Committee I
The Limits of Science?

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MIND AND COGNITION: LIMITS OF UNDERSTANDING

by

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> "Man alone is conscious of himself and is alone capable, as it were, of standing outside of himself and regarding himself as an object. As I come to consider the nature of man, I discover that I have direct access to privileged information about one - namely myself with my self-consciousness."
>
> J. C. Eccles

Biological function of the brain

Mind and cognition are unseparable from the structure and function of the brain. There appears to be consensus among those who analyze the brain, that beside many regulatory roles, the main function of brain is to make representations of the outside world. This idea, in various forms, can be traced back to the school of Hippocrates. In recent times it reappeared in various forms like the "cognitive map" of Tolman (1932), the "hypothesis in rats"of Krech (1932), the "parallel representations" of Craik (1947), the "search image" of ethologists (Tinbergen 1960) and the "neuronal model of the environment" of Sokolov (1963) among others. These representations

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exist in forms of the memory traces and in transient patterns of neuronal excitations that serve as signals and images. The patterns are shaped by sensory inputs, following on sequential transformations they serve to shape motor activity and to predict future sensory inputs (Csányi 1989a).

The concept of cognitive maps

The concept of "cognitive map" first emerged in psychology in connection with studies of animal learning and orientation in the thirties. At that time a favored experimental paradigm was the study of learning by rats in a maze. Mazes were usually made from wooden channels or elevated routes with many crossing points and blind alleys. A hungry rat was placed at the starting gate, and it was allowed to search for a small reward provided at the end of the maze in the goal box. The observed route chosen by the animal, the number of entrances into blind alleys as errors, and the time necessary for finding the reward were recorded. Rats are very ingenious in finding the shortest routes in such labyrinths and are quick learners.

The term "cognitive map" was used first in Tolman's laboratory for the explanation of "**latent learning**", a new finding of the maze studies (Tolman 1932). In the classical experiments the rats got a reward in the goal box and in repeated trials they learned the fastest way to the reward. During

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the trials their runnings were characterized by ever fewer errors and subsequently shorter running times. Usually, after six to eight runnings, a rat performed the task without error. The phenomenon of latent learning was found when the rat was placed in a maze which did not contain a reward. Rats are active creatures, and for a couple of trials they searched the maze out of curiosity. According to the prevailing theories, learning was not possible without reward. Nevertheless, if after some unrewarded trials the rat was fed in the goal box, then in every subsequent running the shortest route was chosen. Tolman explained this result by supposing that during the unrewarded trials the rat constructed a **representation** of the maze in its brain. He called that representation a "cognitive map" and concluded that it was a description of the main physical features of the maze. In the rewarded trials the animal used its cognitive map as a source of reference in orienting itself in the maze and finding rewards.

Rats are able to memorize the features of a maze and, upon necessity, to achieve a purpose; they are also able to modify chosen routes if they encounter obstacles along the way. These basic experiments were repeated many times, and ingenious new ones were designed (Krech 1932). The experiments led to the insight that rats are able to memorize the features of complex mazes and, if necessary, they are able to figure out the results of possible actions without performing them. That is Tolman's work c/ Csanyi/

demonstrated rats are able **to think** with the help of their cognitive maps.

Ethologists have since studied animals in natural environments and found that almost all animals, even some insects, use cognitive maps to orient themselves. Cognitive maps in animal brains represent the most characteristic features of their home ranges and are the result of their learning (Collett 1983). Cognitive maps are not simple static representations of the environment rather they are dynamic models of the various features, events, and processes which are influencing the survival of the animal (Csányi 1987b).

Mental models of the environment

Another important approach to the brain functioning has been realised through the study of the adaptation of animals. It was brilliantly shown by MacKay (1951-52) that the essence of the adaptations performed by the nervous system is **goal directed behavior**, and neither vitalistic nor anthropomorphic concepts are required to explain it. Goal-directed behavior or generally speaking: intelligence, has a simple cybernetic explanation if we consider the organism as a system, with a number of feed-back loops, capable of changing its own parameters. Definition of goal "X" pursued by system "A" would be as follows: let "Y"

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represent "A" and its present environment, and let "X" be equal with "A" in a state in which it has reached its goal. Then "A" will show goal-directed behavior if it performs such internal or external movement, that attempt to minimize the difference between "X" and "Y". This definition of goal directed behavior is valid not only for living organisms but also for artificial cybernetic constructions. It follows from the definition, that a system capable of showing goal-directed behavior has to possess certain mechanisms. It is necessary that the system could distinguish between states "X" and "Y", that is to have some kind of recognition sub-system. Furthermore it is necessary that it be able to change its own internal state, based upon this recognition process, which, in case of artificial systems, can be very simple (e.g. a heat sensor of a thermostat). Finally it is necessary that the system carries **internal representations** of the possible goals, for without them it could not recognize differences and change.

Subsystems of recognition (perception) and change (behavior) are well-known in living organisms. Internal representations are made possible by mechanisms of genetic and neural memory. The question of the organization of internal representations is, however, more complex. The adaptive "goal" of an organism is to survive in its surroundings so the internal representation must be one of the environment including the given organism. The internal representation of the environment can be

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considered as a construction, which in essence is a **model** (Craik 1943), more precisely, a dynamic model of the environment. By model we mean a system science definition, i.e. **a model is always a simpler system in which the components and the interactions of components reflect the components and some interactions of a more complex system** (Mesarovic 1964). Model building therefore is always a kind of simplification and a special identification between two different systems, of which one is the model and the other is the system being modelled. The model is used by **operating it** and based upon its operation we predict the behavior of the system being modelled.

So, the most important biological function of the animal brain is the construction of this dynamic model of the environment, which includes environmental factors and their interactions most important for the survival and reproduction of the animals, the continuous maintenance and operation of the model, and the use of the obtained data for predictions in the interest of the survival and reproduction of the animal.

If we consider **cognition**, as MacKay has done, as **the ability to construct models**, a very useful concept is obtained. It is obvious that all animals, including humans, belong to a common class, because all nervous systems are able to model its environment. That is, all animals have some kind of cognition.

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This definition reflects not only similarities, but differences as well, because a complex system can be modelled very simply, and also in a more complicated way. Simple models may also predict some simple but important events for adaptation. For example, each animal "knows" that dark periods are followed by daylight. It is the model of the dark-light rhythm of the environment that establishes the diurnal cycle in the nervous system of animals. The essence of these mechanisms basically is genetic. Different species may be active in the dark or in the light period, but all have the inherited "genetic memory" of the periodicity of its environment, and in the final performance both genetic and neural memory are contributing. More complex phenomena can also be modelled: the brain of a monkey can make a model including not only the diurnal cycle, but also the behavior of various predator animals, the responses of fellow members of the troop, the order of dominance within the troop, and also other social relations, the effects of past events, and many other things. Ethological studies showed that higher mental functions can also be found in animals (Denett 1983, Griffin 1984, Epstein et al. 1984), as it has also been demonstrated by electrophysiological experiments (John 1972).

As long as the interneuron network of the brain of a species is of low complexity, the modelling of the external world is also extremely primitive. The the model consists of a few "excited" neural elements and their simple,

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temporal connections. In higher organisms strikingly exact images of the external world can be found. Fish, amphibia, birds and mammals are all capable of storing all the essential parameters of the encountered image in their memory, and also of acting expediently in a situation occurring later in time without the presence of relevant stimuli (Beritashvili 1971). Rats can memorize maps of complex mazes and by comparing the actual stimuli with the internalized map, they can precisely orient themselves in physical space (O'Keefe and Nadel 1974, Olton and Samuelson 1976). According to MacKay, the neural model is not only a simple projection, but a kind of complex reconstruction containing also instructions of the possible behavior of the organism in response to the stimuli of the external world (MacKay 1951-52, 1965). The animals's activity is not simply organized by responses to the external stimuli, but also by expectations and analyses of situations based on the internal analysis of the model formed in the nervous system (Gallistel 1980). The model includes sequences of events occurring, which are used by the brain as an internal reference for control, for example, of eliciting fear (Hebb 1946), of orientation (Sokolov 1960), of attack and defence (Archer 1976), and of avoidance of predators (Csányi 1985a, 1985b, 1986, 1988). In higher animals, the formation of an environmental model involves to a great extent the internal representation of the animal itself. This process

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has culminated in the emergence of **self-consciousness** in apes (Gallup 1970), and man (Anderson 1984).

According to neuro-ethological studies the maps or models of the animal brain are not only conceptual tools of neuro-biologists necessary to describe brain's function, but actual **physical entities,** which can be verified experimentally (Collett 1983).

A **functional** description of such models can be given in the followings. Three parted structures can be regarded as functional units of the neuronal model. Percepts originated from outer stimuli of the environment through animal perception play the part of a "**key**" which is the basic connection between the inner and the outer world. The stimuli are always followed by some action of the animal sooner or later. Neural structures which organize animal **actions** form the third part of the elementary units of the neuronal models. Nevertheless there is no direct connection between percepts and actions. The same stimuli could activate different actions, depending on the memory of previous experience. But actions also depend on the actual inner state of the animal, whether it is hungry?, or thirsty? for example. The functional elements that link percepts and actions are called "**referential structures**". The triadic "key - referential structure - action" units can be combined through the reference structures and their complicated makeups are the very models of the environment (Csányi 1988).

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The "key-reference-structure-action" units of the models are called animal **concepts**. A concepts can be considered as a neural controller unit of a behavioral act or thought of the animal brain. The general capacity of the higher structures which can be built from the concepts is rather limited in the animal brain, because each individual can form its models only from its own limited experiences. Every and each model made by animal brains is highly particular in this respect.

Human cognitive maps and models

People also have cognitive maps, as a simple example shows. We can, after observing an environment with various obstacles in it, negotiate a path through it with our eyes shut for six or seven seconds. During this period movement is guided only by the cognitive map of the environment constructed previously. By long practice, complex, three-dimensional, permanent cognitive maps can be constructed.

Features of the physical environment are only one of the significant parts of human cognitive maps. We live in an environment where other people act, artifacts exist, and where information of a linguistic type (signs, orders, instructions, descriptions, etc.) is functioning. Therefore our cognitive map represents objects, living beings and their behavior and also linguistic

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abstractions, their interactions operate a much more complex, dynamic model of the environment than the simple animal cognitive maps.

Evolution of the linguistic competence of man resulted in a fundamentally new model making mechanism. By **naming** something, a key (the word) which has only very loose connection with percepts and actions arises. The "**word** - referential structure - action" segmented units could be combined not only through experiences, but also through grammatical and logical rules and this results in the very complicated superstructures of the **conceptual thought**. A linguistic concept can be regarded as an utterance or human thought. It also could activate actions, but primary experience is no more a prerequisite for these actions as it was in the case of the animals. Mental superstructures built up from linguistic concepts are also reflect experiences, of course, and therefore they can be regarded as models of the outer world so much the more as it is sure that animal type concepts and linguistic concepts combine together to create a world model in man. In evolution of man the symbolic information content of the brain's models plays the most important roles. Animals are capable of thinking in their own ways but according to our knowledge only man uses **descriptions** in their thinking. Descriptions have double functions. First as descriptions they are representations, models of the outer reality, on the other hand they are acting entities in the human brain they could have interactions with other

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concepts of the brain through logical and linguistic rules. Their "meaning" is connected to this second functions. **Meaning** is an acting property of a description bound to the whole conceptual system by which the description was made.

Languages change the medium in which environments are mapped from perceptual mapping to linguistic, conceptual mapping. In perceptual mapping every individual needs direct experiences and makes its own cognitive map from its own percepts. In linguistic mapping we transfer and accept descriptions and prescriptions from others and construct cognitive maps without direct experiences. Ancestor's experiences influence cognitive maps of members of a human society in a very large extent.

Ideas

Linguistic competence opened up of the closed inner world of the individual. By linguistic communication individuals in a group are able to exchange parts of their models in the form of linguistic concepts or even the whole models of linguistic nature (Csányi 1982). In such a way, concepts existing in the individual brains become parts of a higher collective structure which operates at the level of the group, determines the aim and the exact way to its achievement. We call this higher structures of individual concepts as **ideas**.

Concepts consisting of an idea are not selected at random, rather they form a functionally organized set which makes the performances of the group purposeful and possible. Cooperation which is so characteristicly human trait (Eibl-Eibesfeldt 1982) is just an orderly performance of an idea, that is an organized set of behavioral concepts. Ideas are organized hierarchically and the whole is available only in the whole group which activity of is regulated by the idea (Csányi 1989b, 1990).

Individual concepts existing in the brains of the group members can be functionally combined only by a specific self-organization of the ideas. Only those ideas that contains those and only those concepts which are suitable to achieve the given goal can act and accomplish something.

If, for example, we study an ancient craft, like arrow making, it is clear that this craft follows certain rules concerning the selection and preparation of raw materials, and in the sequence of the technological procedures, these are the constituent concepts of the idea of arrow making. It cannot be said that only one sequence or set of the concepts results in appropriate product, but small deviations are allowed during the whole technological process, and therefore the idea of arrow making is a stochastically characterized entity.

Many different competing goals arise in the life of a human group which can be achieved by an appropriate idea. Therefore strong selection is exerted on the formation of the ideas connected to these goals, and those ideas which are unsuitable for a given goal are selected out. This selection process results in the evolution of highly organized ideas. The idea of the arrow making is not a simple set of behavioral concepts. During its performance, first appropriate raw materials must be selected, then some kind of processing follows by drying and cutting the wood culminating in the final assembly. With an other sequence of the concepts it is possible to make an other instrument which express an entirely different idea. Beside its concept constituents it is the **organization** which characterize an idea.

It is obvious that even a primitive group society had many different ideas simultaneously. For hunting, fishing, for the defence of the group from predators or from other groups, they needed various ideas (Lee 1969). It is also clear that the different ideas could not be entirely independent from each other because there are many common behavior elements of these actions, and it is also necessary to co-ordinate the maintenance and expression of the various ideas. The seed of this co-ordination is the group as an entity itself. The ideas organize the maintenance and survival of the group which in turn must harmonize the ideas.

The group and its idea set form a closed system. Well organized ideas help the group's maintenance and survival, while the group takes care of the propagation of the ideas from generation to generation. Biological and

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ethological traits of man like acceptance of group identity, preference of group members and rejection of nonmembers (Eibl-Eibesfeldt 1979), sacrificing someone's life for the defence of the group fit very well with the culturally made ideas about the group. There is an absolute harmony among the individual, the group and the ideas. Emotional and social stability has been solid for hundreds of generations (Csányi 1990). A new kind of cognitive map or a **social-supermodel** came into existence which operates above the individual level and characterizes particular groups and is called **culture** (Csányi 1987a, Csányi 1989b, Csányi and Kampis 1987)).

Emergence of the Mind

Appearance of ideas is only one of the consequences of the evolution of human language which made the effective communication among brain's models possible. The animal's brain, if it belongs to a long living higher species, is able to construct complex concept-superstructures from the individual experiences, but because of the very nature of the animal concept units (Key - Referential structure - Action), these superstructures are bound to the outer reality, exclusively and finally. They are only the representation of the outer environment, good or better, but nothing more.

The linguistic concepts can be detached from reality. If the perceptual

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keys are transformed to words the referential structures could evoke actions which themselves are words again. Words which could be told or written and might became keys again. This feature of the linguistic concepts contributes to the creation of a self-generating system of the concepts which are only occasionally influenced by reality. The development of the linguistic concepts, the ability to form conceptual thoughts in man has led to the emergence of a genuinely new brain system. Abstract thinking creates self-organizing concept-superstructures which are not only primitive models of reality but **autonomous** entities, inner structure and dynamics of which cannot be appertained solely to the outer environment but to the **relation** of the emerged new system and reality. Self, imagination, phantasy independent of experiences and their connections and the relations among them are the most important features of this self-created world, which we name as **mind**. With the help of his\her mind the individual is not only able to react appropriately to the changes in the immediate environment but it could view itself as the part of the environment, it could regard itself as an acting object, it could analyze the relation of itself and reality in a wide range of the time/space continuum, to project its own position to the past or to the future.

Mind can create a world of phantasy where self plays a relatively subordinated role, but rigorous rules exist concerning the dynamics of other abstract entities, such is the world of mathematics. Worlds can be created in which everything is revolving around the self without reflecting constraints of reality, such worlds are the religions. The pure essence of the mind's creative intelligence is personalized in **God**, who is placed above us with unlimited power while we humbly retain only the beautiful concept of the **soul** for ourself.

Inevitably the question arise whether the rules and constructs of these created worlds are really independent from the outer reality or not? Are they independent from the physical structure of the brain or they reflect it in a way incomprehensible for us? Is it right to assume that the world of the Mind are ruled by principles transcending physical reality, and every intelligence emerging in the Universe has a common root? Natural sciences could not give satisfying answers to these questions. May be they never will, it is quite possible that the most serious limitations of our understanding of reality are expressed in these problems.

Understanding

We usually say we understand some phenomena if our brain can make an appropriate neural model of the dynamics of certain selected components of the system which is responsible for the given phenomena.

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The value of the model is tested by its predictions. The internal dynamics of the components of a good model results in some similarity in its overall behaviour to the system being modelled. In most cases this is meant only that the behaviour of the model and the modelled system, more precisely the dynamics of certain selected parameters of both can be interpreted in the same space/time range. Such similarity is only a kind of analogy and it is never produced by the same network of concrete mechanisms. "Understanding" , let it be a connection between two minds or a relation between a mind and reality is always meant that this analogy between the neural model and the system modelled is emerged.

Thinking by brain models has two well recognizable limitations. The first is a result of the nature of the components of the brain's models, the second arise because of the organization of the models.

Limits of understanding

It follows from the nature of the mechanisms of human thinking that whatever type of model are we creating, let it be connected to everyday thinking or be the result of scientific activity or even a pure mathematical model, its final form is always a neuronal network and **its components are neurons**. That is, every man-made or thought model finally is **material** in

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its nature. It follows also that the structure of the models and the internal dynamics of the models are determined and constrained by the possible interactions of the neurons. The genetical constraints of these are well known in behaviour genetics and ethology, but there are some more general constraints which are the consequence of the modelling process itself.

The first type of limitations is due to the nature of the information content of components of the model and the systems being modelled. Information is considered as the description of the observed components of a given system, that is a list of their various properties. Information is embodied in the components and only in the components. The list of the observed properties never could be exhaustive because we define properties from the known interactions and these are necessarily finite and limited by our observations. In fact the list of the properties of any kind of a component is **infinite** this originates from the inherent nature of the interactions of matter, which are infinite and immeasurable (Bunge 1963). Properties other than are included in our description we call **hidden-properties.** It was shown that hidden-properties play a rather important role in the biological and social evolution (Csányi 1991).

Because of the hidden-properties of the components there is a peculiar difference between the information content of the components of a real system and the components of a model. In the real system the components are "given" by existence and because of their hidden-properties their all possible interactions never can be really assessed. Components of the model which we create are **defined**, the information content of them is prescribed and there are no categories of hidden-properties is involved. If we study a cell for example its material is given by nature and the possible interactions of the encompassed components are infinite. While the model of the cell which is formed in our brains contains molecules as components and the list of properties of these molecules are "chunked" because of our limited knowledge of the possible molecular interactions.

This "chunking" process expressed in our brain led to a characteristic feature of our models of the world, that is, to the use of the **organizational levels**. In studying any real entity or object we define certain elements or units using classifications. These units are not existing in reality, these are the products of our models which we create. For example studying the cell we define individual molecules as their components, in that way we create the molecular level of organization which is characterized by the dynamics of the molecular components. This dynamics is dependent upon the properties of the molecules. Most of the properties of a molecule however can only be assessed if we break it apart to atoms and atomic interactions. Indeed the history of chemistry shows that the development of atomic and nuclear physics gave a new impulse to the development of chemistry. That c/ csany/

is, in many cases the relevant information of matter is stored on various levels simultaneously, and only a fragment of it is available on a given level. To go beyond this knowledge, the respective objects have to be taken apart - either logically or even physically. However, if we break our object into the constituting elements, it is no more the original object and we are studying a different system (Kampis 1987a, 1987b).

On the other hand the cell is more than the simple sum of the dynamics of its molecules. The cell is a result of the constraints exerted on the molecular dynamics (Polanyi 1968). These constraints, if recognized, are expressed in our molecular models at the **upper level** of organization. Layering of the organizational levels can be continued, if we regard the cell as a unit, as a component and characterize it with a certain dynamic we will find again constraints exerted on it and therefore the next higher level, the organismic level of organization comes into existence.

Description on a given organizational level always occurs with double exclusion. Dynamics of the components of the lower level are excluded and substituted by the constrained dynamics of the selected level's components and also are excluded the constraints of the higher level. A more or less acceptable description can be made only by two levels descriptions (Pattee 1965, Kampis 1990). However, the inherent limitation of the modeling process can still be recognized and we do not know any scientific method c/ csm y1

which could circumvent it.

The second type of limitations originates from the "material body" of the components of our mental models. Self-structure and properties of the components of the mental models are determined partially by the neuronal structure of the brain and only to a limited extent by the knowledge acquiring process. Realizable properties of the components of the neural networks are certainly not infinite, and the dynamics of the interactions of the neurons also have organizational constraints. It is evident for example that the number of the neurons in the brain is more or less given, the number of their possible connections is higher with several orders of magnitude but it certainly has an upper limit.

Therefore the number of conceivable systems is certainly lower than the number of systems which are realizable in the Universe. This is the most serious limitation of our cognition.

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