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NATURE, COGNITION AND SYSTEM I

Edited by Marc E. Carvallo

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Current Systems-Scientific Research on Natural and Cognitive Systems

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FOREWORD

The three concepts in the title of this book-nature, cognition, and system-have a rich relationship to each other. Indeed, our only means to obtaining some understanding of nature is to model its various facets, i.e., to construct systems that are adequate models of certain aspects of nature. The process of systems modelling is not only the very purpose of science, it is also a basic capability of most living organisms. They construct and constantly up-date internal predictive models of their environments (and, in some cases, of themselves), and utilize predictions derived from these models about the future for making appropriate decisions at the present. In this context, we usually talk about cognition rather than modelling. Since cognition is also a part of nature, any attempt to understand it leads inevitably to systems modelling. In this sense, we attempt to model a modelling process embedded in the mind. Such an activity may, perhaps more appropriately, be called a systems metamodelling.

The issues discussed in this book are all relevant to artificial intelligence. Although the relevance of each of them in this regard has been recognized for some time, their relationship has been largely neglected. The fact that they are presented here together under one cover is a contribution on its own.

The book contains a broad spectrum of topics, covering philosophical, methodological, and mathematical issues related to the three themes expressed in its title. They are presented by well recognized researchers in the relevant areas. Included are not only some key, well recognized, and difficult topics such as the role of natural language in cognition or the meaning of pragmatic information, but also some exploratory topics such as the role of emotion in cognition or the influence of brain research on computer design. Well covered in the book are the concepts of information, complexity, computation, and self-organization.

Nature, Cognition, and System is a sophisticated and significant book. It presents a challenge to the rapidly growing field of artificial intelligence which, unfortunately, is viewed too often solely as a programming discipline. I personally believe that this narrow view of artificial intelligence will not be sustainable in the long run.

The editor of this collection, Marc E. Carvallo, should be complimented for his insight of putting together such an important and timely volume.

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INTRODUCTION: CONVERGING THE TWO TIME ARROWS

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I

The present volume results partially as an outgrowth of a major symposium under the title "Symposium on Nature, Cognition and Systems". This symposium was an integral part of the 3rd International Conference on Systems Research, Informatics and Cybernetics, held in Baden-Baden, West Germany, August 19-24, 1986. These contributions have been since then so extensively rewritten and augmented as to be essentially new articles. Some other contributions (viz. those of Bråten, Kallikourdis, Löfgren, Kampis, Erdi, Vandamme and Stuart and Campbell) are original.
The volume brings together some of the current systemsscientific research results on natural and cognitive systems. It comprises sixteen papers dealing with topics related to these major categories of systems as interpreted from diverse viewpoints and by diverse disciplines. So the themes of the contributions address themselves to a wide range of issues, encroaching on computer science, linguistics, physics, biology, sociology and philosophy, just to mention a few.
In preparing the present volume I have tried to arrange a certain degree of coherence in the ordering of the chapters which was not completely or explicitly present in the original discussion, a coherence which in principle (conformable to the policy of the volume, cf. infr.) and at a closer look is far from being spurious, I presume.
The body of the volume is divided into three parts, generally grouping together sets of papers that approach the theme of the volume in a related way. Of course there are many other connections among the papers and some of these will be mentioned in the introduction to the individual papers (see section IV).
The first part regarding cognition, computation and language is constituted by the following "pairs" of papers. The papers of Shirai and Kobayashi and of Graham Stuart and Campbell make up the first pair. Both deal with topics from computational linguistics. The first more with the technical advancements and the other more with the formal alternatives. The papers of Vandamme and Erdi form the second pair. Both call attention to the many shortcomings of the traditional A.I. programme and of the current computerscience respectively. The last pair of this part, being the papers of Kornwachs and Löfgren, enters thoroughly into the (meta)theoretical issues of the topics of the second pair. Moreover in Löfgren's and Kornwachs's papers the thematic emphasis switches from the area of computation and artificial intelligence towards

M. E. Carvallo (ed.), Nature, Cognition and System I, ix–xxxv.

that of physics and mathematics. The keyconcept of "complementarity" in their papers forms the stepping-stone to the second part of the volume opened by the paper of Goudsmit and Mowitz. In their contribution this concept is employed in (again) another sense for explaining the state of autopoietic affairs. The papers of Bråten and Kallikourdis make up another pair of this part. Bråten's paper is not only a critique upon the "physical symbol systems hypothesis" (which is also the subject of Vandamme's and Erdi's critique) but also upon the idea of the organizational closure Goudsmit and Mowitz are trying to reinterpret and (indirectly) defend. He further proposes an alternative which might be more appropriate for the human systems. The paper of Kallikourdis links on to this suggestion by exploring this possibility from the vantagepoint of genetic psychology. The papers of Carvallo and that of Haken and Wunderlin might be viewed as the last pair completing the second part of the book. Their common denominator is the theme of selforganization in non-equilibrium systems, their congenial lines of approach are that of the theory of the dissipative structures and of the synergetics respectively. The last part touches the problem of modeling the natural and cognitive systems. The four contributions discuss the possibilities and limitations hereof from their viewpoints as theoretical physicists (Moulin and Vallet, Jumarie), biologist (Kampis) and social scientists (Reiter and Steiner).

The policy followed in this volume (and in the possible subsequent volumes) may be summarized as follows. First, to foster interparadigmatic communication and to control scientific quality, the volume has been developed as second reflections upon the papers presented and discussed during the symposium. Secondly, in organizing this kind of symposia we on the one hand do not follow the tradition of large and unfocussed meetings and on the other hand eschew the narrowness of specialism drawing smaller and diminishing crowds. After a long journey through the international congresses and conferences the best possible formula seems to be this: to restrict ourselves to one key-theme, respectively one system of themes that are intricately interwoven, one thematic node or singularity of so rich a content that it provides or can provide material and inducement for doing genuine scientific work. One of these nodes seems to be formed by the perennial themes of nature and cognition. Of course, it is in the first place a matter relying upon the insight and responsibility of the organizer of the symposia and the editor of these volumes to identify the themes constituting this node. Thirdly, in achieving this goal the volume keeps an open attitude, its content is not committed to any specific topic within this node (though specific topics of this viable node might subsequently be the themes of coming volumes), nor formally to any particular paradigm, i.e. to any worldview, style of thinking, or conduct of inquiry. However it emphatically encourages alternative reflections and creative syntheses of fresh ideas. The reader will notice that a good many contributions in this volume convey both criticism upon what is

usually called the classical (scientific) attitude (according to which there is a dichotomy between nature and cognition) and suggestions for better understanding of their mutual encroachment. The authors belong more or less to the non-standard systems-science, the third order cybernetics, or find themselves already beyond the third stage in the history of artificial intelligence[1]). They take the inescapability of the mutual implication of the description of nature and that of cognition seriously. Fourthly, closely linking up with the previous, it emphatically calls attention to the forgotten microscopic dimension of science. If I am not mistaken we have at this moment reached the historic stage where the tremendous renascence of the mechanistic-structural paradigm, remarkably enough, calls for its functional-dynamic counterparts. The volume strives to respond to this secret trend in various disciplines and to put into words that which is tacitly alive in the minds of the ever increasing number of people in this systemsage. The investigation on the intertwinement of nature and cognition finds itself in this very paradoxical niche structured by those two opposite developments.

II

One of the great puzzles of the universe as far as we know it is that the state of affairs of this universe seems to be constituted by two time-arrows: one is the famous second law of thermodynamics that refers to entropy-increase and potential decay, and the other is that of evolution which segregates entropy and builds up increasingly complex structures of order. Let me use this hypothesis as an analogon for the sketchy description of the relation between nature and cognition as each other's counterparts. For the history of ideas is i.a. featured by efforts to structurize man's perplexity when confronted with this puzzle. Passing briefly in review and using also some major ideas on human alienation[2]) as background-music, the proposed solutions might be summarized in the folowing major models:
the bifurcation, the convenance and the fusion.

A. The model of bifurcation

The idea of the bifurcation of nature and cognition might properly be represented by the following variants: the homeric, the platonic and the cartesian.
In the homeric variant cognition is symbolized as someone who leads a solitary life, secluded from this ground of existence and history. Homer describes this man as "tribeless, lawless and heartless", the man outside the community, damned to find his way in the desolate regions outside the warming fires of the clan and family (Ilias: Book IX, verses 63-64).
Two ideas strike me when reading and reflecting upon this symbol. First, that of the estrangement of (the way of) "knowing" from (the way of) "being" and "meaning" so characteristic of the

structural-mechanistic conception of cognition. Many, including some authors in this volume, have recently noticed this tragedy and proposed solutions. Many recent conceptions of the "naturalization of cognition" witness the timely necessity to reconciliate cognition with nature[3]). Secondly, that this estrangement, this farness of cognition from nature, is in principle not bad or unlucky. The tragedy refers to the space where this farness is doomed to dissipate, viz. outside nature. For, this farness ought to be coiled in the very heart of nature, it has to be part and parcel of nature as the trigger of her further evolution (comp. the theory of the dissipative structures). This is due to nature, here alluded to as a closed system where, unluckily, only the law of the entropy increase (here symbolically rendered by the foreseeable decrease in available warmth of the clan's fires) holds.

In the platonic variant the idea of "fall" will be briefly discussed both in the sense as it is conceived by the orphic pythagoreans, the neoplatonists, the gnostics, the hynayana-buddhists, and in the sense of Plato's discourse on the embodiment of the soul (cf. Timaios) which closely links up with Democritus's doctrine of space. The term "platonic" then is used here as a collective adjective for all these ideas dealing with one common puzzle: how to explain the concurrence of the two opposite worlds, the transcendent and the ephemeral world of the shadow-show. In the idea of fall the attention is, quite reversely, focussed on the (homeric) stranger, he is positively appraised, in contradistinction to the closed nearness and warmth of home, which here is experienced as a prison[4]). Cognition is completely alien to nature, cognition and nature are in no way linked by homologous principles (i.e. principles related through their common origins), cognition is superior and more perfect than nature but has lost this perfection during its wandering in an endless succession of imprisonments by nature. It can regain its pristine perfection only by refusing to integrate in the natural existence. This motif of lost superiority, powerlessness, and liberation efforts of cognition from nature might in our days, remarkably enough, be recognized in the context of the technocracy controversy. Using the pictures employed by social philosophers, philosophers of science, and cognitive scientists[5]) as metaphors, cognition might be seen here as "substantial rationality" which is assumed to be superior to, but is now tragically powerless in respect of the "functional rationality" (in our context: nature). Or as culture of the bourgeois epoch which led in the course of its development to the segregation from civilization (in our context: nature) as an independent realm of value that is considered superior to civilization. Its decisive characteristic is the assertion of a universally obligatory, eternally better and more valuable world that must be unconditionally affirmed, a world essentially different from the factual world of the daily struggle for existence, yet realizable by every individual for himself "from within", without any transformation of the social reality. Cognition is

further symbolized as the contemporary scientist who has taken refuge in the pathological forms of escape called the "cult of objectivity" and the "cult of alienation". In this framework of thinking and experience the new emerging systemsage is mistakenly identified by many people with one of its constituents, the technological one, triggering dehumanizing processes.
Cognition is finally regarded as the culture of humanities which is totally alien and incompatible to the culture of (natural) sciences (in our context: nature). Many scientists even from the circuit of computerscience, artificial intelligence and cognitive science support the contention of the imperialism of the instrumental reason. This might be an indication for the powerlessness and the (non selfevident) unviability of the humanities and social sciences! The "great refusal" of the latter can only be justified as a moment in the liberation process of both.
Plato himself seemed to be embarrassed by this puzzle (viz. how to explain the concurrence of his two worlds), and his solution elicits questions, analogous to those raised with regard to our puzzle of the two time arrows: How can this world be a copy of an unique archetype, of the absolute living creature in the world of forms, and simultaneously be the world of disorder and of a chaos of restless motions and falls? How can this life be a copy of an unique archetype of the intellectual and moral personality and simultaneously be a "rehearsal for death" where complete disembodiment is the best state of the soul, and where man needs to transcend this world if he is to attain his proper distiny? How can nature be a copy of cognition without the denial of being itself?
In the cartesian variant the fall is described by the motif of the rebellion of the above imprisoned stranger (in our context: cognition) and the appropriation and domination of nature by him. Cognition now plays the role of the decisionist and technocrat (in the above context of culture and civilization) who dominates and subjects nature (viz. other natural systems, i.e. the physico-chemical, biological, and even other human systems that are not the fittest ones in the struggle for existence). Descartes and Bacon can appropriately be regarded as the representatives of this variant[6]. Serres's description of the metamorphosis of our platonic fall into the cartesian one goes home: 'For Plato and a tradition which lasted troughout the classical age, knowledge is a hunt. To know is to put to death, to kill the lamb, deep in the woods, in order to eat it. Moving from combat with prey outside the species to killing inside the species, knowledge now becomes military, a martial art. It is then more than a game; it is literally, a strategy. These epistemologies are not innocent: at the critical tribunal they are calling for executions. They are policies promulgated by military strategists. To know is to kill, to rely on death, as in the case of the master and the slave. Today we live out the major results of these wolfisch actions... The reason of the strongest is reason itself...' (Serres, 1983:28).

Some interprete this far side of the fall as a metaphor for the discontinuous change in human consciousness (which might be triggered by the evolution of the neocortex), by which human beings are as it were doomed to make 'distinctions'. Two mutually complementary implications of this human predicament are on the one hand the separation of man (in our context: cognition) from nature, and on the other hand the domination and subjection of nature to him.
This subject-object relation in the form of the dichotomy between the observing system (in our context: cognition) and the observed system (in our context: nature) became historically the most suitable setting for the master-servant relation to come about, as has become evident from the world-wide spread of the capitalistic form of production which shows that the great captains of industry, the 'maîtres et possesseurs de la nature' make a doubtful use of the earth's natural riches and the technological potential of the natural sciences. For indeed this use passes on from controlling nature and colonizing the life-world to harmfully disturbing nature, as has been beautifully rendered by Bateson (1978) in the parable of the garden.

B. The Model of Convenance

This model encompasses explanatory worlds where nature and cognition are reconciliated. The following variants might be distinguished: the conversational, the vitalistic and the animistic ones[7]. In the conversational variant the attention is focussed on the way we (as observing systems, and consequently as cognition) are trying to describe (and so interact with) nature, other than the cartesian way. Nature is no more the object of our detached observing, nor our adversary or slave. Instead, we are making pacts, conventions, alliances with nature. This might be rendered by the metaphor of the canoerower: if we are trying to steer our canoe in the stream, in direct interaction with its forces and keeping a proper distance from both banks, we enter into direct relationship with the life forces around us, we deal with them on their proper level, we become involved and try to influence the overall process. Doing so, we might take up one of the following three possible attitudes: (i) our description of nature is indeed not absolute but relative to our point of view, i.e. to our coordinate-system (cf. Einstein); (ii) our description of nature affects nature so as to obliterate our hope for prediction, in other words, our uncertainty is absolute (cf. Heisenberg); (iii) our description of nature is semi-subjectivistic in that nature we describe is not nature as such but nature of our interest, it is even nature that comes into being when we sever a piece of space-time (cf. standard systemsscience and Spencer-Brown).
These attitudes could be recognized with some theoreticians engaged in research on selforganization and with the standard systemsscientists.

Their principal concern is not less scientific than that of the cartesians, they try to understand nature, to decipher the language nature is drafted in, to decode circumstances nature is constituted by, in order to enter into dialogue with this nature. And due to their changed worldview, the paradigm their research is predicated upon is not only the structural-mechanistic one, but also, if not primarily, the functional and dynamic one. It should be remarked, firstly, that in this variant the type of conversation is that of an informational openness between two organizationally closed systems. Secondly, that human systems do not fall into the class of natural systems, in other words, the nature they are describing is still viewed as the 'objective world'. The attribution of mindlike properties such as the ability to perceive and to communicate, means no more than an anthropomorphism (cf. Prigogine and Stengers, 1984: 14, 148, 165; Zeleny, 1980: 21).
According to the vitalistic variant cognition as the principle of selforganization operates indeed in nature but only within the biosphere, in the heart of 'living matter'. So nature is here reduced to and identified with animate nature. One may find this reduction a.o. with Bateson who, maybe due to his ignorance of quantum physics, draws a demarcation line between 'pleroma' and 'creatura' (Bateson, 1978; 1980). Or with the theory of autopoiesis where natural systems are the same as living systems, i.e. biological systems. According to this theory the concept of 'living systems' refers to all organic systems including human systems: '...we ourselves fall into the same class' (Varela, 1979: xvi). Or: 'The observer is a human being, that is a living being, and whatever applies to living systems applies also to him' (Maturana, 1980: 8). Even: 'Living systems are cognitive systems, and living as a process is a process of cognition' (Maturana, 1980: 13). Translated into our concepts this would run simply as follows that nature is cognition, which, I am afraid, is not quite correct because this would imply that autopoiesis theory falls under the (rather controversial) model of fusion, which it is surely not. Nature is cognitive or cognition is natural might be the right translation of this radical assertion. Because indeed, in the vitalistic variant we (i.e. cognition) are challenged to develop a description-invariant 'subjective nature', i.e. nature which includes cognition, and then to attempt to write its description. This challenge also regards the question whether in this nature there is only one consensual domain where conversation takes place in terms of informational openness between (admittedly) two organizationally closed systems. The autopoieticians seem to be still ambivalent with respect to this. Recently Maturana propounded two kinds of worlds, the universe and the multiverse, where the classical and the above mentioned vitalistic description of nature hold respectively (Maturana, 1986).
According to the animistic variant cognition as the trigger of selforganization in natural systems operates throughout the cosmos as well as within the biosphere, where this principle is expressed

simply in a more precise and intense manner. Aristotle's biological view of the cosmos that nowadays looms up again in the form of the s.c. gaia-hypothesis is one of the striking examples. Our attention here however is focussed on his thesis that every being (in this world of senses) has in fact come into being by the very intercourse between form and matter, or is the embodiment of the synthesis of these two principles. If we translate matter and form here roughly as nature and cognition respectively then the above thesis would run as follows: that every being in this world of senses is the embodiment of cognition and nature. Note that both form and matter are here ontic principles, i.e. principles of selfcommunication and selflimitation respectively, operating in the 'second' or 'informed' matter. Thus as principles both, nature and cognition, belong to the cognitive systems! Conversely, all informed matter (in our context and according to common sense: nature) is unintelligible without these cognitive systems.
Another prototype of solution for Plato's puzzle is proposed by Lucretius. In the lucretian interpretation the homeric stranger who has become the platonic prisoner has turned out here to be an important member of the clan. The good craftsman of the 'Timaios' is part and parcel of this world. Translated into our vocabulary, cognition is here the principle of the selforganization of nature. In contradistinction to the platonic variant the 'fall' is appraised positively here. The lucretian fall is charged with the birth of everything and everyone: 'The universe is the global vortex of local vortices...Nature is rivers and whirlwinds...What nature teaches us is the streaming of the endless flow, the atomic cascade and its turbulences-watersprouts and whirlwinds, the celestical wheel endlessly spinning, the conic spiral that generates things. The soul (in our context: cognition)...is the seat of turbulences...The soul is tied in knots, just like the world. And like the world, it is unstable, in a state of disequilibrium' (Serres, 1983: 117-118). Cognition triggering the farness from equilibrium is a constituent part of nature!
In our days many research findings from the vitalistic variant have been reinterpreted animistically. In many scientific and philosophical works, for instance in those of Serres or Jantsch, the main ideas of the theory of the dissipative structures and of autopoiesis hold for the whole cosmos, even for being as a whole. Nature and cognition come both structurally and historically from the same origin. Cognition is the mind of nature. In Jantsch's interpretation of the prigoginean triangle one might, remarkably, also recognize the above aristotelian thesis of the constitution of the second matter. The structural-functional order as the conservative principle of selforganization playing the role of 'matter', and the fluctuational order as the dissipative principle of selforganization playing the role of 'form', might be analogous respectively to the conjunctival, contractual, stable links among atoms themselves on the one hand and the circumstantial and unstable historical contract which would be nothing without the existence of the just mentioned conjunctival links and which

quickly disappears around them, in Serres's interpretation of Lucretius's theory. In Bohm's theory, where also the aristotelian formal and final causes have been re-established, the cosmos, where cognition is the trigger of selforganization, is still more enhanced. Selforganization does not only operate on the level of the explicate order (as assumed by the vitalistic variant), but also on the level of the implicate order, probably the transitional order constituted by the (boundaries of the) aristotelian second and prime matter.

C. The Model of Fusion

In the model of fusion the relation between nature and cognition could be described either as a complementary one or in the sense that cognition is an integral part of nature and (what would be much more difficult to imagine) vice versa. The latter might metaphorically be renderend - to convert our pictures of the homeric stranger who has turned out to be an important member of the clan into strange-loopy ones - like the boy in Escher's printgallery who is an integral part of the gallery and (what would be more difficult to see) as the gallery that is an integral part of the boy. These images are implicitly present in or have been described differently by the variants of the previous model and, to a certain degree, maybe also in some of the papers in this volume. It lies beyond the scope of this volume to discuss the following (not only philosophical but also scientific) quandary, inherent in the fusion model, whether nature is identical to cognition. The answer to the question whether the boy in Escher's printgallery is the printgallery itself, I would rather leave to you.

III

According to some researchers the duality[8)] of the natural and cognitive system belongs to one of the prototypes of dualities constituting systemsthinking. They have tracked the origin and the development of the concept of a system from greek antiquity down to the 19th century (cf. Ritschl, 1906; Stein, 1968; Oeser, 1976; Rescher, 1979). Rescher goes even further by asserting that in the western history of ideas the cognitively oriented conception of an intellectual system and the thing-oriented idea of an ontological system are indeed two rivalling conceptions, but that there are constantly trends to integrate these two orientations, or even to discover the single conception underlying them. The development of general systems theory, is an example of this, according to him (p. 10). Recently Klir thought to draw analogous conclusions, i.e. that all distinctions set up in the concept 'system' are in principle reducible to two basic types: (i) those applicable to the things involved in the system, and (ii) those applicable to the relations recognized among things. Contemporary systemsscience then admmits two types of systemsclassification, the

'thing-oriented' and the 'relation-oriented' one.
The classification of the thing-oriented type of systemsscience is essentially experimentally based. Its specific mode of inquiry is performing and analysing experiments with systems simulated on a computer or, possibly, in some other way. The classification of the 'relation-oriented' type is predominantly theoretically based. Its specific mode of inquiry operates mathematically (Klir, 1985).
Viewing system and systemsscience in a broader and deeper sense than only semasiologically (as has been done by Rescher c.s.) or only within the limited framework of the standard systemsscience (as is presented by Klir), and interpreting 'nature' and 'cognition' in a more comprehensive sense as has been sketched in the previous section, we suppose to be justified in asserting that contemporary systemsscience is just continuing the trend initiated by the general systemstheory and that contemporary systemsscience is constituted by the natural and the cognitive science. It has grown out into a broad and open science, in a less strict sense a scientific culture, whose membership can range from those who, because of their tacit knowledge, may 'gravitate' towards this culture (regardless of what is exactly meant by this), to those who actually are professing members of certain systemsscientific societies (which does not per se guarantee their prerogative rights in the one authentic interpretation of what systems-scientific culture is).
The contributions in this volume are also sensible of this duality and of the converging of the two time-arrows (implicit in this duality) which loom up in their papers under diverse names such as: structure vs. process, emotion vs. cognition, artificial intelligence vs. neurosciences, description vs. interpretation, openness vs. closure etc., just to mention a few. In introducing their contributions I have made alternative summaries and stage-setting comments to give the reader some sense of getting involved in problems that haunt us and above all to invite the reader to be our critic.

IV

Search processes and search representation play a fundamental role in artificial intelligence. The paper by Shirai and Kobayashi will introduce the reader to some of the important issues related to search. To be more specific, the paper is concerned with the R&D subject of intelligent human-machine interface systems, one of the many research topics the fifth generation computer is occupied with currently. The authors view recognition as a search problem and discuss the validity of what they call the feature extraction method for speech recognition in the articulatory domain. The study is based on an articulatory model that contains physiological and phonological constraints in itself which are effective for the calculation of the vocal tract shape.
Although the expected results will primarily be of relevance for

those working with the knowledge representation hypothesis as a tacit assumption, others whose main concern is rather the non-trivial machines, like the autopoietic ones, might also benefit from these findings. What, for example, if they are employed for the psychology and cybernetics of cognition, let us say for simulating the other, as is suggested by Bråten in this volume?

The contribution of Graham Stuart and Campbell is a by-product of certain projects in natural language processing for machine translation, speech recognition and literary text analysis, which are undertaken in collaboration with the university of Kyoto in Japan. In this article the authors are dealing with the foundation of a general theory of systems of symbolic expressions. Cognition forms the covert means used by human beings for representation and natural languages are the overt means used to communicate about representation. Symbolic expressions are assumed to differ from each other on the basis of their semantic information content. A system of symbolic expressions is considered to be an autonomous system which has symbols as elements and the information content of these elements is represented by the position of these symbols in a partial ordering. The partial ordering is an important property of the structures which are formed on the basis of the nature of the symbols in the symbolic system. These structures are identified as complete lattices. So the general theory of symbolic expressions is discussed in term of two system components: (a) the symbolic expressions as elements and (b) the structural organization which relate the symbolic expressions in a specific manner to each other.

Both the symbolic expression as element and the structural organization are considered to be the components of a cognitive system. This cognitive system is open to membership (new elements), but closed in terms of its underlying modularity (separate domains of symbolic expressions) and the nature of local structures (complete lattices). Their approach differs therefore from the hypothetical-deductive one underlying formal language theory (formal grammar) which assumes a fixed structural organization (e.g. production rules). A formal description of the approach in the article is given by presenting aspects of Dana Scott's continuous lattice domain model for the typefree lambda calculus. The authors devote also a good deal of attention to the philosophical background that shaped their understanding during the research process. It is an eastern variant of constructivism called the representation only epistemology, expounded by Vasubandhu, radically elaborated by the japanese monk Kukai and which up to now still influences the cognitive theory of haiku literature. It is up to the reader to judge whether they have succeeded in braiding together the above formalistic mode of inquiry and this philosophy for explaining some aspects of nature and cognition.

Against the background of his critique upon the neopositivistically constructed chasm between non-algorithmic and

algorithmic thinking on the one hand and of his observation that nowadays more and more attention is given, especially by the researchers of the A.I. to the relations between emotion and cognition on the other hand, Vandamme audaciously propounds that emotion is not an epiphenomenon of cognition but rather the basis on which cognition is built: ontogenetically as well as phylogenetically emotion precedes and is a prerequisite for the cognitive organization. Cognition is the field in which structure is given to symbolization and the field of operating upon symbols. (This more or less may be tantamount to Graham Stuart's and Campbell's description of the cognitive system as being composed of symbolic expressions as elements and their structural organization). The author further distinguishes between intelligent and non-intelligent cognition. Non-intelligent cognition is universal, general, and context-independent. Its results are certain and necessary if the application is appropriate. Intelligent cognition know whether the application is appropriate or not. The study of interaction between emotion and cognition is called epistemology by the author. Applied epistemology is then applied knowledge about this interaction. One of the domains of this applied epistemology is A.I. Applied epistemology is relevant for A.I. in that the main goal of A.I. is the implementation of intelligent knowledge in computers. In this connection he seems to share the opinions of others in this volume (e.g. Löfgren, Kornwachs or Kampis) who try to identify the limitations of A.I. Although the author sometimes seems to be not very clear with respect to the question whether intelligent cognition is identical to or different from emotion, that is, whether intelligent cognition is that aspect of cognition lying between emotion and non-intelligent cognition, and although he does no enter into the merits of the question of the implementation of the multidimensionality of emotion and intelligent cognition into computers, his message seems to have some bearing of the general theme of the naturalization of the cognitive systems as artifacts.

In his contribution Erdi ventures to go further into the latter question. To begin with, he traces out some bifurcations within the level of modes of scientific research, viz. the bifurcation between the brain modeling (which regards the neural mechanism as the hardware for cognition) and the A.I. research (which emphasizes the functional behavior at the level of computational algorithms). Or, to be more specific to the level of designing computer systems: the incompatibility of the programmable and computational efficiency (the domain of traditional computers) and the question of the amenability to evolution by variation and selection (the domain of future computers).

Facing this problem, the author argues for the cooperation between neuroscientists and computer engineers which then might result in establishing a new conceptual framework for designing 'neurobiology-based' computing devices. In this connection he mentions the convergence of knowledge accumulated in quite

different fields (e.g. polymer-chemistry, biochemistry of enzymes, computer science, thermo-dynamics and molecular biophysics) which suggests the possibility of designing carbon-based 'molecular computers'. His ideal however is to build machines with brainlike structures utilizing our knowledge about the structure and operation of the nervous system, briefly computers with selforganization-like properties. Upon reading these interesting suggestions it may be asked whether, conversely, 'computer-based neurobiology' (or, sit venia verbo, the 'test-tube-cognition') also belongs to the realm of the realizable possibilities.
The question of the distinction between artificial intelligence and cognitive processes is throughly examined by Kornwachs. At the very outset he draws a demarcation line between these two magnitudes. Artificial intelligence by definition is based on the algorithm-like processes, while cognitive processes are characterized by the ability to generate what the author calls 'pragmatic information' (referring to von Weiszäcker's idea hereabout). Within the realm of the cognitive processes one may come accross the complementary relations between certain matching pairs which seem to be isomorphic to the above distinction between artificial intelligence and cognitive processes. The matching pairs are: structure vs. behavior, reliability vs. autonomy, confirmation vs. novelty, parallel image processing vs. sequential neuronal processing, and physical structure vs. informational structure. Cognition, the author argues, seems to be fundamentally different not only from artificial intelligence but also from the opposites first mentioned in the matching pairs, viz. structure, reliability, confirmation, parallel image processing and physical structure. However these opposites constitute or can constitute the substrate of cognition which by definition exists on the level of behavior, autonomy, novelty, sequential neuronal processing and informational structures. This substrate is a necessary but not a sufficient condition for the occurrence of cognition. (In this connection it might be interesting - as thought experiment - to compare this on the one hand with the quite different point of view of Kallikourdis who conversely argues that the microtemporal functional processes underlie the macrotemporal development, and on the other hand with the idea of rule-substrate complementarity which is convertible in Mowitz's and Goudsmit's contribution).
Within this framework he employs the system theory as propounded in Klir's early work 'An Approach to General Systems Theory'. This leads him (Kornwachs) to the concept of behavior. In explaining this concept he does not follow Klir's ideas on the hierarchy and architecture of systems (especially in Klir's later works), but instead develops a theory of his own by introducing the distinction betweeen the classical and non-classical systems, predicated upon the insights from the field of quantum mechanics. Classical systems (such as systems in control theory, classical mechanics, technical systems and also computers) show a behavior which is characterized by locality, predictability and determinism. Conversely, non-classical systems are systems