unresolvable, for a semiotic Self is part of a system being observed from the inside. Chasing the elusive 'I' watching us now appears an infinite regress in which every answer given to the question "who am I?" must, in principle, create a new 'I', which has yet to be observed. As consequences of continuous interactions, Selves oscillate maddeningly, appearing one moment as a biological individual reflected in a societal mirror and the next as a societal effect projected by an individual.

On the other hand, certain aspects of consciousness can be dealt with more straightforwardly by considering it our experience of social systems operating through and around us. For instance, the sense that we are healthy and solid, which the Egyptians called Ptah, the god of right relationships with the ancestors, would now be a consequence of having aligned ourselves with the collective view of what is expected. We would feel good about ourselves because environmental information—i. e., the reactions observed in the people around us—indicates we have played our social role correctly. When how we were acting is how we had learned to expect the society wanted us to act, inputs carry minimum information. Since inputs are confirming expectations, uncertainty reduces to a minimum and fear that painful transitions were likely in the immediate future virtually disappears. Cruising behavioral space is as unconscious as driving familiar streets. Such stable identities are increasingly rare.

The objection that moral autonomy is merely an illusion when individual humans are socially contextualized could also be dismissed, for the interpretation offered here actually claims the contextualizing role of societies creates the opportunity for moral autonomy. To be moral agents persons must be both selfconscious and free to chose between distinguishable alternatives. Selfconsciousness follows from freely choosing, which is only possible in constrained social situations where acts are morally meaningful because they have distinguishable structural consequences affecting the survival of others. In the absence of societal constraints whose symbol systems provide the criteria for evaluating choices in terms of their systemlevel effects, freedom is meaningless because every choice is equally probable and every consequence equally indistinguishable. Thus, our sense of Self and our moral significance are real, socially created information, and human beings are conceded to be the only known natural phenomenon to be moral agents. Feedback from collectively generated contexts links individuals together and produces selfawareness. Mind and autonomy are evolved attributes of the selforganization of complex societies with no ontological equivalent in material nature.

Once people begin to adjust their choices in terms of meaning (BRUNER 1990), the moral symbols which sanction collectively desirable relations and condemn collectively dangerous ones become the rules for individual calculations. The moral symbols valuing meaningfully variant outcomes between which individuals choose are collectively held representations of the rules of societal computation. Thus the fact that we are free, that our actions matter, and that we are morally aware depends on the existence of a biologically transcending symbolic reality operating our decisionmaking processes.

Recalling that the selfconscious awareness typical of modern personalities is not found in earlier, less complex societies (TAYLOR 1989) makes a societal account of mind more plausible. The heightened sense of selfawareness typical of moderns also exemplifies the tendency of evolving systems to differentiate their component parts (BUSS 1987). Yet because roles constantly change in complex societies, selfawareness heightens, producing a haunting dread that the Self of which we are aware has no 'real', dependable foundations. For generations, humanists have lamented this 'loss of the self' and the disappearance of innerdirected people who knew who they were and protected their identity. They laud the Western 'Self' of glorious memory, which emerged in modern times inspired by religion, anchored in private property, and protected by constitutional politics. The Western categorization of Self inspired independence, selfreliance, and creativity. It provided a technique for preserving who the person was while permitting change in what the society did: An entrepreneur competed vigorously, calculated shrewdly, amassed capital, and honored contracts whether he manufactured books, steam engines, or artillery shells.

But any evolved attribute must be selected—and moral attributes are, so the argument here contends, socially selected. Thus, the modern Self survived because, as a moral identity, it was useful to 'Western' societies, which were, in turn, being environmentally selected. Reading the collective environment at the fine level of an individuated consciousness, the modern Self advantaged more complex societies at the expense of more traditional, communal ones. Individualized agents located new opportunities, and social evolution accelerated. The modern individuated Self emerged in the structure of complex social systems because, vulnerable to perturbations, complex societies are unstable. To survive they must be able to explore their environments in detail and respond to problems quickly. Selfconscious, morally autonomous individuals are effective tools in the quest for societal stability. But in our secular, information-based global economy individuals are cut off from their religiously identifying and economically reinforcing roots. In any case, living in and depending upon networks that are constantly changing, the meaningful consequences of individual actions may now be so vast that the stress of decisionmaking exceeds the limits of our biological endurance.

Individuals forced to frequently abandon familiar roles and launch themselves into unpredictable futures hunger for a calmer, more stable style of life. But no matter how admirable, oldfashioned identities or rocksolid personalities that endure in time and space will be quickly left behind by changing circumstances. If people look to the past and condemn themselves for not sustaining identities like their modern ancestors, however, they will be prone to despair—and an initiativeinhibiting loss of self-esteem. Thus, knowing who we are in any ultimate, final sense is a luxury postmodern societies cannot afford. As postmodern people leave outmoded networks and enter into new ones with unknown possibilities, they must be many things in the course of even a single day. So there must be a way to redefine ourselves as parts of evolving social processes. Postmodern people may have to reconceptualize themselves not as permanent atoms with fixed attributes but as nodes in networks where attributes vary with transient circumstances. Deprived of a moral identity to which they could proudly cling regardless of conditions, postmodern people may have to rest content with a set of rules for redefining themselves as circumstances change. This seems unrealistically hopeful, for it requires living dangerously and embracing symbols of unrivaled fluidity and abstraction.

But the way evolution works suggests mapping ourselves and our world with new symbols is not impossible—the increase in social complexity can be measured by the increasing abstraction of the symbols used to map social environments, after all. Just as legends gave way to myths and myths to science as social complexity increased, process symbols could replace the idealized atoms, frozen boundary conditions, and mechanical forces of the more recent past. In that case, learning to think of ourselves in terms of the shared programs already operating contemporary societal information processors will provide selective advantage.

Symbolizing nature, society, and Self in terms of adaptive processes provides advantages that operate both in our societies and on them. Societies that cultivated members whose flexible identities made them willing to change social roles would increase their collective adaptability. It is, therefore, just possible that we may learn to make a virtue of necessity, because mind will instruct our individual brains to mirror the image of nature reflected by postmodern societies and favor socially advantageous modes of thinking. This is not blindly optimistic, since the Second Law of Thermodynamics, on which so much of this argument rests, favors increased social complexity, not human happiness. Hopefully, the interpretation advanced here will encourage a systematized research program into the social ethology of mind leading to strategies which make collective survival personally satisficing.

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Evolutionary Epistemology as a Self-Referential Research Program of Natural Science

Abstract

Donald T. CAMPBELL (1974) used the term "Evolutionary Epistemology" mainly for POPPER's view. Moreover, in the historical part of his essay, he showed that the notion of extending biological evolution to the phenomenon of human knowledge has been a recurring heresy since DARWIN (EVANS 1977, 82; MARKL 1987, 41). He found no fewer than 22 philosophers and 18 biologists, physicists and psychologists who felt that the a priori forms and categories of perception and of knowledge might be the product of biological development. Since then their number has grown considerably. While then the notion was so ignored that those who held it seldom knew of each other, today it is widely propagated and criticized, sometimes in spectacular manner. By now there are not only several detailed accounts of this theory, but also some collections, mostly based on interdisciplinary symposia or conferences and concerned both with the foundations and the claims of the subject (LORENZ, WUKETITS 1983; RIEDL, BONET 1987; RIEDL, WUKETITS 1987; LÜTTERFELDS 1987).

The double meaning of the term "Evolutionary Epistemology"

What makes the discussion more difficult is the fact that from the start the expression denotes two different research programs, about whose links and differences opinions differ. When the term was translated into German, at the latest in the German edition of POPPER's "Objective Knowledge" 1973, this double meaning had to be grasped from the start (cf. OESER 1984, p. 80). On the one hand it means a biological theory that regards man's cognitive capacities as a product of genetic organic evolution. As such the theory is a "satellite" (H. MOHR) of biological evolutionary theory, wholly dependent on its acceptance and reliability. Still, it can rightly be taken as epistemology proper because it is concerned not only with the genetic make up of the subject, but also explicitly explains the a priori conditions of knowledge , taken as phylogenetically a posteriori. As CAMPBELL has shown, this view was shared by many philosophers and biologists, and indeed held by DARWIN himself. For he assumes that all animals have knowledge without experience, and perhaps man as well (DARWIN, Old and Useless Notes 33, in GRUBER /BARRET 1974 p. 401). That is why he is convinced too that one who understands apes has done more for philosophy than LOCKE (cf. ib p. 281). It was the ethological research of Konrad LORENZ (1941) that gave systematic foundation for this view.

On the other hand the expression EE denotes also any attempts that seek to describe and explain the development of science, including its dynamics, or more narrowly the dynamics of theories, in structural analogy to biological evolution. The main advocates of such Evolutionary Epistemology, which had better be called evolutionary theory of science (cf. OESER 1984, 1987) are S. TOULMIN (1963,1982) and Karl POPPER (1972). My own "Wissenschaft und Information" (1976), with the subtitle "Systematic foundations of a theory of the development of science", belongs to this kind of evolutionary theory of science, though ist does not rest on POPPER and TOULMIN but on the older concepts of MACH and BOLTZMANN.

Although the two forms of Evolutionary Epistemology arose independently, they have direct links from the outset.

Thus POPPER (1972) relies on Lorenz in introducing the method of "trial and elimination of error" into theory of science, calling it a kind of "biology of knowledge", making the famous comparison between an amoeba and EINSTEIN: both obey a mechanism that presupposes a programming based on information acquired phylogenetically (LORENZ 1966, cited by POPPER 1973). This amounts to basic agreement of cognitive equipment in all living beings, from the simplest to the most highly organized in this respect; this view goes far beyond mere analogy. Independently of this, a proposal by TOULMIN

(1982) brings his only metaphoric theory of a evolution of science (1963) closer to the model of a homologous mechanism of life and cognition. He proposes that we should not adopt the basic mechanism of mutation and selection unaltered as basic mechanism for cognition, but emphasize the essential difference between the two, namely that mutation and selection are usually independent in genetic organic evolution, while in the evolution of scientific knowledge they grow increasingly interlinked.

LORENZ originally called his reflections "phylogenetic epistemology" (in the "Russian manuscript" lately rediscovered in Altenberg and now published). Much later (1985, 1987) he accepted for this the German translation of the English expression "Evolutionary Epistemology". By then there were several independent accounts of this (VOLLMER 1975, RIEDL 1980) which refer to LORENZ, though they clearly differ from his "phylogenetic epistemology" both in origin and claims. LORENZ himself was not only aware of these accounts but also spoke of a "fairly simultaneous" discovery and conceptualisation (1985, p. 13), rejecting any claim to priority (he was highly conciliatory).

The two-tiered concept of Evolutionary Epistemology (EE)

While not only critics (e.g. E.M. ENGELS [1990]), but also some advocates of EE (e.g. G. VOLLMER [1987]), distinguish these research programs and even sharply sever them, so that the concept "EE" is to be used exclusively for biological epistemology, and the wider field is to be called "evolutionary theory of science", my view always was that calling a scientific analysis of human cognitive competence "EE" is appropriate only if the result can be used for a self-justification if scientific methodology. This produces a two-tiered concept (OESER 1987, 1988) in which EE, studies the phylogenetic prerequisites for human cognition, while EE2 as a meta-theory looks back at the historical and cultural results of human scientific achievements in a regressive structure of argumentation. For both areas we postulate a single mechanism (not just analogous but homologous) rooted in one common origin. That was LORENZ's basic intention too, as we now see from the Russian manuscript.

This may be called "epistemological completeness of science", in analogy to the "epistemological completeness of mathematics" in HILBERT's formalism. Thus science can develop its epistemological bases internally, not adopting any external principles from other fields. If such a form of naturalized epistemology (QUINE 1971), deducing the a priori conditions for possible experience from the history of the subject as a biological species, is still a philosophy, it is one that could be developed only within the framework of natural science. This requires only one initial 'ontological' tenet, so simple that it can hardly be denied. In LORENZ's words, the philosophy must regard as really existent, what science tries to discern (1992, p. 122). In general this means acceptance of a empirically cognizable real world as such and that the subject is not just a transcendental construct (KANT) or the boundary of the world (WITTGENSTEIN), but a concrete physical being that is part of this world that can therefore be itself examined by means of scientific procedures.

What this denies is not that we can have a philosophical or pure epistemology of the kind KANT tried to formulate, but only a epistemological purism that amounts to a deliberate 'waiver of knowledge', namely of biological results that are not only relevant for any philosophic epistemology, but also act as a criterion for decision in the welter of philosophical—epistemological systems. Why? Not because one insists on putting scientific insights before or above philosophy, but because of the classical philosophic thesis that denies a double truth. Even if we assume that scientific knowledge is always hypothetical and liable to revision, it maintains its role as checking and supporting the various and sometimes mutually contradictory philosophic orientations. For what must count as 'true' for science must be 'true' for philosophy too. At all events this is so for an epistemology that is to yield the basis for scientific procedure. This epistemology must—in a self-referential way—contain the results of natural science.

Biological evolutionary theory as basis of EE

That is to say, beyond the first formal, non-verifiable and non-falsifiable top hypothesis that the object of natural science must be seen as existent, we must accept that evolution is an empirical fact. Only if man himself as the species homo sapiens with all his cognitive capacities is the result of a natural process of development, can we justify a 'natural science of man' going beyond mere examination of bodily structure and function. This also includes, that we cannot accept biological evolution and reject evolutionary epistemology in principle. Conversely, if the theory of biological evolution were to be falsified, EE would be falsified too. Before we can justify this crossing of the domain of science, implicit in any biological theory of cognition, we must be clear on the status of biological theory of evolution within theory of science.

To start with, evolutionary theory is the explanation of an empirical fact. That living beings have evolved and go on doing so is not a conjecture but a solid and undeniable fact, shown by countless fossil finds and by many observations of changes of extant species, and in cases where generations are short-lived, even beyond specific boundaries. The whole practice of breeding, since neolithic times the material basis of civilization, simply is man-made intraspecific and intrageneric 'micro-evolution'. Likewise, 'macro-evolution', changes of fauna and flora during the Earth's history, has led to comprehensive changes in phyla, classes and orders, and is as certain for the paleontologist as the stages of development of individual organisms to the embryologist. That animals are related, their greater or lesser resemblance and the sequence of fossils are not conjectures as in DARWIN's time, but, in the light of current morphology and paleontology, empirical facts no longer doubted by any serious expert.

When it comes to explanatory claims of an evolutionary theory that goes beyond mere description or historical reconstruction, the case is harder. For this involves a very complex theory consisting of several parts largely developed in mutual isolation (theory of common ancestry, theory of changes of species,theory of causes of change) and now covering several types of explanation at variable levels of analysis (from morphology/anatomy to population genetics to molecular biology). Such a wide-ranging theory naturally still harbors differences and disagreements, e.g. about the unit of selection (gene or individual) and the way evolution runs (continuously or in steps). None of this counts as an obstacle to accepting biological evolution in general, for there is no scientifically based alternative. Failing unattainable ideals of absolute certainty, the scientific status of biological evolution has been decided: there are countless individual findings from all over biology and not a single one to contradict it (MOHR 1983).

What about extensions of biological theory of evolution up and down? The origin of life and the development of the human spirit from earlier animal forms are no longer, as DARWIN thought, hopeless questions with answers in the distant future. Thus Manfred EIGEN spoke of "molecular evolution", by directly referring to another dictum of DARWIN's that is often cited, that the principle of life will one day turn out to be a part or consequence of a general law (letter to Nathaniel WALLICH, 1981; cf. M. EIGEN 1982). Much earlier people have spoken of 'cosmic' and 'chemical' evolution, at least in analogy to biological evolution.

Today cosmic evolution is almost generally accepted as a historical fact directly shown by empirical evidence such as black background radiation or directly observed sharp decline of the frequency of galaxies at distances of 11-15 $x10^9$ light-years. For the absence of galaxies there is not due to failure of our radio-telescopes, but to the fact that the further we look into space the further we look into the past. If at a certain range in space-time we find no galaxies or quasars, the reason is that at that time of evolving universe they did not yet exist.

To prevent a widespread misunderstanding, we must here point out that to recognize a cosmic and molecular or pre-biotic evolution does not mean recognition of a universal theory of evolution that pulps all reality into an undifferentiated mass. From the outset of turning the evolutionary idea into a general concept it was clear, that this was a process with distinct phases or steps, which have exfoliated, but are not reducible to each other. As Julian HUXLEY put it, the universal theory of evolution proposes a mechanism that in developing itself not only links the phases of a universal process but also severs them, by assigning their own products and speeds of development to each. In this sense evolutionary mechanisms, too, evolve.

Access via comparative ethology

To attain an EE we must therefore proceed via an evolutionary ethology, the comparative study of behavior which assumes that the behavior of living beings, particularly their cognitive behavior or mechanisms, are species specific marks whose similarities rest on kinship. LORENZ, the founder of this biological discipline, holds that comparative ethology is not only animal psychology, although it deals mainly with animals, but in principle has man as its object. Without knowledge about pre-human beings, one cannot understand man. The path for understanding him goes via understanding animals, just as his rise doubtless ran via theirs (LORENZ 1992, 17). Logically EE then postulates, that cognitive capacities of humans can be understood by analyzing the phylogenetic links in terms of similarity and dissimilarity between extant animals. Our dissimilarity in cognitive capacities explains and justifies our special position, as LORENZ has stressed, though he has been misunderstood. Humans unique position, in terms of his cognitive competences , is a fact based on paleontological finds via ethology, indicating an evolutionary change of course: for it was not optimization of sensory perceptive processing that determined the evolution of hominids, but a better central processing system.

The second tire of EE starts from the special position of homo sapiens, and so lets scientific method justify itself. For scientific knowledge is based on the assumption of a very definite relation between the external world and the way it appears to the cognising subject, without which any research would be simply senseless. That is why phylogenetic epistemology was soon approved by very different scientists, such as PLANCK and HEISENBERG (physicists), REIN (physiologist), KÜHN (biologist), WEIZSÄCKER (psychiatrist) and others (cf. LORENZ 1922, p. 23).

EE applied self-referentially to knowledge in natural science not only explains and justifies the fact that our forms of intuition and mental categories are adapted to the world of medium dimensions accessible to our direct sense experience (by linking its truth content with survival value), but also makes KANT's a priori relative. They are not intangible and absolutely necessary conditions of all experience, but (as MACH saw earlier) heirlooms from the phylogenetic past which can and must be overcome in the course of scientific development. LORENZ mentions the example of PLANCK's "acausal" physics, to him mainly epistemological and only incidentally scientific.

For this species-specific and unique human capacity of overcoming innate cognitive mechanisms there are scientific neuro-biological reasons that lie in the ontogenetic development of the human brain. For uniquely in man, ontogenesis accounts for much more than does phylogenesis. Man's innate cognitive mechanisms are necessary for survival, but not sufficient for scientific knowledge. These latter are not to be found in the genetically conditioned structures and functions of the human brain, in the "innate ground" (KANT), but in epigenetic and self-organizing processes based on internal principles of the complex human central nervous system, which via its peripheral sense organs enters into contact with the external world and thereby undergoes individual change.

The young human brain's ontogeny shows that the universality of human behavior lies in a very general and non-specifically designed genetic 'program structure' which remains highly flexible even if completed and enhanced by specific epigenetic and ontogenetic behavioral structures that in man occur in countless measure. Only in this way we can explain why there is such a thing as creative development in the history of human's cognitive competences. The phases in the life of the human brain clearly show that each single individual has been given the freedom to develop his own cognitive achievements. Here the sequence of steps in morphological maturing follows a general order in time, but in certain critical phases it is in each case determined by the specific external stimulus.

Completition of phylogenetic epistemology by an ontogenetic one

Thus EE as phylogenetic epistemology must be completed by an ontogenetic epistemology as a further naturalized epistemology. This allows to lead back actual developmental processes to the neurobiological base. Only in this way we can reduce human cognition to its neurobiological origins in the form of an actual genesis. KANT had already envisaged what we would call a "neuro-epistemology" (cf. OESER 1985, 1987; OESER, SEITELBERGER 1988; OESER 1992).

Phylogenetic and ontogenetic epistemology do however rest on a basic uniform principle relevant to any epistemology, namely genetic regression. This states that the earlier the phase of development examined, the more basic and general the mechanisms that can be attained. To distinguish the two forms of epistemology based on using genetic regression, we might say that phylogenetic epistemology is that kind of naturalized epistemology that goes deepest into the phylogenesis of living beings , which as "cognitive ethology" compares cognitive equipment and efficiency of the simplest organisms, thus being able to observe different levels of representation and mechanisms.

On the other hand, ontogenetic epistemology is the naturalized epistemology that reaches upward furthest, explaining how the highest forms of cognitive processes (human knowledge) arose, including scientific knowledge with its formal mathematical symbolisms. The development of mathematical thought in children was thus a central concern of PIAGET's ontogenetic epistemology (cf. PIAGET 1973).

Completion of EE by a neuro-epistemology

EE or phylogenetic epistemology needs a further addition, over and above ontogenetic epistemology. For a scientifically oriented epistemology it is not enough to be able to assume internal cognitive mechanisms in order to explain cognitive phenomena as such, but one must state on what material organic structures such phenomena rest and how the associated mechanisms function. Such causal explanation of cognitive phenomena cannot occur at an external macro-level, whether behavioral or linguistic, but only at the micro-level generating these macro-phenomena.

The real internal micro-level of natural cognitive systems or organisms is the nervous system. This was clear from the start both in EE and in genetic epistemology. Both LORENZ and PIAGET hint at it. LORENZ, as early as 1941, states that all, including the highest cognitive attainments, rest on the almost "machine-like structures of the human central nervous system." In his main treatise, concerning EE he says explicitly that the 'spectacles' of our forms of thought and intuition, such as causality, substance, space and time, are functions of a neuro-sensory organization arisen to preserve the species (LORENZ 1973 p. 17). It is thus proper, and in tune with LORENZ's intention, to widen EE at the micro-level of neural structures and processes into an evolutionary "neuro-epistemology". The more so since KANT, on one hand in his actual genetic analysis of cognition was certain that the apriori forms of intuition and thought are necessary. On the other hand he expected a scientific answer to the question of the functional realization of apriori forms of thought and cognition through examination of the human brain—which can be shown both from his early pre-critical writings and from the posthumous work, but above all in his answer to SOEMMERLINGS question of the site of the soul (cf. OESER 1982, 1985, 1987; OESER, SEITELBERGER 1988).

From DARWIN on, there have been many attempts to link to theory of evolution with brain physiology (e.g. Th. MEYNERT 1892 p. 31; cf. OESER, SEITELBERGER 1988), but the decisive advance came quite recently with Gerald EDELMAN's "Neural DARWINISM" (1987). For this extends selection to the development of neural structures as well as to their effectiveness. His basic thesis is that structure and function of natural neural networks arise as results not from instruction but from selection. This can be applied to EE. For hominid evolution was primarily an evolution of the central processor system which became progessively more brain-based: sense organs did not improve, but the number of neurons and their links in the central nervous system grew (OESER, SEITELBERGER, 1988 p. 38). In this way the hominid brain developed into an organ producing results in excess (OESER 1987 p. 71), which in homo sapiens was once more restricted. Ontogenetically this means that at the start of individual development a genetically caused excess of neural connections is produced. These neuronal interlinkages are not increased through the influence of experience of the external world: on the contrary, existing connections are reduced by elimination of those that are not needed. Hence the actual world around us does not instruct us but merely fixes the selective boundary conditions under which a system living in it operates.

However, a merely negative, eliminative selection is not enough to explain either individual ontogenetic development of neuro-anatomic structures, or the resulting diversification of functional patterns as the base of all learning processes. Hence "Neural Darwinism" has no simple selectionism but distinguishes between negative and positive selection. The latter is the active organism's re-inforcement of the neural patterns most activated under given circumambient conditions or ecological niches. The reinforcing mechanism is the recursive interaction whose probability becomes the higher the denser the neuron population. This corresponds to HEBB's rule (1949) in the model of new connectionism, except that it concerns not single neurons and their connections, but whole neuron populations (cf. EDELMAN 1989). This relates to AI research based on the human brain, which likewise takes into account a micro-level of sub-symbolic processes. That the analogy to computer technology was not alien to LORENZ can be seen explicitly from a paper of 1963, which shows a clear account of this micro-level, agreeing in principle with Marvin MINSKY's notion of the society of mind. He sets up an "analogy between the conscious ego and an organization built from many people. The elements of it perform such complex calculations and logical inferences that the great HELMHOLTZ was misled to regard their results as *unconscious inferences*". In perfect clarity, LORENZ adds: "If anywhere in biology humanly excogitated calculators are more than a model, then in the physiology of perception" (LORENZ 1974 II, p. 364). Thus LORENZ reduces his concept of EE not only structurally to the micro-level of elementary neuron processes, but also tries to explain this level functionally by an analogy with the computer. It follows that EE is not a substitute for a philosophic epistemology, of which it is allegedly a competitor. Rather, it must be ranged within the framework of cognitive science (cf. OESER 1993).

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Karola Stotz

The Psychology of Knowledge in the Context of Evolutionary Theory

Reflections on the Link Between Cognition and Sociability

Abstract

The main thesis of the paper is that the implications of Evolutionary Epistemology as regards the phylogenetic basis of our thinking can be subsumed under PIAGET*'s Genetic Epistemology. This entanglement removes the dilemma of one-sided examinations of cognitive development that tend to either nativism or behaviorism. It also allows us to make new inferences about our cognitive capacities, provided we take into account findings from primatology and evolutionary theory with respect to specific questions concerning anthroposociogenesis. Human social reality and the social nature of individual human motivation exhibits its cognition almost as a by-product of social relations. Human cognition and human emotions, our construction of objects and the subjective attributions that necessarily accompany it, the expenditure of energy on majorating equilibration, and the associated freedom to invent and create—all these have their origin in the evolution of social life and the individual's personal development.*

Key words

Adaptation, evolutionary epistemology, functional invariants, genetic epistemology, action, interaction, cognition, construction, object, ontogeny, phylogeny, self-regulation, socialization, structure, symbol formation.

A biology of cognition

Both evolutionary theory—specifically, evolutionary epistemology (EE)—and cognitive psychology as embodied in Piagetian genetic epistemology (GE) prompt a diachronic examination of the problem of human cognition. Both seek to explain the origin and function of our intelligence in terms of their phylogeny and ontogeny. PIAGET located the causes of logical universals in biological action and organization. LORENZ discerned the phylogenetic a posteriori in the apriori structures of our cognition, viz., hypotheses of the cognitive apparatus as to how the world is constituted. Both scientists opted for an empirical, natural-scientific approach to epistemological questions. It is well known that the ethologist viewed life itself as a knowledge-gaining process. For the psychologist, self-regulation was the essence of life. PIAGET too regarded cognition as serving biological adaptation, but he also stressed *internal construction* in order to escape the "dead-end alternatives" (PIAGET 1967/1974, 27; cf. 1950/1975, 258) of Lamarckism and Neo-Darwinism, empiricism and rationalism, thus coming close to both a systems view of evolution (as put forward by RIEDL) and a constructivist conception such as MATURANA's (e.g., SCHMIDT 1987, 1992). A third diachronic dimension, the '*sociogeny*' of our cognition, is generally taken to go beyond the biological-organic realm. Nevertheless, it is already prefigured and prepared at earlier levels. On the one hand, the investigation of our closest relatives, the nonhuman primates elucidates the setting to which evolution has adapted man and his cognitive powers; on the other, the psychology of individual development reveals us the mechanisms and factors that constitute our intelligence.

In view of this, the key to hominization is the coevolution of *sociability* ('Sozialfähigkeit') and *socialization* ('Vergesellschaftung'). The longing for social life thus brings about an individual motivation for cognitive development. Seen from this angle, cognition no longer appears as a consequence of technology, tool use, or object formation, but simply becomes a by-product of interpersonal relations. The question that will concern us, then, is how the phylogeny of human cognition can be subsumed under PIAGET's (onto)genetic theory, and how this impinges on our cognitive powers. Although adherents of both theoretical programs have paid lip service to the importance and indispensability of both the ontogenetic and phylogenetic approaches, EE has hardly pronounced on the individual structure of intelligence, while PIAGET's comments on its phylogenetic foundations are inadequate.

The self-regulation of development

While GE may be said to consider cognition in terms of the subject's adaptation to its environment, PIAGET did not intend this as an epistemological realism. On the contrary, he rejected the description of cognition as adaptation to a 'reality independent of the subject', for in his *constructionist* view, concrete reality means the total system of interactions between organism and environment, which comprises subject and object equally.[1] PIAGET characterizes the interlocking of *assimilation* (the construction of intelligence) and *accomodation* (the construction of reality) as "the circularity of cognition".[2]

Cognitive structures do not just unfold (in the sense of maturation), but develop necessarily according to this pattern. How, then, can they be given to us a priori as phylogenetic inheritance? PIAGET himself does not rule out genetic preformation in principle, but in no way does he want to be misunderstood as endorsing maturation (or an environmentalist theory, for that matter)—he unmistakably calls his theory an "interactionistic" one.

He distinguishes two directions for the possible inherited factors. At the level of perception, he assumes inheritable factors of the structural kind. Beyond this level, he identifies "functional invariants"—the basis of our rational organizing powers —, which create "variable structures". Development proceeds by means of these two unvarying , stage-independent functions, *organization* and *adaptation*, which PIAGET regards as biologically most general and located well below the human level. Thus he holds that organisms have an innate capacity to organize thinking into structures and to adapt it to the environment and to themselves through various processes. Organization represents the internal aspect of development, while adaptation—the exchange between subject and environment—balances out the two poles of action. In assimilation, the individual adjusts reality to its own cognitive organization, almost incorporating it. In accommodation, the subject modifies its internal structures so as to allow it to cope with external requirements. The latter happens whenever events or objects can no longer be apprehended satisfactorily by means of the old schemata, so that contradictions arise. Assimilation and accomodation are the two poles of one and the same process, for every act of cognition comprises a conservative and a progressive moment. If the two are in steady balance, PIAGET speaks of "equilibrium". *Equilibration* as a dynamic process must constantly integrate the factors of development.

What PIAGET labels *majoring equilibration* ("majoration équilibrante") points to the circumstance that this self-regulation not only preserves or restores equilibrium, but tends towards qualitative improvement as well. Cognition "exfoliates" (HOOKER 1994) toward gradual 'autonomization' and decentration, as a new egocentrism arises at every stage of disequilibrium (lack of differentiation of subject and object), which must be balanced through accommodation. Thus, for PIAGET too, the individual undergoes a "Copernican revolution" (cf. VOLLMER 1975), which catapults him from the center of his world.

His cybernetic model of self-regulation allows PIAGET to describe the optimizing process of development towards growing autonomy as a genuine *construction*, without having to rely on a set plan. This constructivist postulate makes development sequential in the sense of a succession of stages characterizing specifically structured cognitive capacities, each of which emerges from the preceding one, without being determined by it. This allows PIAGET to avoid the one-sidedness of both a-prioristic and empiricist theories of development (cf. HOPPE-GRAFF 1993, EDELSTEIN/HOPPE-GRAF 1993).

The concept of equilibration points to an important goal of development and cognition: The adaptive aspect guarantees "correspondence" with the environment, the structural aspect of organization regulates the maintenance of inner equilibrium states, or the *coherence* of inner functions. Both concepts recur in RIEDL (1994), who distinguishes between external and internal selection. The *coherence principle* refers to the adjustment of functions and structures within systems generally; it applies to individuals as well as to societies as units of interaction. In organisms, coherence refers to phylogenetic constraints on mutually related components, in the social group it guarantees the communication between individuals. The *correspondence principle* refers to the fit between organism (system) and environment. Although both principles presuppose different selection regimes, they must interact eventually.[3] In discussing the interrelations between organism and environment, PIAGET points out that, while it is true that the organism "knows" its environment, what genuine correspondence requires is "co-ordination and co-regulation". Finally he postulates "a striving after comprehensive logical coherence, a balance between subject and object (assimilation and accommodation), between and within schemata, and an equilibrium of the whole, which is genuinely the ultimate coherence that motivates cognitive development." (FURTH 1987, 144 and 146). In this respect, then, PIAGET's ontogenetic theory may be likened to RIEDL's (1975) systems approach to evolution.[4]

EE and GE: an evaluative contrast

Vis-à-vis EE's conception of the innate character of our cognitive structures, PIAGET's psychology of knowledge can be elaborated in two directions. On the first interpretation, the role of inherited information is limited to setting the stage for the process of cognitive development, which then takes over according to its own internal logic. This he calls "epigenesis". A second way to go is to assume a hereditary program that regulates the construction of cognitive operations only if certain environmental conditions are satisfied. As ENGELS (1989, 270) puts it, "It is not the categories that can be innate, but the ability to develop patterns of organization—categories—in the struggle with external facts, so as to master the multifariousness that affects us". Thus far, we can say that the assumptions of GE and EE can be integrated if we adopt a specific interpretation. However, ENGELS criticizes a difficulty EE and GE share: their inability to explain ("Erklärungsdefizit"), as both can at best describe structural prerequisites of cognitive development. For "the emancipation of the subject from the mechanism of its own development—which occurs behind its back—involves a qualitative leap beyond conceptual grasp if we assume a continuous development from the stage of reflexes up to that of formal operations" (ENGELS 1989, 271). Here ENGELS discusses the phenomenon of *emergence* ("fulguration", according to LORENZ), which no theory has explained in depth to date, let alone made intelligible. Therefore, it is doubtful whether this argument against the two theories in question really holds, the more so if we remember that PIAGET and LORENZ recognized this problem of qualitative development and did not try to circumvent it by means of reductionist arguments. ENGELS now compares in how far the two naturalized epistemologies succeed in applying their own postulates, and finds some advantages in GE: PIAGET divides his explanatory model of cognitive circularity into a "special" and a "general" GE, depending on the reference system chosen. Special GE refers to the area of developmental psychology and its several attendant sciences. Here we still assume an objective and stable reality, which is regarded as independent. Since psychology cannot occupy a position beyond the epistemic subject, and the very reference system which grounds it transcends its grasp, a further iteratory move in the process of cognition at the level of general GE must open up that system to a critical historical examination. Developmental psychology thus reflects on itself as a discipline and, to the extent that it recognizes its historical and cultural contingency, attains a more circumstantial view of the concept of reality. No matter how far we turn the spiral of knowledge gain, the problem of demarcating subject from object remains insoluble. Much as we might even 'trivially' presuppose an objective reality and regard it as plausible, all our highly complex theories are merely 'assimilatory instruments' all the same: reality is always mediated—an operational construct of cognition. PIAGET's theory may thus be viewed as an extension or completion of OESER's (1987a, 46, and this volume) "internal realism" for the second-tier of EE.

In the same vein, Hans FURTH sees PIAGET's greatest achievement in his having deepened our understanding of the concept of object—and thus of our grasp of objects—as a most basic mental act. He avoided all philosophic speculation as well as the unreflective use of common-sensical concepts: Having said good-bye to the conception of object an sich, he replaces it by the conception of an object which the subject first has to actively build up in a personal historical development. An "object as the product of subjective construction" is indeed basically different from "facts" regarded as true (FURTH 1987, 16; PIAGET 1975/1950, 257; cf. 1975/1950, GW, vols. 8-10).

This, then, is why PIAGET did not string together cognition and perception so much, but rather cognition and action; for it is from action that objects can be constructed and grasped. Cognition in the first two years of age of a child is action knowledge, not object knowledge. Only the latter type of knowledge will allow them to 're-present', i.e., "to make present something not present" (FURTH 1970, 162). The construction of a (permanent) object does not merely bring about a special thing; it must also be viewed as the mode of cognitive access to the world of action, announcing the world of symbolic representation. This is knowledge of the permanent existence of objects in space and time. From now on, the child operates according to two differing modes of action: cognition-in-action and symbolic knowledge.

This insight now facilitates the perception of the significance of the attendant developmental leap in the acquisition of knowledge of objects with respect to the totality of human development, whether phylogenetic, ontogenetic, or sociogenetic.

But first, I shall discuss knowledge acquisition during phylogeny.

Evolution of cognition and the a priori categories

If we view any evolutionary step as a accretion in the organism's information about its environment, humans stand at the end of an evolutionary process of knowledge gain, as LORENZ graphically put it. Evolution, then, owes its quasi-cognitive character to the circumstance that organisms can 'exploit' the entropy law to create order (build structure). This mechanism presupposes a capacity of self-organization on behalf of organisms, which enables them to define internal systemic conditions, both phylogenetically and ontogenetically.

At the outset of this process we find the 'information gain' by the genome, which can be seen as a form of learning by species that lasts over generations. With the rise of the nervous system—a new storage site for information—the rate of knowledge acquisition is speeded up many times through the capacity to process incidental information. The most basic of these mechanisms are homeostasis, kinesis, phobic reaction, taxis, AAM, instinct, and unconditioned reflex. Opening these closed programs first enables us to learn individually. The active mechanisms here are imprinting, conditioned reflex, motor learning, abstraction, gestalt recognition, and central representation of space.

All these mechanisms, which I can only list here without discussion, will interest us insofar as they constitute the evolutionary basis of the human cognitive competence. Even if the behavioral flexibility of the human species is unique among the animals, LORENZ reminds us that the very openness of programs presupposes huge amounts of phylogenetically acquired information—his 'innate teachers', who guide learning along relevant paths. They precede the earliest experience and constitute the a priori conditions of knowledge. With BRUNSWICK, EE calls this foundation of reason the "ratiomorphic apparatus', in order to illustrate the quasi-rational mode in which this 'computational' system works. This pre-conscious, unreflective common sense with its hierarchical structure of 'hypotheses' about the world are the current endpoint in "this selection of world views, consisting of a system of suitable prejudgments about the currently relevant part of the real world" (RIEDL 1980, 27). They function as algorithms that calculate perceptions and decide about the appropriateness of actions.[5]

Universal logic and the co-ordination of biological behavior

Clearly, the goal of a theory such as EE is to identify *universal* structures of human cognitive competence; it is concerned with the results of adaptation of the species. Not so with psychological theories about cognitive development, among which PIAGET's GE is usually classified. In psychology, the *individual differences* in developmental conditions (the individual history of development) that come to the fore. GE has indeed often been rejected for being too abstract and too vague,[6] but PIAGET always insisted that he was interested not in individual differences of knowledge acquisition, but rather in the nomothetic aspect of development, in universals or invariants of cognition. Fundamental epistemological questions about the structure of our knowledge, and PIAGET's specific approach to problems (he was interested in the *genesis* of cognitive powers, not in adult reason) led him to developmental psychology only later. He stuck to his epistemological position, strictly separating his central "epistemic subject" from a "psychological subject" (cf. INHELDER 1989). PIAGET always rejected LORENZ-type a priori structures, yet his postulate of the universality of logical structures faces the same problem at the cross-roads between empiricism and rationalism. LORENZ solved this conflict by postulating universal categories as being a priori for the individual only; in species, they developed a posteriori. PIAGET's solution is a similar one: he characterizes logic, viz. logico-mathematical structures, as part and parcel of biology, since they co-ordinate biological action.[7] He persists that logical necessity, as a functional prerequisite of cognition, is real, for "the a priori categories of logical necessity do not as such embody knowledge. They are procedures that enable us to understand something and to go beyond the given to construct something new, but in themselves they are empty" (FURTH 1987, 163).

To LORENZ's concepts of chance and external necessity he opposes those of biological, mental and moral freedom and internal necessity. The latter he takes to be given by the biological principle of *con-*

structive assimilation (with its dual elements of structure building and openness to the future).[8] For him, this is the ultimate source of logic, not as an abstract, rarefied category, but as the living, concrete organic regulation of development (cf. FURTH 1987, 157ff; WETZEL 1980, 249ff).

Structure building and gain of information

Given the basic principle of all evolutionary processes, viz. the gain of information, the hypotheses of EE can be located at the level of the *neurodynamical* system of information. Information storage requires a certain material structure for its embodiment (cf. CAMPBELL 1979). This may cause confusion as to whether either structure or information is to be given most weight. To clarify this issue, we must briefly consider the concepts of structure and information.[9]

Whereas ontogenetically, structure building is of paramount importance, phylogenetically, *information*—which OESER (1985) regards as basic to evolutionary theory—is quintessential. The concept of information links the lowest stage of the living (the hypercycle) via purely instinctive regulation with subsequent processing of sense data right up to human cognition and the processing of cultural knowledge.

As to the relation between structure and information, it is useful to distinguish between two meanings of the concept of information. Any structure can be viewed as organized information, and any gain of information requires a structure. We must distinguish, then, between "structural" (a priori) and "dynamic" (a posteriori) information (OESER 1976). The robust programs of cognitive structures are loosened to the extent that a growing detachment from the material carrier of the information occurs. WIMMER holds that at this level, although the a priori structures described by EE do not become dysfunctional altogether, their functions are increasingly taken over by "second-order a prioris". These he regards as the PIAGETIAN assimilation schemata, which, once a certain ontogenetic maturity is reached, may be ascribed to the level of intellectual information. "The significance of these second-order a prioris and their essential difference from basic ones consists in their being products of individual behavior and much more flexible. This is most obvious in accommodation, which occurs when a schema permanently shows itself inadequate for a certain class of stimuli." (WIMMER 1988, 45).

The regulatory mechanisms internal to the system are accompanied by an increasingly constructive activity of cognitive structures, which (for PIAGET) reaches its apex in hypothetico-deductive scientific knowledge.

Models which trace a continuous development from instinctive mechanisms up to the highest cognitive achievements have not gone unchallenged. LORENZ (1937) critisized it early, and GEHLEN (1972) discussed it in a similar vein.

Culture and cognition

We now stand at the outset of cultural evolution, even if none of the results of the cognitive apparatus mentioned so far (except for the brief glimpse at the level of intellectual information) belongs to man alone. However, they are all necessary for the human achievement of conceptual thought and language. By being integrated, they have given rise to a systematic whole that differs from all animate systems by a "hiatus" (LORENZ 1978, DUX 1982). In order to understand this "fulguration of the human mind", we must probe the laws of organic evolution. LORENZ compares the chasm between animal and man with that between the inorganic and the organic. In animals a first quasi-cognitive structure capable of acquiring information evolved, but a cognitive apparatus of a new quality originated with man only. In the animal kingdom, too, individual learning became increasingly important, and transmission of acquired knowledge to the next generation took shape; yet the bulk of the information storage was located in the chain molecules of genomes. Only with our cognitive endowment a system came to the fore that does this much more quickly and efficiently. Henceforth, "object-independent" transmission (LORENZ), or, alternatively, "action-independent" transmission (PIAGET) as shaped by conceptual thought will have a huge influence on learning processes, since everything that is acquired becomes potentially "heritable" (in a generic sense). Thus, for LORENZ, cumulative tradition means the "inheritance of acquired characteristics".

It seems to me problematic, however, to rank—as LORENZ did—the various evolutionary steps according to their presumed importance and then to lift out the advent of the organic or that of humankind from the rest of evolution: Since any evolutionary achievement builds on what came before while also being emergent (in the sense of qualitative innovation), all (or no) evolutionary steps are essential.

So far we have shown the general compatibility of our understanding of phylogenetic and ontogenetic development (evolutionary theory and cognitive psychology, respectively). In what follows, this compatibility will be highlighted by means of a reconstruction of the genesis of *conceptual thought*. As studies of child development show, the origin of conceptual thought resides in action, i.e., the interaction of the individual with its social environment, and demonstrates that *action* is central to both phylogeny and ontogeny.

Cognition in the service of *Handlungskompetenz*

ENGELS (1989, 243) thinks that PIAGET's account of cognitive adaptation during ontogeny is the "key for understanding the connection between *cognizing* and *acting*". EE, too, deals with cognition insofar as it is in the service of action. Both theories postulate the "primacy of action". Here it becomes obvious that developmental psychology should matter for EE: For ENGELS, only the reconstruction of psychogenesis can show that cognition is basically related to action. We must ask how it is that we can anticipate the execution of actions in representation space or "Vorstellungsraum" (LORENZ's definition of thinking); or, as POPPER puts it, how it is that we can let our theories die in our stead.

EE describes cognitive structures as the products of a phylogenetic feedback process of variation and selection. They are given inborn to the individual, yet result from the experience of species or genera. How this process should be described cannot be inferred from phylogeny. It can only be gathered from the way cognition and action are intertwined ontogenetically, and by making the adaptation of subject to object concrete, thus filling the gap in EE.[10]

The question how thought is related to action runs like a crimson thread through PIAGET's work, and is expressed in core concepts referring to concrete action (object formation, symbol, representation, and concept). While strictly respecting the (onto)genetic approach, he tries to show that action can in no way be viewed as a mere 'application' of thought that precedes it, but that the reverse is true: thought gradually arises from action performed by *internalization* and *interiorization*.[11] In cognitive development, the individual runs stepwise through specific thought operations which enable him to 'act completely' in conceptual space. PIAGET requires these operations to be *reversible*; they are enabled by object permanence and the *symbolic* or *semiotic function*. For only reversibility allows the complete retraction of mental representations and their substitution by imaginary alternative actions.[12]

Human thought originates from the acting and perceiving of the individual in his interaction with the environment. Subsequently, instinctive and reflex behavior gives rise to sensorimotor action structures and schemata, respectively, according to functional laws. These schemata separate only gradually into active and reflective representations. In this early phase, cognition cannot be severed from action. This *sensorimotor intelligence* PIAGET sometimes calls "practical logic" because of its connection to concrete action situations.[13]

Conceptual intelligence marks the first stage of severance from action as such. Schemata condense and integrate increasingly into operations or active conceptual structures.[14] Now object knowledge is no longer guided mainly by external influences; rather, it serves description and internal maintenance, and also allows absent events to be kept present, thus creating a peculiar new reality. Thus WETZEL concludes: "We can speak of 'thought' only if [cognitive behavior, K.s.] is carried out internally in representation, thereby relying on gestural, pictorial, linguistic, and other symbols or signs as instruments" (1980, 174).

This *representation* at the end of the sensorimotor phase marks the transition to the pre-operational or *symbolic* stage, at about 2 years of age. On the way there, two things stand out: with intelligent action, the *intention* of action can be differentiated into its so-called *purpose* and the *means* to reach it; and objects become independent and permanent.

In PIAGET's psychogenetic reconstruction, intelligence and cognition thus start from action upon matter and social interaction, the goal-oriented activity of sensorimotor structures and their progressive interiorization into schemata for action. Through action, the cognitive functions of perception and thought are united.

The structure of the symbolic world and of conceptual thought

As action becomes internalized into mental representations and interiorized into cognitive operations, symbolization begins. Only now can meanings be generated that are permanently uncoupled from the context of concrete action.[15] PIAGET divides this general symbolic function into several levels: "First we should note that language is but a special case of semiotic or symbolic function, whose totality (displaced imitation and symbolic gestures, symbolic games, internal image, graphic image or drawing, etc.), rather than language alone, is responsible for the transition from sensorimotor behavior to the level of imagination or thought..... Yet language, once articulated as a partial, if important, special case of semiotic function, by no means exhausts the play of intellectual operations, whose origin remains sensorimotoric." (PIAGET 1967/1974, 47f).

Imitation may be seen as the prerequisite of all symbolism, for in imitation meaning substitutes the concrete object. If such internalization is disconnected from the actual context—i.e., takes place at the end of the sensorimotor phase —, then PIAGET speaks of *delayed imitation*. The latter requires a lasting representation of an image, even if still closely accompanied by individual needs. This child-like egocentrism should not be confused with conscious egoism. Rather, for PIAGET the term hints at the non-differentiation of subject and object, or the lacking insight in different points of view, i.e., the non-differentiation between oneself and others.

While imitation is characterized by excessive accommodation and thus a lack of structured cognition, *symbolic play* represents the assimilative side of symbolic intelligence. Whereas play originates in the subject, imitation seems to arise from the (internalized) object. In pre-operative thought, the two aspects of cognition have not yet been equilibrated.

"In symbolic play, imitation merely provides the model to which the object is to be assimilated, but remains subject to the deforming assimilation in the play itself. In other words, it is no corrective that might adapt the assimilation of the subject to the world. In play, what corresponds to an uncritical accomodation of subject to environment [as it happens in imitation, K. S.] is an uncontrolled and deforming assimilation of environment to subject." (HARTEN 1977a, 36).

According to PIAGET, the function of this lack of equilibrium is an *affective* ability to generate *cognitive* structures. A child who has to accommodate an as yet alien adult world of rules and interests, or indeed any other subject, will obviously not be fully satisfied intellectually or emotionally. Hence it seeks support and self-confidence in its private world of symbolic play, which need not yet serve adaptation to the external world and knows no coercion. This "strengthening of the subject" (HARTEN) contributes vitally to the further development of an initially passive accommodation towards an increasingly critical and reflexive accomodation. Alongside the affective aspect, a cognitive one arises, namely the reconstruction of events by means of an intuitive symbolism, since linguistic symbols are lacking.

Developmental psychology thus ensures the adaptation of subject and object as stressed by ENGELS, which in turn illuminates the link between thought and action, and describes the structure of object and symbol as a major developmental accomplishment.

The key to becoming human

In trying to subsume GE under evolutionary biology, FURTH asks likewise: "Would it be so far-fetched to assume that *symbolic function* is the well from which the uniqueness of human psychology springs, just as it is the springboard for all further ontogenetic development?" (1987, 116). LORENZ, too, stressed symbolism as a specifically human achievement and associated its development with the rise of a system of communication between people.[16]

However, can we postulate that the process of hominization took the same course that PIAGET sketched for individual development? FURTH finds some evidence and attendant inferences for this, based on homologous functional courses identifiable in both developments: self-regulation, organization, adaptation, etc. First we must ask what boundary conditions were responsible for the development of our conceptual thought, language and tradition, and thus what evolution has adapted man to? Here many anthropologists (VOGEL, HUMPHREY, REYNOLDS, KUMMER, DE WAAL) show that the discovery of instrumental knowledge can hardly have led to the development of the primate brain, since it plays a minor role in the daily life of anthropoid apes, our nearest relatives. The use and making of tools and the hunting they enabled is observed in animals, living under natural conditions . It is thus natural to assume that human technological achievements are secondary in kind.

Rather, our creative intelligence seems to arise from the highly organized social life of our immediate ancestors (cf. CAPORAEL et al. 1989). This circumstance enabled humans to set up a unique form of communities based on exchange of opinions and the laying down of social and ethical rules, a kind of *supra*-individual system whose constitutive feature is 'spiritual life'. Such an *inter*-individual system we call culture.

The origin of societal communities

The phylogenetic tendency for primate brains to develop is an important predisposition for the process of hominization. The maturation of such a complex

CNS requires prolonged development in utero and improved placental supply. A sharp parallel reduction in the number of offspring in the higher primates was observed by PORTMANN, whom he therefore called "secondary early nest-leavers". Man, however, is in a special position here, for to attain a stage of development corresponding to that of the higher mammals at birth, the intra-uterine phase would have to be one year longer. GEHLEN and PORTMANN see in man a "secondary late nest-leaver" or "physiological early birth".

The "only early contact of man with the world's riches" explains the special position of human ontogeny (GEHLEN after PORTMANN), "so that a series of ontogenetic peculiarities such as the duration of pregnancy, the early growth of bodily mass, and the degree of development at birth, can be sensibly understood only in connection with the mode of formation of our social behavior." (GEHLEN 1972, 45f).[17]

FURTH too locates the concrete, qualitatively distinctive difference between man and animal at this very juncture, namely *childhood*, which was to become so vital for the growth of intelligence that PIAGET took it as the starting point of his epistemology (FURTH 1987, 121; PIAGET 1969/1945). The delayed physical and psychic maturation with simultaneous highly versatile learning powers and a marked sense of curiosity results in an intensive inclusion of acquired components of behavior even in apes. It is true that such a maturation span requires protection by experienced, cherishing adults. Thus the whole juvenile development of primates depends critically on living in a social group.

"Primates are social.... The horizon which they seem to make for is the knowledge of what the other feels and thinks. It brings a multi-edged skill, equally suited for outwitting him, planning with him, and truly helping him with empathy." (KUMMER 1992, 391).

The evolutionary trend thus points towards the *individual capacity for innovation* under extreme *social dependency*. This yields favorable preconditions for the formation of social traditions as well as flexible variants of group behavior with an obvious selective advantage for the most varied conditions of life. A longer individual life span as well as a community ("Gemeinschaft") cutting across several generations promote the formation of tradition even in the higher primates. The basis for constant receptivity in the human female and how this importantly affects the structure of human communities likewise derive from pre-human primate phylogeny. We must not underestimate *female choice*—the reproductive strategy of women through mate selection—as an evolutionary force tending towards co-operation between the sexes, especially as regards the joint raising of the young. (Cf. VOGEL 1975)

Frans de WAAL critisizes the long-standing and unjustified overemphasis on aggression in animals and humans and the neglect of regulation and avoidance of conflict in communities. In his studies on nonhumans, he was able to show how their social communities relied on a highly developed 'calming system', in which sex plays a central role. "During conciliation, chimpanzees kiss and embrace but rarely mate, while bonobos go in for the same sexual behavior as during feeding. This is the first firm proof that sexual behavior is a means for overcoming aggression." (De WAAL 1991, 220)

Sociability and cognitive competence

The growing complexity of socialization is intricately related evolutionarily to the formation of extended capacities for learning and higher cognition. Hominization as the intensification of sociability thus coincides with changes in cognition and sexuality, which, as FURTH explains, provides the energy and motivation for cognitive progress.[18] Here, the transition to object knowledge, symbolic functioning (along with language), and self-awareness occurs, i.e., "the breakthrough from action to personal relations: in a sense this is the birth of the person" (FURTH 1987, 122).

To understand entities as complex as the societies that already exist in higher primates, we must keep in mind that the different aspects of social behavior are not now confined to seasonally bound central activities such as rut, caring for offspring, migration, or dominance contests. Rather, they occur continually and are intertwined, relying heavily on mutually adjusted behavior. The nexus of personal relations and of social role expectations has expanded, and all individuals have to anticipate this in their momentary action. Any failure to notice a peculiar social configuration can be sanctioned immediately. VOGEL summarizes this as follows: "Anticipatory action, planning by weighed probabilities concerning complex situations or constellations, with firm and often restrictive check on one's own behavior, all this nonhuman primates must already achieve in the social field." (1975, 23).

Many anthropologists take these abilities as preconditions for hominid tool production. Merely the transfer of cognitive skills that were already available in the social realm to the technological realm was required. This thesis, then, runs against many paleoanthropologists' traditional fixation on tool development as testimony for cultural and intellectual evolution. As more recent studies of social behavior suggest, they probably overrated the role of technological evolution for hominization.

What all this brings home is how a study of nonhuman primates helps us devise models for the biological basis of the rise of man by pointing to the decisive evolutionary trends that are involved.

Individual development in the context of interpersonal relations

Looking back to the roots of our species imparts a close correlation between, on the one hand, the evolution of the brain and our cognitive capacity, and, on the other ,our social existence on the other. If life in complex social groups makes demands on mutual behavioral adjustment of individuals so great as to provoke a clear selective pressure towards ever greater cognitive ability, it seems natural to expect a similar developmental drive caused by social demands during the life span of the individual. This hypothesis obviously presupposes that we see childhood not as a contingent phase of maturation of already present abilities, but as a psychological coconstruction of cognitive, affective, and social competence, which together constitute "personhood". FURTH stresses that childhood is not simply to be 'overcome', "so that we may advance at last to the really important matters such as conceptual thought and linguistic discourse.... On the contrary, these should be regarded as a by-product of becoming a person." (1987, 128).

As we saw, PIAGET takes the ability to imitate as crucial for the acquisition of symbols, which in turn points to an important developmental factor, namely *socialization*. Whereas practical intelligence is most appropriate in the satisfaction of immediate needs, interaction with other individuals requires the appropriation of other rules of behavior, which confront the child with the problem of *perspectivity* (cf. EDELSTEIN/KELLER 1982). Learning the rules of social communication requires new abilities, for the social partner does not behave merely like an object in space and time. The child must learn to abstract his action on the new 'object' from his current needs. Social experience is indispensable to impart on one the existence of the perspective of another person, and hence of new reference systems. The child learns to see itself as one subject amongst many and turns itself into an object of its imagination, seeing itself through the eyes of others, as it were. The subject thus becomes self-aware. Conceptual thought is thus the result of a decentration of thinking.

Partaking in the communicatively mediated adult world represents a new level of activity, viz. the level of *language* and communicative action. Yet the cognitive structures are still confined to the level of practical intelligence; they cannot be adapted to the new situation by mere imitation, but must be slowly acquired through practice in interaction. Because of this shortcoming of the corresponding cognitive instruments, the individual at this stage falls back into cognitive egocentrism, which subsequently must be decentered again at a new plane of activity through increasing differentiation and integration.

The social construction of cognitive development

In the last decade, a new perspective was established in research in developmental psychology, which aims to widen genetic structuralism and its cognitive paradigm by including the social constitution of competence of action. This new approach relies heavily on the interpretative paradigm as developed in the traditions of *symbolic interactionism* and phenomenology (cf. MEAD 1934/1969; HABERMAS 1981 VOL. 2; ECKENSBERGER/SILBEREISEN 1980; NICOLAISEN 1993; GEULEN 1982; DÖBERT/HABERMAS/NUNNER-WINKLER; also note 15).

On the one hand, this is due to the realization that social context has been systematically neglected in PIAGET's developmental theory, perhaps owing to his emphasis on the epistemic subject at the expense of the psychological subject (cf. INHELDER 1989). ENGELS diagnoses this as a failure to explain: though an active subject is postulated to explain how the building of cognitive structures is kept under way, the same subject can by no means be considered as the 'prime mover' of this process, since the autonomous rational subject arises only in the course of this very construction (cf. ENGELS 1989, 267f).

On the other hand, EDELSTEIN senses a certain "saturation" in this area due to the intensive investigation of processes of cognitive development (EDELSTEIN/KELLER 1982). Even INHELDER (1989) notes a dramatic shift in interest from highly abstract, generic epistemic subject to a heterogeneous plurality of individual, situated, psychological, and social subjects. Today, the subject with its intentions and attributions of meaning stands at the center, which Inhelder attributes to the Zeitgeist in a positive sense.

PIAGET is often blamed for neglecting the social side of development, yet most of his critics point to the possibility of including the vast domain of social relations in his very model of interaction. In fact, he did not systematically distinguish instrumental action on natural objects from social interaction. Most authors would not want a *displacement* of the cognitive theory of development by a theory of socialization, but would rather see its *incorporation* into a social-cognitive theory of development (also called social theory of cognition, cognitive theory of socialization, sociological constructivism, and the like). All these labels express the circumstance that the cognitive development of the individual unfolds itself in interaction with external reality, which defines itself in social relations. EDELSTEIN points out that the origin of all experience is to be found in interaction, and that the sociocultural quality of interaction provokes differential experience, which in turn cause differential development. This theory differs from many current hypotheses about socialization in its emphasis on the process of construction. While they restrict the role of the knower to a rather *passive* one, in which adolescents take over values, knowledge, and skills from adults, social-constructivist approaches in the vein of the theory of cognition start from the 'strong hypothesis', according to which the child must actively acquire basic abilities to act. (Cf. YOUNISS 1994; EDELSTEIN 1982, 1993).

YOUNISS coined the term "co-construction" to emphasize the essential role played by the immediate social surroundings even in the conveying of cultural values and norms in individual development. Above all, this concept involves "co-operation" as a strong factor influencing and favoring development. The more a theory is opened up to individualistic influences, the more it will suit those who suspect a cultural bias and the underpinning of western middle-class notions in the description of universal psychic structures (cf. DASEN 1972, 1977; SCHÖFTHALER 1984; PIAGET 1966/1984). Certainly, as YOUNISS insists—his individualistic stance notwithstanding —an exhaustive concept of development must at least account for both the particular and the universal, the ontogenetic and the phylogenetic, as well as the sequel of self-regulating, individual, and sociocultural factors as a working hypothesis. On this view, even individualistic interaction between social partners deserves some attention. Cognition may be described as acting in internalized space, with the necessary presupposition of reversible operations. With respect to the interpersonal sphere we must ask whether an individual can achieve such organization on her own, or are there stimuli that are conducive to, or even necessary for this. YOUNISS now argues that social interaction brings about the process of differentiation of perspectives. Does it make sense at all to ask whether this individual process of socialization (i.e., the ability to differentiate perspectives) either causes or is the result of the formation of reversible operations, or do we have to envisage a rather more complex causal relationship?

What the principle of "co-construction" suggests is the following: For one thing, social interaction requires some initial cognitive presuppositions, which will subsequently favor the formation of higher levels of cognitive equilibration, so that the individual is enabled to engage in novel processes of socialization at every higher cognitive level. According to VOYAT (1978), a real link between co-operation and cognition may be postulated to the effect that socialized thought promotes the resolution of contradictions. Moreover, cognitive progress should lead to better co-operation and continued socialization. In view of this complex development, it makes little sense to expect linear causation.

Still, VOYAT reminds us that in PIAGET's developmental view, social relations can generate cognitive abilities only if these co-operative actions lead to an equilibrium with the external world, in analogy to what PIAGET has demonstrated with respect to the actions of the individual on inanimate matter. In other words, VOYAT asks whether exchange of thoughts is comparable to any other kind of exchange, such as acting in PIAGET's object world. Next, he analyzes the various interpersonal exchange relations and formulates certain equilibrium conditions that are not fulfilled in all systems of social interaction. He concludes that both egocentrism and social compulsion prevent the balance of social exchange based on regulated reciprocity. Such egocentrism may be related to age (i.e., cognitive level) or to other personal, motivational or mental causes, so that the ability to co-operate may be impaired or prevented altogether. External social compulsion does not warrant stable equilibrium either, since the agreement between the interacting partners would not have been achieved of their own accord (excessive accommodation). Any process of construction is grounded in the very activity of the subject. VOYAT can show that the logic of compulsion is not reversible indeed, and cannot give rise therefore to reversible operating structures. The reciprocity needed for setting up operative structures arises only from a genuine exchange of views during which egocentric concepts that rest on subjective perceptions become socialized concepts through adaptation and organization in the interpersonal system. This we may call co-operation.

VOYAT expands these considerations into a "dialectic of development" that considers an individual able to act in a co-ordinated and cognitively structured way, through the combination of inner organization and interpersonal experiences of co-operation and reciprocity. In other words, an individual who is to form higher cognitive operations must have all the features of a "socialized personality".

However, if social co-operation is so vital for intellectual development, just as the level of cognitive equilibration influences the ability to co-operate socially, it should be possible to show empirically that different conditions of socialization lead to differences in the unfolding of thought, while the formation of societies depends also on the cognitive, hence, social ability of their participants.

A sociology of cognition

It is not well-known that these preliminary steps toward a theory of society figure already in PIAGET's early sociological writings.[19] HARTEN (1977a; b) deliberately analyzed only these studies and ventures to suggest that PIAGET originally understood his GE as a "sociology of knowledge" (cf. also APOSTEL 1986 and the subsequent discussion in the journal *New Ideas in Psychology*). This dialectical approach to a critical theory of socialization, which sees humans as creative beings, focuses on moral development towards a co-operatively acting individual a central place. PIAGET inquired also into the cognitive-societal conditions and limitations of development, the ideal end of which was to be a subject freed from material and societal compulsions (cf. the contributions in BERTRAM 1986).

HARTEN regrets that this concept was gradually replaced by a cybernetic, self-regulating model of development, in which the subject was to follow an optimal strategy in order to be able to reach the highest possible cognitive autonomy. Instead of moral co-operation as the final goal of development we have the application of formal logico-mathematical structures.

In recent years, PIAGET's ideal endpoint of cognitive development has come increasingly under attack from cognitive anthropologists. Most notably, the possibility of altogether different endpoints of development—so-called *post-formal operations*) have been envisaged. For instance, EDELSTEIN/NOAM (1982) proposed to replace the concept of reason by an as yet to be specified concept of "wisdom". The latter refers to the mediation of feeling and cognition, and to the mediation of the conflicting demands of environment and social structure, on the one hand, and the cognitive structures that enable the logical handling of knowledge, on the other (cf. the "Affektlogik" of CIOMPI 1982). EDELSTEIN and NOAM's criticism starts from a GE whose validity claims rest on the postulate that thought structures are universal, as is the theory describing them, the more so if this universality claim amounts to discounting other forms of life and thought. SCHÖFTHALER (1984, 31) too fears the claim to universality of any theory of cognitive development which may ultimately be abused to "legitimate a culturally successful and dominant model for the use of reason".[20] We must always ask, then, whether a theory cast in such general and comprehensive terms is capable of adequately grasping a possible or even factual multifinality in the development of reason across all cultures.

We are thus in the midst of a process of cultural relativization of logical and 'a-logical' ways of thinking. This relativization need not make things more arbitrary; to the contrary, it may actually help give cognitive competence a meaning that comes closer to life itself.

FURTH (1987) took a similar path when he tried to reconcile Freud with PIAGET. He concludes that the key to hominization is not the sole formation of a realm of symbols, but that an emotional covering with deep personal drives accrues to symbols, which rests on the marriage of Cognition and Eros in the symbolic phase of development (cf. note 18). In this period of development the object is no longer just socially mediated as in the suckling phase, in which social ability has yet to be acquired (the so-called "epistemic triangle" after NICOLAISEN 1994; the "sociocultural zero position" after DUX 1982); the object *is* now primarily *social*.

In conclusion, we may state with FURTH that: "The area of expansion is now infinitely greater, and the environmental object became interwoven with the constantly changing interpersonal relations between self and others. To isolate human cognition from its human context is illusory precisely because cognition *is* this human social context (or its construction)." (FURTH 1987, p16).

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Notes

1 Thus FURTH (1960) describes PIAGET's GE as "radical constructivism". ENGELS (1989) would rather call this "constructionism", to avoid confusion with the Erlangen school's type of *epistemological* constructivism. Readers interested in PIAGET's influence on and relation to radical constructivism can be referred to a special Suhrkamp volume (RUSCH/SCHMIDT 1994); see also EDELSTEIN/HOPPE-GRAFF (1993).

2 (ENGELS 1989, 257; cf. ENGELS 1989 and JANICK 1993). On the special significance of the two functional invariants that bring about cognitive structures, assimilation and accommodation, FURTH (1969, 127) writes: "PIAGET uses the concept of 'assimilation' to designate a form of signification or comprehension that is directly connected with the transforming, structuring aspect of recognition [Erkennen, K. S.]. He uses the concept of 'accommodation' to designate the outward-reaching aspect of recognition, the application of an active plan to a given event."

3 "Although selection pressure at first pushes towards coherence only … communications, first about [the system's] presence ["Hiersein"], then about its state ["Befindlichkeit"], do occur, followed by messages about the external system; thus correspondence with the environment comes about, which is conveyed in turn to the coherence of the internal systems." (RIEDL 1994, 41; cf. 38ff and RIEDL 1987, 24, 32).

4 The common ground between GE and EE actually reaches even further: With respect to the mechanism of the epigenetic system, PIAGET has elaborated the concept of *phenocopy*. His usage of "phenocopy" departs markedly from the original meaning of the concept (cf. HOOKER 1994), but it comes close to RIEDL's model of *imitative epigenotype* ("imitatorischer Epigenotypus"), developed in 1975.

5 Along with space and time as intuition forms, RIEDL 1980 distinguishes four additional pre-conscious "hypotheses" for our cognitive apparatus: the hypothesis of *probability*, the hypothesis of *comparability*, the hypothesis of *causality*, and the hypothesis of *finality*. A critical discussion of these controversial claims will have to await a future occasion; cf. STOTZ 1996, where I discuss the culture-dependency of the forms of intuition.

6 Cf. HOPPE-GRAFF (1993), a collection and critical examination of the main criticisms of PIAGET's work.

7 "The mediating behavioral factors for articulating the highest forms of rational adaptation lie in the most general *co-ordinations of human action* by the 'epistemic subject', which is present in all of us and spontaneously creates, under favorable social conditions for development, the construction of those universally accommodated logico-mathematical structures." (WETZEL 1980, 264).

8 "Mathematics and logic at first depend more on the subject's activity than on physical knowledge and lead to the assimilation of reality to the schemata of this activity.... This means nothing else than that the assimilation of reality to mathematical science refers to a deep correspondence." (PIAGET 1950/1975, 254).

9 PIAGET's distinction between *competence* and *performance* belongs here as well. The former designates a structure of behavioral co-ordinations which forms systems of actions, operations, and interactions that are universal and therefore common to all cognizing subjects at a given level of cognitive development. The latter designates the specific cognitive content, the application of the underlying ability, the individual and psychological ability to distinguish intelligence.

10 Thus LORENZ often seemed to underrate the ontogenetic and active construction of cognitive structures when he treated culture as a mere supplier of knowledge: "at the basis of language learning lies a program that has become phylogenetic, which in each child again and again integrates *innate conceptual thought* [italics mine) and the culturally transmitted vocabulary." (LORENZ 1978, 288).

11 For PIAGET, *internalization* denotes the ability to represent, viz., the formation of inner images and inner language by the real weakening of imitative movements and hence the presence of absent events. *Interiorization*, to the contrary, means the internal structuring of general cognitive plans, assimilatory schemata, and their functional dissociation from external cognitive contents. (Cf. FURTH 1987, 120).

12 "The active character of mental life, which arises from the circumstance that action becomes progressively more internalized, underlines the overall importance of the operations. Intellectual operations are really nothing but systems of mutually co-ordinated actions that have become reversible through their constellation. On this view, logical 'groupings' and elementary mathematical 'groups' appear as the necessary form of equilibrium of actions, towards which any mental development tends, the more perceptions, habits, etc., are freed from their original irreversibility and develop towards a reversible mobility that marks the action of intelligence." (PIAGET 1975/1950, 256f).

13 Although sensorimotor structures cannot yet be likened to logical thought in the usual sense, PIAGET (who calls this the "logic of action" elsewhere), discerns specific preformations of logic: the logic of *inclusion*, the logic of *order*, the logic of *correspondence*, the logic of *object permanence*, and the logic of *reversibility*.

14 PIAGET speaks of the "operative" aspect of cognition, in contrast with "figurative" cognition (bound to perception), as a structuring and constructing action knowledge. The concept thus comprises the whole cognitive domain from sensorimotor structures to formal intelligence (cf. KESSELRING 1988).

15 In his sociopsychological theory of communication, the 'symbolic interactionist' Georg Herbert MEAD (1934/1969) attempted to trace the logical genesis of linguistically mediated interaction via three levels of interaction (signal language, interaction mediated by symbols, and norm-regulated interaction) from the earliest beginnings in instinct and gesture. MEAD particularly pursued the transition from gesture-based interaction (with its objective or natural meanings) to a symbolically mediated interaction (with the attendant rise of symbolic meanings). HABERMAS integrated Mead's theory of meaning in his magistral "theory of communicative action" (1981, vol.2, 7-169). For generation of meaning also see BRUNER 1993.

16 However, LORENZ did not overlook that the use of symbols was prepared already amongst higher primates, especially in captivity. "In their dual function of communication and motivation of modes of social behavior, ritual behavior in higher social animals constitutes a holistic system which in spite of its plasticity and capacity for regulation, is a solid framework that bears the whole social structure of the species." (LORENZ 1978, 266).

17 GEHLEN (1972, 44) points to "highly important investigations" by Adolf PORTMANN: Die Ontogenese des Menschen als Problem der Evolutionsforschung. Verh. d. Schw. Naturforschenden Ges. (1945); Biologische Fragmente zu einer

Lehre vom Menschen (1951); Zoologie und das neue Bild vom Menschen (1960).

18 "Detachment of cognition from actual situations would be pointless if the organism did not at the same time ensure that this novel object knowledge is invested with energy.... Setting cognition free must therefore go along with a setting free of energy.... In humans, sexual energy ... was detached from an immediate biological goal and thus became available for being invested in a symbolic representation of satisfactory social relations. Here is located ... the binding of sexual energy that FREUD associated with the pleasure principle as the novel motivating force behind symbolic products.… In the pre-human domain, one could say that evolution had selected sociability in such a way that it served the goal of the sexual drive. With sexuality set free in man, the relation is now reversed: sexuality now serves the goal of social co-operation. This, in my view, is the great turning point, and justifies the assertion that the human brain has developed in correspondence with an environment of social relations to which it has become especially adapted." (FURTH 1987, 123 and 125).

19 Not until the late 1940s did PIAGET formulate the outline of a cybernetic, systems-theoretical approach to GE, in which the monadological subject as a reduced organic system is the focus of interest. By contrast, HARTEN's central thesis has it that PIAGET's early writings can be understood as belonging to a sociological epistemology, which takes cognition as the result of social practice and sees the subject as a dialectically emancipated social being. "For PIAGET, cognitive development therefore always means cognitive socialization in the double sense that pre-societal structures turn into social and political competence, which in turn are built up only through socialization and not in the monadological action of a lonely subject." (HARTEN 1977a, preface).

20 A critique of the cognitive one-dimensionality of western society is also found in HABERMAS (1981, vol. 2, 449, 489ff). Reflections on the development of post-formal structures of thinking are found in KRAMER (1983) and RIEGEL (1975/1978, 91). Riegel suggests that the last stage of cognitive development is that of "dialectic operations", in which "the individual is able to recognize contradictions as the basis of all thought." Here we must mention the reconstruction of KOHLBERG's theory of moral development (as a further elaboration of PIAGET's GE) by GILLIGAN (1977;1980; 1982) and J. M. MURPHY, in which a concept of "contextual relativism" or a relativistic ethic of responsibility is set against a level of post-conventional development. Here, the aspect of justice is linked with those of care and responsibility.

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Manfred Wimmer/Luc Ciompi

Evolutionary Aspects of Affective-Cognitive Interactions in the Light of Ciompi's Concept of "Affect-Logic"

Abstract

In this article we try to provide an affect-cognition integrating view. This is done by reconstructing the main elements of CIOMPI's theory of "affectlogic" in the light of biological-ethological considerations in general, and WIMMER´s "evolutionary theory of emotions" in particular. Both concepts start form the basic assumption that affect or emotion and cognition form a inseparable interactive unit. Depending on the level of ontogenetic or phylogenetic development, this unit contains different types of interactions which are a main topic of this article. One overlaping and essential element within the affective cognitive interactions is the organising and integrating function of affects on cognition. This has far reaching implications especially for ethology, psychology and, possibly for an ecological view of human existence focused on culture-specific affective-cognitive clusters.

Key words

Emotion, affect, cognition, instinct, chaos theory, scheme, moods, phylogeny, ontogeny.

Discussion about emotions has been steadily intensifying during the last years. The number of publications in various disciplines that analyse the role of affects in different human and animal areas of behavior has increased exponentially. It is not yet clear whether this implies an extension or modification of the currently dominating cognitive paradigm. It is obvious, however, that one-sided cognitivist views on organismic behavioral patterns that were based on analogies with computers are increasingly completed by an affective dimension. Only this extension leads to a deeper understanding of numerous seemingly 'purely cognitive' functions, making it clear that 'the cognition' does not exist in itself, but that specific forms of cognitive functioning are always linked to an emotional basis.

One of the first comprehensive approaches that integrates affect and cognition has been proposed by CIOMPI in1982 and further developed since. His concept of "affect-logic" is based on an interdisciplinary system-theoretic approach that tries to link the cognitivist perspective of PIAGET's genetic epistemology with affect-energetic FREUDIAN views and recent neurobiological and emotion-theoretic knowledge. Basic are ideas and terms such as "affective-cognitive schemata", or "integrated feeling-thinking-behaving programs" that develop through action, and operator-like functions of affects that organize cognition. These essentials will be a central focus of the following article.

The consequences of this approach are far-reaching and have also numerous anthropological implications. In the following paper, we try to relate the basic concepts of affect-logic to current results of biological-ethological research. The evolutionary background of central elements of affect-logic will be analysed and compared to an "evolutionary theory of emotions" (WIMMER 1995). This confrontation should also show to which extent the predominantly ontogenetical perspective of affect-logic corresponds to an evolutionary-phylogenetical approach, respectively to which extent evolutionary-phylogenetical concepts based on animal and transitory animal-human behavior may be extended to the ontogenetical range.

In the biological-ethological part we also try to show how originally highly fixed behavioral patterns become more flexible during evolution—a process that is particularly evident in the genesis of human behavior. With this progressive flexibilisation, affective elements acquire new functions that will be analysed separately in the ontogenetical and phylogenetical range.

A common point of departure is the assumption that each element of behavior in the widest sense contains both cognitive and affective components, and that every onesided cognitivist or affectivist view would lead to considerable error.

The first part of the article, written by CIOMPI, contains the core elements of affect-logic including their chaos-theoretic implications. In the second part, written by WIMMER, these elements are related—in parallel to the first part—to biological-ethological approaches. Reflexions concerning relations between ontogenetical and phylogenetical evolutionary processes are included. The third part consists of a common discussion for which both authors are responsible.

Ciompi's concept of affect-logic

The aim of CIOMPI'S concept of "affect-logic" is to integrate relevant current knowledge from neurobiology, ethology, psychology and evolutionary theories concerning the genesis of knowledge, and in particular the role played by affectivity and cognition into a comprehensive functional understanding of the human mental apparatus. The term "affect logic"—a not entirely satisfactory transposition into English of an appropriated composite German word signifying, simultaneously, the "logic of affectivity" and the "affectivity of logic"—points to its central conceptual basis postulating that in all normal and most pathological functioning, affective and cognitive components, or feeling and thinking, affectivity and logic, are inseparably connected in regular but not yet sufficiently well-understood interactions which it tries to clarify. The hypothesis of affect-logic originates from research in psychiatry and psychopathology, especially on long-term evolutionary dynamics of schizophrenia, and developed, eventually, toward a general psycho-social-biological model of human mental functioning.

Current psychological or psychodynamic approaches to this problem such as the behavioristic, cognitivistic, humanistic or psychoanalytical one, have serious shortcomings, being either onesided in different ways, or failing to include recent neurobiological or emotion-theoretical findings. Insufficiently linked and integrated are, in particular, affective and cognitive, individual and social, ontogenetic and phylogenetic aspects of the psyche. The concept of affect-logic tries to avoid these difficulties. It is based on a system-theoretical approach (v. BERTALANFFY 1950; MILLER 1975) including also current notions on self-organization and non-linear (chaos-theoretical) dynamics of complex systems far from equilibrium (HAKEN 1982, 1990; PRIGOGINE et al. 1983; TSCHACHER et al. 1992, 1994). First published in 1982 in a German book (English translation 1988), and further developed since in a number of additional publications (CIOMPI 1982/1988, 1986, 1988a, 1988b,1989, 1991, 1993), it links current neurobiological and psychological notions on affective-cognitive interactions with core elements of PIAGET'S genetic epistemology and psychoanalytical object relation theory (DERRYBERRY et al. 1992;EKMAN 1984; IZARD 1977, 1992, 1993,;ZAJONC 1980, 1984; LAZARUS 1982; PIAGET 1977; KERNBERG 1980).

Biological bases

Significant progress of research on the neurobiological bases of emotions has revealed, during the last 20-30 years, that important emotion-regulating centers are located in the limbic-paralimbic system of the brain, especially in the nuclei amygdalae, the hippocampus and the septum pellucidum. By rich ascending and descending connections, these structures are closely related to neocortical, thalamic and hypothalamic brain areas which are involved in sensory perception and higher-order cognitive information processing on the one hand, and in motor activity and hormonal tuning of the whole body on the other (PANKSEPP 1982; DERRYBERRY 1989; LE DOUX 1987, 1989; MCLEAN 1993). Projections toward distant brain areas, which are innervated by all major neurotransmittor systems related to specific affective states (for example noradrenaline to aggression, dopamine to anxiety and fear, serotonine to depression, and endorphines to pleasant feelings), provide the functional basis both for far-reaching effects of emotions and for constant mutual interactions between emotions and cognitions. Close connections exist also between emotional centers and structures involved in memorization (especially the hippocampus), supporting the hypothesis of a crucial role played by emotions in all learning processes in the sense of state dependent storing and mobilization of cognitive material. Also of particular interest is the discovery of direct connections between thalamus and amygdala, allowing for emotional emergency reactions to sensory inputs without previous high-level cognitive processing (LEDOUX 1989).

Different affect-specific neuronal systems with integrated cognitive, affective, sensory, motor and vegetative components have been identified, or are on the way to being identified, during the last 10–15 years; among them a so-called reward-system characterized by pleasant feelings, an anger-aggression system, a fear-anxiety system, and a panic system (ROUTTENBERG 1978; PANKSEPP 1982; PLOOG 1986, 1989; DAVIES 1992). Integrated neuronal circuits which are self-organized through action by means of the mentioned phenomenon of neuronal plasticity—that is by repeated stimulation of the same synaptic connections which facilitates stimulus transmission and dendritic growth (CHANGEUX et al. 1987)—provide the biological substratum of affective-cognitive-behavioral "building blocks of the psyche", such as assumed by the theory of affect-logic (see below).

Furthermore, at least five basic emotions (interest, fear, anger, sadness and joy) have been identified as significantly different global cerebral states by spectral electroencephalographic methods (MACHLEIDT 1994, MACHLEIDT et al. 1992). Other EEG-research confirms the phenomenon of state-dependent information processing, learning and memory in different functional states of the brain, including wake, sleep, dream, trance, and psychosis (KOUKKOU et al. 1983, 1986,1991). In addition, recent findings concerning the phenomenon of synchronization of EEG-activity in different brain areas during real mental activity show striking parallelisms with results of simulated mental activity in neuronal networks (SINGER 1990, 1993). In both fields, a similar chaos-theoretical approach as proposed by affect-logic is often adopted.

According to a proposition based on the theory of affect-logic, the following overall hypothesis could explain the observed multiple interactions between affects and cognition, mnestic functions, neural plasticity, state-dependent learning, and mobilizing, organizing and integrating functions of affects: An identical "emotional imprint" may be necessary both for generating and for reactivating affect-specific neuronal pathways. In addition, it is assumed that specific combinations of neurotransmittory flows correspond to specific affects, and specific functional-neuroanatomical bifurcations correspond to specific cognitive differentiations (CIOMPI 1991). Thus, if the genesis of relevant neuronal pathways through bifurcations and the eventual reactivation of these same pathways was enhanced by an identical emotional stimulus, not only obligatory interactions between affective and cognitive functions, but also affect-specific organizing and integrating functions of emotions, such as postulated by affect-logic could be economically explained by one single biological mechanism. The hypothesis of an "emotional imprint" is supported also by recent findings speaking for an enhanced maturation of affect-specific dopaminergic limbo-frontal connections in early childhood under the stimulating influence of endorphines related to emotionally positive mother-child interactions (SCHORE 1994).

Basic concepts of affect-logic

Definitions of *affects* (or emotions, feelings, moods etc.) in different fields of science are manifold, often overlapping and contradictory, as strikingly demonstrated in an overview by KLEINGINNA et al. (1981) where no less than 92 definitions are reported from the literature, subdivided into 11 classes (affective, cognitive, externally stimulated, physiological, expressive, disruptive, adaptive, multiple, restrictive, and motivational) according to the predominating characteristics. A supraordinated and generally accepted phenomenological concept is however lacking.Within the theoretical framework of affect-logic, in contrast, affects are understood as a supraordinated notion which covers the above listed partial aspects. They are defined as *global psycho-physiological states which obligatorily "affect" not only the mind, but also the brain and the whole body*. Such a broad definition, which is in agreement with a current trend in neurobiology (e.g. PANKSEPP 1982, 1991; GAINOTTI 1989; MATURANA et al. 1994), has not only the advantage of covering all the above mentioned significations under one simple and biologically consistent concept. It is also entirely free of cognitive aspects (as defined below), and remains deeply rooted both in ontogeny and phylogeny Prototypical examples of affects in this sense are sympathicotonic (or ergotropic) states related to agressivity or fear (fight or flight), and parasympathicotonic (or trophotropic) states characterized by a pleasant state related, for example, to food intake, sexuality, care of the brood, or sleep. Most authors believe that there are only a few so-called "basic" or "primary" affects which are identical in all cultures and well rooted in evolution, among them initial interest or "stimulus-hunger", anxiety/fear, agressivity/anger, sadness/depression, pleasure/joy, and in addition perhaps also surprise, disgust, shame and some other, proposed by certain authors (HINDE 1972; EKMAN 1973; GAINOTTI et al. 1989; MACHLEIDT et al. 1989; LAZARUS 1991; PLUTCHIK 1993). The great number of more subtle emotional nuances are usually explained as combinations of several basic emotions resulting from differentiating interactions with cognitive elements (IZARD 1992). In the following, only the five generally accepted basic affects will be considered in more detail.

Affects in the defined sense are, at the human level, global qualititive psycho-somatic conditions which need not be conscious. Their duration may vary between a few seconds (emotions in the neurophysiological sense, which rather correspond to transitions from one affective state to another) up to hours, days, and even weeks (moods in the sense of psychology and psychopathology). A far reaching implication of the proposed definition is the fact that it is impossible not to be in a certain affective state. Even so-called 'neutral' everyday mental functioning which is usually related to quite automatic rational thinking and behaving, corresponds on this view to a specific affective state, characterized by a relatively relaxed average mood with small fluctuations between more pronounced emotions such as irritation and anger, pleasure or joy, or moderate dysphoria. In addition, we must allow that previously conscious emotional connotations of cognitions may become unconscious with increasing automatization, continuing nevertheless to have important organizing and integrating effects on thinking (see below).

Cognition, too (including sensory perception, cognitive-intellectual functions, thinking), is not univocally defined in the literature. Main difficulties concern the delimitation against affects or emotions on the one hand, and against elementary, or 'organic', forms of cognition on the other hand, such as those found in primitive organisms, or even in the genom (ZAJONC 1984; LEVENTHAL et al. 1987; IZARD et al. 1987; IZARD 1993; MURPHY et al. 1993). Again, a supraordinate phenomenological concept of cognition is lacking, but is proposed under the following definition within the framework of affect-logic: *Cognition is understood as the perception and further neuronal elaboration of sensory differences.* Again, this broad definition covers narrower ones such as the one recently advanced by IZARD (1993) who proposes to restrict the notion of cognition to information processing at higher levels only, which involve memorization, mental representations, and appraisal. As even very simple organisms such as worms and snails can be conditioned to certain behaviors and therefore must have some cerebral representation of their environment (v. FRISCH 1967; MENZEL et al. 1984), it is, however, practically impossible to define the beginning of mental representations, phylogenetically and also ontogenetically.

In agreement with the broad definition of affects, the proposed definition of cognition includes cognitive phenomena at widely different levels of complexity from elementary sensory inputs up to highly differentiated concepts and theories. In contrast to many other propositions, it establishes a clear delimitation against affects as defined above, thus facilitating the study of their mutual interaction. It also facilitates an evolutionary approach and corresponds to other theoretical approaches of cognition such as the cybernetic concept of information based of the notion of "a difference which makes a difference" (BATESON 1979). It is also in agreement with the notion of cognition, proposed by the British mathematician SPENCER-BROWN (1979) who has shown that the whole cognitive world can be reduced to the perception and further processing of sensory differences. Moreover, distinguishing between differences (variances) and non-differences (invariances) corresponds to one of the most basic performances of neural networks. An additional advantage consists in the fact that the proposed definition leads to an unbroken ontological continuity from primitive to highly abstract cognitive phenomena: Since any perception of a difference presupposes a comparison, a relation, an abstract or logicomathematical component, is present already in the most elementary forms of cognition.

On these bases, mental structures and activities of all kinds are understood, in affect-logic theory, as the result of constant complementary interactions between two global and clearly different systems with deep onto- and phylogenetic roots, an affective (or qualifying) one and a cognitive (or quantifying) one in the defined sense. Their interaction leads to different types of selecting and connecting cognitive elements in different affective states, that is to different types of information processing, or "logic" in the following general sense: *"Logic", in affect-logic theory, is understood as the specific way of linking cognitive differences.*

This equally broader than usual definition leads to the notion of different types of logic (or 'truth', or reality) depending on the adopted perspective—a view which is in agreement with a general trend in contemporary scientific and philosophical thinking illustrated, for example, by relativistic versus nonrelativistic physics, EUCLIDEAN versus non EUCLIDEAN geometry, or current constructivist philosophy (PIAGET 1977b; WATZLAWICK 1981; v. FOERSTER 1985; VATTIMO 1990; v. GLASERFELD 1987). It includes formal ARISTOTELIAN logic as well as "everyday-logic", that is the way how cognitions are actually connected in everyday life, which varies greatly under the influence of operator-like organizing and integrating effects of affects. On this basis, the general notion of affect-logic can be differentiated into a specific "anxiety-logic", "fear-logic", "anger-logic", "sadness-logic", "pleasure-logic", "love-logic" etc. characterized by affect-specific ways of connecting cognitions. Everyday-logic is characterized by the mentioned average emotional state and comprehends, mainly, all kinds of culture-specific (and also group-specific, family-specific, individual-specific) habitual patterns of thinking and feeling. As KUHN (1970) has shown specific patterns of thinking, or paradigms, varying with time and culture also exist in science.

Integrated feeling-thinking-behaving programs generated by action as essential "building blocks" of the psyche

As shown in detail by PIAGET (1977a; 1977b), cognitive structures of all kind are always generated through action, on the basis of innate sensory-motor schemata which are differentiated, equilibrated, automatized, internalized and finally mentalized by continual assimilatory-accomodatory processes since the first days of life. In spite of emphasizing inseparable functional links between cognition and emotion and postulating mobilizing and energizing effects of emotions on cognition with unconscious aspects of both (PIAGET 1973; 1977a; 1981) PIAGET did not include nor systematically conceptualize the participation of affects in the generation of cognitive structures. However, actions without emotions do not exist. From the point of view of survival, it is crucial to store them together with corresponding cognitive and behavioral elements, as illustrated for example by numerous conditioned reflexes including emotional components.

According to the concept of affect-logic, *affective*-cognitive schemata or programs (and not only *cognitive* schemata) are therefore generated through action and selected, repetitively reinforced if they are operational. Together with situation-specific cognitions and corresponding behavioral patterns, specific affects are encoded in neuronal pathways by neuronal plasticity (see below) and stored under the form of integrated *affective-cognitive systems of reference,* or context-specific *feeling-thinking-behaving programs* . These provide, eventually, the operational matrix for all further cognition and communication in similar contexts. Action is already operating on the phylogenetical level in the sense that mutation-generated or acquired new behavior that is more useful for survival will be privileged by evolutionary selection. Mental structures are continually built up by combining comparatively slow affective changes (relative invariances) with quick cognitive modulations (relative variances). Through repeated experiences in a expanding field of activity, an ever more differentiated hierarchical network of context-related programs for feeling, thinking and behaving is thus gradually generated by action, ranging from the above mentioned simple conditioned reflexes up to highly complex transference phenomena in the psychoanalytical sense (as for example stereotyped aggressive, or submissive behavior with typical father-figures as a long-lasting consequence of traumatic experiences in early childhood). The so-called self-representations and object-representations, too, which are generated by early imprinting experiences which determine, eventually, all kinds of transference behavior (JACOBSON 1964; MAHLER 1968; KERNBERG 1976, 1980), correspond to integrated feeling-thinking-behaving programs of high hierarchical order. Similar, but usually less complex affective-cognitive programs exist also for interactions with inanimate objects, with places and spaces, and for specific activities.

In summary, according to the concept of affect logic, context-specific integrated feeling-thinking-behaving programs generated by action for every kind of learned behavior form the essential building blocks of the psyche. The whole mental apparatus may be understood as a complex functional structure of similar programs on widely differing hierarchical levels. As they are biologically imprinted by neural plasticity into the structure of the neuronal network and contain, simultaneously, intrapsychic-subjective as well as interpersonal-social components of experience, the proposed conceptualisation provides a basis for a comprehensive psycho-socio-biological model of the psyche which integrates affective and cognitive, individual and social, ontogenetical and phylogenetical aspects.

Operator-like organizing and integrating functions of affects on cognitions

As research in most of the relevant fields has typically been specialized either on cognitive functions or on emotions, and emotions are more difficult to objectivize than cognitions, the question of specific interactions between both has for a long time been either neglected, or approached in an unilaterally cognitivistic way. At the human level, emotions have often been understood as only energizing or simply accompanying side effects which impede correct logic and rational thinking. PIAGET (1981), too, accepts only energetic (mobilizing and motivating) effects of emotions on cognition, denying any additional structure-generating influence. In contrast, a functional primacy of affects over cognition, with important organizing and integrating effects of the former on the latter, has recently been proposed and discussed in the literature (ZAJONC 1980,1984; CIOMPI 1982/88, 1986,1991; IZARD 1977,1993). Careful analysis reveals in fact that there exist circular affective-cognitive interactions, presumably with flexibly changing primacy of affective or cognitive elements according to the overall situation. Moreover, at least the following operator-like organizing and integrating—that is structure-generating—effects of emotions on cognitions are constantly at work:

Firstly, the focus of attention is continually conditioned by basic emotional states. These states have a decisive influence on selection and linkage of relevant cognitive stimuli in learning processes. Specific types of logic in the above mentioned sense are thus generated by different emotional states. In addition to conventional forms of logic and of culturally determined cognitive self-evidences in the sense of the above-described everyday-logic, a specific "fear-logic", "anger-logic", "sadness-logic", "happiness-logic" etc. emerges under specific affects. In melancholic states for example, only negatively connotated cognitions are selected and combined into an entirely negative view of the world, whereas in mania, a pervasively opposite positive "logic" is on the contrary created by predominating euphoric affects. Analogue affect-specific cognitive contents and logical chains are activated when being in love, or in hate, and so on.

Secondly, storage and remobilisation of cognitive material, too, is state-dependent for the same reasons, and can be illustrated by the same examples. Cognitive information without a specific emotional connotation is hardly noticed nor stored, and emotion-specific memories are remobilized in corresponding states. Affect-specific memorization, too, has been shown by experimental work. If specific emotional states were induced by suggestion, hypnosis or drugs, cognitively widely differing life-events scattered over many years, but linked by common affective connotations such as shame, or rage, or pleasure, were remembered "en bloc" (GROF 1975).

Thirdly, both above mentioned phenomena contribute to create affect-specific diachronic and synchronic coherence and continuity of experience according to context. Context-relevant cognitive stimuli are activated, whilst irrelevant stimuli are suppressed by specific affects. In a fearful situation caused by a fire, for instance, all other cognitive elements but those directed to salvation—which are highlighted—are eliminated from the field of consciousness. It is obvious that this has a high survival value. More subtle mechanisms of the same type are, however, also at work in less dramatic situations in everyday life. Even in scientific work,the focus of attention, as well as the storage and mobilization of mnesic material is continuously directed and conditioned, consciously or not, by underlying global states, or moods, with clear emotional connotation as for example interest, ambition, competition.

Fourthly, this last example shows that emotional factors may moreover play an important role in the reorganization of cognitive material at higher levels of abstraction, or "majorising equilibrations" in the sense of PIAGET (1977a). Unpleasant feelings caused by contradictions or inconsistencies furnish the needed energy for looking for new solutions. Detecting tension-reducing hidden invariances and finding new solutions is in itself pleasurable, because more economical and efficient. When found, these new cognitive structures are immediately linked to pleasant feelings. Several pleasant cognitive elements are eventually linked and combined into positively connotated higher-order cognitive structures, as for instance in a new overall hypothesis, or theory. Common positive or negative feelings, thus, guide and connect pleasant cognitive elements, respectively disconnect unpleasant ones. These initially intense and quite conscious emotional connotations are stored together with the corresponding cognitive elements and continue, eventually, to manifest themselves as a specific "pleasure of function" which accompanies all easy going mental and psychomotor activities. On the other hand, strongly unpleasant feelings (anger, agressivity, sadness or fear) are immediately activated, when long-lasting automatized affective-cognitive patterns are suddenly questioned and disturbed by new scientific paradigmata (KUHN 1970; CIOMPI 1982).

Last but not least, dominant and subordinate affects create a corresponding hierarchical order of cognitive functions. This is particularly important for motivation and an affect-centered understanding of the phenomenon of will which represents an "affective regulation of regulations", that is something like a compact supraordinate affect, according to PIAGET (1981).

The described organizing and integrating effects of emotion on cognition are common to all types of affects, and may therefore be called non-specific. In addition, there are also specific cognition-organizing and integrating functions of each particular affect. So, interest—which is closely related to the orientation reaction that can be observed even in very low animals—has the function of arousing general attention and cognitive activity. Anxiety or fear specifically direct attention to potential dangers, mobilise, select and connect danger-specific cognitions, induce flight or avoidance-behavior, and have thus highly survival-relevant functions as repulsors. Aggressive feelings, on the other hand, focus the attention on cognitions that are relevant for fight. They presumably originate in defense reactions against invaders and have the vital function of setting limits, thus maintaining or expanding the proper living space. Feelings of sadness, on the contrary, direct cognitive affectivity toward lost objects and thus promote what FREUD has called the "work of mourning", that is of letting loose and overcoming bonds that are no longer functional. Positive feelings such as pleasure, joy, love finally have powerful attracting and binding effects. They serve as major connecting forces not only between persons, but also between cognitive elements of all kinds, thus contributing to the generation of higher-order mental structures.

It is interesting to note that self-similar (fractal) specific and non-specific effects of emotions are not only present at the individual level, but also at the collective level. Affects are, in fact, highly contagious. They generate common patterns of feeling, thinking and behaving in couples, groups, and even in whole nations, by creating a common focus of attention and connecting cognitive contents with common emotional connotations. They also mobilise state-dependent collective memories and eliminate others, establish a common hierarchy of cognitive values, and thus create collective diachronic and synchronic continuity and coherence of experience and action. Common actions without common feelings are practically impossible. Extreme examples are collective hysteria, panic, enthusiasm, and agressivity, and collective rememorisation or, on the contrary, repression of certain historical facts under the influence of highly emotional political situations.

In summary, in addition to their energizing power, affects have multiple organizing and integrating effects on cognition. Both on the individual and on the collective level, one main common denominator of their function is filtering and reducing cognitive complexity. By focalising, selecting, storing, mobilizing and connecting relevant cognitive material according to the situation, basic affects such as interest, fear, aggression, sadness or pleasure as well as their multiple more subtle derivatives thus act as typical operators on cognition, regulating and directing cognitive activities and contents in ways appropriate to the situation.

Chaos-theoretical aspects of affect-logic

Chaos-theory (and also the more recent complexity theory) deals mainly with non-linear shifts (or phase-transitions, bifurcations) which can suddenly occur in complex physical, chemical, biological and psychosocial open systems with multiple feedback-loops, under the influence of increasing energy-inputs far from equilibrium. Other central characteristics of the dynamics developing in such self-organizing systems is high sensitivity for initial conditions (small initial differences can lead to important deviations with sufficient time), complex dynamics under the influence of various types of so-called strange attractors (unpredictable dynamics in detail, remaining however within a foreseeable range), and so-called fractal geometry (self-similarity of dynamic phenomena on small and big scales —see HAKEN 1982, 1990; PRIGOGINE et al. 1983; TSCHACHER et al. 1992, 1994; CIOMPI 1996).

The psyche is a highly complex open system with multiple feedback-loops and often typically non-linear dynamics. All the above mentioned characteristics are relevant for normal as well as pathological mental functioning, according to the theory of affect-logic. The genesis and eventual dynamic functioning of the described feeling-thinking-behaving programs can be understood as regulated by strange attractors which maintain context-related repetitive feeling and thinking within a given overall range, with unforeseeable self-similar small variations. Sudden shifts from one attractor-basin to another and global non-linear transitions toward a qualitatively different mode of mental functioning can occur under the influence of energy input under the form of strong emotions both under normal and pathological conditions. This is illustrated, for example, by changing forms and contents of normal thinking-feeling-behaving under the influence of different moods or tempers, or by sudden shifts to psychotic functioning such as melancholia, mania, schizophrenia. Normal or pathological ambivalence, too, with high sensitivity to initial conditions in states of critical mental labialization corresponds closely to non-linear dynamics, and typical self-similarity on different scales is also observed—as already described—between mental phenomena at the individual level and various degrees of collective levels.

Most of the above described organizing functions of affects on cognition, too, are characterized by non-linear dynamics. Affects do not only furnish the needed energy for sudden shifts of overall feeling-thinking-behaving patterns, but also stabilize the mentioned attractors by maintaining context-appropriated continuity and coherence of feeling and thinking within an appropriate range. By provoking sudden phase transitions at a certain level of emotional tension, affects also function as typical so-called control parameters in the sense described by HAKEN's synergetics, whereas cognitive elements (e.g. a suddenly predominating 'idée fixe', or a delusional idea) often behave as so-called order parameters which may "enslave" the whole field of feeling-thinking-behaving. Empirical data which confirm the utility of a chaos-theoretical approach of mental functioning are in particular emerging in the field of schizophrenia-research (AMBÜHL et al. 1992; CIOMPI 1996; TSCHACHER et al. 1992; SCHIEPECK et al. 1992; KOUKKOU et al. 1993, GLOBUS 1994).

In summary, the chaos-theoretical or complexity-theoretical approach provides a useful conceptual framework for understanding both normal and pathological psychodynamics in close agreement with currently leading dynamical concepts in other fields of science.

*

The four parts of this following chapter closely correspond to CIOMPI's reflections on affects in general, cognition in general, action-generated integrated feeling-thinking- behaving programs and organizing-integrating functions of affects on cognitions. The main elements of "affect-logics" will be confronted with a biological-evolutionary perspective .

Affects

The definition of affects in affectlogical terms proposes affects as global psycho-physiological states, affecting mind, brain and body. This definition is close to evolutionary-ethological considerations, which will be exhibited.

Emotions have long been studied in evolutionary terms. Some of the most popular ideas, formulated by DARWIN (1871), MCDOUGALL (1933) and PLUTCHIK (1980, 1984), place emotions within a biological, functionalist context. They appear as parts of behavioral programs (instincts) with a long phylogenetic history and high adaptive values. The arguments sometimes touch on ethics and aesthetics, where specific moral and aesthetic emotions are postulated (e g. Wimmer 1995a).

MCDOUGALL writes: "Emotion was regarded as a mode of experience which accompanies the working within us of instinctive impulses. It was assumed that human nature (our inherited inborn constitution) comprises instinct, no matter how brought into play, is accompanied by its own peculiar quality of experience which may be called a primary emotion" (MCDOUGALL 1933, p128)

The close relation between instinctive behavioral pattern and basic emotions, as well as the postulate of phylogenetically based emotional universals within humans are some of the most important topics within these concepts. Universal facial expression of emotions (EKMAN 1984; IZARD 1971; EIBL-EIBESFELDT 1986), and neurophysiological substrates of emotions (cp. PANKSEPP 1986) have been widely researched.

All these attempts view organisms and humans as consisting of different behavioral areas, each containing an internal state, sensory and motor components, which all are main topics of emotion research. First some general points in relation to these components, which will further be related to the concept of "primary emotions".

Internal specific physiological or psychophysiological base or state

These internal conditions or states are a fundamental element of ethological, as well as physiological research. At the behavioral level these states generate action tendencies, guiding the organism towards a specific behavior. The emphasis on internal factors in ethology was directed against the behavioristic tradition mainly focused on environmental conditions.

Witness LORENZ's notion on "endogenous built up excitability", which beside tissue needs and external stimulation plays an essential part in generating behavior (LORENZ 1981, p187). This perspective also includes the assumption that all types of learning contain inherited mechanisms, influencing the learning process more or less seriously.

From a more physiological point of view-e.g. VINCENT postulates a "fluctuating central state" (SPECTOR 1980, transl. by M.W.) as the basis of behavioral acts as well as of learning processes. This concept is defined as predominantly physiological, but it contains more than just elements of physiological homoeostasis (VINCENT 1990). The assumption of internal tendencies to actions, being generated without any direct physiological disturbance, shows close correspondence to ethological results.

This "fluctuating central state" in animals as in humans is a global phenomenon, appearing as the read out of internal conditions as well as the connected reaction and perception of the 'world'. It determines attention, perception, storage of experiences and cognitive processes (VINCENT 1990, p183f).

The underlying neural structures are a main topic of PANKSEPPS research; he postulates "emotive command circuits" which "are structured in the brain as sensory-motor command systems…executive neural circuits of the hypothalamic-limbic axis,…" (PANKSEPP 1986, p 95).

Organismic preparedness (readiness, dispositions) and the role of internal pace makers also is a main topic of neurophysiological research as done by CHANGEUX (first in 1983).

Sensory part

Ethology considers these capacities as the IRM (inborn releasing mechanisms) working in close correspondence to the 'key stimuli'. The IRM directs the organisms sensory input towards specific stimuls configurations. Within phylogenetic development the close and rigid connection between IRM and corresponding stimuli gets modified by learning experiences (see below).

Motor capacities

Within ethology this part—at a basic level—is called "fixed action pattern" (LORENZ 1981,1969; TINBERGEN 1951), appearing as a genetically determined movement pattern. This part is less modifiable, and early modifications of behavior by learning concern the sensory part.

Close to these assumption of organisms consisting of different behavioral areas, each containing a internal state, with a combined sensory and motor part is the idea of "primary" or "basic emotions", a major topic within emotion research. These basic emotions are deeply connected with these behavioral areas and show the following characteristics:

- genetic base
- specific physiological pattern
- typical expressive pattern
- universality
- specific phenomenological component

The idea of basic emotions is proposed e.g. by IZARD (1977), PANKSEPP (1986, 1991), PLUTCHIK (1980, 1984) and TOMKINS (1984). Critical arguments against the concept of basic emotions can be found especially in ORTONY/TURNER (1990), and in ORTONY/CLORE/COLLINS (1988).

SCOTT (1980), in favor of the primary emotions concept, argues that "…behavior patterns are organized into systems around each major life function, and that there is an underlying physiological system corresponding to each behavioral system." (SCOTT 1980, p39).

He recognizes nine systems, reaching from a basic physiological level e.g. 'ingestive system' to very complex social levels as e.g. 'allelomimetic system'.

SCOTT clearly exhibits the basic lines of arguments in the biological part of emotion research. There is no unspecific physiological arousal, which gets specified by cognitive activities—as proposed by different psychological concepts (SCHACHTER/SINGER 1962; DUFFY 1972) but the organism itself can be divided into different physiological, psychological and cognitive areas of activities (SCOTT 1980, 1985). The classical ethological literature also provides this argument (TINBERGEN 1951; LORENZ 1981; HEINROTH 1911).

For arguments coming from a biological—evolutionary field it is always essential to deal with the conditions or the context, responsible for the evolution of the topic analysed. Emotions thus viewed can have evolved in three kinds of field.

The first two fields are closely related and deal with the physiological level and the attendant. Although these levels are not separate they represent different forms of complexity. The third is the level of social systems (e.g. SCOTT 1980; WIMMER 1995a).

21. emotions at the physiological level are organised around fixed homoeostatical circles and show few degrees of freedom. The typical 'body-feelings' appearing as direct correlates of physiological configurations, like hunger and thirst are essential at this level.
22. behavioral level will be analysed in more details in the following chapters. The functional aspect of emotions at this level is found in activation, evaluation of the effects of behavior and of stimulus events. This last two points demonstrate the vital role of affects in increasing flexibility of behavioral pattern.
23. with increasing social behavior a new type of social elicited emotions appears, (e.g. love) which shows much more flexibility than the former levels.

All these levels seem to be closely interrelated—as can be seen in humans, where a disturbance at the social level (e.g. attachment behavior in BOWLBY 1960) seriously influences the physiological area.

In humans further levels appear in connection with the development of the 'self' and combined norms and rules, constituting our "social self" (SCHERER 1984; KEGAN 1989).

In general the first two levels are closely interrelated with environmental conditions and normally appear in relation to specific, concrete events (events with a 'material' base or a base consisting of a concrete action or behavior). Emotions in the social area have developed under different selection principles and show increasing distance from the concrete environmental influences.

One further important issue of biological considerations about emotions is their functionalist aspect. Functionalist arguments relate emotions to specific survival functions and connected survival values. Emotions on this view play specific roles in the 'game of life' and provide the organism with necessary informations for basic life-functions.

This functionalist way of thinking, e g. demonstrated in the PLUTCHIK´s works, proposing a chain of reaction sequences as follows: "Stimulus event–cognition– feeling–behavior–effect." (PLUTCHIK 1980, p11).

The function of the feeling part is primarily the evaluation of cognition in relation to the organism's actual needs and preferences. In biological concepts of emotion research, emotions fulfil specific survival functions. They work as parts of behavioral programs dealing with various kinds of life crises or survival problems. Emotions, on this view do not have a value in themselves but accompany more complex processes. This seems trivial for biologists, but e.g. for psychologists this functionalist way of thinking produces serious problems(cp. ULICH 1982, p123f).

In evolutionary terms functionality has to be seen as having stages, where each step involves specific functions, beside the overlapping ones. Here, if we discuss emotions, we must define the stage of development at issue, because the functionality of emotions in a bird is very different from that in a chimpanzee, who seems to have something like the consciousness of a 'self' . In taking into account the different complexities of cognitive capacities at different developmental stages, as well as the above mentioned different contexts and their respective characteristics, different functions of emotions occur. This must be remembered, or else a biological-evolutionary way of arguing leads to reductionism and crude biologistic ways of thinking.[1]

Cognition

Following the main principles of "affect-logic", cognition is defined as the perception of differences. This very broad definition, which does not reduce cognition to symbolic, conscious processes, is closely related to biological-evolutionary definitions, which also regard cognition in a very broad sense and are deeply rooted in organic processes (LORENZ 1977, PIAGET 1967, HESCHL 1990) .

In evolutionary theories, evolutive processes are seen as generating differences.

Following H. SPENCER, evolution is characterized as "…a change from an indefinite, incoherent homogenity to a definite, coherent heterogenity through continuos integration and differentiation." (SPENCER, from HILLMAN 1992, p158)

This shows the close relation between evolution and cognition, as well as the possibility of a deep organic foundation of cognition.

In general, evolutionary theories consider cognition in a functionalist way, as a process leading to a maintenance and growth of structures and their functions. These processes are analysed at different levels - reaching from the level of the genom and simple learning mechanisms to the functions of higher nervous activities—as seen in the so called ratiomorph mechanisms (BRUNSWICK). At the top level we find typical human cognitive abilities characterized by consciousness and reflexivity (RIEDL 1984; OESER 1987).

Essential components of the term 'cognition' can be exhibited at two levels: that of organic processes, being dominated by the basic biological tendencies of self preservation and preservation of the species and where it makes sense to speak about 'gain of information' (RIEDL 1984, p2, 15; OESER 1987, p9); and more complex ones characterized by complex brains, consciousness and reflexivity, and where it is useful to speak about 'gain of knowledge'.

For both levels the general definition of cognition as perception of differences is adequate. The element or content of perception depends on the quality of the system at work (OESER 1987, p21) and can also be directed more toward 'external' or 'internal' events. For a biological foundation of the affect-logical cognition definition it is important to mention that almost all information processing mechanisms have a phylogenetic base—the so called "mechanisms exploiting instant information" as described by LORENZ (1981, p221f). These mechanisms determine, what gets an information or which difference will be perceived as difference. The underlying structures are products of phylogenetic learning and work as follows:

"Every single piece of information thus received is evaluated and exploited, to be erased immediately afterwards. The message must not leave any vestiges whatsoever—so that they cannot impede any contrary response which may be demanded at the very short notice of a hundreth of a second." (LORENZ 1981, p222).

Within this basic field, the response to the perception of a difference is probably fixed to a very high degree and the perceptions do not get stored. One example of these 'mechanisms exploiting instant information' is homoeostasis—a process which allows an organism's conditions to remain within given 'values of reference' (Sollwert). The 'perceived' differences are just specific parameters as e.g. decrease of glucose level in the blood and the actions that follow are strictly fixed by genetically determined pattern.

At more complex levels more and other 'differences' become relevant.

At the level of 'gain of knowledge', typical for human cognitive abilities and characterized primarily by reflexive consciousness the cognitive processes are working in a field transcending the basic biological imperatives of self- and species preservation. Nevertheless these transcending levels are deeply rooted in the underlying biological mechanisms. The "mechanisms exploiting instant information" are still at work but are completed by structures that are the result of ontogenetical development, being generated by individual actions and experiences. This level is completed by a level characterized by consciousness, language and symbol production. Even this level shows that the basic assumption of cognition as perception of differences remains valid.

It should be mentioned, that in developmental processes a permanent change of structural (fixed) and fluid (dynamic) flow of information takes place (OESER 1987, 1985, see below). This means that a dynamic flow of information can be fixed and stabilized, forming a new structural base for a new type of dynamism.

Action generated integrated feeling–thinking–behaving programs as essential building blocks of the psyche

The affectlogical notion of action generated integrated feeling–thinking–behaving programs, as essential building blocks of the psyche shows—as CIOMPI mentioned—close relations to PIAGET's schemes. For PIAGET schemes can be understood as basic pattern constructed by the organism (PIAGET 1967, p181), guiding the sensomotoric actions, perceptive processes as well as mental operations. Within human ontogenetic development schemes are considered as highly felxible and modifiable by actions as well as internal organizational processes. CIOMPI expands PIAGET's cognitive schemes in integrating affective components (CIOMPI 1982) leading to the term affective-cognitive scheme or feeling-thinking-behaving program.

With regard to ethology the schemes can be put in relation to instincts, with the main difference, that instincts in their sensor, central and motor component are highly fixed and less modifiable than schemes. Further differences will be analysed below.

Three main points have to be discussed in this chapter: actions, feeling–thinking–behaving programs and the notation of building blocks.

Actions

As mentioned by PIAGET action is a essential part of development providing growth and differentiation of schemes.

Results of neurophysiological research as well as developmental psychology closely agree on this.

In the phylogenetic field the role of action is much more difficult to define and the assumption that action plays a part within phylogeny is a highly controversial one.[2]

In general, behavior can influence phylogenetic development in two ways—both in relation to the relevant selective conditions. One appears in the organisms individual choice of a specific niche, which always contains characteristic selective criteria. E.g. if a bird 'decides' to live in special parts of trees in search for food, it 'chooses' selective criteria, which influence further development. In this way, individual behavior (or individual choice) effects evolutionary processes (WADDINGTON 1975). This 'choice' does not influence the random processes of mutation and recombination itself, it just influences the selective processes, in relation to these variabilities.

The second element—beside the choice of a niche—is the organism's state of needs. Each state produces specific needs in relation to basic life functions: need for reproduction, territory, etc. All these needs (e.g. the successful search for a mate) produce a selective field, which again seriously influences the variation-selection circle (cp. LORENZ 1975). We must remember that speaking about the role of behavior in phylogeny can be misleading, because behavior always is just a product of an individual organism, appearing just in its own life span. The influence on phylogenetic processes is considered as working in an indirect way, i.e. individual choices have an effect on the selective criteria, which directly influence the genetic variations.

To return to ontogeny, phylogeny is assumed to be the basis. All learning processes involve an inherited base and it seems, that the increasing importance of action has its roots in the much more flexible and intense feedback processes between the mechanisms producing variations and the corresponding selective processes. Individual experiences, needs, preferences, habits … are not just working as selective instances dealing with blind variation products, but they can also deeply influence the process of generating variations. On this view many ontogenetic developmental processes are considered as LAMARCKIAN.

Beside these differences, it is a main goal of evolutionary considerations, to find some common elements or mechanisms within ontogenetical and phylogenetical processes (cp. HAECKEL 1905; SPENCER 1882; OESER 1987, p143f).

However we must first discuss some more abstract and theoretical elements that will bring out some mechanisms common to phylogenetic and ontogenetic development. These considerations are necessary for understanding the role of action as well as the 'feeling – thinking – behaving programs' from a biological-ethological perspective.

Development or change of structures figures prominently in evolutionary theories, both in phylogeny and in ontogeny.

A useful model applicable at both levels, and very helpful for a analysis of the 'feeling – thinking – behaving programs' was developed by OESER (1976) and MAC KAY (1950). The distinction between structural-fixed and dynamic information offers a tool for an analysis of structures at different levels. The level of fixed, or stabilized information contains the 'hardware', i.e. the underlying fixed pattern, responsible for different functions. The level of dynamics contains the 'fluid' information, i.e. the part of actual function, or processes. Each structure—responsible for a specific kind of action or function—contains built-in information, as a condition for the function of the structure. Genetically all structures have a 'history', i.e. they appear as a result of prior dynamics. These considerations also underline that information is always relative in relation to the underlying structure. There is no information per se, but speaking about information, the structure responsible for generation and transformation of information has to be taken in account (OESER 1985, p115).[3]

This point of view provides a useful instrument in comparing ontogenetically and phylogenetically developed structures; the main difference is that within ontogeny the feedback between the actual dynamics of a structure and the 'fixed' base is much more intense, so that underlying structures become more modifiable. Minimal modifiability can be seen in structures, LORENZ calls "mechanisms exploiting instant information" (LORENZ 1981, p221f). They appear as (see above) phylogenetically 'hard wired' structures, whose actual dynamics has minimal influence on the basic structures.

Common to phylogenetically and ontogenetically established structures is the split between stabilized or fixed information and the dynamics of these structures.

A closely related common element of phylogenetic and ontogenetic developmental processes is pointed out by Evolutionary Epistemology: all developmental—learning processes (from organic to cultural learning) have in common a circular or spiral like configuration, being part expectation and part experience (RIEDL 1984, p 185).

The expectation is guided by the underlying structure, which offers a more or less rigid frame for different functional components. The dynamism of this part establishes the experience, whose feedback can modify the basic structure in more or less intense ways. E.g. the structure of a reflex arch is highly determined in its perceptive as well as in its motor part. As shown by classical conditioning, small changes can take place within this area.

As a main difference between different levels of complexity within phylogeny as well as ontogeny appears the fact that with increasing complexity more and more selective devices guiding developmental processes are working within the system itself, and the influence of external conditions diminishes (comp. RIEDL 1984, p 141,185). E.g. an unicellular organism is highly dependent on the surrounding conditions, which directly influence its behavior. At the other end of the scale lies human social behavior, where the main criteria for e.g. the evaluation of a complex social situation depends to a high degree on learnt, culturally given standards of behavior.

This goes along with increasing importance of constructivist elements as parts of organismic actions, i.e. the guiding instances responsible for the development of structures increasingly appear as the result of individual experience.

As individual experience grows more important, the time scale for these changes shrinks, and the role of errors and disturbances in the improvement of structures becomes different. Errors within genetic learning in most cases means death for the organism, while with evolved learning capacities errors are necessary to improve structures.

In general, within phylogenetic learning the underlying bases always are genetically fixed and the resulting dynamics limited to this base, while ontogenetic learning shows that these underlying bases can themselves be products of individual activities and the resulting dynamics can influence the structural base much more radically. For generation of these bases through individual activities, the phylogenetically programmed standards seem to work as limiting constraints, reducing the range of possible developmental pathways.

The following results of ethological research will show—in a more concrete way—the elements of these phylogenetically developed structures of behavior as well as their dynamics and possible modifications directly leading to CIOMPI´s "feeling-thinking-behaving programs".

Feeling-thinking-behaving programs

In putting CIOMPIS "feeling–thinking–behaving programs" out of the sphere of human ontogeny into a more phylogenetic context, many ethological considerations must be taken into account. Ethological research (including neuroethology and behavioral physiology) includes a phylogenetic angle and puts forward the notion of the earlier mentioned 'functional areas' (Funktionskreise) (UEXKÜLL/KRISZAT 1970), or instinctive behavioral pattern consisting of specific motor and sensor components as well as of a central, coordinating part (LORENZ 1981; TINBERGEN 1951). These pattern appear as products of phylogenetic learning, and it is a merit especially of ethology to show that behavioral patterns can be genetically transferred in the same way as anatomical structures and demonstrate the relationships between different species as clearly as morphological structures.

CIOMPI's action generated "feeling–thinking–behaving programs", viewed ethologically, can be separated into a sensor, a motor and a central component, but it has to be taken into account that they form one inseparable unit; each separation cuts into pieces, what in its functional aspects is just working as a global mechanism. They show a lot of similarities to PIAGETs senso-motor schemes.

Next, let us analyse these components from a biological-ethological perspective.

■ *Sensor part (thinking part):* this would be the more 'cognitive' part, called "innate releasing mechanism" (IRM; German AAM = angeborener Auslösemechanismus)—a functional concept—describing the sensory capacities which allow organisms to perceive and react to specific, relevant conditions. Compared to the motor component, which appears as very rigid this sensory part is a major target of evolutionary changes (LORENZ 1975). E.g. social behavior is full of IRMs which are highly sensitive for specific behavioral acts of the conspecific, showing the role of behavior within evolution.

The sensitivity of the IRMs depends on the internal—central— motivational state (a component of the central part) of the organism, making the organism sensitive for categories of stimuli, relevant to its actual state.

The IRM appears as function of the nervous system and shows increasing specialization with increasing complexity of neuronal activities. Invertebrates, especially insects and spiders (Arachnidae), show inborn releasing mechanisms, not modifiable by learning (LORENZ 1981, p175). In 'higher' animals (especially vertebrates) all IRM can be modified by learning, what O. STORCH calls "receptor learning", demonstrated e.g. by SCHLEIDT.

"The filtering effect of the IRM is often enhanced during ontogeny by the learning of additional characteristics or by habituation to stimulus configurations which have been encountered repeatedly. I propose to separate conceptually from the IRM (in a strict sense) those IRM 'modified by experience' and to use the acronym IRME. Releasing mechanisms which either have lost the originally existing structure of their IRM, or which have developed without an underlying IRM, can be separated from the previously mentioned types as 'Aquired Releasing Mechanisms'." (SCHLEIDT 1962—cit. from LORENZ 1981, p273)

These IRMs demonstrate the first 'opening' of rigid, genetically preformed sensory mechanisms by experience. The class of experiences, able to modify the IRMs is very small and limited and in close relation to the "inborn teaching mechanisms", to be discussed below. This early modifiability of inborn pattern by individual experience (beside the imprinting phenomenon, which is a special type of modifiability) is the first step leading to increasing interaction between the genetically fixed structures and the actual dynamics.

Examples for further modifications of this sensory and motor component are "conditioned appetitive behavior", "conditioned aversion" and "conditioned action" (LORENZ 1981, p289 ff; HASSENSTEIN 1987, p274 ff).

Conditioned appetitive behavior can be seen, if an organism stores the relevant elements, which occurred, before a relief of drive tension (consummatory act) was reached. An example is given by FRISCH in his work "A Catfish that Comes if one Whistles for it" (FRISCH 1923—cit. from LORENZ

1981, p296). Before feeding the fish, FRISCH whistled to test the auditory sensitivity. At first the fish did not react but after some trials the fish reacted to the whistle with intense swimming and searching activities.

Conditioned aversion can be seen, if "…the perception of a neutral or even an appetite—inspiring stimulus situation has been followed once or several times by a punishing experience, it becomes associated with a response of avoidance which can take the form of escape or of inhibition to approach." (LORENZ 1981 p301).

Finally areaction is conditioned if a specific behavioral ct is rewarded by a reinforcing stimulus situation and an association between the motor behavior and the motivation, satisfied by the reward, can be established (LORENZ 1981, p303; HASSENSTEIN 1987, p290f).

All these modifications of the sensor as well as the motor component (shown below) of behavioral schemes cannot be properly understood, if the emotional components are not taken into account. In general they provide the organism with a necessary feedback of behavioral acts, which color specific actions or situations. It seems evident that as behavior became more modifiable, those emotional capacities grew, whose main function was to evaluate the outcomes of actions and their attendant conditions. These evaluations 'emotionally color' the sensor as well as the motor component.

In changing to the ontogenetic sphere, the relation to PIAGET's schemes seems obvious. The sensor component of the schemes is their sensitivity to specific stimulus configurations (grasping scheme; sucking scheme…). The main difference to the IRM is their tremendous modifiability and the reciprocal assimilation of originally separated schemes which leads to higher levels of coordinations. These modifications are much more far reaching than the proposed IRME or IRM within ethological research.[4]

■ *Central component (feeling part):* The central part can be viewed as a mediator between a sensor surface and motor pattern.

Looking at this part from a neuro-ethological-anatomical point of view, it is situated mainly in brain regions, above all within the limbic system (MCLEAN 1973; PANKSEPP 1984). This brain region is closely related to instinctive behavior.

Concerning the motivational component of these behavioral programs, it is one of the main merits of ethology to make clear that organisms are not just reacting to external stimulation or to actual tissue needs. Although both components must be taken into account, there is also an internal, endogenous production of excitability, preparing the organism for specific behavior, (appetitive behavior) before actual deficiencies in the physiological field become dominant (LORENZ 1981; HOLZKAMP-OSTERKAMP 1981, p86f; VINCENT 1990; CHANGEUX 1984).

The relations between this central, coordinating part and feelings is a controversial topic. One line of argument interprets the feeling part merely as accompanying the completion of these instinctive behavioral patterns (MCDOUGALL 1933; CELERIER 1927, SULLIVAN 1955). Within this tradition the feeling part is a secondary phenomenon, an epiphenomenon, appearing as the result of brain and motor activities and neuro-physiological changes. These are the primary sources of feelings, which arise as a 'side effect' of such activities.

A similar position is that of W. JAMES who likewise proposes a close connection between instincts and emotions:

"Instinctive reactions and emotional expressions thus shade imperceptibly into each other. Every object that excites an instinct excites an emotion as well." (JAMES 1890, p442, cit. from HILLMAN 1991, p49).

The core element of JAMES theory of emotions postulates "…that the bodily changes follow directly the perception of the exciting fact, and that our feeling of the same changes as they occur is the emotion. […] Every one of the bodily changes, whatsoever it be, is felt, acutely or obscurely, the moment it occurs." (JAMES 1890, p449f, cit. from HILLMAN p50)

So for JAMES, feelings are just perceptions of physiological-motor changes.

Other, more functionalist models view emotion as a mediating instance between cognitive and motor parts (e.g. PLUTCHIK 1980,1984).

We shall not list all the different models dealing with the relations between the activity of the 'central part' and feelings. Only one element must be kept in mind: the accomplishment of behavioral pattern (with all three components—sensory input, central part, motor part) is considered to be closely linked with the generation of feelings. This can be seen at the elementary level of the so called 'body feelings', e.g. thirst, being accompanied with negative feelings and drinking with pleasure. The generation of these 'body feelings' is a result of peripheral tissue changes and of central neuro-physiological processes. At this basic level feelings and physiological changes are closely interwoven and feelings appear as immediate correlates of physiological changes. At more complex levels—e.g. the accomplishment of a complex motoric pattern, or social behavior—the combined feelings become more differentiated and less combined with physiological changes.

The close relation between instinctive behavioral pattern and emotions seems evident, but the hypothesis of "emotion as an accompaniment" (HILLMAN 1991, p45f) does not take into account the evaluative functions of emotions leading to a broad scale of experienced emotions as well as to modifications of behavior.

The basic level of these evaluative mechanisms can be found in the "inborn teaching mechanisms" and the connected reward and punishment systems.

The "inborn teaching mechanisms" prove to be a very useful concept for discussing the functional components of the feeling part at this level.

Following LORENZ, the "built- in teacher" is defined as follows: "The built-in teacher, checking on the exteroceptor and proprioceptor input coming in as re-afference of a fixed motor pattern, is a physiological mechanism in many ways comparable to an IRM." (LORENZ 1981, p299)[5]

The "built in teaching mechanisms" provide the organism with a 'scale' for the evaluation of behavioral pattern. As LIVESEY points out, the basic affects are generated by these mechanisms, which appear as "…products of genetically established neural systems and accompany such stimuli as the taste and smell of food and drink, the tactual sensations of sexual intercourse, the pain of a burn and so on. These feelings are immediate perceptual correlates of the particular stimuli and constitute affects without cognitive interaction, though they are vital for the establishment of cognitive associations." (LIVESEY 1986, p251).

If an executed motor pattern conforms to this teaching mechanism, it is combined with pleasure; or, at more primitive level, does not cause any disturbances. Deviations from this prefixed standard lead to feelings of disharmony and disturbance.

In general the inborn teaching mechanisms can work at two levels. One is the mentioned motor control function, comparing the actual action with the 'ideal' one, the other can be found in a class of feedback processes, concerning success or failure of the action (KLIX 1980, p10). The underlying anatomical structures of these feedback signals are the pain and pleasure areas, as analysed by OLDS/MILNER (1954), which can be differentiated in specific and non specific areas. They are situated beside the lateral hypothalamus, forming areas whose stimulation colors actions with specific affects (VINCENT 1990, p217).

Combined with motor pattern the most elementary types of feedback mechanism are the "instincts without feedback reporting success" (LORENZ 1981, p286):

This simple type of behavior just includes information about performance of the action. This can be demonstrated e.g. in the behavior of a spider-building up a web. The behavioral feedback just contains information about the number of abdominal movements necessary for builiding up a web, without any information about concrete results of the action (e.g. if the web was in a bad position or something like this). Behavioral programs of this type are extremely rigid and do not allow any modification.

Much more complex feedback mechanisms with a combination between motor part and success-failure feedback are the "instincts with qualitative feedback" (LORENZ 1981, p289f), providing the organism with a qualitative feedback, giving more or less detailed information of success or failure of the action that has taken place.

"Without any known exception, animals that have evolved a centralized nervous system are able to learn from the consequences produced by their own actions, success acting as a 'reward'or 'reinforcement', failure acting as 'punishment' tending to 'extinguish' the animal's readiness to repeat the action just performed." (LORENZ 1981, p289).

Within the human sphere, much more complex and socially transmitted norms and standards work as evaluative criteria of performed actions, being rooted in biological programs.

■ *Behavioral part: the motor component.* Starting at the most elementary level with the fixed action patterns and reaching to complex voluntary movements.

In search for the 'building blocks' of behavior, different levels of analysis can be chosen. The most elementary one is the level of motor activities as e.g. the muscular pattern necessary for a specific movement (to fly, to walk, to cry…). As shown by v. HOLST and v. ST. PAUL (1960) these muscular-motoric pattern can be released by different more highly ordered centers, such as the centre for flight, or attack.

A similar order is shown by BAERENDS (1956) with the lowest level consisting of muscle movement, which is controlled by a fixed action pattern (see Figure 1). The low level units can be under control of different higher instances and they are called "multi-purpose" activities (LORENZ 1981, p220), which can be released or activated by superior instances, or by the internal, autonomous production

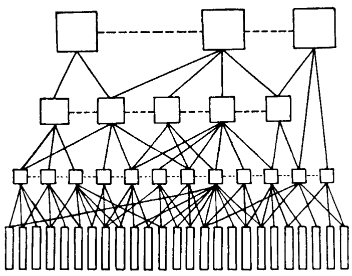

Figure 1: BAERENDS dicsriminates between four levels (BAERENDS 1956, p12): high order instincts (e.g. migration) low order instincts (e.g. territory) fixed action pattern (fight, flight, mating…) muscle movements. Dotted lines represent inhibitory relationships between mechanisms of the same order. (from LORENZ 1981, p198).

of excitation. So the question of motivation has to be analysed at different levels. The dependence of the motor pattern of different behavioral ambits shows the difficulty of drawing clear lines between separate instincts: we must put singular behavioral acts into a broader, functionalistic context.

The higher command areas (such as attack or flight) are closer to the sensor surface and to internal pace makers.

Ethological research shows very clearly that the 'building blocks' of animal behavior are quite rigid, hierarchically organized and strictly combined with specific pattern of internal or external releasing mechanisms, forming a linear hierarchy. A big phylogenetic step to a more flexible stock of these 'building blocks' is the so called "relative hierarchy of moods" as shown by LEYHAUSEN (1975) especially in Felidae.

"The acts of lying in ambush, stalking, catching, killing, and finally eating prey, form a sequence which is obligatory only with regard to their common teleonomic function. Physiologically, each of the motor patterns involved retains the character of a consummatory act that possesses its own appetitive behavior independently of whether it is performed under the pressure of the higher level of tissue need or acted out in play, for its own sake. " (LORENZ 1981, p203)

The 'step forward' towards increasing flexibility of behavior is the possibility to perform singular elements of the behavioral range of prey catching for its own sake and the ability to combine elements of different behavioral ranges; this can be seen in playing activities and curiosity. Especially curiosity leads to the performance of different behavioral elements in relation to exciting objects what leads to an immense growth of experience.[6]

Organizing and Integrating functions of affects on cognitions

Ethologically, organizing and integrating functions of affects on cognition presupposes that behavioral pattern can be modified. Otherwise behavior is strictly combined with specific internal and external conditions and performed in a rigid manner. Some essential features regarding greater flexibility of behavior as e.g. the feedback from behavioral acts—as shown in LORENZS concept of the "innate schoolmarm." (LORENZ 1981, p8, p260)

"The innate schoolmarm, which tells the organism wether its behavior is useful for the detrimental to species continuation and, in the first instance reinforces and in the second extinguishes that behavior, must be located in a feedback apparatus that reports success or failure …". (LORENZ 1981, p9)

The two types of feedback processes (feedback without reporting success and instincts with qualitative feedback) were mentioned above. Clearly, the feedback processes are essentially emotional.

The organizing function of these feedbacks in the phylogeny of learning mechanisms has different steps:

- Association between a previously neutral stimulus and an IRM (innate releasing mechanism). This type of learning is also called stimulus selection (LORENZ 1981, p276; LIVESEY 1986, p212).
- Selection of a specific stimulus which receives a signal for performing a specific behavior (conditioned appetitive behavior) (LORENZ 1981, p296). LORENZ' example is the dog, using the same digging and scratching behavior to bury a bone in different situations, e.g. on a parquetry floor, until it finds the right soil conditions for digging and burying. These conditions acquire the quality of a releasing stimulus (LORENZ 1981, p289).
- Association between a behavior pattern and a specific situation. Here an organism is performing a stock of behaviors to find out, which will achieve success—as THORNDIKES cat in the puzzle box. A behavior pattern is selected, and performed under specific circumstances. This type of behavior just appears in organisms with exploratory behavior (conditioned action) (LORENZ 1981, p303).
- Further modifications of behavior linked with emotional feedbacks are motor learning, voluntary movement and insight.

Within these developmental trends, the emotional feedback becomes ever more important. The evolution of learning mechanisms and emotional differentiation appears to be a co-evolutionary process.

In general the role of emotions can be regarded as stated by SCHERER:

"Emotions 'decouple' the behavioral reaction from the stimulus event by replacing rigid reflex-like stimulus response patterns or instinctive innate releasing mechanisms." (SCHERER 1984, p295)

One important step of this 'decoupling process' is the fact, that the complex instinctive behavioral pattern are cut into pieces. The genetically fixed sensory and motor components can escape from their organizing frame. The new organizing principle is essentially guided by emotions, evaluating or coloring sensor as well as motor components. As shown above, these emotions—at basic levels—are in close relation to fundamental survival values, providing something like a guarantee that the increasing freedom of behavior keeps in touch with basic imperatives. They offer a "yardstick" for the evaluation and integration of sensoric as well as motoric experiences (WIMMER 1995).

Within affect-logic the following components of these organizing and integrating functions of emotions are mentioned: focus of attention; storage and remobilisation of cognitive material; creation of affect-specific diachronic and synchronic coherence; reorganization of cognitive material at higher levels; creation of an hierarchical order of cognitive functions.

■ *Focus of attention:* for biological-ethological conceptions it also seems evident, that the basic, affective state (mood or internal state) highly determines the way in which the world is perceived and which elements are of interest. The type of IRM (inborn releasing mechanism) which is activated and sensitive for specific key stimuli greatly depends on the quality of the internal state. The affect-logical terms of "fear-logic", "anger-logic", etc. directly refer to the ethological term 'mood' (Stimmung) showing similar contents. Animals in a specific mood perform mood-specific behavior reacting just to relevant classes of stimuli. Although humans, too,always are in a specific mood, in animals these moods are much more specific.

■ *Storage and remobilisation of cognitive material:* as underlying anatomical structures there exist the reward and punishment systems in the brain. As shown by OLDS/MILNER these systems can be connected with several different behavioral areas and stimulation of pleasure areas by electrodes underlines the great strength of such stimulation. As pointed out by LEDOUX, the thalamus as well as the amygdala play an essential part in affective classification as well as storage of experiences (LEDOUX 1994).

Beside these pleasure and pain areas, specific motor mechanisms (the inborn teaching mechanisms)—as mentioned above—form 'ideal types' of specific movements causing strong pleasurable effects, if a motor pattern is produced in this 'ideal' way.

Each action (expect those performed automatically) seems to be combined with an affective component generated either by the effect and the combined reward and punishment systems or by the inborn teaching mechanisms.

Creation of affect-specific diachronic and synchronic coherence

This topic is closely related to consciousness in that synchronic coherence is characterized by consciousness of context relevant elements. Which mental elements become conscious is determined by the actual context.

The question of consciousness in animals is a very controversial topic. Here we shall mention only anticipation. There is growing evidence that higher organized animals can anticipate the outcomes of actions or anticipate emotions in specific situations.

As THROPE states: "…a living organism is essentially something that perceives. Therefore some element of anticipation and memory, in other words, some essential ability to deal with events in time as in space is, by definition, to be expected throughout the world of living things". (THROPE 1956, p4)

THROPE's "Principle of Expectancy" assumes, "that a reinforcement must be such as to confirm an expectancy. […] for reinforcement to be effective we have to assume some kind of anticipation during the appetitive behavior to account for the retroaction of the reward". (THROPE 1956, p104)

Anticipation seems to provide the diachronic coherence in that it offers selective devices for possible experiences and goal directed activities.

In this way anticipation can become a major element in motivation.

As to reorganization of cognitive material at higher levels of abstraction, this function seems to be related primarily to the human sphere.

Conclusion and Discussion

Our aim here was to link CIOMPI's "affect-logic" with evolutionary and ethological reflections, and with WIMMER's "evolutionary theory of emotions".

"Affect-logic" starts from ubiquitous interactions between cognition and affect. On the basis of "operator functions" of affect that organize and integrate cognition, we obtain, depending on the prevailing affective state, a functional 'logic' (in a broad sense) of fear, anger, grief, joy, or everyday life. This last is marked by a link between fairly weak and varied affects and largely automatic cognitive processes. WIMMER's "evolutionary theory of emotions"studies the origins of affect and cognition, starting from elementary forms of life up to the human domain.

Our main concern was therefore the phylogeny and ontogeny of interactions between affect and cognition. After surveying the aspects of "affect-logic", we gave a parallel account of evolutionary aspects of these interactions. Moreover, we discussed some more general problems of links between phylogenetic and ontogenetic development. We found similarities and differences as follows:

■ *The roots of emotion and cognition.* This concerns their early forms as discussed by WIMMER (1995). "Evolutionary theory of emotions"and "affect-logic"converge throughout.In "evolutionary theory of emotions"emotion and cognition are understood as regulative mechanisms what corresponds to "affect-logic's" biological extension of the definition of emotions as global psycho-physical states or "moods".

It remains an open question how we might usefully speak of "affects" in a single cell, but this is a matter of terminology rather than of principle. An evolutionary view suggests that even elementary regulative equilibrium processes contain primitive forms of affect and cognition. To confine affects only to complex conscious activities ignores evolutionary continuity. Components of both kinds inhere in primitive behavioral dispositions such as 'towards' and 'away'. As these develop, they become refined through growing central motor and sensory differentiation. "Affect-logic" views affects as global psychosomatic states, or invariances, that are modulated by cognitive variance (CIOMPI 1982). This corresponds with findings from ethology and psychology of learning which stress that in elementary learning, the affective background plays a basic role, and is also in agreement with CIOMPI´s postulate of affects as organizing and integrating cognition.

■ *Building blocks (integrated feeling-thinking-behaving programs generated by action):* Comparing the ethological division of organisms into different "functional areas" (instinctive behavioral domains, UEXKÜLL 1970) with action-based feeling-thinking-behaving programs in "affect-logic" (leading to specific logics of fear, anger, grief or joy), we find some common features. PIAGET's notion of a scheme, which "affect-logic" adopts and completes by adding affective components, and the classical ethological notion of instinct are central here.

Relating instinct to scheme seems justified in that the latter (above all in its sensory-motor aspect) contains sensory, central and motor components, as does the former. The basic difference is that instincts tend to be rigid while action based schemes (feeling and thought in humans) are highly flexible. However, to relate centrating assimilation with emotion, and decentrating accommodation with cognition as "evolutionary theory of emotions" does seems questionable for "affect-logic", because it assumes that at a higher level, both assimilation and accommodation apply to affective and to cognitive components as well. This remains consistent with the view of "evolutionary theory of emotions" that every building block includes such centrating elements that, depending on level, can represent a specific physiological status or an invariant cognitive category. Starting from such elements, the sensory and motor components belonging to each case become differentiated and modified, which can result in new centrating elements being set up, especially as regards ontogeny.

■ *The genesis of "building blocks".* In this domain similarities and differences between the ontogenetic and phylogenetic approach are of particular importance. For "affect-logic" action, or behavior matters equally in phylogeny and ontogeny. Survival behavior is selectively advantageous, whether innate (arising from mutations of genes) or acquired by learning. Phylogenetically, action mainly concerns choosing certain factors of selection. Thus, the range of the organism's actions determines its conditions of life and selection. Behavior patterns depend largely on fairly rigid genetic neuronal patterns and show just a small range of possible modifications.

In humans, this changes because behavioral acts help to develop and differentiate structures even in ontogeny. Concrete action brings about genetic possibilities that allow various lines of further development. Behavior becomes much more flexible and capable to build up new patterns. How such patterns are set up remains controversial, adaptationists (PLUTCHIK 1980,1984) being opposed by constructivists (AVERILL 1980, AVERILL/NUNLEY 1992, KEMPER 1991). PLUTCHIK denies that there are constructive elements in ontogenesis of human emotion, and regards its great variety as due to varying blends of biologically determined primary emotions (1980, p205). AVERILL, on the contrary, views social and cultural influences with their attendant emotions as the essential factors.

Here "affect-logic" and "evolutionary theory of emotions" provide an intermediate approach. A non-reductionistic evolutionary biological understanding of the emotions clearly shows how phylogenetically determined biological constraints are overlaid in humans, by individually established social and cultural influences. This is where "affect-logic" appears as an ontogenetic extension of "evolutionary theory of emotions".

Linked to specific cognitive structures, basic affects (like fear, anger, hat, mourning...) gradually form specific affective-cognitive-behavioral clusters (or 'personal worlds', ecologies of feeling and thinking) as those, for instance, of particular cultural or ethnical groups, fundamentalist movements, or sects. A detailed analysis of similar affective-cognitive connections and their development could therefore contribute to a better understanding of many of todays problems. Simultaneously this overlap of ontogeny with phylogeny seems a substantial field for future research into their mutual influences.

■ *Information.* "Affect-logic" uses the term in the spirit of G. BATESON (1983, p583) when he says that "information is whatever makes a difference". The core of CIOMPI's notion is that any in-formation in an operational sense is always embedded in an affective context, and never just cognitive. This agrees with "evolutionary theory of emotions", and with ethological findings, many of which suggest that an organisms range of perception is determined by the underlying psychophysical state. "Evolution-ary theory of emotions" here developed the thesis that what becomes an operational information largely depends on the underlying centrating structure, that is the assimilating data processing system and its actual state. For support, see OESER (1976, vol.2, p24), who regards the pragmatic side of information as more basic than the semantic and syntactic. His distinction between structurally fixed and dynamically fluid information is essential too. According to "affect-logic", integrated "feeling-thinking-behaving programs" rest on specific neuronal patterns containing specific affective imprints.

■ *Chaos theory*. For "affect-logic", since 1982, chaos theory plays a growing part as a basic framework, in particular as regards the role of affects in organizing cognition. Specific affective states may be understood as attractors and repulsors within a historically structured potential landscape in which the dynamics of thought and feeling move linearly or, under certain conditions, in non-linear phase-jumps or bifurcations. In "evolutionary theory of emotions", such an approach, though plausible, has not yet been developed.

In sum, CIOMPI's "affect-logic" and evolutionary theory in general and WIMMER's "evolutionary theory of emotions" in particular, seem to converge throughout. The two approaches not only support each other, but in several ways (e g. as to building blocks, or operational affect-specific behavioral units, the organizing and integrating operator functions of affects, and finally the chaos theoretical approach) genuinely supplement each other. There are minor differences, such as the weight of action in phylogeny and a possible parallelism between centrating assimilation and affects on the one hand, and decentrating accommodation and cognitive functions on the other. These divergencies seem to be due partly to terminology, and partly to as yet scarce empirical findings.

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Notes:

1 One serious deficiency of these evolutionary concepts is that they place emotions at a specific and quite high level of complexity (instinctive behavioral pattern) but they do not take into account the early phylogenetic stages of emotional development.
Continuity seems therefore to be broken at a specific stage. My aim has been to formulate a hypothesis of early roots of emotions, which showed the emotional parts of information processing mechanisms in basic regulative processes (WIMMER 1995, 1994).
Thus viewed, emotions appear very early in phylogenetic development and their main function can be found in the centrating-homeostatic tendencies, forming an elementary scale that provides an evaluation for deviations from the homeostatic state.
The combined cognitive element can be found in the registration or perception of this difference as regards this centrating, evaluative point.

This cooperation between an emotional centrating, underlying base and a decentrating cognitive procedure seems to form a general principle of interaction between affect and cognition. Both are inseparably combined, and one makes sense only in relation to the other.

2 Especially PIAGET, referring to WADDINGTON, as well as to his work on plants (sedum sempervivum) and snails (lymnea stagnalis), postulates that behavior plays an essential role in evolutionary processes (PIAGET 1976).

3 The question dealing with priority of structure or function appears in this case as not too important—e.g. PIAGET relies on the priority of function.

4 A fundamental change occurs, when organisms reach the ability to form symbols, i.e. the capacity to deal with objects or events in a "mentalized" way. Within ontogeny these changes are analysed quite clearly, especially by PIAGET who speaks about the "semiotic function". These changes have tremendous effects on the behavioral as well as on the affective part. The behavioral part, the 'concrete actions' lose their dominant position in dealing with the world and the affective part experiences strong differentiation, in that the affective qualities are combined with cognitive—symbolic elements.

5 Although the built in teachers are closely linked with the motor pattern, they are discussed in this part, because the produced feedback processes are closely connected with the central reward and punishment systems.

6 With the formation of symbols the motoric component in general loses its dominant position. According to FURTH (1990), the preserved energy is a necessary precondition for building up the symbolic sphere.

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Roumen Tsanev

Evolution and Genetic Networks – the Role of Non-linearity

One of the objectives of science is to explain more and more with less and less
—H. Plotkin

Abstract

A rational appraoch to the problems of biological evolution is to take into account the integration of genes into genetic networks due to trans-cis interactions. By using the law of mass action a general differential equation is derived describing both repression and activation of genes. This equation shows that any modulation of gene activity is governed by non-linear relations. The properties of a cellular system depend on the matrix fixing the trans-cis interactions and on the parameters controlling the metabolic pathways. The non-linearity of the system segregates the parameters space into zones of stability and zones of unstable chaotic behavior (zones of lethality). This implies that gradual DARWINIAN changes in these parameters are the driving mechanisms producing changes for the natural selection. Thus, different features of evolution—may be explained by the natural mechanisms of gene control.

Introduction

Our planet has the privilege of displaying the enormous diversity that Nature can produce by creating life. Unlike the very restricted variations in inorganic matter, the diversity of biological forms amounts to about 2 million classified species, the total number of living forms being estimated between 10 and 50 million (MAY 1988), not counting the extinct species. This biodiversity is one of the features that make Earth such a pleasant planet. The molecular mechanisms of this productive morphogenesis in evolution still present a challenge to the scientist.

Nature has achieved a difficult task combining in life two contradictory properties—heredity, conserving the existence of a living form, and the potential for changes leading to the emergence of new forms. Molecular biology has provided data that the reproduction of a living form is realized during embryogenesis by the activity of special sets of genes involved in the developmental program (for refs and discussion see NIJHOUT 1990).

However, the question remains as to how the information content of the genes is translated into a strictly specific phenotype. This translational mechanism is formally explained by the concept of an '*epigenetic system***'** which controls 'in a specific way' and according to 'specific rules' the phenotype expression (for details and refs see DIETTRICH 1992). Still more complicated is the problem of the mechanisms which alter the relationship genes/ epigenetic system to produce new forms for the natural selection.

Since DARWIN had established his theory of natural selection based on small individual variations, many debates took place concerning the pace of evolution. The DARWINIAN phyletic gradualism is often opposed to "un-DARWINIAN" abrupt changes (KERR 1995). The latter concept gains more and more support ever since the famous declaration of DARWIN that "*Natura non facit saltum*".

In summary, the following features of the evolution have caused disagreements and should be explained by a theory of evolution:

a) In some species gradual transitions are documented supporting the original concept of DARWIN;

b) At the same time, in contrast to the Darwinian gradualism, paleontological finds clearly show the existence of big gaps among different species, a fact which cannot be explained by incomplete discoveries;

c) Long geological periods of stasis exist when species have been 'frozen' in evolution before the appearance of new forms;

d) During some geological periods a mass extinction of species has taken place (e. g. see STANLEY/YANG 1994) which has not yet found a satisfactory explanation.

These facts have led to various ideas such as the theories of "*quantum jumps***"** (SIMPSON 1994) and "*punctuated equilibrium*" (GOULD/ELDREDGE 1993). The apparently contradictory features of the evolution have raised many questions and it was recently asked whether DARWIN "did get it all right" (KERR 1995). All these discussions caused the division of opinions referred to as a "gradualist-saltationist" schism (TURNER 1983).

To explain saltatory phenomena non-linear models have been proposed. However, the approach was to artificially introduce variables, such as for example a non-linear field (BRANDTS/TRAINOR 1990), genome operators (DIETTRICH 1992) etc. which in fact do not contribute to understanding the molecular mechanisms underlying the process of new pattern formation. Such a formal approach substitutes one unknown factor for another. It has been concluded that "we have not yet managed to build a theory of evolution that satisfactorily incorporates development as well as genetics" and "for the time being there is no theory at the molecular level which could provide a model for long-term evolution based on non-stationary recursive mechanisms" (DIETTRICH 1992).

Genes and genetic networks

Any approach to this problem has first to answer the question whether the emergence of new forms is a problem of genes only or essentially to gene regulation. Although a number of species have acquired in evolution some specific genes, there is strong evidence that genes *per se* cannot determine the phenotype. Many experiments show that a heterogeneous transfer of genes does not change any phenotypic features of the host. Human genes can be transferred and become perfectly active, for instance in mice, in yeast, in bacterial cells, without altering the morphological pattern of the host. In other words, genes are mutually interchangeable among species.

On the other hand genes involved in basic cellular functions such as cell cycle (see WARBRICK/FANTES 1988), embryonic development (see HOLLAND/WILLIAMS 1990; PATTEL 1994), transcription control (see GUARENTE/BERMINGHAM-MCDONOGH 1992; HERNANDEZ 1993), housekeeping genes, histone genes (see TSANEV 1980) etc., display a high degree of evolutionary conservation. In terms of information content humans, for example, are 99 percent identical to chimpanzees (see O'NEILL et al. 1994). Thus, an additional information is needed to make a phenotype out of a given set of genes. Accordingly, it has been already suggested by a number of authors that the important factor is the 'architecture' of the regulatory system which should influence the rate and direction of evolution (e.g. KAUFFMAN 1987; MACINTYRE 1982; DICKINSON 1988).

To understand the integrating function of the genome it should be taken into account that genes do not function as separate entities, but are interconnected in regulatory circuits, or more precisely *genetic networks,* due to the basic molecular mechanism controlling their functioning. This mechanism is based on the presence of a specific set of regulatory genes coding for proteins (transcription *transfactors*) which bind to specific DNA sequences (*cis elements*) nearby or at a distance (PTASHNE 1986) of the coding sequences of each gene (promoters, silencers, enhancers, upstream activating sequences). These *trans/cis interactions* may activate, repress or modulate gene activity and thus integrate genes into networks.

A genetic network can be formed in two ways. One possibility is when one cis element controls several physically linked genes (*operon*), a system operating mostly in prokaryotes. A second possibility is a set of physically dispersed genes having identical cis elements (*regulon*) which is mostly characteristic of eukaryotes. Many examples of functionally related genes exist such as the networks of cytokines, oncogenes, homeogenes etc. It cannot be excluded that the whole genome represents an extremely complex network.

It should be noted that genes coding for trans proteins, as well as cis elements are also interchangeable —i.e. they can also be transferred to heterologous species where they fulfil their function without changing the phenotype. This again shows that separate elements of a genetic network are unable to translate phenotypic features.

A mathematical model of genetic networks

Although the idea that new pattern formation is essentially linked to the regulatory system of the genome is not new, the consequences of the basic regulatory mechanism—trans/cis interactions—have been neglected. We have shown that by using a JACOB-MONOD regulatory circuit based on gene repression, a non-linear system is naturally obtained, which may explain abrupt changes in biological systems (TSANEV/SENDOV 1966; 1971). However, recent data have demonstrated that gene control operates by both repression and activation (see TSANEV et al., 1993). Thus, it seems necessary to derive a general expression for modulation of gene activity.

A genetic network can be described by a matrix showing which trans factor (T_R) interacts with which cis element (C_j) $(i = 1, 2 \ldots N;\ j = 1, 2 \ldots M)$. The interaction

$$T_i + C_j \underset{k_d}{\overset{k_a}{\Leftrightarrow}} T_i \cdot C_j \qquad (1)$$

where k_a and k_d are the association and the dissociation constants, respectively, is dependent on the concentration of the trans factor and therefore should obey the law of mass action. The matrix of a genetic network can be defined by the equilibrium constant

$$\sigma_{ij} = \left(\frac{k_a}{k_d}\right)ij \qquad (2)$$

expressing the binding of the *i*-th transcription factor to the *j*-th cis element.

Two types of genetic matrices $\|\sigma_{ij}\|$ are possible. A matrix where every *i*-th trans factor can interact with one only exactly fixed *j*-th cis element. This *rigid matrix* has $N = M$ and may be fixed as $\sigma_{ij} = 0$, if $i \neq j$. Another possibility is when σ_{ij} may have any value which could be normalized between 0 and 1. This means that a trans factor can interact with many cis elements with different affinity, the strongest characterized by a $\sigma_{ij} = 1$ and the absence of binding—by a $\sigma_{ij} = 0$. Such a *flexible matrix* allows a trans protein to control several genes, although with a different strength. On the other hand a cis sequence may bind several trans factors.

Experimental evidence from sequencing data shows that the second type of interactions takes place in eukaryotic organisms (see TSANEV et al. 1993). Such a complex overlapping of trans/cis interactions has been interpreted as a way of opening more possibilities for a fine control of the genome with less DNA (TAKIMOTO et al. 1989; ECHOLS 1986).

A general equation common to both repression and activation may be derived as follows. The rate of mRNA synthesis should be proportional to the fraction of time θ the cis element is associated with an activator and to $(1-\theta)$ if the cis element is free of repressor. Then, from the law of mass action it follows that:

$$\theta = \frac{1}{1 + (\sigma T)^n} \qquad (3)$$

where

$$n = \begin{cases} 1, \text{ if } T \text{ is a repressor } (T_r) \\ -1, \text{ if } T \text{ is an activator } (T_A) \end{cases}$$

and the changes of mRNA (*m*) concentration may be described by the following differential equation:

$$\frac{dm}{dt} = a_1\theta - b_1 m \qquad (4)$$

where the binary variable ε expresses the fact that a threshold level of the concentration of *T* should be reached in order to start or to stop the synthesis:

$$\varepsilon = \begin{cases} 1, \text{ if } T_R \le B_R \text{ or } T_A > B_{RA} \\ 0, \text{ if } T_R > B_R \text{ or } T_A \le B_{RA} \end{cases}$$

where B_R and B_A are threshold concentrations.

The changes in programmed ribosomes (*r*) and in the concentration of trans proteins (*T*) can be described as before (TSANEV/SENDOV 1966) :

$$\frac{dr}{dt} = a_2 m - b_2 r \qquad (5)$$

$$\frac{dT}{dt} = a_3 r - b_3 mT \qquad (6)$$

Due to expression (3) for θ, eq. (4) is non-linear and the behavior of the whole cellular system shows all features of non-linear dynamics. This has been studied in detail by numerical computer experiments in the case when T was used as a repressor T_R ($n = 1$ in eq. 3). The equations were applied to model systems simulating different cellular configurations—proliferating cell culture (TSANEV/SENDOV 1966), regenerating rat liver (SENDOV/TSANEV 1968), liver cancer (TSANEV/SENDOV 1969), wounded epidermis (SENDOV/TSANEV/MATEEVA 1970), a developing cylindrical animal (TSANEV/ SENDOV, 1971). In all cases the data obtained have shown that the behavior of such systems is a non-linear function of their parameters. As expected, regions of the parameter space were found where the system was stable, while outside these regions abrupt changes took place leading either to a chaotic unstable state or to a new, different steady state characterized by a different set of active genes and a different phenotype.

Here we show that the involvement of gene activating trans factors T_A changes only $n = 1$ to $n = -1$, but eq.3 remains non-linear leading in principle to the same general conclusions. The situation is still further complicated by interactions of the trans proteins with other proteins thus forming active or inactive complexes (see TSANEV et al. 1993). This introduces additional non-linear relations.

All this shows that the parameters of the system regulated by the above equations are of primary importance for the expression of its phenotypic features. Each parameter may play a crucial role. Among these parameters are:

a) The equilibrium constants σ_{ij}. They may be affected by point mutations in trans factors and in cis sequences, by chemical modifications of the trans factors and the cis elements and by the interaction of T with other proteins. Thus, the affinity of binding and therefore σ_{ij}, will be changed, even if the function of the T/C interactions is preserved;

b) The threshold values B_R and B_A which may be a function of the binding affinity and can be affected by the same factors as in *a*;

c) The steady-state concentrations of trans factors which are affected by the rates of synthesis and degradation (the parameters *a* and *b* in equations 4–6), by the membrane permeability, by the position of the cell—positional information (WOLPERT 1969)—etc.;

d) Half-life of mRNAs, especially that of stored mRNA in the oocyte (TSANEV/SENDOV,1971) which may be affected by a number of other factors;

e) Superhelical density of chromatin loops affected by intergenic distances, scaffold (matrix) attachment regions of the chromatin fibers etc (see TSANEV et al. 1993).

Many other, even unsuspected parameters, may be involved in the control mechanisms.

The impact on non-linearity

The non-linearity of this system segregates the parameters space into many zones of stability and zones of unstable chaotic behavior— zones of lethality for a living organism. These considerations imply that small gradual DARWINIAN changes in the above parameters may be the driving mechanism producing variations for the natural selection. Such changes may lead to two drastically different events:

a) As long as the values of a parameter remain within a zone of stability, their changes will only slightly modify the phenotype of a species. This situation may remain for a long period—a period of stability or *stasis*—producing gradual species variations.

b) When the value of a parameter reaches the boundary of the stability zone, extremely small changes in this value will lead either to instability (death) or to the transition into a new stability zone. The latter means the abrupt emergence of a new phenotype—a new species—and a new period of stasis.

It is important to stress that lethal mutations could not be important for the process of species extinction since they affect separate individuals only. Due to the non-linear interactions in the genetic networks the evolutionary phenomena are driven by small DARWINIAN variations in the parameters of the living system which cause a genetic drift of the population towards the border of the zone of instability. Crossing this zone, lethality or saltatory changes will occur. The fraction of population affected will depend on the bell-shape curve of the parameter's distribution. A constant genetic drift may finally shift the whole population into the zone of instability. Under the pressure of natural selection, the result may be :

a) Species variations (possibly also *branching* of related species);

b) A lethal effect—*extinction* of species;

c) A total abrupt transformation into a new species (*speciation*);

d) A fraction of the population transformed into a more or less related species (again *branching*);

e) Long periods of *stasis* separating these events.

Therefore, the non-linear relations in the genetic networks reproduce the different aspects of evolution—the DARWINIAN gradualism, the "quantum jumps" (SIMPSON 1994), the "punctuated equilibrium" (GOULD/ELDREDGE 1993) and the mass extinction of species. All these phenomena are mutually related by the basic molecular mechanism of gene control obeying the law of mass action.

It should be stressed that the small initial changes may be neutral with respect to natural selection, occurring without any adaptive value. Such interspecies, apparently non-adaptive, biochemical variations have been observed in different animal classes (for discussion and refs see DICKINSON 1988). Due to the non-linearity of the system only, they may lead to big jumps producing a new phenotype for the natural selection. If an important role of a genetic drift is assumed to result in adaptation at a higher level, the question arises "what process supplies the raw material (differences among demes) that higher-level selection must utilize to produce adaptive changes?" (GOULD 1983 and references therein). As shown, this question could be answered by the non-linear properties of the system.

The organization of the genome in genetic networks may help to understand the meaning of the somewhat vague but otherwise useful concept of 'epigenetic system'. It has been stated (DIETTRICH 1992) that "the genome acts as operator on the epigenetic system and by this generates a phenotype and a new epigenetic system". Our considerations show that the matrix of the genetic network with its parameters plays the role of epigenetic system translating the genome informational content into a given phenotype. In other words the difference between two species are not essentially the genes, but the parameters of the genetic network. The role of the genome as an 'operator' consists in the organization of the genes into networks with a matrix fixing the rules to be followed.

This concept shows that there might be two ways leading to a new pattern:

1) By gradual, most probably non-adaptive changes of the parameters (a genetic drift) leading to new steady states due to the non-linearity of the regulatory system, as outlined above;

2) By some rearrangements in the genome (a structural mutation) leading to new trans/cis combinations, i.e. to a new matrix.

The second possibility is practically equivalent to the combinatorial models proposed by several authors to explain the emergence of new patterns (GIERER 1973; MACINTYRE 1982; DICKINSON 1988). However, it has been also admitted that new combinations would be unable to change some features without changing others, thus being unable to produce "conceivable" cell types (DICKINSON 1988). For this reason the first type of gradual changes seems to be more productive leading—if not lethal—to new steady states.

Such a solution of the problem could probably put an end to the "gradualist-saltationist" schism. May this approach also acquit the molecular biologists of the accusation (MADDOX 1992; 1994) that they have never used the law of mass action?

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Gisela Miller-Kipp

What Pedagogues May Expect From Evolutionary Epistemology With Regard to Learning and Education

Abstract

Education, upbringing, and teaching are the primary objects of study with which pedagogical science is concerned, both in terms of theory and of practice. Such study is underpinned by an array of recognised auxilliary disciplines among which human biology has, even in its newer variants, not been counted. That pedagogics ought now to address itself to Evolutionary Epistemology (EE), needs to be linked to tangible interests. I here want to specify such interests and to characterize a number of notorious educational problems to which EE is able to testify or which can be elucidated by EE. Those are a number of crucial learning situations seemingly constant and especially common at school, as well as the question of the end and orientation in cultural education. To these, EE is able to offer pronouncements or explanations in her character as a natural history of human knowledge. To foster that relation to education, EE itself ought to direct research into the ontogenetic field. This would at least be my recommendation for promoting the dialogue between EE and pedagogics.

Key words

Children, didactics, drawing lessons; (cultural) education, educators, evolutionary epistemology, learning, juveniles, pedagogics, Jean PIAGET, ratiomorphic (models of) cognition, school, teaching mathematics.

In general, pedagogues tend to expect very little or indeed nothing from human biology due to two traditional prejudices: firstly the suspicion, that human biology is about to make their discipline redundant—what is the point of education, if everything has already been established by Nature?— and secondly the suspicion, that human biology is to reduce human *being* to inalterable *existence*. This so-called 'suspicion of reductionism', historically justifiable and more than sufficiently discussed by philosophers, is theoretically obsolete since the failure of determinism in biology, yet it still accounts for the anti-biological bias in pedagogical research—a bias that has its own course in the overall debate of nature vs. nurture. Every now and then, an option in favor of nature has been forwarded there, especially so in the field of grasping at intelligence and talents (recently HERRNSTEIN/MURRAY 1994, who were widely discussed in public because of their affronts towards the black community). This discourse is in its turn ideologically charged, as shown off lately by the interlingual efforts of "political correctness" (instance given by HRDY 1993). Thus the relation between education and human biology is downright ambivalent in all aspects today; and at least in the German pedagogical debate an open-minded approach towards human biology is but faintly in sight.

This, however, is due in particular to the peculiar tradition of the German Humanities and to the misuse of biology in the Third Reich (MILLER-KIPP 1995a), accounting for the fact, that the suspicion of reductionism is still just below the surface. Hence the rather narrow basis for a dialogue between education and human biology in Germany is understandable. A half-hearted interest prevails, and only recently more attention is arising (PROMP 1990, ADICK/KREBS 1992, EWERT/RITTELMEYER 1994, OELKERS 1994, UHER 1995; take into addition the sudden increase in published copies of one of the pioneering works [LIEDTKE 1972, 2nd and 3rd editions 1991]). Yet, reservation is predominant, especially as regards biological research in the *epistemological* field (MILLER-KIPP 1992a). A greater degree of interest and openness is directed towards biological research describing the plasticity of human nature on all physical levels (LERNER 1984), and especially humans' neuronal make-up (CHANGEUX 1983, DICHGANS 1994); this latter then is seen as an empirical warranty for learning. On the other hand, and consequently so, rather extreme reticence continues where biology makes claims on the human mind in terms of evolutionary biology (MILLER-KIPP 1994, 1995b). Asserting, that pedagogues would expect assistance from EE, thus strikes a rather presumptuous note voicing a hope more than a fact. One would be well advised, therefore, to present the research and hypothesis of EE to pedagogues in a plausible manner, to state the given propositions and results logically precisely, and to convincingly assign them to the available pedagogical categories.

For this state of things, I will proceed to elucidate the form in which pedagogues ought to make recourse to EE; next, I shall consider three possible problem areas, and finally I try to sketch the contours of a likely dialogue between EE and education.

EE's Hypothesis of Learning and the Claims of Educators

Endeavoring to teach if possible all mankind, to organize learning and teaching methodically, and to therefore proceed intelligently on the basis of empirical, that is, sensual data, has been the claim and systematic aim of European educators for the past 350 years—this ever since the "Great Didactics" of COMENIUS ("Große Didaktik" [Didactica Magna], 1632) with its emphatical program, 'to teach everyone everything' (recently renewed literally by TENORTH 1994, lat. original: *omnes omnia omnium*). Educators have ever since been searching for information serving this imperative, first—as well as occasionally nowadays (KOCH 1991)—via philosophy, next, and primarily so, via psychology. Hence, varying categories and concepts of learning are common within the pedagogical field. The question then is, as to which of these concepts EE and its hypothesis of learning should aptly be connected.

It is possible to agree to it, that 'learning' seen as a *result* means a change in three different aspects: a change in information or in the level of knowledge and accumulated data, a change in ability or in capacity and skills, and a change in individual behavior or in attitudes and forms of conduct. Such changes are accessible to scientific observation. Just *how* they come about inner-subjectively and ontogenetically, cannot, however, be directly—and indeed may only be sequentially—observed, and henceforth is the object of continuing research. It is these 'concealed', yet for the individual life-story decisive learning *processes,* which I have in mind, when recommending educators to turn to EE in matters of learning. EE is able to provide information on the 'nature' and development of cognitive structures within the individual as well as on its learning potential. Being aware of that, is fundamental for all pedagogical arrangement of learning. Yet the lack in helpful knowledge is just as big today as it was 350 years ago, even if so on a different epistemological level. 'Adventure Learning' was not surprisingly the headline of the biggest German weekly news magazine just over a year ago (Der Spiegel 36, 1994). Any research to deal and come to terms with this 'adventure' should be welcome to educators. EE considerably contributes to it.

As a result of its investigations into human cognition, EE provides information on that part of the make-up and acquisition of cognitive structures in the ontogenesis determined by natural history. EE thus carries on the information asked for by pedagogues at the point where PIAGET left off (e.g. Piaget 1973, 1975b), and where cognitive psychology did not further venture while concentrating on empirically based models of learning. Furthermore, PIAGET's *genetical* interest got for a time out of view in the didactic turn (PIAGET 1972) and detailed application (AEBLI 1963) of his studies. EE now anew fosters the genetic perspective from the hypothesis of biological evolution. It thus urges pedagogues, initially in a heuristic function, to consider the relationship between the cognitive active human individual (the 'subject', in their terms) and the environment again as a process of structural adaptation. Next, EE brings to the attention the phylogenetically predetermined rules and pattern of this process, and it also provides proof of the logical forms of such predetermined structures. I suggest, that these propositions should be adopted into the field of education with of course sufficient attention paid to its epistemological quality.

Information on the inherited *ratio* or cognitive basis of human learning is provided for pedagogues by EE in its form of a natural history of human cognition. That is to say: EE should be used by pedagogues as an insight into the phylogenetic past of the subject's cognition as outlined above. This, of course, means to narrow the complex figure of the discipline resulting from its versatile research situation (BONET/RIEDL 1987), but offers the big advantage of permitting to refer to the EE solely as to a *theory of evolution.* This then allows pedagogues to remain aloof from the dispute on EE as an *epistemological theory* (sketched by RIEDL/WUKETITS 1987, presented in detail by ENGELS 1989, and most recently by PÖLTNER 1993, POBOJEWSKAJA 1994). Such an attitude is indispensable for an unambiguous understanding and clear-cut transfer of propositions from EE into the pedagogical field, and can only be propitious to formulating *common* goals of research. Moreover it can only prove propitious to an interdisciplinary dialogue to come, to firstly address EE in its home field, in *matters concerning cognition* , and secondly to address her as a natural history of emotion and behavior. For such an address constitutes a project in itself, which cannot be dealt with by the present paper anyway; its range of discussing EE for pedagogical interests is frankly limited and should be notified (for a broader scale of interest see MILLER-KIPP 1992b). The point of the abstination is, that in the field of behavior EE will unavoidably have to deal with the deep-seated resentment of ethology and behavioral biology in the—German—pedagogical debate (see my introductory remarks), and will thus provoke a lively and antagonistic discussion (for note of this uncomfortable situation: BRUMLIK 1990).

Educators will steadfastly keep in mind, that all data provided by EE as well as all pronouncements made on the grounds of evolutionary theory are hypothetical. Nevertheless, such propositions are sufficiently plausible; thus, the hypothetical realism of EE in the thesis of phylogenetic adaptation of cognition to the environment of our species (the mesocosmos) has diversely been proved. The standard reference, though, as to the (prehistoric) ape that would have been a dead ape if unable to perceive its trees spatially correct, is not likely to convince pedagogues fully: after all, ape-children right up to present days have to *learn* to grasp adequately and to climb with assurance. On the other hand, it is quite simply legitimate to assume, that the learning process called 'life', understood in terms of information theory, is an evolutive continuum encompassing cultural history. The learning history of life is then at least three billion years old and in its higher forms several hundred million years old. Given in the time measure of the earth-age, adapted to a 12-hour-clock, the history of learning has already lasted at least six *hours*, whereas cultural and within it pedagogically assisted learning came onto the scene not earlier than 12 *seconds* to 12 o'clock. It is highly irrational to suppose, that the stated six hours should not have exerted any influence on the mentioned 12 seconds. *Ex negatione* the supposition of phylogenetically predetermined cognitive structures thus gains sufficient plausibility without being in need to hide the harsh critique of EE's concept of adaptation (ENGELS 1989).

Educators are thus able to gain a fruitful and practically-geared insight into the nature as into the natural history or phylogeny of learning—a process they are required to organize in the ontogenesis. In the light of evolution learning is to be comprehended as a constructive interaction with environment in accordance to a hereditary pattern. That learning and perception are constructive acts of cognitive 'equilibration' between a subject and the object-world, has been common knowledge among pedagogues since PIAGET. However, he reserved this adaptive process or cognitive homeostasis to ontogenesis, and partly explained endogenous occurrences as phenocopies or as results of such (PIAGET 1975a). In opposition to this, EE provides for a phylogenetic origination and states, which general processive rules, which structures, and which possible limits of cognitive development are at stake as being endogenous. Educators may thus expect from EE a contribution to the *pedagogically* conducted process of learning without needing to fear either its formalization in terms of information theory or its biological determinism or even the impairment of their own subject-hypothesis. For it is their home business to decipher learning with respect to the individual subject (compare most recently HOLZKAMP 1995) and to place it as a phenomenon *sui generis* solely in cultural history, favorite sub-division individual life history. Learning here occurs in a multitude of forms; it is in particular seen as being discovering, problem-solving, creative, and sense-orientated. It is the difficult and challenging task as well as claim of the educator, to underpin this subjective learning process, and to be professionally responsible for it, where it is officially organized. To help him on that way EE provides a plausible hypothesis on learning *complementary* to his own one, a hypothesis capable of generating practical and helpful insight.

EE based knowledge and propositions are especially in demand for education, where learning situations *constantly* incline to crisis. This can be best observed in instituted learning processes, thus for example in the case of school and classroom teaching. I would here like to draw attention to three of such crisis-situations. They arise at the commencement of the school period as well as in mathematics and tart classes during puberty. All three are reputed to be didactically difficult, if not chaotic. They place extreme demands both on pupils and on those present to facilitate learning, that is in most cases, on the teacher.I shall now proceed to sketch the three mentioned cases in their problematic cognitive nature, as this can be dealt with by EE. In my opinion, they are only three among some more still insufficiently known or so far insufficiently tackled with crisis situations.

The 'School-entry-crisis'

'Every beginnings is difficult', and particularly so the commencement or beginning of school. This at least is the generally valid social experience where school is organized along European rules and commences at the age of six. We are, of course, here observing a transition, a passage from one world into another, which can in particular be sociologically investigated. In German educational research, the case is known as the 'school-entry-crisis' ("Schuleintrittskrise"). There is certainly no lack of good advice appealing for 'organizing the beginning of school along pedagogical lines' (KNÖRZER/GRASS 1992). Such advice is mostly based on the precepts of genetic and cognitive psychology, and it aims at the institutional organization of learning according to the age group, including the physical set-up of the learning environment. Of course, this accord concerns all age classes, whose developmental specifics as well as adaptive difficulties and needs as far as known are laid out in detail in the respective psychological hand-books (p. e. OERTER/MONTADA 1995). Yet despite all scientific knowledge, the critical phase here at stake still remains the most tackled and startling one with respect to social and psychic adaption, and the most demanding one with respect to its practical handling. The difficulties concern in particular the cognitive aspect, which I will deal with selectively here.

Since PIAGET at least, has been scientifically tested beyond everyday pedagogical experience, that children perceive differently as well as see and think differently from adults. Nonetheless, the 'start of school in line with the needs of children' (SUSTECK 1982), specifically in line with the cognition of children, has by no means been achieved to satisfaction. Gaps in communication and problems of understanding between school-beginners and teachers remain notorious. Furthermore, the form of perception and intelligence of six-year-old and of children per se up to the acquisition of 'cognitive maturity' (understood as formally developed reasoning; I am not dealing with the ideas in reason and how they come about) endlessly continues baffling teachers and adults in general. In a recent contribution to the pedagogical discourse, ASELMEIER (ASELMEIER 1992a, b) called for pupils' 'cognitive level' to be taken into consideration. The continued and expressed asking for such basics indicates, that despite cognitive psychology ,gaps of knowledge persist amongst pedagogues as regards pupils' 'cognitive level' as well as the adaption of teaching specifically. Especially, they have still not fully got to grips with school-beginners' specific perceptive make-up. They may well induce them to refer to EE for supplementary information. Where EE actually deciphers the child's cognitive condition and its perception of the outside world, it furnishes the knowledge requested in addition to cognitive psychology. EEs specific contribution consists in its description of ratiomorphic cognition under the claim, that the latter constitutes the child's cognitive world conception ("Weltbildapparat", LORENZ 1973).

From the perspective of EE, the beginning of school is to be seen then as the imposition of rationality on children, even if this imposition meanwhile occurs in an insinuous manner. The imposition consists in the subjection of the child's perception and understanding as well as of its individual faculty of learning to the primacy of rational thought and rational thinking—and these, of course, are the rationality of the adult world and the formal standards of the school curriculum dictated by society, or, in other words: the established and predominant world-view. Consequently, the 'school-entry-crisis' could be understood as the public collision between two cognitive worlds. This understanding fosters a new contribution to crisis-management, forwarded by EE; and this is the description of the child's cognitive world conception.

If ratiomorphic structures of cognition guide or even determine children's grasp on the world and understanding of it up to the conventional school-age, crisis-management would consist in organizing the start of school as an externally imposed transition from a ratiomorphic to a rationally cognitive world, and doing that in an objectively and personally tolerable manner. Objectively tolerable means, that EE's description of the child's 'world-view-faculty' is taken into account both didactically and curriculum wise. Personally tolerable refers to the fact that the pupils' own cognitive worlds as well as their rich cognitive inventions are *officially respected*. For the cognitive 'creativity' of children, as it was exclusively attributed to them by PIAGET (cp. KUBLI 1982), is noticed as such by the adults, due to the fact, that they are unable (or no longer able) to produce and comprehend such patterns of thought and perception. Henceforth, the cognitive 'creativity' of children must not be hampered in school. This would perhaps make possible to preserve the wonderful (inexplicable!) ease with which children are able to learn, while it is still available to them.

In the human biography of learning, at least one further transitory phase can be observed that is generally considered to be almost as difficult as the one dealt with above—namely the entry into 'higher' education. It occurs during the passage from youth to adulthood, that is at around the age of 18, if one adopts the limits drawn by genetic psychology. Within the—universally exported—European system of education this is to coincide with the entry into university. Here,again, two cognitive worlds meet conflictingly and critically with constant and sufficient regularity. One may well assume, that this is *also* a crisis down to deficient harmony between inborn and socially fixed patterns of cognition. Should this prove to be the case, EE may shed light on this learning crisis as well. The supposition, however, needs investigation first. It would be necessary to find out, whether inborn patterns and rules of cognition are still able to exert an impact at the age under review and, if so, then just in which scale or form. In order to answer these questions, EE would need to differentiate its research into ontogenesis. Even so, it remains to observe, whether the transition at stake is not but a widespread phenomenon in cultural history, which then would best be investigated by cultural anthropology (cultural sociology and cultural psychology), as it has indeed been up to now.As I am hesitant as far as the cultural part of this passage is concerned, and as I am not familiar with its non-European forms, I should like to leave this point open with this research indication attached.

Teaching Mathematics

Both of the following collective crises of learning dealt with, occur *within* the institution of school. Once again, two different cognitive worlds clash, yet differently from the above described instance not in the frame of an institutionally-imposed transition, but intra-institutionally as a result of a curriculum-imposed change. In both cases the curriculum (of German schools) relies on certain cognitive capabilities, which obviously are anything else but reliable. Both crises of learning appear to be culturally constant at least as far as the bitter pedagogical experience of the last several centuries is put into account. Though further comparative cultural and biographical data would be necessary, I here accept the historically based collective experience to be a sufficient documentary basis. If thus the crises referred to are admitted as being culturally constant, EE is able to contribute to an explanation of their causes at root.

Perhaps the best-known chapter of the painful history of the European school system is written by the mathematics class. Mathematics is a problematic subject in all class-rooms and all age-groups, even if so for different reasons. Yet in any case and time and repeatedly , it is the abstract logical operations, that constitute the main hurdles and stumbling blocks for all pupils right up to the age when, according to school experience and cognitive psychology, they have mastered such operations both potentially and actually—that is at around 14 or 15 years of age. The exceptional pupils, of which there are one or two in every class, rather confirm the finding. They are and remain the constant exceptions and tend to be explained away in terms of 'mathematical gift'—something, which to the great disappointment of all school clients, is sparsely distributed (and reputedly even more sparsely amongst members of the female sex). As for the didactic organization of mathematics, maths teachers in Germany have continued to be guided by the—assumed—logic of their discipline, and have for the past 30 years, starting with PIAGET, allowed themselves to be led by cognitive psychology. Despite that approach, their teaching problems are still exist.

On many occasions PIAGET examined the development of abstract logical operations and mathematical thought in ontogenesis (PIAGET 1965, 1975b 1977) as well as with didactic reference (PIAGET 1955). Although his approach was rivalled at his time by, for instance, behavioristic theorists (e.g. DIENES 1970) or representation concepts of cognitive growth (e.g. BRUNER/GREENFIELD 1966), and despite the vivid discussion springing up from this rivalry with respect to mathematical education (HOWSON 1973), the basic problems at stake with it can still best be put with PIAGET's findings. I shall, therefore, shortly deal with them:

PIAGET counted logical-mathematical operations squarely among the 'broad spectrum of purely endogenous cognitive constructions...which are solely based on the faculty for reflective abstraction' (1975,p97). He saw the development of the latter as the central structural change in the observable transformation of cognition during adolescence and interpreted it as a constructive cognitive effort of adaptation within the process of integration into society. The effort of adaptation itself is described as an achievement of cognitive equilibrium between the individual (or nervous system) and the given social (or physical) milieu.This concept, then, puts forward an unsolved question: While the formal logical structures appear with regularity from puberty onwards (as at the age of 11 or 12), the process of integration into society varies greatly. The diachrony between the stated cognitive and social transition now suggests the assumption, that the cognitive transition also has a phylogenetic basis. It would—additionally—appear as a process of resetting and remoulding inborn cognitive structures. Those could then be described by EE.PIAGET himself strongly denied that 'inborn or a priori forms of intellect' (1977,p325) came into play. Nevertheless, this assumption would help to explain the permanent problem of teaching mathematics.

Cognitive psychology after PIAGET, indeed has out-laid his position in both ways: into the purely cognitive and into the socio-cultural direction. As mentioned above, a vivid debate ensued from the epistemologically originated discussion on cognitive growth with respect to mathematical operations (GROUWS 1992); it was put forward in thousands of publications on *learning* and on *teaching* mathematics, followed by several waves of respective reforms at school across (European) countries (HOWSON/WILSON 1986, ROBITAILLE 1989). Hence, the research and discussion site of mathematical education is more than complex today (BURSCHEID et al. 1992, NESHER/KILPATRICK 1990), yet the problems are still in place. Teachers of mathematics can rely on quite an array of theoretic models and practical findings, none of which explains satisfactorily what happens in the heads of pupil when learning mathematics. Only recently has research been directed towards the process pupil *actually* undergo when constructing or analyzing mathematically. There is one such study in Germany (RAUIN 1992), I am going to refer to, for its finding should elicit the attention of EE. Before, I proceed to discuss the didactical aspect of education in mathematics:

Both, pedagogical theory and mathematics didactics in Germany continue, as mentioned, to rely on the common sense of their subject. This means that the organization of mathematics classes until recently has been, and *in practice* still is, directed by the unshakable conviction, that mathematics is *the* logical discipline *per se,* and that participation in maths classes must inexorably induce logical thinking. This collective supposition no doubt has, along with its psychological fundaments, since long been refuted by pedagogical theory. Thus in Germany, HERBART objected to the HUMBOLDT-inspired variant of mathematics as being by its very nature a subject propitious to cultural education (a "Bildungsfach") by the assertion, that the reason *of* mathematics remained *within* mathematics. This assertion raised the so-called transfer problem, i.e. the question, as to how the reason within *mathematics* was supposed to promote logical thinking within *people's heads* (HERBART 1806). Yet despite such early critiques, mathematics' claim to account for logical thinking and its aura as a "Bildungsfach" (as it is the case in Germany) remained untainted. Only very recently has this aura been dulled, as a result of the public discussion about studying on the necessary scale and the best form of mathematics classes (HEYMANN 1996). In short: theoretical critique and epistemological debate failed to exert a great influence on the didactics of mathematics and to unchain its attachment to formal logic. Just how mathematics classes might be organized so that its notorious problems could be solvedbecame a topic of intense practically led investigation .

As a result of the establishment of integrated types of schools, pupils of largely differing abilities and cognitive levels found themselves subjected to one and the same curriculum and classroom. In order to deal with the learning and teaching difficulties predictably to arise especially in the subject of mathematics, external differentiation of teaching in accordance with the class performance was attempted first; next, so-called 'internal differentiation' or more individualized teaching was turned to for remedy. However, neither of these two strategies based on the psychology of learning, brought with them the success expected. By the end of the 80s it became clear that a 'sufficient correspondence between the characteristics of learners and the methods of teaching' had not been achieved (RAUIN 1992,p1). In other words: school-children have their own minds and their own patterns of learning; they cannot be served adequately by methods of individualized learning assistance.This finding finally posed the question, as to how pupils proceede if left on their own in mathematics lessons. As mentioned, an initial study so far has attempted to answer this question. If already the continous classroom misery could attract the curiosity of EE, the study in question could do so as it provides material to be interpreted by EE. I shall, therefore, now briefly refer to this study (RAUIN 1992):

The research project examined the "introduction of concepts relating to fractions in mathematics classes in the 6th school year", and this for the reason, that "a particularly striking imbalance between investment and return was to be evidenced here" (RAUIN 1992:2).Generations of teachers have worn themselves out trying to present rational numbers to pupils in a way adapted to their brains or needs. In doing so, they were generally guided by the supposition (see PIAGET) that these numbers would be generated by abstraction from sensual perception (of the 'part-in-whole-situation', loc.cit). They are now, however, willing to admit: "We do not exactly know how children come to and gain a differentiated and coherent concept of fractions" (RAUIN: 2f.). In order to find out about that, the study did away with all genetic psychological and information-theory-based explanations and explanatory models. Instead, it turned to investigate the actual 'processing-structure' ("Bearbeitungsstruktur") and to see, whether the latter corresponded to the so-called 'subject-structure' ("Sachstruktur") as conventionally postulated by didactics (RAUIN,p 5). Under the heading of 'processing-structure' the study investigated among others, if relations and comparative possibilities or functional similarities existed between the tasks , if they fitted into a logical sequence, or if their logical difficulties differed; purely arithmetic and problem-oriented sets of tasks were offered.

The overall result showed that the tasks constantly caused new problems in every new group of pupils, who, above all, refrained from classifying the level of difficulty of the tasks according to mathematical criteria. Furthermore, in terms of overcome maths didactics, they all made completely illogical mistakes and irregular or non-standard calculation-steps. Thus, for example, they dealt with complete tasks before treating preliminary partial ones, did complex or probably 'difficult' tasks before the 'easy' ones and the former even better than the latter, if they were put illustratively. In addition, they did not transfer the results of preliminary steps to complete tasks and solved 'problem-tasks' ("Problemaufgaben") differently to the corresponding arithmetically put tasks etc. This confirmed the thesis: "that there is no connection between 'problem tasks' and 'calculation-based tasks' in the cognitive structure of many pupils. It almost appears as if the keys to the solution of closely related logical problems are stored in two separate cognitive worlds" (RAUIN: 153). The correspondence between "suppositions based on the logic of the subjects and the cognitive structure of the empirical performance"(RAUIN: 155) was found to be slight. That "unsatisfactory result of the investigation" (loc.cit.) from the point of view of formal mathematics didactics is doubly illuminating for EE. For once, the result contains an indication of segments and activity of ratio-morphic cognition in the logical thinking of 12-year-olds. Secondly, it gives EE the chance to interpret the 'unsatisfactory' result of the study to teachers in a positive and didactically helpful manner:

If 12-year-olds stubbornly continue to ignore the precepts of mathematical logic, just which cognitive rules or patterns do they use then? The author of the study draws two main conclusions from his findings: Firstly, that the learning progress of the pupil is strongly dependent on the learning environment; and secondly, that pupils unconsciously—and henceforth also in a manner didactically unnoticeable—take to solving mathematical tasks on recognition or by recognizing (see RAUIN,p 154f.). The author certainly draws the attention of mathematics didactics to this cognitive phenomenon, without, however, being able to further define it or pin it down.Now, recognition in this case might be described by EE as an achievement of inborn rules of comparison and association. Supposing—and the century-old complaint and curse of teaching mathematics as well as late empirical research into it strongly foster this supposition—that ratio-morphic structures of cognition continue to obtain right up to the sixth form, would supply mathematics teachers with clear evidence. The evidence is, that their pupils operate concretely even as regards abstract calculations, that they register problems in terms of a whole, and that their concept of numbers and sizes is linked to graphic features. This means, that the cognitive competences of the learners ("Lernereigenschaften") are 'naturally' opposed to the formal logic or rationality of the taught subject. Thus, EE would contribute to solving the puzzle of the lacking correspondence between the learning subject and the method of classroom teaching of mathematics.

In addition, EE sheds light on the general pedagogical experience, that learning is best and occurs with greatest ease in a concrete context and with graphic support. Experienced teachers are well aware of this and their professional experience fortunately enables them to (go on with their) work even if there is no research to come to their aid. In the case under review, the cited pedagogical experience does but confirm the suspected cause of the lasting calamities of mathematics classes, as derived from EE. Should such suspected causal factors be confirmed by more ontogenetic studies, the didactics of mathematics could advance a good step further.

The drawing class

Among the teaching that often fails dramatically, art classes in the sixth or seventh year of school as well belong. According to the experience of generations of art teachers of all schools, pupils suddenly discover that their pictures are no longer 'right' or 'good'. They appear to be at odds with themselves and with their artistic works. Naive and schematic painting is considered to be 'out', and realistic painting is 'in'. Those pupils who are able to paint realistically, and thus 'properly', are envied and regarded with a certain awe, though as a matter of fact every pupil sooner or later learns to paint in such a manner. Today, art teachers usually are prepared for the regularly occurring changes in aesthetic judgement and manners of perception on the side of their clientel, and they are prepared to offer realistic concepts of artistic expression. They have learnt from experience that their classroom catastrophe is due in general in the sixth and seventh form, augured by the end of childlike drawing at the age of 12 or 13. Aside from this observation by experience, the phenomenon, as for my knowledge, has not been dealt with formally or been treated by educational research. It has been described by psychology in the context of the ontogenetical development (MÜHLE 1975).

The fact that pedagogues so long have not enquired into the roots of the occurrence described, is above all, due to the fact that it comes along with the very period of life marking the end of childhood and the transition to youth. Then, educators are overburdened with the problems caused by puberty, the onset of which tends to monopolise their attention. As a result, they turn to those sciences or rather theories of development that provide information on the process they are primarily interested in, namely learning along with the development of the individual's personality. Biology is taken into consideration for the description of the somatic occurrences; recently, evolutionary biology was referred to for a better understanding of the morphological changes during puberty (RITTELMEYER 1993; an explanation of morphology based on evolutionary theory was proposed by RIEDL 1987). EE so far has remained outside of reference—astonishingly though, as puberty is commonly linked with cognitive structures as well. Yet teachers and educators concentrate on the *acquisition* of cognitive skills and hence to bother little about their transformation or replacement, whereas the classroom phenomenon to deal with seems to be such a case of cognitive transition. It does not come in view, when puberty is comprehended on the basis of sociology and psychology and thus is accepted *in practice* as being more or less naturally inevitable.

This, however, hints by chance at the contribution EE is able to make in this particular case. EE is to be taken into consideration if one assumes—as evidence goes—that the observed 'sudden' transformation in perception and aesthetic judgement has biological roots. Such a supposition is backed up by the fact that (as to collective pedagogical experience) art classes in the sixth or seventh school years *exceptionally* are confronted with the said sort of behavior on the part of the pupils, and that it takes place as mentioned above regularly, reliably, and *irrespective of styles*. This is strong evidence in favor of culturally independent and naturally constant causal factors. More evidence could be provided by autobiographical reports as well as by the history of art teaching (KEMP 1979). This history, however, is still full of gaps; so EE would be required to undertake further research in its own interests. Research and documentary material is above all available in the form of the drawings and paintings by the relevant age-group itself. In these, the observed change in perception has or must have left its prints. Now, aside from art collections, collections of children's drawings and paintings are well accessible to scientific inquiry, even on cross-cultural level (KOPPITZ 1984, SOMMERS 1984, SCHUSTER 1990). This material must, however, be foremost evaluated by and in favor of EE; for it is mostly psychologically arranged and collected, and often so for therapeutical interests. Nevertheless such material contains numerous indications and possible examples of inborn cognitive structures, in particular relating to spatial perception, world vision or concept of reality, and special figures of thought (compare the characteristic statistics provided by KOPPITZ 1984). Such publications in their turn pose questions, EE can attach itself to, for example questions concerning the "internal determinants of the characteristics and the development of the child's drawing" (SCHUSTER 1990:76f). In general, EE's attention should be drawn to the instance, that across the cultures the characteristic of children's sketches is their *distance shown to cultural phenomena and traditions*.

Regarding the age-group under discussion , the state of documentation however is rather poor. The material in demand is or was apparently uninteresting for arts—perhaps just because of its aesthetic switchover. In addition, the available collections mostly contain works authoritatively classed as 'beautiful' or 'advanced' according to tastes, and as such do not document the aesthetic break of interest here. I only know about one single relevant work paying attention to drawing at the end-phase of childhood in an unselective manner (RICHTER 1987). RICHTER considers the cognitive phase in question from aesthetic aspects and characterizes it as the dissolution of the "highly schematized children's drawing' into a realistic image-concept. Interestingly so, even children with ocular defects undergo this phase 'without any considerable delay" (RICHTER 1987:69). These remarks advocate a biology of cognition.

They are indeed able to confirm the assumption, that inborn cognitive structures are beyond the grasp of reality, or that inborn mechanisms bear on the development of the perception of reality, and that these are at the bottom of the described aesthetic phenomenon. In terms of EE, this could mean that during puberty the inborn cognitive world conception recedes and perhaps fully disappears . Just what this may have to do with the biotic and psychical development at the same age, remains open—in any case, the cognitive change occurs simultaneously. The cultural world and its concept of reality—culturally stamped and transmitted patterns of cognition that is—establish themselves in the individual's mind in opposition to its ratiomorphic structures. Just how, when and in which precise forms would need to be researched in greater detail by EE. This would then provide pedagogues with a key to the cognitive make-up of pubescent children, which in particular may be able to unlock the mystery of the catastrophic situation of art classes in the sixth and seventh school years.

To sum up: pedagogues may well expect information and aid from EE in comprehending all notoriously difficult and constantly recurring classroom and teaching situations. Such situations indicate, that biologically determined perceptions are rooted at their base—an indication already due to and taken from EE. I have here described three such problematic learning situations and transitory phases. Further situations may be pinpointed and their specific difficulties may be elucidated in combined research efforts. In general, the great merit of EE consists in the fact, that it is able to get hold of those parts of cognition that are not within the reach and hands of education, to give the characteristics of those parts of cognition, and to line out the transition or the transitions from inborn perceptive proclivities to formable ones—to those, susceptible to education. EE provides pedagogues with a sharper sight of the limits of humans' cognitive "plasticity" (LERNER 1984), while the pedagogues in their place experience the "plasticity" of these limits. Due to the fact that the different viewpoints of the two disciplines here complement each other *necessarily*, the basis for an interdisciplinary dialogue is as well prepared as could be hoped for.

Education of the mind

The third area for which pedagogues may turn to EE can be classed under the heading of 'cultural education' ("Bildung"). It is of course necessary to specify just what is exactly meant by this term (special to the German language), for it encompasses quite a lot elements, is used in a number of different senses and, at least in the German educational debate, tends to be ideologically charged. From the perspective of cultural history, the concept must be attributed to the so-called "Bildungsbürgertum" (the social strata that attained social mobility by dint of education), which was at the same time the social representative of this educational concept. The idea of it did not, however, die out with the demise of this class. On the contrary, it has continued to be used to cover a whole variety of ideal educational meanings. I shall here completely ignore the whole complex of the *social* process of 'cultural education' circumscribed as 'educational system', and shall use the term without further delay on the basis of the definition for that process of education geared to the individual subject and aiming at its personal accomplishment. In this sense, the term holds its place in German pedagogics by serving as a category for differentiation and legitimation. Thus, in opposition to 'learning' and 'upbringing', it attaches importance to and indeed concentrates on the individual process of *inner self-constitution*— with regard either to emotional or to intellectual capacities or to both. At the same time, it conceives this process in a normative fashion with regard to culture. Thus linked up to the idea of 'culture', the concept has obtained an unmistakable historical aura (recently BOLLENBECK 1994). It is welcome to embellish educational rhethoric especially in Germany every now and then.

'Cultural Education' hence means a decisive personal process of intellectual and emotional improvement as well as the very aim of this process. Right up to the present day, these are understood to be the forming or cultivation of the mind and the cultivated mind respectively ("Geistesbildung"). The corresponding educational discourse is directed descriptively as well as normatively. EE could contribute to both: On the one hand it is able to describe the cognitive *potentials* to which the forming of the mind is bound; on the other hand it may shed light on the norms included. Henceforth, EE may well be expected to help to determine the *possibility* and the *direction* of such education of the mind. I dealt with this at length (MILLER-KIPP 1992a) and shall here shortly come back to the item.

The possibility to back up the cultivation of the mind will largely depend on just how much educators know in particular about the process conceived and aimed at. This knowledge, though, is still lacking. The leading thinkers of this educational concept have, of course, always endeavored to present it as comprehensively as possible, otherwise their notion of 'education' would have been nothing more than an idea of reason (KANT) capable perhaps of giving normative guidance to educational practice, but not, however, of organizing it. Laying out the concept as comprehensively as possible needs setting forth its fundaments realistically or indeed empirically, to use today's scientific language. In order to ensure that, educators first turned to philosophical, later to psychological theorems and findings concerning the forming of the human mind. It is obvious that EE, too, is in a position to offer assistance. German pedagogical science had once been close to taking such a recourse, when in the 30s the so-called humanities-based pedagogical theory ("geisteswissenschaftliche Pädagogik") searched for certain supposed 'original layers of reality-awareness' (SPRANGER 1974; 1934 lecture given at the Prussian Academy of Sciences). Then, reflection was given on the genesis of those forms of mind that the mentioned school of pedagogical thinking was (and still is) in particular need of knowing with respect to its basic suppositions. In the 30s, however, the putative 'original cognitive layers' were explained with reference to the psychology of life. For obvious reasons down to the history of science, attempts towards a biology of cognition were not made—compare here my opening remarks. Even today, theorists of the said school think that their supposition of the primacy of the perceptive subject is threatened by biologically-based development research.However, those wishing to put education of the mind into practice, will not be satisfied in the speculative slant inherent with that very concept. Realising it , requires as clear and as exact a knowledge as is possible about the organization of intellectual abilities.

To achieve this, educators today may expect a descriptive contribution from EE to the extent as the latter is capable of specifying the *direction* and the *adaptive logic* of human cognition. Such a proceeding would be profitable for the discourse on cultural education, as I shall indicate by dealing with three separate points: namely with the so-called 'productive moment of the educational process'(1), with work schools and creative learning (2), and finally with the conception of the very cognitive process as it exists within the classical idea of cultural education itself (3). All three points are linked to the interest or are indeed compelled to discover, just how intellectual activity is translated into to perceptive activity, and how it is generated *within* the subject.

1. The 'productive moment of the educational process' (COPEI 1966 [1950]) was a clever phrase coined over 40 years ago, which in a semantically convincing manner has, right up to the present, served to qualify that temporal moment, when educational efforts could be brought to an optimum. What then, after all, is *not* dependent on 'good' timing in the fields of learning and education! Timing things right, is the first premise to the successful exertion of influence on the subject and first of all it should be ensured that classes are well organized—see above. In order to underpin the type of intellectual development the said author has in view, it is indispensable to be familiar with the sensitive phases of the forming of the individual mind *in its constituent relation to the 'world'*—'mind' in this context is conceived as being the 'higher' or conscious forms of cognition or the cognitive totality of intellect and reason, and 'world' in the cited concept refers to the cultural world. It is almost self-evident, that the 'productive moments' within *this* instance of cognitive development, too, are not independent of the ratiomorphic structures of perception which underlie the ontogenesis of rational thought and comprehension. Hence, the productive moment of the conceived cultivation of the mind is dependent on the ontogenetical presence of these structures, that is to say, on their impacting force, on their prevailing or their regression at various stages of life. Similarly, since HUMBOLDT (1903 [1791,1793]) the moment to get hold of has been conceived by educators in terms of cognitive 'receptivity' and 'formability'. EE is particularly able to specify these notions:

'Receptivity' and 'formability' circumscribe the conception that the individual that is to be imbued with reason will, at different stages of his life, be differently open to the cultural world, to interaction with it and to adoption of it. A generally accepted timetable for this process is not, however, available. The suppositions as to just when the 'productive moments' occur, are repeatedly based on the prevailing psychological opinion. Nowadays, the reference goes to the stages of intellectual development as laid down by cognitive psychology (first of all: PIAGET). Yet so far, no *sufficient* indication for practising has been advanced; and this acknowledged accounts for one of the notorious weak spots of this educational concept (HANSMANN/MAROTZKI 1988,1989; MILLER-KIPP 1992a). Its lack in empirical validity is related to the instance, that in contrast to, for example classroom learning, educating the mind very much depends on—knowing of—the *direction* reason takes in its development beyond the mere formal stages of it.

It is important to know, *how* a growing individual relates himself to the outside world, in order to be able to organize this relation into cultural education.

Now, EE has delivered a notion of how individuals relate themselves to the outside world by describing life as a cognitive process and hence derive the naturally born rules or 'logic' of all cognitive activity. This description tells as well how the relation of the individual to the outside world would be logically constituted, its cultural forming apart. It would be—in key-words: eco-logical, analogical, constructively comparative, and empirically hypothetical. It would make no sense for educators, to ignore this natural 'logic' and to conceive cultural education along, let's say, analytical lines of reasoning with the outside world. On the contrary, they should take into consideration the 'natural', the phylogenetically based logical direction of the mind, and thus enable the growing individual to grasp even at the cultural world 'naturally', i.e. in a manner of self-defining ease. If EE would provide more information as to when exactly or up until when in ontogenesis those 'natural' cognitive rules direct reason, educators might have more evidence as to *when* the incipient individual mind is especially receptive to *which* of the various cultural worlds. They would have to take into account and to freely strengthen or diminish or replace the 'natural' direction of the mind.Just which, however, may be the *desired* direction of the mind, is a normative question to be debated in educational theory. EE thus bequeathes it with a respective discourse along with its descriptive specifications regarding the 'productive moment of the educational process'. I shall return to the normative aspect later in the third point stated below.

2. In dealing with the work school ("Arbeitsschule"), I turn to the history of education and to the German pedagogical reform movement, which had particularly been devoted to that specific form of general school. Quite a number of concepts and practices of linking work to classroom study were conceived and tried out during the later period of the German Empire and the Weimar Republic. They are just being about to be—for once again—re-discoverd by the current debate on school policy in Germany (AMELUNG/HAUBFLEISH/LINK/SCHMITT 1994). This rediscovery also indicates, that the old concepts remain the source of unfulfilled educational and sociopolitical hopes. The historical hope had been (and still is), that the work school could be capable to pursue both: cultural *and* vocational education thanks to wholesale teaching and practically oriented classwork. From amongst the diverse types of it, one in particular entirely relies on *intellectual* work and understands this to principally cover free and self-determined intellectual activity 'for the sake of the individual personality' (GAUDIG 1930). This school then was intended to bring into practice within *one* institution a central element of German educational thinking, e. g. cultivating the individual by cultivating the mind. The undertaking remains a unique didactical feat; it has been reached out for until the present time.

The lack of methodical organization in the said school project is due for one thing to the fact, that the aim itself does not well lend itself to such methodical organization; this deficiency is thus not capable of being overcome. In fact, the individuality of a form consisting of personalities to be, only allows open classroom teaching. The lack of methodical organization in 'free and self-determined intellectual activity' at school is also due to the fact, that the formal principle does not provide a concrete conception to be put into practice. Indeed, educators are utterly convinced of the autonomy of the human mind; if, however, asked to organize the corresponding intellectual activity in such a way, that it is propitious to the development of a personality and does not impose itself on this process, their knowledge is at loss as to the *bounds and rules* of this intellectual activity. To know (of) them would be extremely desirable for classroom teaching not to break down due to continued cognitive differentiation. Such a breakdown—as to all relevant experience—is near, whilst this work school takes to association as to a cognitive principle of teaching (in work projects). Yet, an other one is not at hand.Hence the question arises, which other principles or cognitive figures could serve the purpose without hampering the desired *intellectual autonomy* of the pupils from the very outset? One answer is: at the start of this work school and at the start of each classroom project only those cognitive figures can be given that are *common* to all pupils; these needs must be naturally born cognitive figures.

Such figures may be taken from EE. They derive without problem from the phylogenetical logic of cognition like the four basic functions (or 'hypotheses') of ratiomorphic thinking as described by EE. Thus, for instance, the establishment of analogies and causal links can serve to organize the classes or teaching-projects. Where those cognitive figures come into the game, they would, according to EE, bind 'free and self-determined intellectual activity' back to collectively uniform or—terminologically expressed—'unfree' cognitive patterns. The result could be, that phylogenetically preformed and ontogenetically newly formed patterns of cognition would at least initially, and perhaps also for the whole school period, be linked into a 'planable' set.

This, however, is but a hope to start with. The fruitfulness of applying EE to the didactic of the work depends on the kind of research undertaken by EE itself—as goes generally for the concepts of education of the mind. As I have already stated above, EE ought to turn its attention to the evolutive 'logic' in the genesis of *subjectively available* cognitive abilities. It is precisely here that EE *and* pedagogics come face to face with the problem of 'creative learning'. From the viewpoint of pedagogics, 'creative learning' is the subjective precondition to the education and cultivation of the mind. From the viewpoint of EE, it is a form of learning that cannot be attributed to biological evolution alone and hence is ceived by opposing it to biological learning. Thus, creative learning does not perform constantly, does not manifest itself in an homogeneous manner, and is not reliable or certain. On the contrary, it is connected to uncertainty, relies on chances, which it integrates into plans, and constantly manifests different forms and figures. Educators, as shown above, are foremost vexed by creative learning in their *practics*, particularly in the cited instances. In the cognitive sciences, however, creative learning is primarily a problem of *research*. The subject was recently discussed in depth by the latter disciplines (BODEN 1994).

At present, educators in Germany seek to get hold on 'free and self-determined intellectual activity' or creative learning as it has been here referred to, under the notion of 'self-organized' learning. The concept of 'self-organization', as inspired and derived from chaos theory and neurobiology, provides educators with a descriptive model that is more adaptive, however, to the inter-subjective process of learning than to the intra-subjective process of cultivating the mind. For the former process the concept of self-organization offers leads to organizing , wheras for the latter it does not make any additional contribution to the given state of knowledge. In the theoretical context of cultural education, 'self-organization' is merely a new term for an old notion that does not further enlighten the given experience, that the intellectual effort of cultivating the mind finally is autonomous.

3. As noted in the introduction to this section, cultural education specifically is conceived as an act of individual self-constitution by the intellectual acquisition of 'world' or, in the classical sentence of it: by the 'linking of the self to the world for the purpose of the most general, most free and most active mutual exchange' (W.v.HUMBOLDT 1903,p 283). In the humanities-based educational theory (in Germany), this 'linking' is seen as an act or process of reason, explained epistemologically; again, the reference to 'world' here goes to the cultural world.—Since its first elucidation, this very demanding concept every now and then degenerated into a program of acquiring cultural goods, and this primarily so, because then it became adaptable to the curriculum of higher (school) education. The German work school of the type dealt with above, was just a reaction against such materializing of the original concept of cultural education.The full significance and reach of the early conceived cognitive dialectics between the individual and the world can be reconstructed in the perspective of a non-determinist natural history of human cognition. Pedagogues may measure this perspective by help of EE. In this case, the specific contribution of EE as a natural history of (human) cognition can be seen on three different levels: Firstly, EE offers an extension of the notion of 'world', or rather an explanation of it in accordance to the current state of science. Secondly, it offers a clarification of the intellectual 'linkage' between the self and the world; and thirdly, it specifies the direction of this linkage. I shall conclude by shortly explaining these three points:

EE extends or rather modernizes the notion of 'world' handed down from the classical concept of cultural education, in a manner appropriate to the current scientific world-view. Relying on EE for this purpose, 'world' would now encompass culture *and* nature as being *one* process of learning or gaining knowledge. Consequently, the cultural world as well as the biosphere present themselves as objects of intellectual self-constitution to cultural education and the cultivated mind.—The 'linkage' between the individual subject and the world without is now to be understood in *ecological* terms or rather, it may now be understood in this perspective as a cognitive activity preprogramed by natural history and geared towards adaptation to environment. Concurring with EE in this point would be to say, that an evolutionary biological drift underlies the individual's process of intellectual linking to the word. The latter then is not free-lancing in the cultural world, but is rather based on an inborn orientation that guides and classifies all experience of the world according to biological criteria. This way, the shaping of the individual's mind is connected to phylogeny. Just how this connection shows itself in the individual life, could be further investigated by ontogenetical observations on the side of EE. CIOMPI has presented a blueprint of such research, when he enquires into the linkage of psychical structures and their development to the environment (CIOMPI 1988). The instance, however, *that* the cultivation of the mind is linked to nature, may finally be conjectured on the basis of EE.

This conjecture however has certain theoretical consequences. At least it suggests—see above—to think again of the idea of 'subject' and 'world' as presented by the cited educational theory, and to comprehend the cognitive interaction between the individual and the outside world as a form of structural link-up. Metatheoretically, one could go as far as to assert, that the cited idea of cultural education is itself an expression of the conjectured ecological direction of the human mind. For seen by evolutionary-biological investigation into cognition, "rationality presents one solution to the problem of survival in a hostile world" (POLLOCK 1993, p563, one of the latest summaries of research work on the phylogeny of rationality; also HAWKINS 1987).

The ecological direction of cultural education as described by reference to EE, is at last of a normative significance and may be interpreted normatively in different respects. Thus, as already noted in the first point stated above, the question can be put as to *which* direction should be imposed on the cultivation of the mind. Furthermore, educational goals could be ecologically inferred and criticized for whether yes or no they accord in a tolerable manner to the living and learning conditions laid down by evolution including the human species. Finally, EE itself proposes certain educational goals derived from an ecological reading of history.When such propositions express themselves normatively in favor of human interests, EE, however, transgresses the field of natural history, and the logical status of its statements does alter from descriptive to prescriptive. Hence, epistemological care will have to be taken, where in the educational context EE is called upon to provide normative advice. It is to keep in mind that the hypothetically based findings of EE do not bear out a prescriptive status; they may be considered as being explicative of norms, but do not themselves constitute norms.

To sum up, I would state that if the educational discourse incorporates the propositions of EE, and if the theory of cultural education is adressed to EE as sketched, the very concept would gain in clarity, a number of its practical problems could be illuminated in additional or better ways, and several questions of cognitive transfer could be solved. The—German—theory of cultural education at least would gain in empirical substance and be enriched in scientific logics. In particular, ecological thought in education would win foundation. The project of an ecological theory of education—provoked by the public debate on environment (BEER, de HAAN 1984)—has been dragging along in German pedagogics for a good decade, and although far from being completed today, its main goal, that of forming an ecological mind, has already gained political status, as it is laid down in a number of school-laws or bills for school-laws respectively. Still, in order to apply these precepts fully, you have to actually concretise the fine guiding ideal and to put it into classroom practice. Environment education is already attaching itself to this strenuous and comparatively unspectacular task. Such projects, too, can only gain from inquiries into the direction of EE. In fact, the cognitive conditions of an 'effective environment education' have already been sketched by recurring to EE (FRIEDE 1992, p218). One may hope for a whole series of such studies.

A Dialogue Between Education and EE

A broad dialogue between pedagogical theory and research and EE still remains wishful-thinking. Apart from the mental reservations of educators as mentioned introductorily, the whole project is strained on both sides due to simple ignorance. Konrad LORENZ considered mutual ignorance to be the real 'social force' at the root of the separation of scientific faculties (LORENZ 1973,p 29). In contrast to this notation, the cognitive-sciences-complex nowadays is indeed a paragon of interdisciplinarity (IRRGANG 1993). The basis of such cooperation is a common object of research and a homogeneous interest in it. Both are not, however, found at the outset between education and EE—the areas of mutual interest still need to be outlined. I have attempted to do so from the quarters of education and have aligned the statements, perspectives, and propositions of EE with a number of permanent pedagogical problems, the discourse on cultural education inclusively. In this, I have drawn the attention of EE to research questions and tasks in the educational field. As it turned out, EE could enhance contributing to it, if it were to gear its research efforts further to ontogenesis.

Hence the dialogue I have sketched between the two disciplines assumes the form of supply (on the part of EE) and demand (on the part of education). A reversed order of connection could also be possible, as I have here indicated in the context of cognitive development and children's drawings. A mutual research dialogue is imposed on EE to line out and formulate its own specific interest with regard to education. Although it is not for me to venture so far, I would nevertheless like to state that both sciences in their perspectives are concerned with an overall concept of development in ontogenesis, without so far having conversed upon it. For the purpose of such a research performance the cooperation of all sciences dealing with human development would be necessary. The summary of research work on development conceived by FORD and LERNER 1992 as a systems theory, could serve for a first step towards the cooperation desired. Although it is not my intention to preach a reunification of humanities on the grounds of evolutionary theory, it is certainly permitted to reflect upon such an eventuality from time to time.

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Are Artifacts Living ?

Abstract

Organisms are formed through the interplay of genes and the environment which they experience. Both genes and the environment can be seen as forms of information. Artifacts, such as bird's nests, are a consequence of this genetic and environmental information. A third form of information is cultural, information passed from mind to mind. An artifact, such as a computer, results from the interaction of all three forms of information. Are these artifacts dead structures or are they extensions of the animals that contributed to their construction, and so living? This article will consider the coevolution of these three types of information and the artifacts that have resulted.

It is generally believed that life evolved through a progression of complex chemicals in some primordial pool. Multiplying chemicals survived differentially. In time the chemicals clustered to form cells surrounded by membranes. These basic cells underwent considerable internal evolution to become robust multiplying structures in their own right. The cells formed in groups to make the plants and animals we know today. Traditional definitions of life include properties such as growth, reproduction, irritability and respiration. These properties would not apply to the original replicating chemicals. However John MAYNARD SMITH has taken a different approach. "We shall regard as alive any population of entities which has the properties of multiplication, heredity and variation" (1993b,p109). He further suggests that some polynucleotides, could, if they acted as templates to reproduce further nucleotides, fulfil these three properties and so be living.

Say there is an entity that multiplies and that these new entities survive differentially. Provided that some of the new entities vary from the original entity, these entities would fulfil the above three properties of multiplication, heredity and variation. The phrase "differential survival of variations" captures all the features of MAYNARD SMITH's definition. The process of the differential survival of variations, defines life. However, where is the boundary between the living chemicals (such as polynucleotides) and the dead chemicals that preceded them? This would be difficult to find as there are always intermediate forms that fall into both categories. A different approach to seeking a boundary would be to consider that life is 'drawn out' from a dead substrate. There is no boundary between the two. The amount of 'lovingness' would increase in entities with a polynucleotide having the least, while a single celled organism, a tree and an animal with self-consciousness having progressively more livingness.

An organism interacts with its environment: all that surrounds it. This environment contains variable physical conditions and other organisms and so is continuously changing. An organism could then be seen as surrounded by a series of environments or a continuum of environments. The development of the organism, and later the adult itself, is affected by variations in this environment. "For a geneticist, all variance which is not genetic is, by definition, 'environmental'. It would therefore seem logical to treat all transmission which is not genetic as cultural" (MAYNARD SMITH 1993a, p66). The use of 'cultural' here is a very broad one, one that some may be uncomfortably with. I will restrict 'cultural information' to be that information which is passed between animals directly through signals, or indirectly through one animal observing the actions of another. All other information that is present in an animal's environment could be called 'environmental information'. The third form of information is 'genetic information'.

MAYNARD SMITH's use of "genetic" above can be extended. A germ cell contains not only information in nucleoplasmic DNA but information in cytoplasmic DNA, RNA and proteins. In sexual organisms, this cytoplasmic information can be transferred through the maternal line and constitutes information inherited by the germ cell. (JABLONKA / SZATHMARY 1995). As such it would be more correct to use the term 'cellular information' than genetic information. In this case I will use 'gene' in the broadened sense of a unit of cellular information.

For an animal, its physical body as well as its genetically driven behaviors represent its phenotype. DAWKINS (1982) extended this concept of the phenotype to include animal built artifacts such as birds' nests and termite hills. The nest is part of the living bird and it multiplies through the interaction of genetic information within the bird and the environment of the bird. The style of nest may change if there is a variation in genetic or environmental information. The nest is living in the sense that it is part of a living bird or at least it has a component of 'livingness'; the genes that code for its production.

Other artifacts, such as a water hole in a dry creek bed, may be dug and extended by a number of different animals, even different species. Within all these animals is genetic information that drives the animals in the formation of these holes; those not having such a drive may die during drought. Clearly the hole is the phenotype of a number of animals. A change in genetic information in any one of these animals may result in a different digging behavior and so a differently shaped hole. The differently shape hole will affect the subsequent digging of the next animal and represent environmental information to that animal. The hole is a living part of a number of animals.

The act of an animal breathing changes the ratio of different chemicals in the air surrounding the animal. This change would also be an phenotype although less distinct than the hole or nest. A change in genetic information may change the way breathing is done and so change the ratio of different types of molecules. Carbon dioxide was removed from our atmosphere by the activities of organisms which eventually allowed aerobic respiration. Our current atmosphere is then, the phenotype of all past organisms. The gradual change in the atmosphere selectively advantaged particular variations of organisms over others. The atmosphere (environmental information) and life forms (genetic information) coevolved. Life forms, through their activities, modify the environment around them, and these modifications in turn represent a new environment that selectively advantages different variations than the previous environment. The hole in the river bed may allow others to drink that may not have the physical capability of making such a hole. Here the phenotype of one animal represents environmental information to another.

It might be tempting here to define life by being organized from within while dead things, such as artifacts, are organized from without. This was done by Jacques MONOD (1971) and with this definition he concluded that crystals as well as organisms are living. While crystals multiply and inherit structure from a seed crystal, they do not have variation. A crystal forms an unvarying distinct lattice based on properties of the chemicals that make it up. The crystals only vary in size. Similar arguments could be made for things such as snow flakes. There is much variation yet none of the variations survive to reproduce. In contrast, strings of amino acids not only multiply but some strings are better at doing this than others. They have properties of multiplication, variation and heredity.

A bird's body is organized from within while its nest is organized from without so the nest would not be considered living in MONOD's definition. However, organisms have various mechanisms for their survival in their environments. A grass may use the wind for fertilization, a flowering plant may use bees, some orchids have elaborate mechanisms for fertilization using wasps, and some fruit bearing plants exchange a meal for seed dispersal. Here the grass depends on environmental information for fertilization, the orchid on external genetic information within a wasp for reproduction, and fruit bearing plants on genetic information in a number of other animals for dispersal of it seeds. Organisms are, to varying extents, organized from without. Environmental information (a part of this environmental information is the phenotypes of other organisms) is external to organisms yet, as organisms coevolve with this external information, they are significantly organized by it. A change in this external information can lead to the organism's extinction, and extinction is certainly organization from without. The phylogenetic history of a species is a record of successful past interactions between genetic and environmental information.

Other plants have humans as a component of their environment. Humans may affect a plant's numbers and distribution for purposes such as agriculture. For the cultivated plant, the human is just environmental information; another directional selection pressure that makes up its environment. By collecting seeds, preparing beds, eliminating or reducing competition from other plants and insects, removing plants not of quality and supplying extra water and nutrients, the plant becomes human dependent. Some variations of the plants are selectively advantaged in a human environment. (Cultivated fruit trees returned to the wild usually return to their original form of a hardier tree with smaller fruit.) Plants, in having a dependence on other animals, bind their fate to those animals. These plants are organized from without from environmental information and the genetic information of other organisms. The plant is, in part, the phenotype of humans.

The brain is an organ that allows environmental information collected by the senses to be processed. Konrad LORENZ (1977) gives the following reason for its evolution: it is a device that allows an organism to pretrial proposed actions in the brain and by so doing avoid mishaps that may result if that action was directly applied. A mountain goat that can make a mental calculation of a jump and so possibly avoid injury will be selectively advantaged. LORENZ distinguished between generalists and specialists. A generalist ranges over a broad niche and so experiences a variety of environments. It is amongst generalists that the selection pressure for increased brain size and/or reasoning ability is strongest. An animal that can better pretrial actions will be selectively advantaged over an animal of lesser ability.

The kidney also varies in its action depending on its environment but the variety of the action is extremely limited in comparison with the brain. The kidney 'senses' the incoming chemicals and acts on them differentially. These chemicals could be seen as information. The variety of actions possible for this information is limited with no pretrialing of actions. Chemicals are either returned to the blood or discarded.

A generalist is selectively advantaged by a variety of actions that allow full use of its broad niche. Genetic information provides an animal with a set of messages that anticipates a variation in environmental information. It allows for a number different behaviors depending of that information. In this sense genetic information can be seen as 'knowledge' of an environment. Yet change in this knowledge can only occur through genetic mutation. The brain is distinguished from the other organs in that it can change its knowledge of the environment through learning *during* the life of the animal. Genetic variation is not needed for a new behavior. This ability underlies the importance of the brain and the reason for its evolution.

Richard DAWKINS (1976) coined the term "meme" as an analogous unit to the gene. The meme is unit of cultural information that is passed from mind to mind. The meme itself is not conscious. Its genetic equivalent is something like a polynucleotide. The meme is a chemical and/or neuronal pattern within the mind and survives or fails depending on whether it is replicated by other minds. While our knowledge of the mind does not provide a full account of how ideas are stored, I will assume that the mind and brain are the same and that there is no nonphysical realm to which mental knowledge can be passed (DENNETT 1991, p33–39). In this case any meme must be represented in the brain in a physical sense, either a chemical or electrical representation or a combination of both. It is a physical structure that is reproduced (probably not identically) in a new mind upon that mind's exposure to it, and acceptance of it. A behavior resulting from memes is the phenotype of those memes. For example, a person's way of eating food is ritualized by memes passed to him through his sensors and stored within his mind. It is the observation of these phenotypes by other individuals that may lead to the memes' possible multiplication. But eating of food is not entirely memetic and has environmental and genetic components. The form of the body with its arms, hands and fingers affect memetic rituals. As well the metals dominate on the earth's surface will affect the characteristics of the artifacts used in eating and the type of food available will affect the style of consumption.

The phenotype of a meme is modified by other memes with which it is associated. No meme expresses itself in isolation. If a number of people are asked what is meant by 'house' then the answers will vary considerably. The meme 'house' does not exist independently in the mind but is linked with countless other memes which will flavor the perception of 'house'. Yet within all descriptions there is a core understanding of the meaning of 'house'. Similarly, no gene can express itself in isolation, and it is the combined effect of many genes that is required to form a new organism. The meme for 'house', while it is stored physically, is no doubt stored in different ways in different minds. The storage of memes is probably more flexible than the storage of genes. The answer to this problem of storage will become more clear once the physiology of the mind is better understood. For the present, I will use the term 'meme' very loosely, referring more to the observable phenotype than its unit of storage.

A meme has the properties of multiplication, heredity and variation. The meme, by being retained in a new mind upon that mind's exposure to it, multiplies. This new meme may be a variation of the old meme. A meme may also survive in one mind yet not be accepted by another; memes survive differentially. The meme then, fulfils the conditions for life defined above. But is the meme living in the sense that it is part of a living animal, or is it a new type of life? For a kidney to operate differently, there needs to be a variation in genetic information. But an animal may behave differently through its mind adopting new memes, that is, by learning from other animals. Through memes an animal's behavior need not rely on new genetic information for change. This is a significant distinction. It is this new level of change that allows the pretrialing referred to by LORENZ. The generalist can interact more effectively with its environment by being able to rapidly alter its behaviors in that environment. The meme could be taken as a new level of life.

New memes may be environmentally or culturally led. If a person sees some plant that he thinks will benefit him through its cultivation, he will take the plant and grow it, and assist its growth possibly by supplying extra water, nutrients and preventing predation. Here the thought 'that plant is of benefit' is a new meme , the production of which was stimulated by environmental information. This new meme then interacts with the mind and, in case of our plant, has survived (as the person has gone on to grow the plant). A new meme that is produced 'struggles' for acceptance within the mind. It will survive or fail depending on this struggle. As our meme for the cultivated plant has survived, then a positive use for the plant was perceived. Now, rather than memes initiated by environmental information, imagine new memes that arise from within the mind. A new meme is created by the interaction of the existing memes. These memes are derived from cultural information and a new meme undergoes basically the same process as the environmentally led meme. This meme must now 'struggle' for survival with established memes.

It is a mistake to see the meme as an adaptation of the physical body (the body without its resident memes), such as the kidney. Rather the memes are like many 'animals' that the physical body has to interact with. Generally the physical body is in a symbiotic relationship with these. Memes that contain information for fishing, hunting, cooking, building and so on, all assist with the survival of the physical body. The meme's 'reward' is its multiplication. A new meme, struggling for acceptance, will be in conflict with some memes and in harmony with others. For example, the cultivation of the plant will align with the genetic information that drives the body to eat. When the volume of cultural information passed between humans reaches a certain 'critical mass', opportunist parasitic memes containing information such as celibacy, suicide, martyrdom and so on, all lessen the chances of the physical body's survival and reproduction. The meme is a living unit in its own right, not an adaptation of the physical body.

I will now outline some of the differences that appear between genes and memes.

(1) How do new memes come into existence? An apparent discrepancy appears here. New genes are generated randomly through mutations. In contrast, humans pursue answers to problems so the creation of new memes appears intentional, that is, not created randomly. STEIN and LIPTON (1989) suggest a solution to this problem. The production of memes in our minds is in part random, with that randomness disguised through many thoughts being eliminated by unconscious selective processes. This creates the illusion that we are actively seeking problems to solutions. Thoughts are often triggered by random events such as chance meetings, accidents, flashes and visions. New ideas are also constrained and guided by cultural knowledge from the past so that an individual's thoughts are variations on an existing theme. For example, a person with no knowledge of chemistry cannot solve a scientifically posed chemical problem. The solution can only come from a person with a certain 'critical mass' of chemical knowledge. The new ideas depend to a large extent on the substrate from which they arise. The production of new memes contains both random and guided components.

Similarly with new genes, a mutation can only be a variation from the existing genetic information. A new gene is not random in the sense that *any* gene can result, rather, variations are highly constrained to a particular range of possibilities. Within this range, variations of may also not be entirely random. There appear to be two types of genes. One type controls the production of structure (for example, red blood cells, muscle and bones), while the other makes enzymes which are responsible for replicating DNA and correcting errors in this replication. As this replicated DNA is the genes themselves then the errors (or mutations) are under genetic control (MAYNARD SMITH 1993a,p184). The rate of mutations can be controlled. In periods of stasis where the organism is well adapted to the environment, a high mutation rate (as mutations are more likely to be unfavorable than favorable) is a disadvantage. During periods of rapid environmental change, a high mutation rate would be of advantage as it may allow an organism's offspring more variability and so the chance of at least some of them surviving. An organism, then, would be selectively advantaged if it could control the mutation rate within its germ cells. Genetic and memetic change both contain guided and random influences.

(2) Memes are passed from parent to offspring. This appears to be the passing of acquired characteristics and so would seem LAMARKIAN. However memes are also passed from adult to adult, child to child, and child to adult. These other transmissions

could not be considered LAMARKIAN. It is clear that memes can be passed in *any* direction simply depending on whether a mind exposed to those memes retains them. Further, meme exchange is not limited to humans. The training of animals requires a transfer of memes from humans to those animals. A bird, the honey-guide of Africa is transferring memes to humans as the human follows it.

(3) A person is more than just ideas. She has feelings such as love and happiness. Are feelings memes? Certain feelings are unique to a person and cannot be experienced by others. As they cannot be transmitted they cannot constitute memes. The part of the mind which is not memes can only be the environment of the memes. Thus feelings represent that part of the mind not used for storing memes. Feelings are an ongoing state reached by the interaction of memes with each other and the rest of the mind. However a person can describe their feelings to another using words. Through this description a person may experience something like the original feelings. For example, a person who meditates has a particular experience. She may describe her technique to another who will also have a particular experience but this is different (presumably) from the original experience. The way a person *experiences* genetic and memetic information is unique to that person.

What is thought and does it have an analogy with genes? Imagine a number of vultures feeding from a dead animal. Each bird tries to obtain as much meat as possible. The birds will also try to avoid injury. Some will obtain more of the meat than others. Yet no new birds need be created nor die in this process. If feeding is guided by genetically driven behaviors, then the action of feeding represents the phenotypes of the genes governing those behaviors. Success in obtaining food reflects on the likely survival of those genes. Instead of birds, imagine memes also in competition, with the length of time (prominence) memes engage the attention of a person as a payoff instead of the volume of meat. Our experience of thought *is* the phenotype of the interacting memes. No new memes need be made or lost in this process yet some might obtain more prominence in the mind than others. Because of this prominence, the phenotype of the memes, that is, behaviors resulting from memes, will be observed more often by other people and so be more likely to be retained in those new minds.

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So far I have considered three forms information: environmental, genetic and memetic. The boundary between these three is not so clear. Genetic information can be transferred to memetic information and vice versa. For example, say a population exists in which there is a gene that, if present, prevents disease 'A'. Those without the gene always die when contracting disease A. Now a scientist discovers (say) a cure for those rare cases where people without the gene contract disease A. These people no longer die and so the proportion of people without gene A increases. Eventually gene A may be lost to the population. Here the frequency of the disease may not have changed, yet the cure has changed from a genetic to a memetic one. Genetic information has become memetic information. Some medical cures lead to a shift from genetic to memetic information. Caesarian births will represent a selection for smaller hip size. The gene for large hips failed in its competition with memes (stored in various doctor's minds) that allow for a successful caesarian section. A consequence of this information transfer in medicine is the increasing proportion of human activity devoted to medical practice.

HITLER's eugenics was a memetic attempt to produce particular genetic types. The selection of a mate in humans is also eugenics at the level of the individual rather than the society. A person seeks an 'attractive' partner with that person's idea of attractive having a large cultural component. Memetic beliefs reinforce themselves through the genetic make-up of children produced. Here memetic information is transferred to genetic information. This process is not restricted to conspecifics. The human eugenics of cultivated plants encodes human memetic knowledge into genetic knowledge of the plant. This may be through the differential selection of plant variations or the direct insertion of genetic material into the plant. In this latter case, the human is the mutating agent for the plant. One trend that is clear in humans is the progressive accumulation of memetic information at the expense of a diversity of genetic information.

The three forms of information coevolve. Life forms, through their activities, modify the environments around them, and these modifications in turn represent new environments that selectively advantage some variations over others. An artifact may be the product of environmental, genetic and memetic information. A bird may build a nest modifying the genetic drive to do so with new mental ideas formed in its own mind or ideas copied from another bird. The nest is now a phenotype of both memes and genes. For our hole in the river bed, an animal may modify its digging through new mental knowledge it has thought up itself or through copying another animal. Here the characteristics of the hole is a convergence of environmental, genetic and memetic information. It may be part of a number of animals' genetic and memetic phenotype, with those animals not necessarily of the same species. In animals with complex mental abilities, the idea of genetic and memetic information could be better seen as two ends of a continuum rather that separate concepts in their own right.

I will now turn to our most complex artifact; the computer. With the 'networking'of these devices, computer 'viruses' have appeared. There are two types. The first is written by a human and released onto the network. This algorithm is a meme. A variation in this algorithm must come through the mind of its writer. A second type may come into existence accidentally. A program may be copied incorrectly such that a piece of program is chopped of and is lost in the network. If this piece can multiply itself, and occasionally varying during this multiplication, then these variations will survive differentially. It would represent a third level of life (genes the first and memes the second). It is self changing, not relying on the mental activity of humans for change. It would be equivalent to a rogue piece of DNA becoming cancerous. We would then need another name for them, say remes (reme is an ancient form of realm and would signify the new mental realm of the computer). These remes would, like genes and memes, undergo variation and differential survival in their electronic environments.

Remes could also be programs, purposely created, that allow self- modification through some system of random change. A random change that is detrimental would result in a return to the original state. A random change that is successful would remain as part of the program. Here the new remes would be 'drawn out' out of a memetic environment. There is no reason to believe that these remes will not progress in complexity as have genes and memes. Scientists working in artificial intelligence are impressed by a computer's ability to mimic aspects of human behavior. At the same time they concede that the apparent intelligence lies in the intricacy of the human generated algorithm. Geoff SIMONS (1983), in his book *Are Computers Alive?* is convinced that computers are an emerging life form. He believes that at some time a computer (or similar artifact) will be developed that is self-conscious and capable of a meaningful conversation. This may not happen but it is a reasonable belief given the progress in electronics in the last thirty years and combined with the knowledge that the earth as we know it has some few billions of years of life left (saving some catastrophe). A reme will evolve into more complex forms with the right conditions. One of these will have to be a greater rate of random/self guided variation within programs. It is at least theoretically possible that a self- consciousness could be gained through this process. After all it is essentially the same process through which we gained ours.

Yet independent mental abilities for computers will not mean independence from humans. Computers will continue to need electricity made by humans. Similarly memes can only exist in human minds and human made artifacts. But freedom from the environment from which an entity arises is not a condition for life. Humans depend for their energy on plants and animals that they eat as well as direct environmental sources such as solar energy. It is unlikely we will ever be free from the energy of other organisms nor would it be efficient to do so. The leaf is the most efficient converter of sunlight to energy that we have. The relationship between humans and computers will be a 'symbiotic' one.

Conclusion

The original living entities were multiplying chemicals that varied and survived differentially and the progressive accumulations of these variations led to the organisms we know today. Some of these organisms were animals that range over a broad niches (generalists). Those generalists that could better pretrial possible interactions with their environments were selectively advantaged. The organ that specializes in the processing of sensory information and the pretrialing of possible actions, is the brain. The brain allowed ideas stored within it (memes) to be expressed externally and so copied by others. Animals could learn from each other. These memes constituted a second level of life. Thought is a manifestation of the interaction of memes. Change could now come to an animal's behavior without a corresponding genetic change. The memes increased in complexity resulting in physical forms; artifacts. One of the most recent of these, the computer, is increasing rapidly in complexity. If this trend continues computers will gain self

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consciousness as we know it. The electronic 'mind' of the computer shows some signs of having free agents ('viruses') that can vary with that variation no longer dependent on new memes. These viruses, and other programs capable of self change through random processes constitute a third level of life.

Life then can be seen as a progression of entities. The variation and differential survival of these entities is the single process separating life forms from the other physical forces we know (gravity, nuclear, magnetic, and so on). The progression of these entities is characterized by a nested series of levels, with new levels open to invasion by new life forms. A new life form is characterized by being able vary independently from the unit of variation of the level it colonizes.

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