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MIND AND BRAIN: REDUCTION OR CORRELATION?

by

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Introduction: Demarcation of the topic.

The meaning and implications of "reduction" in relation to a unity of science has, from different points of view, been the topic of several contributions at ICUS XII. The presentation included methodological, ontological, epistemological, terminological and conceptual points of view as well as specific problems, relating to different sciences.

The present paper deals with a question which represents a special case and a very general one at the same time: the qustion is if "psychology" can be reduced to "biology" ? (the terms here are intentionally used in a broad sense).

Initially some of the general aspects of the question may be given as an illustration:

1. Since the brain and nervous system are part of a biological organism, their psychological manifestations (behaviour and experiences) may be treated within a biological context. In this sense "psychology", at least partially, may be viewed as a biological discipline.
2. All human activities, including scientific and cultural ones, have their origin in activities of the brain. This fact is self-evident to a degree that we are not always aware of its importance. The implications of this fact, however, lead to questions about the nature and meaning of knowledge and thus to epistemology and ontology.
3. More specifically, a study of the relationship between mental ("psychological") and neurophysiological ("biological") events in a broader sense, inevitably touches upon the body-mind problem and thus again upon ontology.

While the above mentioned questions will be dealt with as part of a necessary frame of reference, the emphasis will be on the meaning and implications of consciousness as a phenomenon which characterizes certain modes of information processing and which, as far as we know it, seems to be restricted to a class of living organisms, which utilize a nervous system.

The model, which is given below, is characterized by the following features and assumptions:

* The intrinsic reletionship between "life" and "consciousness" will be stressed, since comsciousness, as we know it, seems to presuppose the existence of life.
* The meaning of both phenomena, i.e. the connotations of the terms "life" and "consciousness", seem to change with respect to scope and quality as

a function of critical system properties of the organism to which they are related. Properties of this type are the complexity level of the organism or functional features of its information processing system etc. This means that both phylogenetic and ontogenetic aspects of evolution are reflected in this way.

Now, with respect to the main topic of this paper, the question can be dealt with from at least two different points of view, one leading to a partial reduction, the other to a correlation:

* Reduction in a proper sense here has two aspects, which can be phrased as follows:

  a) Given a complex system, is it then possible to explain its functions solely in terms of properties of its subsystems or elements ?

  b) Given a set of simpler systems, is it then possible to predict the result of their integration into a supersystem, i.e. to predict the functional properties of the latter ? This amounts to a predictability of "emerging" system properties.

  One may view an organism as a very complex, hierarchically organized system in the above mentioned sense. An application of the task of reduction to such a system would at least demand sufficient knowledge about the relationships between its neurophysiological, biochemical, physico-chemical and quantumphysical levels of function.

  But would this knowledge be sufficient ? Are there principal or perhaps only technical limitations with respect to our ability to understand such systems ? Are these limitations due to unavailability of the necessary information or to an inadequacy of our theoretical concepts ?

* The second view leads to a line of approach which makes it necessary to state an ontological position, which will then determine the interpretation of what is said below.

  The problem of "classical" psychophysics is related to an attempt to establish a metric relationship between physical stimuli and their subjective correlates (subjective experiences). Within any experimental context, this means a correlation. An interpretation of these correlations in terms of a Cartesian ontology would nevertheless imply a causal relationship, which underlies the body-mind interaction.

  In terms of a monistic ontology (body-mind identity), however, the interpretation of a psychophysical relationship as a correlation would be preserved at a more basic level. One should not be confused by the fact, that "psychophysical functions" are expressed in terms of mathematical equations which imply a "direction" in that they make use of dependent and independent variables. While the psychophysical model works satisfactorily with respect to intensity scales, it breaks down, if it is applied to other metric aspects of stimuli such as the frequency of light or soundwaves. The reason is that the latter aspects of stimuli have a different type of internal representation: quantitative differences between stimuli are transformed into qualitative differences between corresponding experiences. The latter may be illustrated by pitch, timbre or colours. A closer analysis shows, that the models of classical psychophysics are too simple. One has to introduce multi-stage information processing models. While stimuli may be mediated by a single external channel, they usually convey complex information. At the receptor level this information may be split up and distributed into several internal channels. The receptor processes may trigger a sequence of partly competing neural processes, which ultimately determine a state of the brain. This brain state may then be the neurophysiological correlate of a mental state, i.e. a state of awareness about an external stimulus. The process, which is touched upon here reveals a complex relationship between external stimuli and their internal representation: while "simple" features of the stimulus can be described by single parameters, this is not possible for the resulting states of the brain. The mechanisms behind the sensory processes are adapted to complex patterns of stimuli, which explains their features. Messages from the outer world are based on selected information, which remains invariant during all stages of information processing, while the code and mode of representation may vary between different steps of the process.

* The external world can in this way be "mapped" in terms of cognitive constructs, which may be called "mental objects".
* Entropy should finally be mentioned as a key concept, which in a sense links together the different phenomena, mentioned above.

Entropy and order show an inverse relationship. The main direction of all physical processes in our universe is defined by an increase of entropy, which then may be said to characterize the "arrow of time". In contrast to this, living organisms tend to increase their order durin ontegenetic development, which means a decrease of entropy. Furthermore negentropic flexibility may be said to chracterize the efficiency of the process of adaptation, which fits the organism to its environment.

The transfer of information, finally, means the transfer of organizing principles, which increase the degree of order within the receiving organism (system). The storage of processed information then means a growth of knowledge, which not only implies an increased amount of order, but also the stepwise emergence of more efficient ways to organize information into comprehensive patterns: general concepts and theories, simpler descriptions, more efficient models which discriminate essential from occasional elements or features of our world. An example is Newton's important distinction between "Laws of Nature" and "Boundary Conditions". Knowledge (both at the individual level and in the sense of cultural heritage) has features in common with entropy. Both grow as a function of time, but increased knowledge means a growth of order, while increased entropy means an increase of disorder.

Life.

"Life" and "consciousness" are phenomena, which like "energy", "matter", "space" and "time" seem to be basic attributes of our universe. Physical theory has ultimately led to a description of nature in terms of particles and interaction between them. But life and consciousness represent different levels of existence. They are intrinsically dependent on matter, energy and negentropy in that they presuppose the existence of complex systems of organized matter. Nevertheless, they may be said to exist as a potential of our universe , although their emergence as manifest phenomena is bound to restricted conditions. Of course, I am only speaking of "life" and "consciousness" as we know them on earth.

This may be the place to make some remarks on energy. Energy is a quantitative attribute of both matter and (electromagnetic) radiation, but it is not known if energy exists independent of them. The well known mass-energy relationship

$$E = mc_0^2$$

just means that a quantity of matter (mass, m in kg) is equivalent to a quantity of energy (E in Joule, J), related to radiation. (c_0 = velocity of light in vacuum = 2.997· 10 m/s; c_0^2 then is a constant of proportionality, the "exchange rate" between mass and energy). E here means the total energy, including the initial kinetic energ ($E_V = \frac{1}{2} mv^2$) of a moving mass. If an elementary particle of mass m is annihilated, the relationship

$$E = mc_0^2 = h \cdot f$$

gives the frequency (f) of the radiation (or the energy h·f of its photons; h = Planck' s constant = $6.625 \cdot 10^{-34}$ Js).

While the different "types" of energy (such as chemical, electrical, heat or mechanical energy) are well known, there is still no generally accepted definition of this "something" we call energy. Hence, the term ἐνέργαια (which at the time of Aristotle meant activity, force, power or "action" as the cause of movement) still held some of this meaning in common language.*)

The definition of energy as "the ability to perform work" is only partly true, since it applies solely to that part of energy which is actually available for work. At the beginning of the 1950 s, Z.Rant proposed the name exergy for this part of energy. Exergy is formally defined as the product of negentropy and environmental temperature (T). Negentropy here means the difference between the actual entropy of a system and its maximum entropy (Nordling, 1982). While energy, according to The First Law of Thermodynamics neither can be created nor destroyed, exergy can be lost. It should be noted here, that the term "negentropy" will be used later on in a slightly different way.

While the exact nature of energy may still be the object of discussion. it is without doubt a necessary condition for life. "Life" is the label for an intuitively well-known phenomenon, which nevertheless until about 30 years ago eluded attempts to define it strictly. This has several reasons:

* Life is bound to very complex chemical systems in certain states.
* Life is not a uniform concept; it has different ranges of connotation in different connections. The term applies to a large number of different systems, which vary greatly with respect not only to complexity, but also with respect to features. Life, hence, means partly the same and partly different things in different cases.
* There are aspects of life, which could not be grasped and understood by the models of classical science.

These difficulties promoted the emergence of vitalistic theories and supported their existence up until today. Vitalistic theories try to relate the existence and function of living organisms to the effects of a non-physical "life force". Additional difficulties arose from the connection of these questions with the problem of life's origin in relation to devine or other metaphysical influences, but also from the connection with teleological speculations about the "purpose" and "meaning" of life within the great scheme of our universe. A good survey on these aspects has been given by Wuketits (1982). It is important to remind oneself of the influence which the "Zeitgeist" or certain ideas may have on the promotion or impediment of scientific progress. At the

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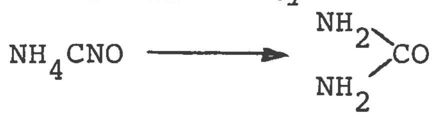
*) note: the term energy was introduced in 1807 by Thomas Young to denote half the amount of "vis viva" = "living force" = mv^2. In a broader sense the term was first used by W.J.M. Rankine in 1854.

time of Lavoisier (late 18th century), "organic" compounds were thought to be dependent on living organisms for their existence (the notion "organic" for carbon compounds has its origin here. It was then a discovery of importance, not only for chemistry, when Friedrich Wöhler (a pupil of Justus Liebig) in 1828 synthesized urea from ammonium cyanate:



ammoniumcyanate *urea = carbamide*

Urea is a typical metabolite from animals and ammonium cyanate is an "inorganic" compound, which under certain conditions, can be synthesized directly from its elements.

This illustrates nicely how our opinions about which questions principally can be answered (in this case "reduction" of organic matter to inorganic) is dependent on the actual level of knowledge.

During the 19th century, biology gradually became a science in a modern sense (with hypotheses, experimental tests and predictive theories). Some main steps in this direction were the development of genetics, cellular theory, the biochemistry of metabolism, the theory of evolution and the application of concepts from physics to living organisms. We know today, that organisms are very complex, hierarchically organized systems, which are structured in minor detail. There is, furthermore, a predetermined functional interaction between all levels of the system. The genetically determined, high degree of coupling between the elements of living systems is also the main reason that makes any comparison between organisms and organisations (other than superficieally analogies) misleading or nonsensical.

All living systems are characterized by a set of properties, some of which are common to all organisms, while others are specific to certain types of them. The following four characteristics are presently viewed as sufficient conditions for life:

1. Metabolism
2. Reproduction
3. Mutability
4. Interaction between functional elements (such as proteins) and carriers of information (DNA and RNA), which seems to be a precondition for evolution.

Furthermore there are additional characteristics such as
activity, reactivity, homeostasis and self-regulation, exchange of

energy with the environment, maintenance of flow equilibria, self-mend and maintenance of structure, program controlled growth (ontogenesis), exchange of information with the environment, behavioural modifications by learning, consciousness etc.

These characteristics are found in most, but not all living systems. A more detailed treatise of the subject is given by Kaplan (1978).

The above mentioned characteristics, however, can only express themselves under certain conditions, since they are critically dependent on the total state of the system. The functional characteristics, which are necessary to sustain the existence of a living organism may be called its life functions. If some of these functions are disturbed or blocked to a certain critical extent, the entity ceases to exist at the level of the organism. The organism, e.g. a dog, dies. Meanwhile, after the clinical death of the animal has occurred, its heart may be surgically disconnected, placed into a Lindbergh-pump and submerged into a suitably oxygenated solution of nutrients, which is then circulated. As already shown by Carrel over 40 years ago, the life functions of the heart may thus be preserved a long time after the death of the organism to which it once belonged (Carrel & Lindbergh, 1938). Undoubtedly an organ may be described as a living subsystem of an organism. This subsystem shows a range of life functions, pertinent to the functional role of the organ. Since the life functions of the organ can be destroyed, one may speak of "life" at the level of the organ. While some people want to restrict the use of the term "life" to organisms, there undoubtedly is a distinct holistic difference between any system in a"living" and a "dead" state.

Now, the heart may be dissected and thus be destroyed as an organ, but it is still possible to keep its subunits, the single heart cells, functionally intact and they may, under certain conditions, be stimulated to grow and to devide. This means that there still exist typical life functions at the cellular level. But there the limits of living systems seem to be reached. If the cell is damaged physically, it dies. But still some elementary life functions persist: the contractile properties of the actino-myosin molecules, which are responsible for the cell's ability to contract. This property of actino-myosin (two types of specifically interacting proteins, which are found in muscles), remains intact even outside the cell body if the molecules are dispersed in a suitable solution of nutrients. As in the living cell, contraction may be triggered by ATP (adinosine triphosphoric acid, a molecule able to deliver energy) (see Fulton, 1956). This illustrates clearly, that the term "life" means partly the same, partly different things at different levels of complexity. It furthermore implies several aspects: a set of system properties, which partially change during ontogenesis, a state of the system (living or dead) and a process, limited to a time-span between "birth" and "death".

Living organisms are in a sense highly improbable to such an extent that a cynic once defined life as a peculiar disease of matter. Since living organisms show a very complex structure, the probability of their occurrence by chance is infinitesimally small. During growth and development the complexity of the organism increases steadily. This means that growth implies the occurrence of consecutive states with steadily decreasing probabilities. In order to maintain its structure and life functions intact, the organism has to rely on well-established and stable principles of self-organization, homeostasis and self-mend. In a certain sense, mechanisms of defence and the ability to change the environment so as to fit the needs of the organism may be looked upon as an extension of homeostatic functions outside the physical boundaries of the organism. Their task is to prevent any disruption of the organism's life functions and integrity.

A key concept regarding living organisms (systems) is entropy. The concept entropy was introduced into thermodynamics by Rudolf Clausius as a principle which could characterize the direction of possible processes within isolated systems of constant energy content (no energy exchange with the environment). In terms of this principle, The Second Law of Thermodynamics can be phrased as follows: "In any closed system, the entropy of the system either increases or remains constant":

$$dS \geq 0 \quad (dS = \text{change of entropy})$$

This is supposed to be one of the most general laws of nature and probably valid for the universe as a whole (if the universe is closed and has a finite mass). It also gives a mathematical formulation of the extent to which a given quantity of energy (originally formulated for heat) can be used to perform mechanical work (see e.g. Sears, 1953; Fermi, 1956). This quantity has earlier been mentioned as exergy. Different forms of energy can be transformed into each other. Energy cannot be destroyed, but for each transformation a part of the given quantity of energy is "lost" in the sense taht it is no longer available for useful work, i.e. exergy is lost. The entropy of an amount of energy increases as its ability to perform an equivalent amount of work decreases. Now, entropy has an aspect which is related to the degree of order (or randomness) of elements. Energy states of high entropy have high probability. So have states of systems with a high degree of randomness (lack of order). This is the reason why the concept of entropy is used within the Mathematical Theory of Communication to denote the degree of order for elements of a message (Shannon & Weaver, 1959). The information content (amount of information) of these elements is described in terms of information theoretical entropy. The thermodynamical entropy (S) of a physical system (of molecules) is according to Boltzmann a logarithmic function of its thermodynamic probability (P) of its occurrence: *)

$$S = k \cdot \ln P$$

(k = Boltzmann's constant = $1.38 \cdot 10^{-23}$ J/deg.)

The information content (H) of a message (information theoretical entropy) on the other hand, is a negative logarithmic function of the probability of its elements:

$$H(A) = - \sum P_a \, {}^2\log P_a$$

(a are the elements of an ensemble A (a message)).

Thus both types of entropy and the concept of information are related to the probability of the state of a system. The main formal difference is the minus sign. The relationship between the concepts has been interpreted so, that information theoretical entropy (information content) can be looked upon as a negative function of thermodynamical entropy, which means that H increases as S decreases. This fact gave rise to Brillouins and Wieners characterization of information as negative entropy or negentropy (Wiener, 1961; Brillouin, 1962). The deeper implications of this relationship have, however, been the object of slightly different interpretations.

The transfer of information means the transfer of structural or organisational principles. Living organisms receive their vast store of basic instructions through genetic information, which is stored and encoded as sequences of nucleotides within the DNA of genes. Later on the organism receives information through sensory processes and stores it in different types memories.

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*) note: Strictly speaking, P is not a probability in a statistical sense, but a large number, denoting the amount of possible microstates of a system that correspond to a given macrostate. However, the thermodynamical probability is proportional to the statistical.

The living organism, during its life, maintains a high level of negentropy. This is made possible by the use of energy-rich components which are extracted from the environment by the expenditure of an excess of energy. Thus living systems have to be open systems whose negentropy is maintained by a corresponding increase of entropy (disorder) in their environment. This resolves the apparent contradiction between their functional principles and The Second Law of Thermodynamics. It is also the basic issue behind the energy problem of mankind: the need for low-entropic energy. The energy crisis of mankind seems really to be an exergy crisis. The role of living organisms in this context has been nicely formulated by Sayre: "Life thus is a catalyst, working to increase disorder within its hosts environment, acting more effectively in life forms that are more complex" (Sayre, 1976, p. 93).

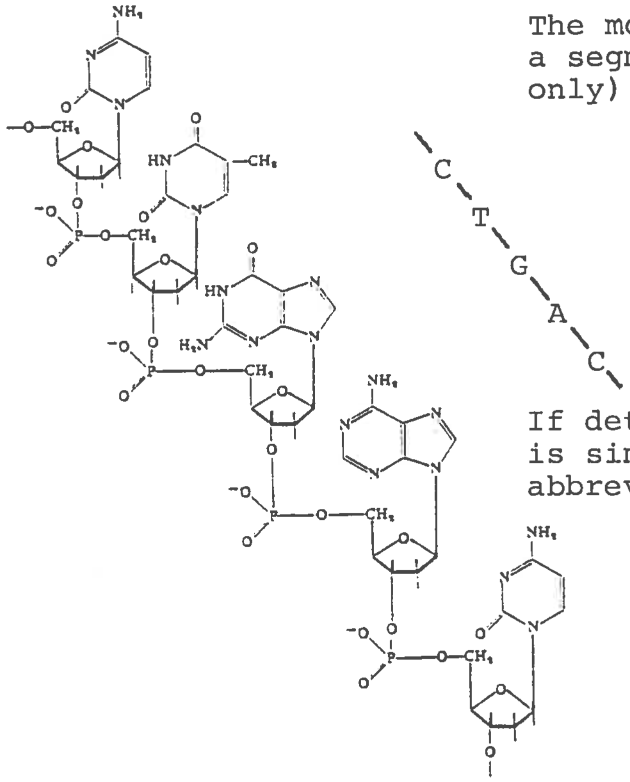
A short note concerning information and negentropy should be added. One has to be careful how to use the terms. The transfer of information proper in the sense of Shannons Theory is formulated for energetically closed systems. The theory presupposes the existence of established channels, transmitters and receivers. No net energy is transferred to the receiving system, only the structuring impulse (information). Meanwhile, all living systems are thermodynamically open systems, exchanging energy and matter. The apparent contradiction may be solved by assuming that information is gained by different processes at different stages of ontogenetic development and by different processes at different levels of the hierarchy:

1. Flow systems (living systems belong to this category) tend to decrease their entropy when moving from an arbitrary initial state to a final stationary state (equifinality i dissipative systems; Prigogine, 1967).
2. The increasing order (negentropy) of organisms during ontogenetic growth is due to the effect of genetically transferred instructions (order through order).
3. Transfer of information (in the sense of Shannons theory) starts in connection with learning and feedback processes when underlyingmechanisms have been developed. This type of information transfer is restricted to certain structures which at the given hierarchical level of the system behave as thermodynamically closed subsystems. Hence, this presupposes the existence of established networks (subsystems) which encode transferred information in a way which confines it to the boundaries of this subsystem. It also implies that the internally coded information is comparatively stable to the influence of metabolic processes, which always bring about a change of thermodynamical entropy.

The survival of vitalistic theories up to the present day may primarily depend on the fact that the concept of "life" could not be grasped by the models of classical science. The theory of dissipative systems as developed by Prigogine and scholars shows that complex structures could emerge outside the range of thermodynamic equilibria by dissipation of energy and matter and that local information could be gained by processes which selectively filter away noise. An example is the spontaneous emergence of dissipative structures in thermodynamically unstable systems by a principle denoted "order through fluctuation" (restructuring of the system in order to gain stability with respect to fluctuations). This implies the possibility of self-organizing systems from a thermodynamical point of view. A general evolution criterion has also been derived by Glansdorf and Prigogine (Prigogine, 1967). Thus the creation of artificial life seems to be a technological and economical question rather than a principal one (Eigen & Winkler, 1975).

This may essentially also be the answer to questions about the relationship between "biology" and "chemistry". Biology here favours a reductionistic view, since biological systems are very complex chemical systems. An excellent treatment of the subject, both comprehensive and extensive, is given by James Greer Miller (1978). The difficulty then is to describe such systems, since the problem of reduction leads to the task of handling complexities. What one normally does is to apply the principle of Pandora's boxes (small boxes within larger boxes within still larger boxes etc.) to this kind of problem. It means the stepwise compression of detailed information into more general and formally simpler concepts and symbols. The different levels of description then reflect the hierarchical levels of the system to which they relate. This may easily be illustrated by the example, given on the next page.

A scientific description of our world makes use of its redundancy to describe it simply (Vollmer, 1983). In living systems, however, one mostly finds common mechanisms and principles mixed with unique ones. The same hormone may affect different receptor sites of similar response characteristic all over the organism, but each single receptor may then trigger quite different functional subsystems. Nevertheless, these subsystems then may be part of a higher order regulatory system, which serves the stability of the organism as a whole. In this way organisms, and particularly their nervous system, may be descibed as highly cooperative systems or synergistic structures. This topic will be dealt with more extensively in other papers of the present committee. The above given picture is corroborated by a study of phylogenetic evolution.



The molecular arrangement of a segment of D N A (one chain only).

C = cytidine phosphate
T = thymidine phosphate
G = guanosine phosphate
A = adenosine phosphate

If details are omitted, the figure is simplified by the use of letter abbrevations.

Figure from Lindahl et al. (1967).

<u>Phylogenetic aspects on life.</u>

It has already been mentioned that living organisms are highly improbable from a stochastic point of view. Nevertheless, they exist, which fact has been the basis of speculations about the possible existence of living organisms elsewhere in the universe. This idea is not new, which is known from the tragic fate of Giordano Bruno, who was burnt as a heretic in 1600. While our knowledge in this respect is still fragmentary, it is coherent enough to allow for educated guesses (cp. Ball, 1983; Mustelin, 1983). As to direct evidence, only the existence of simple carbon compounds outside our earth have been reported. Recently a report from China states the discovery of an amino acid in a meteorite. Nevertheless, the fact that there exists at least one species of observers, homo sapiens, gave birth to the Anthropic Principle, which is said to "explain" a quite improbable chain of events and conditions: initial conditions during the BIG BANG determined the formation of heavier elements; furthermore a suitable planetary mass, critical distance from a sun of suitable spectral class, planetary rotation, the tilt of the axis of rotation with respect to the ecliptica, the "abnormal" properties of water, the homeopolar bound of carbon atoms (ensuring the formation of larger carbon chains) and so forth are a few of the conditions which had to be met in order to make life possible on earth (Breuer, 1981; Gale, 1981).

Our knowledge about the origin of life on earth is to a large extent based on conjecture, even if some details are known with a reasonable degree of certainty (detailed references are given by Löwenhard, 1981). The age of our earth is estimated to about 4,600 million years. The first signs of life seem to have appeared some 3,200 to 3,900 million years ago (Halstead, 1975; Sagan, 1978). The timepoint somewhat depends on where (at which level of complexity) the limit for forms of life is set. With a high degree of certainty, only simple carbon compounds (chains of 2 to 3 atoms) existed 4,500 million years ago, while 3000 to 4000 million years later highly differentiated life forms had emerged (Ehrensvärd, 1961). The oldest known microfossiles date back to about 3,500 million years, while the first "modern" unicellular organisms seem to have appeared about 1,500 million years ago (Mustelin, 1983). Microscopic fossiles, identified as remnants of the earliest eukaryotes (originally called acritarchs = of uncertain origin), have been shown to be unicellular planktons, about 1,400 million years old (Vidal, 1984). Recently it was mentioned (Lagerkvist, 1983) that prokaryotes and eukaryotes might have a common origin in archaebacteriae.

The mergence of early forms of life and their development into the existing forms, reflect a complex interaction with and interdependence on that environment which gave birth to them. According to Haldane and Oparin, the early predominantly reducing atmosphere (anoxygenic atmosphere) of earth was supposed to promote the origination of a chemical bachground from which the earliest protoforms of living systems could emerge (Dickerson, 1978; Mayr, 1978). *)

During some billion years one-celled, mainly anaerobic organisms were the only forms of life. However, these early primitive microorganisms gave rise to biochemical systems and the oxygen enriched atmosphere on which modern life depends (Schopf, 1978). It also seems that these changes created the necessesary conditions for a more rapid diversification of life

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*) note: Recently F.H. Crick and E.Orgel made the suggestion that life perhaps did not arise on earth at all but may have been deliberately seeded by highly intelligent beings from outer space. This venturesome hypothesis, which is a modern variety of Arrhenius' theory of panspermia, tries to explain why many key enzymes are dependent upon very scarce elements such as molybdenum (Dickerson, 1978).

forms and the emergence of multicellular organisms with steadily increasing efficiency.

After the first stable forms of life had been established, further evolution was mainly governed by two mechanisms: genetic variation and selection. Genetic variation is accomplished by mutations, i.e. rearrangements of molecular sequences in DNA and RNA. Another mechanism depends on the exchange of corresponding chromosomal segments between homologous chromosomes by formation of chiasms and crossing over.This means rearrangement of genetic information at the chromosomal level. Gene drift and jumping genes are mechanisms which were proposed more recently.

Genetic variation is a necessary precondition for evolution. Modern molecular genetics have also shown that variations within a species are much larger than Darwin once postulated (Ayala, 1978). The present view is confirmed by studies about protective colour adaptation for different kinds of insects in relation to a changing environment. While random mutations safeguard continued variation and recombination for the development of new capacities to deal with environment, the test of survival accomplishes the natural selection of organisms which are best adapted to existing conditions.

What then could be said about the probability of occurrence of living organisms ? To illustrate this, suppose that a simple organism without redundancy could be built on the basis of 1,000 bits of information. The selection of this organism from alternates of possible atomic arrangements would mean a single choice from 2^{1000} possible ones. This gives a random probability of about 10^{-301}. If one considers the low magnitude of these probabilities, the question arises if the time period of earth existence is sufficient to allow for the development of such complex organisms as the mammals of today ? To quote Laszlo: "The unqualified random shuffling hypothesis runs into difficulties at this point, since the probability of achieving systems of the order of complexity of living beings far exceeds the order of the time-span indicated by astronomical and geological evidence. However, when we take systems as ordered wholes, adapting to environment in order to compensate for changes, and realize that atoms and molecules are systems of this kind, we get a more conservative time estimate. Using Simon's hypothesis, according to which the time required for the evolution of complex from simple systems depends critically on the naumber and distribution of potential intermediate stable forms, organic evolution fits into the physically available time period. .... it becomes evident that nature can build complex structures relatively rapidly by using existing systems as building blocks and combining them into stable associations under favorable conditions (Laszlo, 1973, p.95).

Cybernetic self regulation is a universal system property. While homeostasis may be defined as adaptive self-stabilization, adaptive self-organization characterizes selective progression towards the emergence of better adapted species, capable of handling increasing amounts of environmental changes:

external forcings ⟺ internal constraints ⟹ adaptive self-organization

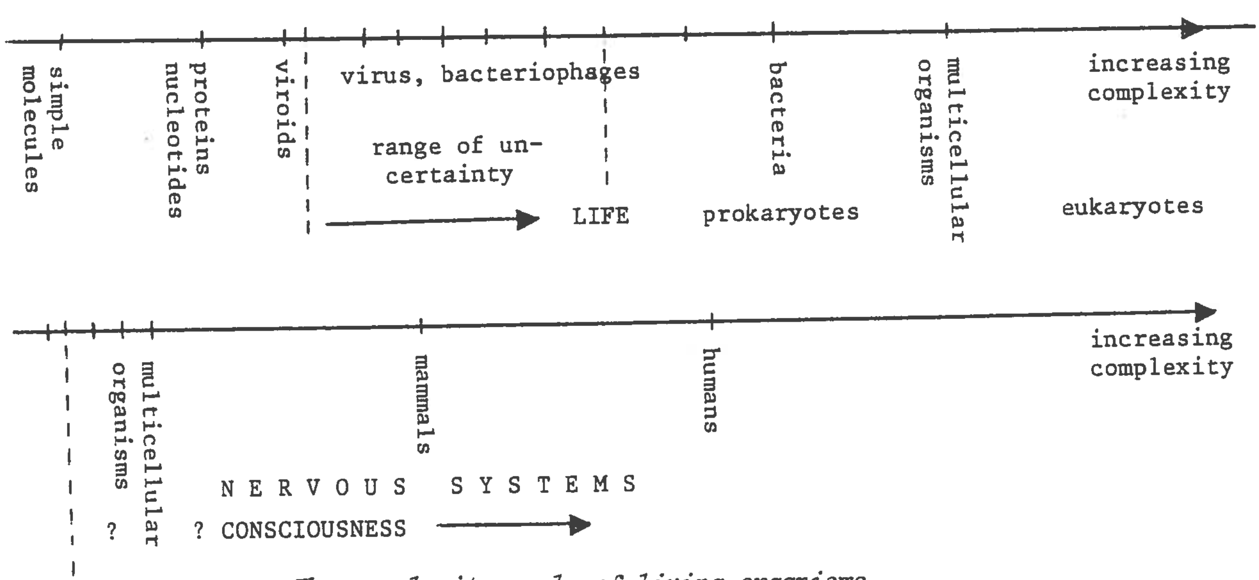
According to Ashby, adaptive self-organization inevitably leads to known biological systems. "In the isolated system life and intelligence develop" (Ashby, 1962, p.272).

The importance of "system theoretical" aspects in relation to phylogenetic evolution may be summarized in the words of Dobzhansky: "Adaptation and emergence of new genotypes is a feedback process within a reproductive group, natural selection is homeostasis within a relatively isolated biotic system. The results of these two processes operating together is the evolution of established species" (Dobzhansky, 1955, p. 131).

A mark of success of an organic form in evolution is the ability of its memvers to achieve stability within their environment. This amounts to persisting ability on the part of the organism to feed upon the negentropy of its immediate environment (Schrödinger, 1951). Sayre coins,in this connection, the term negentropic flexibility : In speaking of flexibility in the assimilation of negentropy I refer to the capacity of an organism to establish efficient couplings with its environment, under a range of different conditions, through which negentropy can be obtained to support growth and metabolism and to control its response to environmental contingencies. Let us name this capacity negentropic flexibility. Mobility supports the development of negentropic flexibility . Individuals with superior mobility will tend to replace others within their reproductive group, thereby strengthening the genetic factor that makes mobility possible. Among such factors, however, is perceptual sensitivity, which contributes dirctly to the organism's capacity to acquire negentropiy in form of information." (Sayre, 1976, p. 117).

If one looks for the results of evolution, reflected in life forms of today, one finds a large variety of interdependent living organisms, where complex multicellular organisms coexist with unicellular ones and with protoforms of life. It is interesting, and a lucky circumstance from the standpoint of the scientist, to find a reflection of phylogenetic evolution in the existence of a whole scale of organisms with varying degree of complexity. All life forms together, fauna and flora, constitute the large ecological system of life on earth. This does not imply that simple life forms such as bacteria of today are identical with their early ancestors. Their total amount of information may approximately be unchanged, but the "quality" of their genetic information, expressed in terms of the organism's biochemical efficiency, is probably higher in organisms of today.

One can arrange systems in order of increasing complexity. The given scale should be interpreted as an ordinal scale, since no estimates of the reals magnitude of complexity can be given.



The complexity scale of living organisms.

This presentation does not, of course, consider qualitative differences between life forms on approximately the same level of complexity, which would imply a comparison between plants and animals. The increase of complexity reflects the emergence of additional life functions. Proteins and nucleic acids show some of the basic properties which are the foundation of life functions proper.

Aggregates of complex molecules show an increasing versatility in their rections with the chemical environment. With increasing complexity the systems gain independence from their environment. This means that their demands on the environment with respect to certain premanufactured components decreases. At the same time, more regulative functions are incorporated within the boundaries of the system. An important mark of progress is the emergence of closed cells, protected from environment by membranes which facilitate the selective absorption of nutrients and the excretion of metabolites. The earliest types of cells, prokaryotes, lack nuclei. They are represented by bacteria and cyanobacteria. The next essential step is the development of eukaryotes, cellular organisms with distinct nuclei. All higher plants, animals and fungi are based on this type of cell. The main differences between prokaryotes and eukaryotes are summarized by Schopf (1978).

A final illustration will conclude this chapter: reduction in relation to the complexity of a system. While a given system may be analyzed in principle (if not always in a strict quantitative manner), this may for economical reasons not always be possible in detail. The structure and genetic layout of some simple virus, such as the bacterial virus ϕX 174 (Fiddes, 1977; Sanger et al., 1977) or the Tobacco Mosaic Virus (TM) (Butler & Klug, 1978), are known in detail. The genome of the ϕX 174 contains 9 genes of different length and shows a remarkable economy by partial overlapping of genes. The genetic informstion is stored in a single circular DNA molecule of 1.8 μm length, comprising 5,375 nucleotides. A print-out of this genetic array (using letter abbrevations) would demand one A 4 page. A corresponding description of our intestinal bacterium, Escherichia coli, would probably demand a space corresponding to several volumes of Encyclopaedia Britannica. Also there is the question of <u>implicit</u> genetic information. A gene not only specifies a protein, it specifies implicitly the secondary or tertiary structure of the protein and, hence, its chemical behaviour and biological enzyme function. The description of these functions would demand further knowledge about this specific protein and about each amino acid component. The given picture thus speaks in favour of a partial, but not radical reductionism.

The purpose of this chapter has been to show, that "life" from a phylogenetic point of view is no unitary concept. Rather the meaning of the term and its range of connotation changes with the increase of complexity of the systems (organisms) to which it is applied. There seems to be no definite demarcation which allows an exclusive classification into so called living and non-living systems. Rather there is a continuous transition from non-living matter which nevertheless may show typical basic life functions, via an extended range of uncertainty to definite "living" systems. The transitory types of systems show the gradual incorporation of an increasing number of homeostatic life functions and metabolic processes into their boundaries. Thus it has been shown that "life" is a label, used to denote the totality of life-functions , which are necessary to sustain the continuous existence of the system (organism) as a whole. It is also evident that the exact connotation of the term "life" is a function of the set of life functions which define the orgsnism in question.

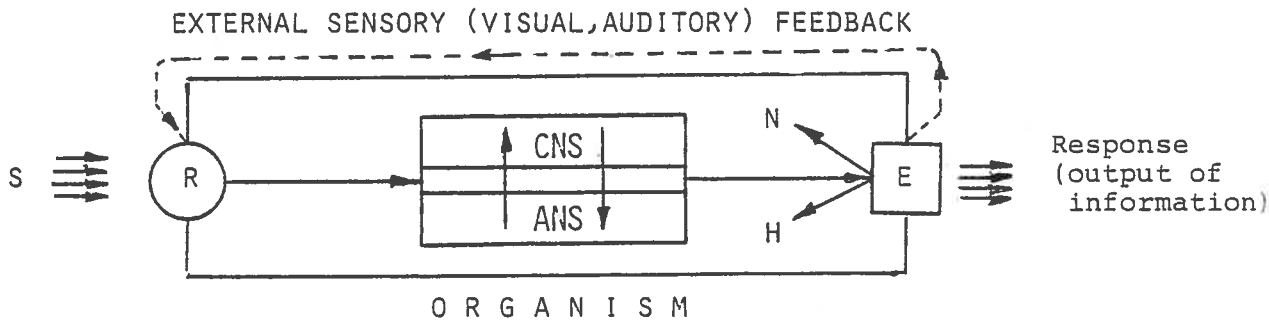
The information system.

The above given sections on living systems had several purpses.

1. The brain is a very specialized subsystem of an organism. Its functions are more easily understood against the given background. *)
2. Psychology deals with manifestations of living organisms (behaviour and experiences) which in fact are consequences of brain functions or acitities of the nervous system.
3. The specific problem is of course related to conscious experience. The model of "consciousness", which is given below, follows the "system - theoretical" approach, since consciousness here is viewed as a consequence of system properties of the brain.

There are, however, differences. The principle of reduction applies to physiological (biological) systems, while the phenomenon of consciousness is more easily treated as a correlate of physiological processes.

The brain and nervous system are essentially information systems of an organism. The following picture may summarize the essence of it:



S = stimuli, information input
R = receptor units
E = effector units (muscles, glands)

N = neural feedback
H = hormonal feedback

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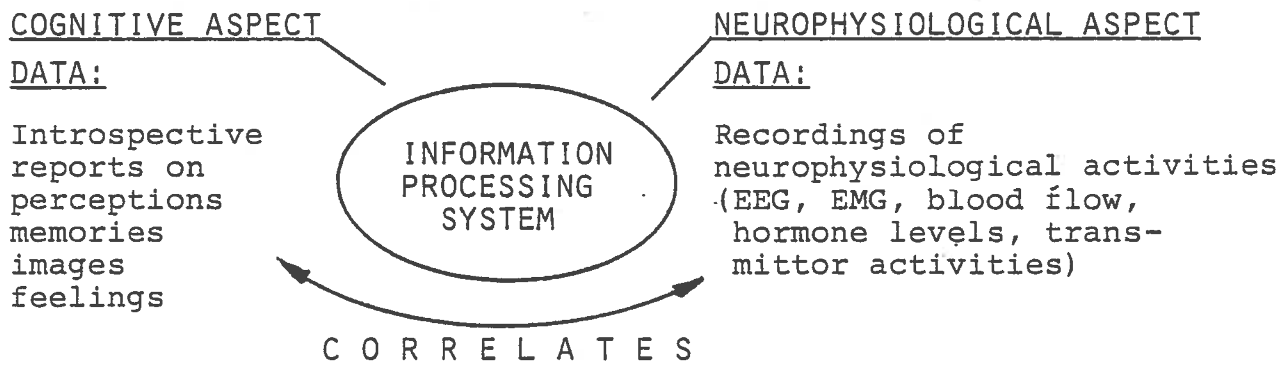
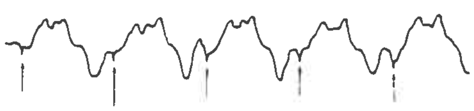
*) note: In a more strict language, one should make a distinction between anatomical structures such as the brain or nerve substrate and functional systems such as the CNS ar RAS (reticular activation system).

Both the nervous system and the endocrine system are information systems. The endocrine system, however, conveys solely internal information, using hoemones as signal molecules, which are distributed by the blood stream and affect specific receptors all over the organism. The nervous system and endocrine system interact at the synapses.

Essentially the brain may be viewed as an autoanalytic instrument, which is able to detect, recognize and record its own states. This implies the availability of internal information about the brain itself and, hence, an access to different sources of information: external and internal ones. Since the processing of information often (but not always) is based on conscious processes, this gives rise to the so-called psychophysical problem, which may be illustrated by the following picture:



A simple example may illustrate the meaning of correlation in this case. If the eyes are stimulated by a slowly flashing light, each flash is perceived separately. If the EEG (electroencephalogram) is recorded simultaneously from the occipital lobes of the cerebral cortex (area striata, the site of visual information processing), one gets a sequence of evoked potentials as a response to the repetitive light stimuli : (arrow indicates flash; f = 5 Hz).



However, when the flicker frequency reaches a certain critical value, the light is perceived as a steady one. This makes it possible to use alternating current (AC, 50 - 60 Hz) for illumination purposes. The critical value is called CFF (critical flicker fusion frequency) and changes as a logarithmic function of the light intensity (I):

$$CFF = a + b \cdot \log I$$

(a and b are constants). Now, when this limit is reached, the separate EEG-responses disappear and the (mainly) spontaneous EEG-activity is restored.

The very close correspondence of subjective experiences and EEG responses as a function of the CFF value makes them to correlates.

Consciousness.

This section will start with a clarification of the terminology used. Consciousness is used as the technical term to denote the phenomenon behind what, in subjective language, is described as awareness, subjective experience and so on.

Awareness is used as an equivalent of consciousness from the standpoint of the subject.

Sensation is used as a general term to denote the effects in terms of subjective experience of the activation of receptors.

A clear distinction is made between the phenomenon of consciousness and the "objects" onto which it is directed (= content of subjective experience, mental objects, symbols, images etc.).

Feelings (Gefühle) is the most ambiguous of the terms. In everyday language it means both sensations, moods, emotions and unspecified qualities of awareness, not related to mental objects. In the words of Jaspers the concept may be restricted according to the following definition: "Gewöhnlich nennt man Gefühl alles Seelische, das weder deutlich zu den Phänomenen des Gegenstandsbewusstseins (awareness concerning objects; my note) noch zu Triebregungen und Willensakten zu stellen ist. Alle unentwickelten, unklaren psychischen Gebilde heissen Gefühl, mit einem Wort, alles was man sonst nicht zu nennen weiss." (Jaspers, 1984; c.fr. Zethraeus, 1962, p. 146).

Self-consciousness is not used as identical with consciousness. The distinction is treated later on. Consciousness has a larger connotation.

Mind is used as a label to denote the non-physical "universe of mental phenomena" (world 2 in the terminology of Popper), a conceptual framework, which is related to all phenomena of conscious experience. The use of the term here does not imply any connotation of a homunculus.

The following postulates should be regarded as speculative hypotheses, or, in some cases as descriptions of observable phenomena. They should serve as starting points for discussion and model building.

Postulates:

1. Consciousness, as we know it, seems to be restricted to a certain class of living organisms, utilizing nervous systems.
2. Consciousness may be described as a phenomenon which accompanies certain

modes of information processing, characterized by a direction of attention onto the information content of the ongoing process. This amounts to an ability of the participating nerve net to sense its own states. Consciousness is one of the principles which enables the brain to work as an autoanalytical instrument. It should be noted, however, that the subjective nature of "immediate knowledge" which characterizes conscious information processing, does not seem to be a necessary condition for a system to "sense" changes in its own states or to analyze its own functions. This would only demand a suitable hierarchy of analyzing agents. Also a distinction should be made between the phenomenon of "being aware" (i.e. the participation in an immediate act of experience) and knowledge about the principles which underly the emergence of this awareness.

3. The human brain and probably that of other animals (which show periodic phases of sleep) seem to utilize both "conscious" and "non-conscious" modes of information processing.
4. Consciousness may arise as a consequence of system properties which a computer lacks. The critical system parameters are, as yet, not known, which does not mean that they are inaccessible. Consciousness is, hence, probably not solely a consequence of a systems complexity as such, but reflects an inherent principle, which gives rise to the phenomenon. This principle may be related to the cellular level, the subcellular level or both. A tentative guess may be that the phenomenon arises as a consequence of basic properties of the neuron, but menifests itself only clearly in sufficiently complex systems. Such a basic property may be an extrapolation of the excitability of complex aggregates of protein molecules. At the cellular level, a complex interaction of large aggregates of cells creates a spatio-temporal pattern of slow potentials and discrete pulses (bioelectric fields) which fulfil certain conditions (though not in detail known) regarding structure and temporal continuity ("world lines"). It is furthermore empirically known, that a number of necessary conditions must be fulfilled in order to let consciousness occur. Such conditions are the activation of the brain by the thalamo-reticular system and an ongoing electrophysiological activity in the cerebral cortex.
5. Consciousness as a phenomenon seems to change with respect to both quantitative and qualitative aspects as a function of the complexity of the system to which it is related. Thus the concept of "consciousness" is, in analogy to "life", no unitary concept. In a phylogenetic sense "consciousness" seems to develop alongside of new system properrties of living organisms.

"Consciousness" here means a phenomenon which increases in quality and scope from primitive awareness at lower phylogenetic levels to abstract thinking in humens alongside an increasing complexity of the corresponding brain structures.

6. Conscious information processing is supposed to represent a principle which combines a high efficiency regarding sensory discriminative power with economy regarding the necessary amount of neural elements.
7. Subjectively we speak of different states of consciousness, corresponding to different neurophysiological states. It is well known, that conscious experience is influenced by biochemical cahnges within the brain. However, there have to be physiologica, states of the brain or nervous system, which do not correspond to any conscious experience.
8. There is a distinction between consciousness (awareness) as a phenomenon and the content of mental experience. Very broadly one may speak of two classes of mental experience: mental objects, which are related to sensory information from the external world and feelings, emotions or motivational states, representing changes of internal physiological states. Both types of experience are, of course, interrelated. Mental objects (symbols) may be said to represent an "internal mapping" of external objects and relationships between them. They generally reflect essential features of the external world with high degree of fidelity. There are, however, other symbols, such as abstract concepts, imaginations or hallicinatory experiences which do not primarily reflect the presence of external equivalents.
9. Consciousness as a phenomenon is dependent upon the perpetuation of all life functions which are necessary to support the normal functions of the information processing system (organism) to which it is bound.
10. The essential genetic instructions, necessary to develop the system properties which underly the emergence of consciousness, have to be encoded into the genome as part of the explicit and implicit genetic information.

Consciousness from a phylogenetic point of view.

The study of consciousness is limited by its very nature as a "private phenomenon", i.e. due to the lack of direct access. Since the phenomenon as yet cannot be analyzed directly in humans, the same is true to a still higher degree for animals, since not even the communication of introspective reports by means of language is available. The study of this area is, hence, restricted to indirect assessment.

According to postulate (5), consciousness develops slowly together with other system properties of living organisms. This means that with increasing capacity of the organisms information processing system, the extent and quality of the accompanying phenomenon of consciousness is supposed to increase in proportion hereto. Furthermore, consciousness is supposed to develop in all species which are equipped with sensory organs and associated information processing circuits. This also implies, that consciousness at a lower phylogenetic level does not mean exactly the same thing as at a higher level. In analogy to what has been shown regarding "life", there are probably protoforms of consciousness since the system property which underlies the emergence of consciousness is the result of a continuous development. One may ask why consciousness did arise at all ? A suggestion is, that consciousness represents a principle of economy that makes information processing more efficient and reduces the the amount of elements, necessary to perform this task (postulate 6). A hypothesis of this import was already expressed by Culbertson (1963, p. 79 and chapter 7). But the existence of such a principle would mean a strengthening of the organisms "negentropic flexibility" and thus would have survival value for the organism. A similar view is held by Sayre: "Human consciousness, like learning, is the product of evolutionary bias towards life forms with superior negentropic flexibility, for conscious organisms excel in their abolity to receive information and to apply it under a wide variety of living conditions. Like learning, also consciousness is a form of adaptation parallell to the evolutionary process in its feedback characteristics." (Sayre, 1976, p. 139). This relation of consciousness to learning is also stressed by Laszlo, (1973, p. 190).

To be more specific: any organism which is confronted with the problem of coping with its adaptation to a very complex environment not only has to integrate a large amount of different information, but this integration also has to be done in a way which makes it possible to optimiza a holistic response. Such a task includes, for example, the probability matching of different sensory messages in space and time in order to reveal their possible causal relationship.

The performance of an appropriate behaviour within the given context has to be based on a processing of information which includes an internal representation of the organism itself together with elements of its environment. An animal that successfully wants to jump over a cliff, has to judge its own trajectory in relation to distance and initial acceleration. Hence both information about the environment and the organism itself has to be integrated into an internal "model or program which determines complex actions. It is probable, that "conscious" modes of information processing have developed as being superior in relation to this type of task which demands the simultaneous integration of large amounts of information into a single pattern. A detailed discussion of this topic from a phylogenetic point of view is given by Jerison (1978).

It is, at present, not possible to prove the above mentioned principles conclusively, but there are several indications which all point into the same direction. If one compares different species of living organisms, let us say frogs, rats, dogs, monkeys and humans, one finds striking similarities in the way these organisms react to different classes of stimuli: painful stimuli, light stimuli, sound stimuli and so on. This is, of course no proof of the existence of consciousness in the above stated sense, It may, in the terminology of Ryle (1949, 1967) be described as a propensity or disposition to react. To this, Blakemore comments: "If this kind of unmasking of consciousness destroys its special qualities, must we conclude that consciousness does not exist at all ? To call "knowing" a disposition to act may bring consciousness within the professional realm of brain research (and this is an essential step), but it does not mean that there is nothing to explain. Ryle has exorcised the Ghost from the Machine, but he has left a machine of much greater complexity" (Blakemore, 1977, p. 35-36).

As mentioned above (postulate 2 and 4) the phenomenon of consciousness reflects the existence of a system property which seems to be common to organisms which are equipped with subsystems, able to process sensory information. This implies that the principles behind the emergence of conscious modes of information processing somehow have to be encoded in the genome of the organism. But this reflects an essential fact: the instructions which are necessary to develop the system properties in question have to be part of the explicit and implicit genetic information. This means that the principles which underlie the functions behind "consciousness" can be expressed in terms of a material code.

A principle which represents superior qualities is likely to be preserved in phylogenetic evolution and will probably, at a very early stage, be "adopted" by all organisms which can make use of it. Concerning concious experience, this implies that we probably share the basic features with our ancestors from earlier stages of evolution. There are strong reasons to believe the existence in most animals of sensory awareness as well as certain types of cognitive abilities, related to sensory analysis and memory functions. Elementary mental functions have been shown to exist in very simple systems of neurons and isolated neurons (Kandel, 1979; Sokolov, 1981).

It is well known that animals show behavioural signs to recognize objects and other animals both as individuals and members of a species or a class. Also there are several reports which indicate dream activity in animals (Sagan, 1978). However, a cat is not a dog and a chimpanzee is not a human. One should be careful not to project human concepts or modes of experience into other animals. This is pert of the relevant criticism which early behaviourists made against the animal psychology of the 19th century.

An adequate action of an organism demands access to appropriate environmental information. This gives reason to assume a general adequacy of its receptor mechanisms. But this also gives reason to believe that the perception of the external world shows speciesbound variations. Von Uexküll states already in 1928: "It would be a very naive sort of dogmatism to assume that there exists an absolute reality of things which are the same for all living beings. Reality is not a homogeneous thing, having as many different schemes and patterns as there are different organisms."

A last question shall be raised: Does a distinct borderline exixt between "conscious" systems and protoforms of them ? Has, for instance, the bee awareness ? Nobody can answer this question today, but the possibility that the bee is aware, cannot be denied, even if awareness here would mean a very rudimantary form. From what has been said earlier it is probably not possible to state the existence of a definite borderline. Rather in analogy to "life" it seems probable that there is a transition from "unconscious" life forms via a range of uncertainty to definitely "conscious" ones.

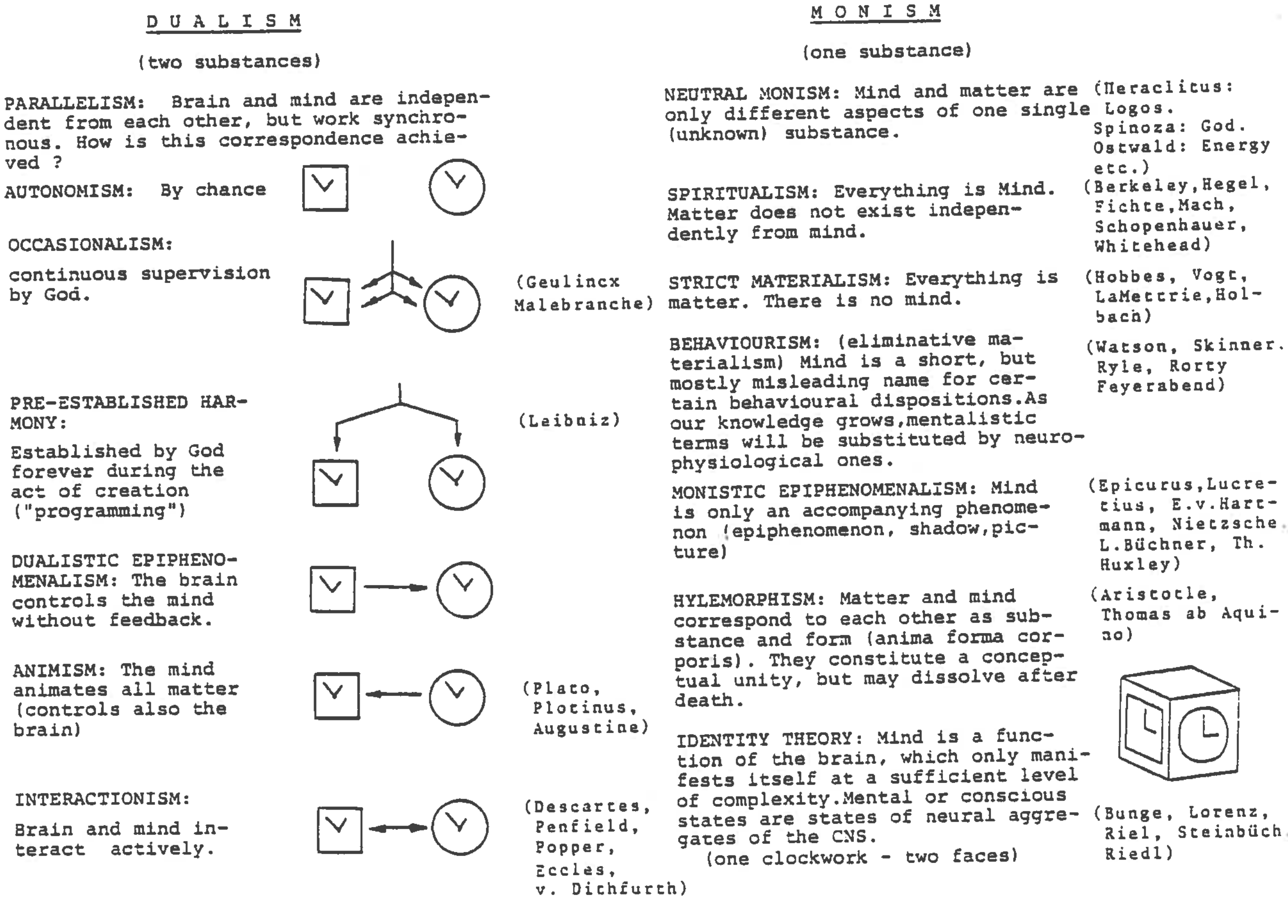
Due to lack of space, further details have to be omitted. A more extensive treatment of the model is given by Löwenhard (1981, 1982). From a much broader point of view, the evolution of the human mind and its cultural products has been the object of a rapidly developinf section of philosophy: evolutionary epistemology. Since the field has been the object of an earlier ICUS session, only a few references will be given (ICUS proceedings, 1982, vol.2., p. 783 - 910; Lorenz & Wuketits, 1983; Radnitzky, 1983, Riedl, 1979, Vollmer, 1981).

Returning to the question of reduction vs. correlation, the answer within the framework of an evolutionary model will be: both principles coexist in a complementary manner. The classical "reduction" of biology to chemistry seems to be a matter of terminology (or more precise the conceptual level of it) in relation to system complexity. The "reduction" of psychology to neurophysiology is split up into two main problems. One deals with'the control of behaviour', viewed as a high level manifestation of integrated systems. Partially this also applies to advanced computer technology and robotics. One may think of the difference between low level (binary) and high level computer language. This problem is essentially similar to the above mentioned about biology.

The other problem regards consciousness. Here the ontological position is essential for an interpretation of facts. If consciousness is viewed as a function of the nervous system (or a phenomenon, related to certain properties of the CNS), then the correlation model applies strictly. This also means that the manifestation, which we call consciousness, shows a covariation with the properties of the neurological system to which it relates. In a deeper sense, however, consciousness may reflect a very basic integrative potential of matter to achieve the reflexive property of awareness, if the necessary preconditiona are given.

Mind and brain.

The final section will deal with the correlational aspect of the body-mind problem. As known from the history of philosophy, the classical treatment of the body-mind problem is part of ontology. For reference see e.g. Leahey, (1980) or Vollmer (1980). The well-known clock analogy, which normally is used to illustrate Leibniz' principle of pre-established harmony, may serve this purpose for other monistic and dualistic ontologies as well.



Initially, the general ontological notion of a "substance" can be excluded from the present context. The problem then is reduced to the relationship between "brain and mind". Nevertheless, the classical psychophysical problem was born out of a (monistic or dualistic) concept of parallelism. While G.T. Fechner (1801 - 1887) tried to give mathematical proof to the identity hypothesis of Spinoza, E.H. Weber (1795 - 1878) tried to describe variations in humen experience against a background of Leibniz' theory of monads. The results were well-known psychophysical laws, such as the Weber ratio

$$\frac{\Delta S}{S} = \Delta R = k$$

(ΔS = just noticeable difference in stimulus intensity; "law" here means an empirical generalization). The term ΔR was supposed to represent the constant "unit" of a subjective intensity scale. If ΔS and ΔR are viewed as approximations of differentials (dS and dR), then an integration gives the Fechner Law:

$$R = k \cdot \log S$$

(k = a constant, S = stimulus intensity, R = response intensity).
It has, however, been doubted, that the assumptions behind Fechner's reasoning (ΔR = constant and adding up to a linear scale of sensation) are valid. S.S. Stevens (1906 - 1973) hence proposed a power law, based on comparative judgements:

$$R = k\ (S - S_o)^n$$

S_o = a threshold correction. A logarithmic transformation of this law then gives a linear relationship, which makes it easy to compare different stimulus modalities.

For a sound of 1000 Hz, the relationship between subjective loudness (in sone units) and physical intensity (in dB units) is

$$R = k \cdot S^{0.3}$$

The equation says, that an increase of the intensity S by a factor 10 gives an increase by a factor 2 in loudness (both scales are logarithmic ones).

Now, a generalized psychophysical problem mainly is identical with the brain-mind problem. Behind this, however, lies all the complexity of the brain. It is not possible to consider the wealth of relevant facts, concepts and hypotheses within the limited space of this paper. The following summary just gives a hint of it.

1. In accordance with what has been said above, "consciousness" seems to exist separately for each nerve structure which is capable to produce it. This

is indicated by obervations on split-brain patients (with surgically dissected corpus callosum = the great cerebral commissure) or in connection with cerebral angiography (X-ray mapping of the cerebral arterial network), where sometimes one half of the brain is put into narcosis by unilateral injection of amytal (ethyl-isoamyl-barbiturate). This drug has a hypnotic effect of short duration and induces sleep in the injected hemisphere of the brain.

The corpus callosum provides the facility for a mutual exchange of highly specified neural codes, which allows for a balanced availability of information for both hemispheres. This is a necessary precondition for an integrated mind (Gazzaniga & LeDoux, 1978).

2. It seems probable, that different modes of consciousness are related to different stages of information processing. This includes reactivation of the memory content, images etc. A model of this umport has been proposed by Aurell (1979).

   It is well-known that the vivid intensity of sensory awareness is different from the pale reproductions of past experiences. Nevertheless, there exist conditions during which images may reach some of the qualities of actual sensations: hallucinatory states, which may be induced by hypnosis, intoxications, infections or mental diseases.

3. The brain uses both conscious and non-conscious modes of information processing. Strictly, one has to make a distinction between unconscious processes (information not retrievable except by inference), subconscious processes (information only retrievable under appropriate circumstances) and non-conscious processes (information not stored in memory) (Hilgard, 1980).

4. Our conscious experience can be characterized with respect to content, mode and state of consciousness. These distinctions are, however, not always quite clear, since several modes of experience may exist simultaneously (e.g. "seeing", "hearing", "feeling a touch" etc.) and transitory states can make it difficult to define the category of a momentary state. The modes of conscious experience (awareness) are most easily demonstrated by reference to sense modalities. It is a different sensation to hear or to see. The implication of the concept sense modality is clear from the fact that sense modalities represent distinct internal sensations, which means that a given modality cannot be transformed to another. It is normally not possible to image "what a sound looks like" or "how a colour smells" (notwithstanding hallucinatory experiences of synestetic nature, e.g. a sound stimulus which evokes colour experience).

As to the states of consciousness, one generally makes a difference between normal states of consciousness (NSC) and altered sates of consciousness (ASC). NSC varies with respect to vigilance (effects of arousal and reticular activation), attention (selective cortical activation) or changes in alertness due to circadian rhythms. ASC occurs naturally during sleep and its different phases, during transitory states, such as the hypnagogic state (= transition from NSC to sleep) or as an effect of psychotropic drugs or toxins.

5. As to the content of conscious experience, our mental objects are no simple projections of corresponding external objects, but sophisticated constructs based on a selective flow of information from the external world. One has to remind oneself, that only a fraction of existing information is available for our senses. Also there is an integration of temporal sequences of information into a single "momentary sensation". Perception is defined as the interpretation of an actual sensory message in terms of earlier experiences. But this includes a process of reconstruction, where lost or otherwise missing sensory information may be "regained" in a hypothetical way. This demands the existence of earlier stored knowledge. Actual perceptions, experience and science share a common feature in that they are related to knowledge in the sense of "insight" (Erkenntnis). There are, however differences. The internal reconstruction of mental objects in connection with perception is generally unconscious, uncritical and non-revisable, but instead perspicuous.Experience, which includes language, logic and conceptulizations makes use of conscious, but still uncritical reconstructions.In science, where mathematical models and highly abstract concepts are used, reconstruction is critical, but very often no longer perspicuous (Vollmer, 1982).
6. The activities of the brain are highly integrated, which means that subjective experience generally comprises both cognitive (symbolic) and emotional elements. This implies that all brain structures, including subcortical structures such as the hypothalamus, limbic system etc. in specific ways contribute to the total experience. Mental constructs are superimposed by moods, emotions and motivational states. This does not only mean a coexistence of cognitive and emotional elements, but motivational states exert control functions on sensory filter mechanisms (direction of attention), which selectively influence the flow of information.
7. The necessity for an organism to make a distinction between itself and the

environment may have been the origin of self-consciousness. Higher organisms then probably have developed the ability to create an internal cognitive representation of themselves.

At least humans have an awareness about being aware. This seems to be the essence of Descarte' s "cogito, ergo sum". Humans perceive themselves as feeling and sensing entities of continuous existence. In this connection the use of terms such as the "ego" or the "self", makes it easy to slip into the fallacy of an internal homunculus" ("the little man in the outer man") (Crick, 1979).

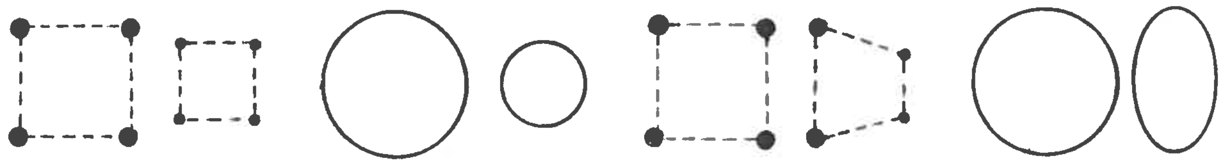
8. The way we perceive our world is to a high degree determined by the innate functions of our brain and receptors. Some examples may be given:

a) The brain is self-programming in a way which (in the language of computer technology) makes any distinction between "software" and "hardware" rather subtle. Principally, the brain runs without anyone telling it how to run and it develops further during this process.

b) The brain is genetically preprogrammed to react to specific stimulus patterns. If these evoke a predetermined response, we speak of instinctive behaviour. The organism here mainly makes use of receptors in connection with filters and trigger mechanisms. The brain seems, for example, to show innate expectations regarding the solidity of three-dimensional objects (Bower,1971). There are specific forms of learning, which are bound to critical stages of development. Imprinting in birds may illustrate this issue. A key stimulus, which fulfils certain minimum conditions, may trigger an innate behaviour: to keep close to the stimulus object. The conditions regarding this stimulus-object may be that its retinal image covers a certain percentage of the retina and that it moves within roughly specified limits of velocity. This rough genetic specification then is substituted by the detailed picture of the key stimulus object.

c) Hubel and Wiesel have analyzed the hierarchical organization and functional architecture of the visual cortex. This has revealed a mechanism, which analyzes the composition of our visual world in terms of figural elements : contrast and dots at the lowest level, bars and edges at a higher level. Essentially, the visual cortex is composed of columns ("chips") which work as orientation detectors with respect to linear elements (Hubel, 1963; Hubel & Wiesel, 1979). Later on, however, it has been suggested, that these "bar detectors" really might be viewed as spatial frequency filters, which perform a spatial Fourier analysis across a strip of the visual world (De Valois & De Valois, 1980).

d) A randomly moving group of dots is perceived as independent dots. An example would be an illustration of Brown'ian motion of microscopic particles. If, however, some dots show a common motion, they are perceived as forming a group. This means the spontaneous formation of a visual pattern. If some of these dots show a systematic movement in relation to others within the same group, this is perceived as the movement of a subgroup within a larger group. An example would be the movement of legs and arms in relation to a walking person. Essentially the visual system performs a vector analysis with respect to the degree of coupling between the velocity vectors in space for each single dot. The mechanism works equally well for lines. The phenomena, which in psychology are called size constancy and shape constancy may be explained in terms of this mechanism. It makes us perceive the shape and seize of an object as constant (i.e. the object is always perceived as identical with itself), despite a changing shape and size of the retinal image. In terms of this analysis the set of changing retinal images may be said to form a geometrical transformation group. Size constancy then corresponds to the group of equiform transforms and shape constancy to the group of projective transforms (Johansson, 1964, 1975).
The mechanism is able to perform several modes of analysis simultaneously.



SIZE CONSTANCY

A continuously changing size of a retinal image is perceived as a linear motion in depth of the corresponding object.

SHAPE CONSTANCY

A continuously changing shape of a retinal image is perceived as a rotation in space of the corresponding object.

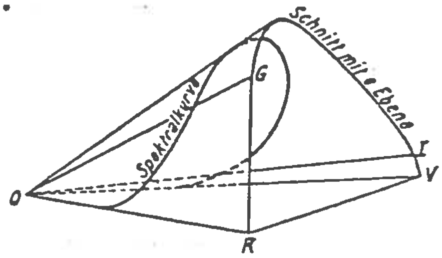
The pictures illustrate "samples" of the continuously changing retinal images (due to the movement of external objects) at different points of time.

Corresponding mechanisms exist for brightness constancy, colours and contrast.

How does this complexity affect the correlation between "brain and mind" ? The simple stimulus-response medels of psychophysics are inappropriate outside the range of pure intensity scales, irrespective of the usefulness of moderns varieties such as the Signal Detection Theory (Swets, 1964), were the detection of signals is described in terms of binary events (yes-no, non-all etc.). Instead one now has to approach the problem of quality. In order to illustrate the issue, one may initially compare the eye and the ear. Primarily the eye mediates spatial information (secondarily temporal information, which is implicit in motion), while the opposite is true for the ear. Written language, for example, is based on spatial sequences of graphic symbols, while spoken language is based on tenporal sequences of phonetic symbols. The eye integrates complex stimuli (such as a mixture of light rays with different wave lengths) into a single colour perception. A mixture of monochromatic "red" and "green" light of equal intensity is perceived as "yellow". *) A composite sound stimulus, however, is mostly (but not always) analyzed in terms of its components. This phenomenon is called "Ohm's Acoustic Law" (Georg Simon Ohm, known from the theory of electricity). This makes it possible for us to hear the timbre of a sound or polyphonic music. The perception of pitch quality is essential in this connection. If the frequency of a simple sound is doubled, e.g. from 440 Hz to 880 Hz, we perceive this jump in musical terms as an octave. This gives a linear relationship between frequency and perceived pitch, the "musical scale". This scale, however, is partially the result of learning, related to the "well tempered clavichord" (J.S. Bach). Thorough laboratory measurements give a more complex picture. Up to a frequency of 500 Hz, there exists a linear relationship between pitch (in "mel" units) and frequency (in Hz). Above 500 Hz, the relationship is logarithmic:

$$z\ (\text{mel}) = 500 + 1{,}300 \log \frac{f}{500}$$

But the picture becomes still more complex, if we regard colour perception. Colours may be described in terms of hue, brightness and saturation. It is, however, not possible to arrange perceived colours within an orthogonal euclidean space. This implies that the dimensions of description are not independent. The arrangement of colours within a three dimensional colour space can, however, be described in terms of a non-euclidean geometry, in this case a Riemann geometry (Born, 1963; Schrödinger, 1920; spherical geometry is an example of non-euclidean geometry).



SPEKTRALKEGEL

Figure from Schrödinger (1920)

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*) <u>note:</u> "red", "green", and "yellow" are used here according to common language as labels to denote dominant wave lengths. In a more strict language the wavelength numbers should be given.

Each perceived colour corresponds to a finite point in this space.

It has been known for centuries that colours are not properties of external objects, but rather reflect properties of our perceptual mechanisms. Light is basically electromagnetic radiation. Monochromatic light is defined by its wavelength or alternatively by the energy of its photons, i.e. quantitative measures. But what are the quantitative values of different colours ?

λ_1	red
λ_2	orange
λ_3	yellow
λ_n	blue
physical scale	subjective scale

Obviously there are no such measures. It is evident that quantitative differences in wavelength (or energy) are transformed into qualitative differences in colour perception. The discriminative power of this principle is evident from the fact that the normal eye is able to discriminate about $7 \cdot 10^6$ different shades in direct comparison. This result is obtained by stepwise information processing. The eye contains three types of spectral sensitive receptor elements (cones). Their spectral sensitivity characteristics have maxima at about 445 nm, 535 nm and 570 nm respectively. The elements may be described as equivalents to band pass filters within the range of visual light and with partially overlapping characteristics. Edwin Land pointed out that colour perception demands a contrast situation, i.e. a comparison of signals from different receptors within the same receptive field (Crick, 1979). Hence, colour perception is based on competing processes within nerve nets. The nature of these processes, in turn, is determined by the relative intensity of signals from the three wavelength discriminating receptor elements (cones); (for reference see Biernson, 1968). The balanced interaction of these signal inflows (both excitatory and inhibitory) determines a very large number of different states of the nerve net and, hence, corresponding states of conscious experience. Meanwhile, how the latter comes about is part of the mystery of conscious experience.

The given examples show, that basic conscious experience is due to intrinsic properties of the brain, while it is the role of receptors to establish a transfer function which gives the necessary coupling to external patterns of stimuli.

It is quite clear, that any description of very complex phenomena, such as colour perception, is outside the range of simple correlations. Living organisms furthermore show an intrinsic true variability (not due to error variance of measurements) as one of their characteristics. Any state of the brain is determined by a multitude of interacting factors. In psychology it is common to account for this by the use of multivariate statistical methods (multiple correlations, eigenvalues, principal factors etc.). These methods are mainly based on linear algebra (which does not mean that they are simple). The description of brain states (including e.g. feedback or "autocatalytic" processes) may demand the introduction of non-linear models, which adds to the technical difficulties.

The brain is a marvellous instrument. The understanding of its most salient manifestation, the mind, is still outside the range of contemporary science. Nevertheless, each really new discovery will change our understanding - sometimes in quite unexpected ways. As yet, we don't even know if we ever will get the whole picture, but it would be an unjustified overestimation of our present state of knowledge, to give a decisive answer in either direction.

R E F E R E N C E S

Ashby, R. Principles of self organising systems. In Foerster & Zopf (eds): Principles of self organization. New York: Pergamon, 1962.

Aurell, C.G. Perception: A model comprising two modes of consciousness. Perceptual and Motor Skills, 1979, 49, 341 - 444.

Ayala, F.J. The mechanisms of evolution. Scientific American, 1978, 239 (3) 38 - 61.

Ball, J.A. Extraterrestrial intelligence : where is everybody ? American Scientist, 1980, 68, 656 - 663.

Biernson, G.A. A review of models of vision. In: Levine, S.N. (ed). Advances in biomedical engineering and medical physics, 2. New York: Interscience Publishers (Wiley & sons), 1968.

Blakemore, C. The mechanics of the mind. London: Cambridge University Press, 1977.

Born, M. Betrachtungen zur Farbenlehre. Jenaer Rundschau, 1963, 8 (6), 235 - 248.

Bower, T.G.R. The object in the world of the infant. Scientific American, 1971, 225 (4), 30 - 38

Breuer, R. Das anthropische Prinzip. Wien/München : Meyster, 1981.

Brillouin, L. Science and information theory. New York: Academic Press, 1962.

Butler, P.J., Klug, A. The assembly of a virus. Scientific American, 1978, 239 (5), 52 - 59.

Carrel, A., Lindbergh, C.A. The culture of organs. London: Harper & Harper Broth. , 1938.

Crick, F.H.C. Thinking about the brain. Scientific American, 1979, 241 (3), 181 - 188.

Culbertson, J.T. The minds of robots. Urbana: University of Illinois Press, 1963.

De Valois, R.L., De Valois, K.K.: Spatial Vision. Annual Review of Psychology 1980, 31, 309 - 341.

Dickerson, R.E. Chemical evolution and the origin of life. Scientific American, 1978, 239 (3), 62 - 78.

Dobzhansky, T. Evolution, genetics and man. New York: Qiley, 1955.

Ehrensvärd, G. Liv, ursprung och utformning. Stockholm: Aldus, 1961.

Eigen, M., Winkler, R. Das Spiel. München/Zürich: R. Piper, 1975

Fermi, E. Thermodynamics. New York: Dover Publications, 1956.

Fiddes, J.C. The nucleotide sequence in a viral DNA (ØX 174). Scientific American, 1977, 237 (6), 54 - 67.

Fulton, J.F.A. A textbook of physiology. Philadelphia/London : W.B.Sounders, 1956.

Gale, G. The anthropic principle. Scientific American, 1981, 245 (6) 114 - 122.

Gazzaniga, M.S., LeDoux, J.E. The integrated mind. New York/London: Plenum Press, 1978.

Halstead, L.M. The evolution and ecology of the dinosaurs. London: Peter Lowe, Eurobook Ltd, 1975.

Hilgard, E.R. Consciousness in contemporary psychology. Annual Review of Psychology, 1980, 31, 1 - 26

Hubel, D.H. The visual cortex of the brain. Scientific American, 1963, 209 (5), 54 - 62.

Hubel, D.H. Wiesel, T.N. Brain mechanisms of vision. Scientific American, 1979, 241 (3), 150 - 162.

Jerison, H.J. The evolution of consciousness. Proc. of the Seventh Intern. Conf. on the Unity of the Sciences. (ICUS). Boston; 1978, 711 - 723.

Johansson, G. Perception of motion and changing forms. Scandinavian Journal of Psychology, 1964, 5, 181 - 298.

Johansson, G. Visual motion perception. Scientific American, 1975, 232 (3), 76 - 88.

Kandel, E.R. Small system of neurons. Scientific American, 1979, 241 (3), 66-76.

Kaplan, R.W. Der Ursprung des Lebens. Stuttgart: G. Thieme, 1978

Lagerkvist, U. Gene Technology. Lecture given at The Institute of Physics, Chalmers University of Technology, Göteborg, Nov. 18, 1983.

Laszlo, E. Introduction to systems philosophy. New York: Harper & Row, 1973.

Leahey, T.H. A history of psychology. Englewood Cliffs: Prentice Hall,1980.

Lindahl, P.E., Kihlström, J.E., Kiessling, K.H., Sundell, L.E. Zoofysiologi. Stockholm: Almkvist & Wiksell, 1967.

Löwenhard, P. Consciousness - A biological view. Göteborg Psychological Reports, 1981, 11 (10).

Löwenhard, P. Knowledge, Belief and human behaviour. Göteborg Psychological Reports, 1982, 12 (11).

Lorenz, K. Wuketits, F.M. (eds.) Die Evolution des Denkens. München/Zürich: Piper & Co., 1983.

Mayr, E. Evolution. Scientific American, 1978, 239 (3), 38 - 47.

Miller, J.G. Living Systems. New York: Mc Graw Hill, 1978.

Mustelin, N. Livets utbredning i universum. Kosmos, 1983, 60, 213 - 233.

Nordling, C. Energi - en introduktion. Kosmos, 1982, 59, 19 - 34. Stockholm: Forskningsrådens Förlagstjänst.

Prigogine, I. Thermodynamicas of irreversible processes. London/New York: Interscience (Wiley), 1967.

Radnitzky, G. The science of man - biological, mental and cultural evolution. in: Cappelletti, V. Luiselli, B., Radnitzky, G., Urbani, E. (eds): Saggi Di Storia del Pensiero Scientifico dedicati a Valerio Tonini. Rome: Societa Editoriale Jouvence, 1983.

Riedl, R. Biologie der Erkenntnis. Berlin/Hamburg: Paul Parey, 1979.

Ryle, G. The concept of mind. London: Hutchinson, 1967 (originally publ. in 1949).

Sagan,C. Die Drachen von Eden (Das Wunder der menschlichen Intelligenz). (trans. E.vom Scheidt). München/Zürich: Droemer-Knaur, 1978.

Sanger, F., Air, G.M., Barrell, B.G., Brown, N.L., Coulson, A.R., Fiddes, J.C. Hutchinson, C.A. III, Slocombe, P.M., Smith, M. Nucleotide sequence of bacteriophage ØX 174 DNA. Nature, 1977, 265, Feb. 24, 687 - 695.

Sayre, K. Cybernetics and the philosophy of mind. London: Routledge & Kegan Paul, 1976.

Schopf, J.W. The evolution of the earliest cells. Scientific American, 1978 239 (3), 85 - 102.

Schrödinger,E. Grundlinien einer Theorie der Farbenmetrik im Tagessehen. Annalen der Physik, 1920, 63, 397 - 520.

Schrödinger, E. Was ist Leben ? (trans. H. Mazurczak). Bern: A. Francke, 1951.

Sears, F.W. Thermodynamics. Reading, Mass.: Addison-Wesley, 1953.

Shannon, C.E., Weaver, W. The mathematical theory of communication. Urbana: University of Illinois Press, 1959.

Sokolov, E.N. Introduction to learning in isolated neural structures (intracellular mechanisms of the associated learning) in: Adam, G., Mészáros, I., Bángai, E.I.(eds): Adv. physiological science, 17, brain and behaviour. Budapest: Pergamon Press/Akademiai Kiado, 1981.

Swets, J.A. (ed.) Signal detection and recognition by hyman observers. New York: Wiley, 1964.

Uexküll, J.v. Theoretische Biologie. Berlin: Springer, 1928.

Vidal, Gonzalo. The oldest eukaryotic cells. Scientific American, 1984, 250 (2), 32 - 41.

Vollmer, G. Evolutionäre Erkenntnistheorie und Leib-Seele-Problem. In: Böhme, W. (ed.) . Wie entsteht der Geist ? Herrenalter Texte 23, 1980, 11 - 40.

Vollmer, G. Evolutionäre Erkenntnistheorie . Stuttgart: Hirzel, 1981.

Vollmer, G. Das alte Gehirn und die neuen Probleme. Aspekte und Folgerungen einer evolutionären Erkenntnistheorie. Contr. to Darwin Symposium über "Das Phänomen Evolution" . University of Technology, Wien, May 1982.

Vollmer, G. The Unity of Science in an evolutionary perspective. Communication to the XII th Conference on the Unity of the Sciences (ICUS) Chicago, Nov. 1983.

Wiener, N. Cybernetics or control and communication in the animal and the machine. New York: MIT Press and John Wiley Inc. 1961 (2nd ed.).

Wuketits, F.M. Das Phänomen der Zweckmässigkeit im Bereich der lebenden Systeme. Biologie in unserer Zeit, 1982, 12 (5), 139 - 144.

Zethraeus, S. Känslan. Stockholm: Natur & Kultur, 1962.