A. Ya. TEMKIN

SOME IDEAS ON INFORMATION PROCESSING, THINKING AND GENETICS

Contents

PREFACE

The author hopes that this book will contribute at least a small drop to efforts of many scientists to understand the nature of the human thinking. This hope justifies its writing and publication. The approach to this problem represented in this book is very general one, and just because of this it allowed us to consider from the single point of view not only the human thinking, but also problems of molecular genetics, heredity *etc.*.

Dr. Alexander Ya. Temkin ©
Department of Interdisciplinary Studies
Faculty of Engineering
Tel-Aviv University
Ramat-Aviv
Tel-Aviv 69978
Israel
E-mail: temkin@eng.tau.ac.il
April 15, 1999

INTRODUCTION

The human thinking is the most wonderful wonder of the World and the most mysterious enigma attracting attention of scientists, especially during the last period of time, when the number of them attacking this terribly complicated and difficult problem essentially increased. This is a great goal by itself to understand the nature of the human thinking. But the significance of researches in this field is not limited only with the advance to the achievement this goal. Really, consequences of the successful progress in this field and obtained results are (or are expected to be) significant also for other important fields of science and techniques. For example, two questions arises from the fact that fundamental physical theories are products of the human thinking: 1)Whether its laws and peculiarities influence such theories? 2)Maybe some difficulties and contradictions contained in these theories are consequences of our thinking properties and peculiarities? *These questions can be answered only on the grounds of the knowledge of the human thinking nature*. Something on this subject the reader will find in Chs. 4 and 5. Another example is the following question: whether such systems, other than the brain, may exist that process the information by the same mechanism than that of the brain, in other words, systems thinking as the human brain does? The mechanism of the information processing by the human brain must be found to enable us to answer this question. This problem is considered in Chs. 3 and 5, and some possible consequences of the existence thinking non-biological systems are considered in Ch. 6. It would be interesting to consider, in particular, whether astronomic objects such as Galaxies, star-clusters, interior of a star *etc.* can process the information as the human brain does. Notice that the processing of the information implies not only the processing of the information going in to the considered systen, but also the production of new information by the considered system itself.

The same thing refers also to researches aiming to understand the mechanism of the human thinking by the creation artificial systems (or their mathematical models) thinking like the human brain, which are developed in two main directions: 1) artificial intelligence (AI) and 2) artificial neural networks (NNWs). Though the goal is not yet achieved (there is not yet adequate model of the human thinking), these researches have already led to many very interesting results. They also engendered the whole fields of applications important by themselves, not obligatory connected with the brain activity, as, for example, the use of NNWs in nuclear engineering.

But what is the cause that the goal of these researches is not yet achieved? Whether the creation of an adequate model (or models) of the human thinking is principally impossible or it is only the question of time and additional efforts, **or something is to be changed in essence of such researches?** In Chs. 4 and 5 is found what namely is to be changed in essence of researches aiming the human brain modeling by NNWs.

When we try to approach the problem of the human thinking , two main questions arises: 1) *what method of the information processing is used by our brain? 2) how this information processing is governed?* Without answers these two questions a theory of the human thinking cannot be created. The second question contains a constraint: any answer this question *must* explain how a person is able to govern *his own* thinking, and how he can be acquainted on *his own* thinking processes.

In the light of the written above it would be natural, first of all, to search for an information processing mechanism as general as possible that, just because of it, can be fit for the information processing in many different systems of different nature. Then it can be expected that the mechanism of the information processing by the human brain is a certain version of this general one. The mechanism of the information processing described in Chs. 1 - 3, is very general because it is built in the framework of the abstract set theory and the nature of the considered sets and their elements is not concretized in the general theory. Of course, they must be concretized in each particular case of the theory application as mathematical, physical, chemical, biological a. o. objects. This mechanism is based on the concept of chains of binary relations (CRs) , each of which is constructed of elements of a subset of the given ordered set $\mathcal{A}$, and their activation (ACRs). An equivalent theory can be built, if CRs be replaced by chains of structures defined on these subsets of the set $\mathcal{A}$. The content of Ch. 4 is based **on the hypothesis** that the human brain processes the information by ACRs, and consequences of this hypothesis are studied. Probably, on a certain stage of this study their comparison with the experimental facts concerning the human thinking will allow us to confirm or to disprove this hypothesis.

It is important that the activation of a CR (Ch. 1, §1.3) is executed by use of a well-ordered set which is a generalization of time ("ordinary" physical time also can be used in some very important particular cases). It allows one to define different types of time, *e. g.,* different types of biological time (circadian clocks, thinking time *etc.*), and to formulate the *mathematical condition* that the time has only one direction. This condition contains equality that allows one to connect this condition with laws of nature, *e. g.,* with laws of physics. We hope that it will permit, in particular, to understand why the *physical time* is directed to only one direction. An interesting question arises: whether a system, *e. g.,* a biological system, can possess different types of time directed to different directions, for example, circadian time directed to the direction opposite to the one of the "ordinary" physical time? And, if yes, to what consequences it will lead?

In Ch. 7 other objects processing the information by ACRs are considered. These objects are polymer molecules. Our attention is focused on DNA (as well as RNA) molecule, but the consideration refers to a wide class of polymer molecules. Using CRs and ACRs we expressed in terms of *information* and *information processing* properties of polymer molecule rotational, vibration and electronic movement, and, correspondingly, *processes* occurring on their levels. In the case of molecular genetics it opens the way to describe uniformly, in terms of the information and its processing, chemical structure of DNA (as well as RNA) molecule (by genetic code), its electronic structure, vibration and rotational states (by CRs) and their changes (by ACRs) . In particular, when it is done, it opens the way to find connection between molecular genetics and information processing by the brain (thinking), which, in its turn, opens the way to study hereditary transfer of intellectual faculties and, in general, intellectual peculiarities.

In Chs. 1, 3 and 4 the subsequent expansions of the primary set $\mathcal{A}$ (we call it the source set $\mathcal{A}_S$ - see Ch. 1) are considered. The possibility of such expansions naturally leads to the existence of different levels of the information processing. For example, the information processing by the NNW hardware itself (without use of ACRs - basic level, in our terminology) is the only type of the information processing that is considered in all works on NNWs. Much more complicated and developed constructions such as CRs (and corresponding ACRs) are not considered, in general. This is the main cause of that why NNW is seemed not to be even an approximation to the adequate model of the human brain . In Ch. 4 the application of the proposed information processing method to NNW is considered.

If the brain processes the information by ACRs, it can explain the effect of "volume transition in the brain" discovered by Luigi F. Agnati, Börje Bjelke and Kjell Fux (see, for example, Am. Scientist **80**, 362-373 (1992)). In this article they write: "Just as electrons flow along wires in a circuit, the neurons in the brain relay information along structured pathways, passing messages across specific points of contact called synapses. Information can no more leave the neuronal circuitry than a train can safely leave its tracks. But there is increasing evidence that neurons can communicate without making an intimate contact. The relaying of messages across synapses may be the fastest means of processing information, but it is quite likely that information often leaves the track." A CR is not localized in a certain point of the brain being a combination of many neurons filling up a certain *region*.

Therefore, the picture that the neurons in the brain relay information along structured pathways, does not correspond to the information processing by ACRs, but to the one without ACRs' participation, to the basic level information processing, as we call it. Thus, the effect of volume transmission not only is naturally explained in the framework of the ACR based information processing by the brain, but the existence of this effect confirms that at least a part of the information processing by the brain is done by ACRs. Complicated thoughts can be represented only by ACRs of different levels, or, in other words, the human thinking corresponds to the information processing by ACRs, but not to the basic level of the information processing (Ch. 4).

Conformably to the human thinking, the existence of different levels of the information processing means the synergetic character of the thinking. However, synergetic character of the thinking consists not only in this. It consists also in the fact that on all *biological levels* from molecules DNA and RNA up to the macroscopic level of the brain the information is processed by the same mechanism, ACRs, which is repeated when we transit from one level to another. Thus, a set of biological levels of organization exists from molecular microscopic level up to the macroscopic one, and on each biological level a set of information processing levels exists. The genetic information contained in DNA molecules may be transferred to the cellular level and may affect neurons and inter-neuron connections. If be found that these two effects really exist (*i. e.*, these two "may" must be removed), the genetic information contained in DNA molecule and written such as it was described above, influences the CRs structure on the level of neurons and inter-neuron connections. Therefore, it influences the information processing by the brain (thinking), at least, its first level. It was clarified that changes of a lower level of the thinking influence all its higher levels. This means, properties "written" in terms of information on DNA molecule may be transferred to the human thinking up to its highest level. This is a (the?) possible microscopic mechanism of the hereditary transfer of the intellectual peculiarities, talents as well as mental diseases. As it is known, the learning affects inter-neuron connections. In view of the written above, the learning performed on the high level of thinking influences the thinking on lower levels and vice versa. This means, principally, it is not impossible that changes produced by the learning on a high level of the thinking will reach the molecular (DNA and RNA) level, *i. e.,* will change the heredity. It can be expected that such a possibility will be rejected flatly by the big majority of biologists, who will consider it as the return to the theory of Lamarck. However, the science demands to check it by scientific methods honestly and without prejudices.

The content of Ch. 5 is connected profoundly with the one of Ch. 3. In Ch. 3 was established that the information processing by ACRs can be measured by use of the ACRs' intersection. It was found that not in each pair of such measurements they are compatible (which means that one of them does not influence measuring results of the other one). The set of all possible measurements can be divided into a number of subsets such that in any pair of measurements belonging both to the same subset they would be compatible, while those consisting of measurements belonging to different subsets, would be incompatible. In the framework of the hypothesis that our brain processes the information by ACRs this conclusion is valid for the mind self-measuring. Concentrations of the thinking on different subjects corresponds to the execution of different types of self-measurements. On the psychological ("macroscopic level") known that when a person is concentrated on a certain subject of thinking, he obtains maximum of information on this subject and minimum of information on other subjects. On the level of the thinking mechanism it corresponds to the execution of the certain type of mind self-measurements. Then other types of them, even if they are also executed, provide a small amount of the information because their results are essentially influenced (up to be destroyed) by measurements corresponding to the actual concentration of the thinking . Notice that in Ch. 4 is shown that the concentration of the thinking on a certain subject is inevitable and dictated by the demand not to create too "dense gas" of ACRs.

Thus, the existence of incompatible pairs of self-measurements of the mind creates the situation like the one in the physics of the micro-world, where, for example, the measurements of an electron co-ordinate and the corresponding linear momentum projection are incompatible. An adequate mathematical formalism describing the behavior of such a system is algebra of non-commuting operators acting upon points of an abstract space representing states of the considered system. In Ch. 5 is argued that, unlike the quantum mechanics of the micro-world, states of mind are represented by points of a metric space, but not of a Hilbert space. In Ch. 5 was found that the thinking is governed on the level of this metric space of states by means of states' probabilities defined there. If namely the logical thinking is considered, the logic is the quantum one, but different from the one corresponding to the quantum mechanics of the micro-world. Thus, the quantum theory of the mind determines that the logic of the human thinking is quantum by nature. Moreover, as it is found in Ch. 5, it is not obligatory objective, but depends on the individual. The quantum theory of the mind allowed us to define *personality* as a set-theoretical concept that can be studied by rigorous mathematical methods. In particular, it would be interesting to study symmetry properties of the personality which are very important because they influence the thinking and its logic, as it is shown in Ch. 5. Possibility of the existence connections between symmetry properties of the physicist professional personality and those in physical theories of the micro-world is considered in Ch. 5.

The same arguments that had led to the quantum theory of the mind, allowed us to find a possible natural mechanism of ESP phenomena (Ch. 6). As distinct from Ch. 5, where the thinking of one person was considered, in Ch. 6 the thinking of two persons **A** and **B** is considered. In this case not only a number of different realities of **A**, corresponding to different concentrations of his thinking , is considered, but also those of **B** including the reality created by his measurements of different quantities characterizing the **A**'s state. The person **A** may be in such a state that these realities (concerning **A**'s state) are different, and measurements done by **A** himself and by **B** would be incompatible. This means, consideration of Ch. 5 can be applied to the system $\mathbf{C} = \mathbf{A} + \mathbf{B}$, if **C** be considered as one quantum mind. In Ch. 6 is shown that the quantum character of **C** mind may lead to ESP phenomena. Why this "may"? Because this is a *possible* mechanism of ESP phenomena, but there is not yet enough proof that it really works. Consequences of this hypothesis are considered, in particular, with the purpose to find out how it can be corroborated or disproved experimentally. Notice that in the framework of the proposed theory ESP is an aspect of psychology, but not something esoteric. The author considers it as an important success of this theory. In this connection it would be useful to remind that about two hundreds of years ago *magnetism* was still considered as something esoteric.

Chapter 1

CHAINS OF RELATIONS AND INFORMATION PROCESSING

1.1 INTRODUCTION

The present chapter is dedicated to construction such combinations of elements of a given ordered set $\mathcal{A}$ which can be transformed into information processors.

If each element of $\mathcal{A}$ is a set consisting of more than one element (in some particular cases, *e. g.*, neural network, it can be interpreted so that each element $a \in \mathcal{A}$ have more than one possible states), chains of relations defined on different subsets of $\mathcal{A}$ can be transformed into information processors by their mapping to segments of the time axis or, in the general case when the existence of time is not supposed, by their mapping to a well-ordered unbounded single-connected subset of a complete metric space. They process the information not using a language, though, if necessary, a language can be created by chains of relations at a certain stage of the information processing and thereupon can be used in the following information processing. The translation of information expressed in terms of chains of relations into the language-using form is accompanied by an inevitable loss of a certain part of the information.

In the present chapter we use the following logical notations: $\wedge$ - conjunction (... and ...), $\vee$ - disjunction (... or ..., but not both), $\forall$ - universal quantor (for all (...)), $\exists$ - exists (...), $\nexists$ - does not exists (...), $\Rightarrow$ - implication, $\Leftrightarrow$ - equivalence, necessary and sufficient condition, *i. e.*,

$(\varphi \Leftrightarrow \psi) = (\varphi \Rightarrow \psi) \wedge (\psi \Rightarrow \varphi)$.

1.2 CHAINS OF RELATIONS

Let $\mathcal{A} = \{a\}$ be a non-empty finite or infinite (countable or continuum) ordered set of elements $a = \{a_u\}$, each of which is a set of elements a_u.

Let $\mathcal{V} = \{v\}$ be a non-empty set of elements v of arbitrary nature, such that $\mathcal{V} \bigcap \mathcal{A} = \emptyset$. Then put a subset $\mathcal{V}_a \subset \mathcal{V}$ in correspondence to an element $a \in \mathcal{A}$ and call $\mathcal{V}_a$ PROPERTIES OF ELEMENT a. In special cases $\mathcal{V}_a$ may be also the properties of elements $a_u \in a$, which means that $\mathcal{V}_{a_u} \equiv \mathcal{V}_a$, but in the general case $\mathcal{V}_{a_u} \neq \mathcal{V}_a$. If a $\mathcal{V}_b \subset \mathcal{V}$ exists that is put in correspondence to a subset $b \subset \mathcal{A}$, this means that the subset b possesses properties. For our general consideration *only the existence of* $\mathcal{V}_b$ is necessary, but not how it can be determined. *In some particular cases* $\mathcal{V}_b$ may be function of $\forall \mathcal{V}_a \subset \mathcal{V}_b$.

Using properties of corresponding not empty subsets of the set $\mathcal{A}$, define relations ρ^b_α of different types α that are denoted also $c^b \rho^b_\alpha c'^b$, or $\langle c^b, c'^b \rangle \subset \rho^b_\alpha$, or $\langle c^b \mid \rho^b_\alpha \mid c'^b \rangle$ on subset $b \subset \mathcal{A}$, and, by analogy, relations $\rho^{b'}_{\alpha'}$ of different types α' that are denoted also $c^{b'} \rho^{b'}_{\alpha'} c'^{b'}$, or $\langle c^{b'}, c'^{b'} \rangle \subset \rho^{b'}_{\alpha'}$, or $\langle c^{b'} \mid \rho^{b'}_{\alpha'} \mid c'^{b'} \rangle$ on subset $b' \subset \mathcal{A}$ (Čech 1966, Gries & Schneider 1993) between **different non-empty non-intersected** subsets $c^b \subset b$ and between **different non-empty non-intersected** subsets $c^{b'} \subset b'$. Here and below (up to the end of this paper) b and b' are chosen so that $(\forall (b \subset \mathcal{A} \wedge b' \subset \mathcal{A}))[[(m(\mathcal{A}) \leq \aleph_0)[b \bigcap b' = \emptyset] \vee (m(\mathcal{A}) = \aleph)[\mu(b \bigcap b') = 0]] \wedge b \prec b']$,where $m(\mathcal{A}) \equiv Card(\mathcal{A})$ is the power of the set $\mathcal{A}$, and by $m(\mathcal{A}) < \aleph_0$ we denote the power of finite set. We shall use notation of the type $\langle || \rangle$ for relations because it is more comfortable in the present text than notations of the three other types written above. Notice that in the present chapter only binary relations are used (Čech 1966). All subsets of a set, *e. g.*, of the set $\mathcal{A}$, used in the present chapter are single-connected, *i. e.*, such that the following condition is satisfied: $(\forall ((a \in b \subset \mathcal{A}) \wedge (a' \in b \subset \mathcal{A}) \wedge (a \prec a') \wedge (a^* \in \mathcal{A})))[a^* \notin b] \Rightarrow ((\nexists) a^*)[a \prec a^* \prec a']$.

It is evident that $(\forall (b^\# \subset \mathcal{A}))[\langle c^{b^\#} \mid \rho^{b^\#}_\alpha \mid c'^{b^\#} \rangle = \Phi_\alpha(\mathcal{V}_{c^{b\#}}, \mathcal{V}_{c'^{b\#}})]$, where Φ_α is the function determining the subset $\rho^{b^\#}_\alpha$ of the set of all possible tuples at different $\mathcal{V}_{c^{b\#}}$ and $\mathcal{V}_{c'^{b\#}}$.

DEFINITION: *Two single-connected subsets* $b \subset \mathcal{A}$ *and* $b' \subset \mathcal{A}$ *are called* **neighbor subsets** *iff* $b \bigcup b'$ *is a single-connected subset of* $\mathcal{A}$.

DEFINITION: *Two relations* $\langle c^b \mid \rho^b_\alpha \mid c'^b \rangle \prec \langle c^{b'} \mid \rho^{b'}_{\alpha'} \mid c'^{b'} \rangle$ *are called* **neighbor relations** *iff* c'^b *and* $c^{b'}$ *are the neighbor subsets of* $\mathcal{A}$.

DEFINITION: *Two relations* $\langle c^b \mid \rho^b_\alpha \mid c'^b \rangle \prec \langle c''^b \mid \rho^b_\alpha \mid c'''^b \rangle$ *are called* **neighbor relations** *iff* c'^b *and* c''^b *are the neighbor subsets of* $\mathcal{A}$.

At each α the pair $(b, \langle c^b \mid \rho^b_\alpha \mid c'^b \rangle)$ is a structure on the set b (Enderton 1977) that, in its turn, is a subset of the set $\mathcal{A}$. Thus, the proposed theory can be expressed in terms of structures defined on different subsets b, b', b'' *etc.* of the set $\mathcal{A}$. It must be equivalent to the theory represented here.

Let us order two relations $\langle c^b \mid \rho^b_\alpha \mid c'^b \rangle$ and $\langle c''^b \mid \rho^b_{\alpha'} \mid c'''^b \rangle$ on the same non-empty subset $b \subset \mathcal{A}$ as well as two relations $\langle c^b \mid \rho^b_\alpha \mid c'^b \rangle$ and $\langle c^{b'} \mid \rho^{b'}_{\alpha'} \mid c'^{b'} \rangle$ on two different subsets $b \subset \mathcal{A}$ and $b' \subset \mathcal{A}$ correspondingly. Both subsets b and b' were introduced above.

DEFINE **I)** that $(\forall((c^b \subset b) \wedge (c'^b \subset b) \wedge (c''^b \subset b) \wedge (c'''^b \subset b)))[c^b \bigcap c'^b = \emptyset) \wedge c^b \bigcap c''^b = \emptyset) \wedge (c'^b \bigcap c''^b = \emptyset) \wedge (c'^b \bigcap c'''^b = \emptyset) \wedge (c^b \prec c'^b) \wedge (c'^b \prec c''^b) \wedge (c''^b \prec c'''^b)] \Leftrightarrow$
$[\langle c^b \mid \rho^b_\alpha \mid c'^b \rangle \prec \langle c''^b \mid \rho^b_{\alpha'} \mid c'''^b \rangle]$ and **II)** that $(\forall(c^b, c^{b'}))[[(m(\mathcal{A}) \leq \aleph_0)[b \bigcap b' = \emptyset] \vee (m(\mathcal{A}) = \aleph)[\mu(b \bigcap b') = 0]], c'^b \prec c^{b'}] \Leftrightarrow [\langle c^b \mid \rho^b_\alpha \mid c'^b \rangle \prec \langle c^{b'} \mid \rho^{b'}_{\alpha''} \mid c'^{b'} \rangle]$.

DEFINITION: The ordered sum (Kolmogorov & Fomin 1968, Abian 1965)

$$\mathbf{J}_n(\rho^{b^{(1)}}_{\alpha^{(1)}} \mid \cdots \mid \rho^{b^{(n)}}_{\alpha^{(n)}}) \stackrel{def}{=} \bigcup_{i=1}^{n} \langle c^{b^{(i)}} \mid \rho^{b^{(i)}}_{\alpha^{(i)}} \mid c'^{b^{(i)}} \rangle \qquad (1\text{-}1)$$

is the n-th - order CR at $n \geq 2$, iff the following conditions are satisfied: **1)**

$$(\forall(1 \leq i \leq n, 1 \leq j \leq n, j \neq i, j \neq \pm 1))[[(b^{(i)} \subset \mathcal{A}) \wedge b^{(i)} \neq \emptyset) \wedge (b^{(i)} \bigcap b^{(j)} = \emptyset) \wedge (m(\mathcal{A}) \leq \aleph_0)[b^{(i)} \bigcap b^{(i\pm1)} = \emptyset] \vee (m(\mathcal{A}) = \aleph)[\mu(b^{(i)} \bigcap b^{(i\pm1)}) = 0]], b^{(i-1)} \prec b^{(i)}]$$

2) $(\forall(1 \leq i \leq n{-}1))[(b^{*(i,i+1)} \subset \mathcal{A}) \wedge (b^{*(i,i+1)} \bigcap b^{(i)} = \emptyset) \wedge (b^{*(i,i+1)} \bigcap b^{(i+1)} = \emptyset) \wedge (b^{(i)} \prec b^{*(i,i+1)} \prec b^{(i+1)}) \wedge (m(\mathcal{A}) \leq \aleph_0)] \Rightarrow [b^{*(i,i+1)} = \emptyset] \vee (\forall(1 \leq i \leq n-1))[(b^{*(i,i+1)} \subset \mathcal{A}) \wedge b^{*(i,i+1)} \bigcap b^{(i)} = \emptyset) \wedge (b^{*(i,i+1)} \bigcap b^{(i+1)} = \emptyset) \wedge b^{(i)} \prec b^{*(i,i+1)} \prec b^{(i+1)}) \wedge (m(\mathcal{A}) = \aleph)] \Rightarrow (\forall(1 \leq i \leq n-1))[\mu(b^{*(i,i+1)}) = 0]$, or instead **2)**, the condition **2a)** $(\forall(2 \leq i \leq n))[\langle c^{b^{(i-1)}} \mid \rho^{b^{(i-1)}}_{\alpha^{(i-1)}} \mid c'^{b^{(i-1)}} \rangle$ and $\langle c^{b^{(i)}} \mid \rho^{b^{(i)}}_{\alpha^{(i)}} \mid c'^{b^{(i)}} \rangle$ *are neighbor relations*], and **3)** (at $n \geq 2$)

$$\mathbf{P}(\bigcup_{i=1}^{n} \langle c^{b^i} \mid \rho^{b^{(i)}}_{\alpha^{(i)}} \mid c'^{b^i} \rangle) > 0 \qquad (1\text{-}2)$$

The condition **2**) means that there is no non-empty (when $m(\mathcal{A}) \leq \aleph_0$) or having non-zero measure (when $m(\mathcal{A}) = \aleph$) subset of $\mathcal{A}$ between two subsets

c'^b and $c^{b'}$ such that $c'^b \bigcap c^{b'} = \emptyset$. The condition **2a)** is more restrictive than **2)**, and, if **2a)** is used instead **2)**, three conditions **1), 2a), 3)** together form the sufficient, but not the necessary condition that $\mathbf{J}_n$ is the n-th-order CR.

Notice that in this general consideration *only the existence* of the probability (1-2) is demanded while its concrete definition can be different. The application of the proposed theory to a concrete case is legal only after this probability is defined and the inequality (1-2) is proved. For example, the probability (1-2) in the case of finite or countable set $\mathcal{A}$ can be defined as the number of configurations of elements $a \in \mathcal{A}$ forming the considered CR, divided to the number of all possible configurations of elements of the set $\mathcal{A}$. Of course, this expression is not negative.The generalization of this definition to the case of continuum set $\mathcal{A}$ is evident.

As it is seen from Eqn.(1-1), a n-th-order CR is defined on the set $\bigcup_{i=1}^{n}(b_i \bigotimes b_i)$.

Let us consider the set $\mathcal{M}$ of all possible CRs that can be constructed of subsets of the given set $\mathcal{A}$ and thereupon ordered using properties of CRs. Let a set $\mathcal{A}'$ exists such that **a.)** $m(\mathcal{A}') = m(\mathcal{M})$, **b.)** $\mathcal{A}' \bigcap \mathcal{A} = \emptyset$, and **c.)** $\mathcal{A}' \bigcap \mathcal{M} = \emptyset$. Let us establish an isomorphism between the set $\mathcal{M}$ and a subset $\mathcal{A}'_{\mathcal{M}} \subseteq \mathcal{A}'$ such that $m(\mathcal{A}'_{\mathcal{M}}) = m(\mathcal{M})$. $\mathcal{A}'_{\mathcal{M}}$, in its turn, can be used to construct CRs of its subsets exactly by the same way as CRs can be constructed of subsets of the set $\mathcal{A}$. CRs can be also constructed using mixtures of subsets of $\mathcal{A}$ and subsets of $\mathcal{A}'_{\mathcal{M}}$: one CR could be built of relations defined on subsets of $\mathcal{A}$ as well as those defined on subsets of $\mathcal{A}'_{\mathcal{M}}$. The next step consists in the definition of 1-st expansion of the set $\mathcal{A}$ as $\mathcal{A}^{(1)} \stackrel{def}{=} \mathcal{A} \bigcup \mathcal{A}'_{\mathcal{M}}$. Then CRs will be built of subsets of the same set $\mathcal{A}^{(1)}$, and, therefore, among them can be subsets $b^{(i)}$ containing (in the same subset) elements of the set $\mathcal{A}$ as well as of the set $\mathcal{A}'_{\mathcal{M}}$. As the next step, let us replace elements of the subset $\mathcal{A}'_{\mathcal{M}} \subseteq \mathcal{A}'$ in the obtained CRs by their originals of the set $\mathcal{M}$, which themselves are CRs. Then we shall obtain constructions generalizing those (of $n > 2$ tuples) considered by Čech (1966), p. 24: $\langle\langle A, B\rangle, \langle C, D\rangle\rangle$;
$\langle X, \langle Y, Z\rangle\rangle$; $\langle\langle X, Y\rangle, Z\rangle$ *etc.* (in his notations), where $A,\ B,\ C,\ D,\ X,\ Y,\ Z$ can be subsets or, in particular, elements of a set. The same procedure of the expansion can be applied to the set $\mathcal{A}^{(1)}$. Then the second expansion $\mathcal{A}^{(2)}$ of the set $\mathcal{A}$ will be obtained *etc.*.

DEFINITION: *THE ORDERED SUBSET* $\mathcal{A}_S \stackrel{def}{=} (\mathcal{A} \setminus (\mathcal{A} \bigcap \mathcal{A}'_{\mathcal{M}})) \subset \mathcal{A}$ *IS CALLED THE* **SOURCE SET**.

If N subsequent expansions are possible, in the definition of the source set one must replace $\mathcal{A}'_{\mathcal{M}}$ by $\bigcup_{K=1}^{N} \mathcal{A}^{(K)}_{\mathcal{M}^{(K)}}$, where $K = 1, 2 \ldots N$ is the number of expansion, $\mathcal{M}^{(1)} \equiv \mathcal{M}$ and $\mathcal{A}^{(1)}_{\mathcal{M}^{(1)}} \equiv \mathcal{A}'_{\mathcal{M}}$.

In the case considered above the set $\mathcal{A}$ itself is the source set and, therefore, $\mathcal{A} \bigcap \mathcal{A}'_{\mathcal{M}} = \emptyset$. Indeed, the set $\mathcal{M}$ was obtained starting from the set $\mathcal{A}$, while the set $\mathcal{A}$ was considered as given. However, it must be taken into account that $\mathcal{A}$ may be defined so that it will denote, for example, the $\mathcal{A} \equiv \mathcal{A}^{(1)} \stackrel{def}{=} \mathcal{A}_S \bigcup \mathcal{A}'_{\mathcal{M}}$, while $\mathcal{A}_S$ will be given. In an abstract mathematical theory the nature of elements $a \in \mathcal{A}$ is not defined concretely, they can be of arbitrary nature, and because of it *one can postulate* that $\mathcal{A}_S \stackrel{def}{=} \mathcal{A}$. However, in certain particular cases, elements of the source set can be identified, for example, as neurons of the brain or units of an artificial neural network (where a_u are states of neuron a) or to be abstract mathematical objects created by the computer program, which means that an isomorphism is established between the set of these objects, *e. g.*, neurons in the brain or units of an artificial neural network, and an abstract set $\mathcal{A}_S$. Then the choice of the source set is not arbitrary, but is determined by the nature and structure of the studied system.

1.3 INFORMATION PROCESSING BY THE CR ACTIVATION

Let $\mathcal{H} = \{h\}$ $(\mathcal{H} \bigcap \mathcal{A} = \emptyset)$ be a well ordered unbounded single-connected subset of a complete metric space (Kolmogorov & Fomin 1968, Bachman & Narici 1966), where the distance $\mathbf{r}(h, h')$ between two points h and h' is defined. Denote $\mathcal{H}^{(k)}_{\mathcal{Y}}$ homomorphism keeping the order of a certain well ordered single-connected set $\mathcal{Y}$, e. g., $\mathcal{Y} \subset \mathcal{A}$, to a certain well ordered single-connected subset $\mathcal{H}^{(k)} \subset \mathcal{H}$, where k is a natural number. Then **1.** $(\forall(k \geq 1, k' \geq 1))[\mathcal{H}^{(k)} \prec \mathcal{H}^{(k'>k)}, \mathcal{H}^{(k)} \bigcap \mathcal{H}^{(k' \neq k)} = \emptyset] \Rightarrow (\forall(k \geq 1, k' \geq 1))[\mathcal{H}^{(k)}_{\mathcal{Y}} \prec \mathcal{H}^{(k'>k)}_{\mathcal{Y}}, \mathcal{H}^{(k)}_{\mathcal{Y}} \bigcap \mathcal{H}^{(k' \neq k)}_{\mathcal{Y}} = \emptyset]$ and **2.** $(\nexists(\mathcal{H}^{(k'')}))[\mathcal{H}^{(k'')} \prec \mathcal{H}^{(1)}] \Rightarrow$ $(\nexists(\mathcal{H}^{(k'')}_{\mathcal{Y}}))$
$[\mathcal{H}^{(k'')}_{\mathcal{Y}} \prec \mathcal{H}^{(1)}_{\mathcal{Y}}]$. This means, the set of considered maps is well ordered as a consequence that the set $\mathcal{H}$ is well ordered. It, evidently, remains valid also when maps of different $\mathcal{Y}$, *e. g.*, $\mathcal{Y}^{(1)}$, $\mathcal{Y}^{(2)}$, ..., to these subsets of the set $\mathcal{H}$ are considered. Thus, $\mathcal{H}$ can be used as the generalization of time, if $\mathcal{H}^{(k-1)}_{\mathcal{Y}}$, $\mathcal{H}^{(k)}_{\mathcal{Y}}$, $\mathcal{H}^{(k+1)}_{\mathcal{Y}}$ (for all values of k) be neighbor subsets. In some particular cases time can be chosen as $\mathcal{H}$, in other cases $\mathcal{H}$ can be used in systems where time does not exist, as well as in systems where a number > 1 of different kinds of the time exist, *e. g.*, biological systems where the physical time exists as well as some different types of biological time.

The physical time t has only one direction (the excellent discussion of the time direction problem is contained in the book of Ilya Prigogine (1996) and we refer the reader to this book). It seems reasonable that other types of time, *e. g.,* different biological times , are also single-directional. The necessary and sufficient condition that (generalized) time is single-directional, can be written as follows: $(\forall(\mathcal{Y}^{(1)},\mathcal{Y}^{(2)}))[\mathcal{Y}^{(1)} \prec \mathcal{Y}^{(2)}, \mathcal{Y}^{(1)} \bigcap \mathcal{Y}^{(2)} = \emptyset] \Leftrightarrow (\forall(\mathcal{H}_{\mathcal{Y}^{(1)}\bigcup\mathcal{Y}^{(2)}}))[\mathcal{H}_{\mathcal{Y}^{(1)}\bigcup\mathcal{Y}^{(2)}} = \mathcal{H}_{\mathcal{Y}^{(1)}} \bigcup \mathcal{H}_{\mathcal{Y}^{(2)}}, \mathcal{H}_{\mathcal{Y}^{(1)}} \bigcap \mathcal{H}_{\mathcal{Y}^{(2)}} = \emptyset, \mathcal{H}_{\mathcal{Y}^{(1)}} \prec \mathcal{H}_{\mathcal{Y}^{(2)}}]$. The first equality in the right hand side allows one to connect this condition with the laws of nature, for example, physical laws. Thus, the Bohr time-energy uncertainty principle (see, for example, Landau & Lifshiz 1977) states that this equality would not be implemented, if two events $\mathcal{Y}^{(1)}$ and $\mathcal{Y}^{(2)}$ (in our notations) are separated by the time interval shorter than the time uncertainty. It would be very interesting to check whether this condition is implemented, for example, for all types of biological time.

If in a system a number > 1 of different types of time exists, *e. g.,* in a biological system, different processes in such a system may occur according different types of time. For example, in kinetic equations the physical time will be replaced by a biological time relevant to the considered type of processes. In an organism different processes may influence each other, and because of this time relevant to one type of such processes could appear in equations of processes occurring according another type of time. Such an "entanglement of times of different types" suggests the idea that in the general case a **set of relevant types of time should replace the "ordinary" physical time**. Whether such a set forms a matrix, maybe even tensor, it should be checked in each concrete case.

If the ordering of $\mathcal{Y}$ and the one of a certain $\mathcal{H}$ do not permit the above-mentioned homomorphism keeping the order, this $\mathcal{H}$ cannot be used as a type of time. It refers, in particular, to the physical time t: in this case the physical time t cannot be introduced and it is to search for other than t set $\mathcal{H}$ that can replace it. This means, **a criterion of the existence of a certain type of time**, *e. g.,* "ordinary" physical time t, is the possibility to establish homomorphism *keeping the order* between the considered subsets $\mathcal{Y}^{(1)}$, $\mathcal{Y}^{(2)}$, $\ldots \mathcal{Y}^{(k)}$, $\ldots$ and the corresponding set $\mathcal{H}$, *e. g.,* physical time t.

Denote $\mathcal{P}_{\mathcal{A}}((\forall(a \in \mathcal{A}))[a_u \in \{a_{u'}\} = a])$ the probability of different a_u in set $\{a_u\}$ at each a for all a (but not the probability of different a or their sets!), assuming that only such sets $\mathcal{A}$ are considered where this probability exists. In the case when **1)** such probability exists for each $a = \{a_u\}$, **2)** these probabilities for different a are statistically independent, and **3)** $\mathcal{A}$ is a countable set $\mathcal{A} = \{a^{(j)}\}$, $a^{(j)} = \{a_u^{(j)}\}$ ($\{j\}$ is a finite or infinite subset of the set of natural numbers), we have $\mathcal{P}_{\mathcal{A}}((\forall(a \in \mathcal{A}))[a_u \in \{a_{u'}\} = a]) = \prod_{\forall j} p_u^{(j)}$, where $p_u^{(j)}$ is the probability of element $a_u^{(j)}$ defined on the set $\{a_u^{(j)}\} = a^{(j)}$ at a given value of j.

The probability $\mathcal{P}_{\mathcal{A}}$ may be changed if an operator $\hat{U}_{\mathcal{A}}$ operated upon the set $\mathcal{A}$, acting upon elements a_u at each a as follows:

$$\hat{U}_{\mathcal{A}}((\forall(a \in \mathcal{A}))[a_u \in \{a_{u''}\} = a]) = (\forall(a \in \mathcal{A}))[a_{u'} \in \{a_{u''}\} = a], \qquad (1\text{-}3)$$

which means that a_u is replaced by $a_{u'}$.

Then

$$\mathcal{P}_{\mathcal{A}}(\hat{U}_{\mathcal{A}}((\forall(a \in \mathcal{A}))[a_u \in \{a_{u''}\} = a])) = \mathcal{P}'_{\mathcal{A}}(\forall(a \in \mathcal{A})[a_{u'} \in \{a_{u''}\} = a]) \qquad (1\text{-}4)$$

$[\hat{U}_{\mathcal{A}} = \hat{I}_{\mathcal{A}}] \Rightarrow [\mathcal{P}'_{\mathcal{A}} = \mathcal{P}_{\mathcal{A}}]$, where $\hat{I}_{\mathcal{A}}$ is the unit operator, but the statement $[\hat{U}_{\mathcal{A}} \neq \hat{I}_{\mathcal{A}}] \Rightarrow [\mathcal{P}'_{\mathcal{A}} \neq \mathcal{P}_{\mathcal{A}}]$ is not correct as the *general* one. Define the probability

$$\mathcal{P}_{\varrho}(\forall(a \in \varrho)[a_u \in \{a_{u'}\} = a]) \stackrel{def}{=} \sum_{\forall a \in (\mathcal{A} \setminus \varrho)} \mathcal{P}_{\mathcal{A}}(\forall(a \in \mathcal{A})[a_u \in \{a_{u'}\} = a]) \qquad (1\text{-}5)$$

(if $m(\mathcal{A}) = \aleph$, the sum must be replaced by an integral), where $\varrho \subset \mathcal{A}$ denotes the set of elements a included into relation ρ. Notice that Eqn. (1-5) defines such a probability not only for ϱ, but for any subset of the set $\mathcal{A}$. Let $\hat{U}_{\varrho}$ be the operator acting upon ϱ (or upon any other subset of $\mathcal{A}$) as follows:

$$\hat{U}_{\varrho}((\forall(a \in \varrho))[a_u \in \{a_{u''}\} = a]) = (\forall(a \in \varrho))[a_{u'} \in \{a_{u''}\} = a] \qquad (1\text{-}6)$$

Then

$$\mathcal{P}_{\varrho}(\hat{U}_{\varrho}((\forall(a \in \varrho))[a_u \in \{a_{u''}\} = a])) = \mathcal{P}'_{\varrho}((\forall(a \in \varrho))[a_{u'} \in \{a_{u''}\} = a]) \qquad (1\text{-}7)$$

$[\hat{U}_{\varrho} = \hat{I}_{\varrho}] \Rightarrow [\mathcal{P}'_{\varrho} = \mathcal{P}_{\varrho}]$, where $\hat{I}_{\varrho}$ is the unit operator, but the statement $[\hat{U}_{\varrho} \neq \hat{I}_{\varrho}] \Rightarrow [\mathcal{P}'_{\varrho} \neq \mathcal{P}_{\varrho}]$ is not correct as the *general* one.

Let us establish the homomorphism $\mathcal{H}_{\rho}^{(k)}$ of $\hat{U}_{\varrho}\rho$ to a single-connected bounded subset $\mathcal{H}^{(k)} \subset \mathcal{H}$. The pair $\mathbf{t}_{\rho}^{(k)} \stackrel{def}{=} (\hat{U}_{\varrho}\rho, \mathcal{H}_{\rho}^{(k)})$ we shall call the **activation of the relation** ρ. *In the following text we shall write for short* $\rho_i \equiv \rho_i^{b(i)}$ *for relations belonging to a CR.*

DEFINITION: The ordered sum

$$\mathbf{T}_n \stackrel{def}{=} \bigcup_{i=1}^{n} \mathbf{t}_{\rho_i}^{(i)} \equiv \bigcup_{i=1}^{n} (\hat{U}_{\varrho_i}\rho_i, \mathcal{H}_{\rho_i}^{(i)}), \tag{1-8}$$

is called **activation of the chain of relations (ACR)** of n-th order, iff a)$\mathbf{t}_{\rho_i}^{(i)}$ $(i = 1, 2, \ldots, n)$ keeps the order of ρ_i in $\mathbf{J}_n$, b) ordered sum $\mathcal{H}(\mathbf{J}_n^*) \stackrel{def}{=} \bigcup_{i=1}^{n} \mathcal{H}_{\rho_i}^{(i)}$ is a single-connected subset of $\mathcal{H}$, c) $(\forall(\rho_i \subset \mathbf{J}_n))(\exists \mathcal{H}_{\rho_i})[(\hat{U}_{\varrho_i}\rho_i, \mathcal{H}_{\rho_i}) \neq (\hat{I}_{\varrho_i}\rho_i, \mathcal{H}_{\rho_i})]$, where $\mathbf{J}_n^*$ means $\mathbf{J}_n$, in which $(\forall(\rho))[\rho$ *is replaced by* $\hat{U}_\varrho \rho]$.

If $(\exists h_1 \in \mathcal{H})[\mathcal{H}(\mathbf{J}_n^*) \prec h_1]$, i.e., $(\forall(h \in \mathcal{H}(\mathbf{J}_n^*)))[h \prec h_1]$, then $\mathbf{T}_n$ is called a **complete ACR**. A complete ACR can be stored in a memory and thereupon recalled from the memory so that all $\mathcal{H}_{\rho_i}^{(i)}$ in Eqn.(1-8) will be replaced by $\mathcal{H}_{\rho_i}^{'(i)}$ such that $(\forall(1 \leq i \leq n))[\mathcal{H}_{\rho_i}^{'(i)} \succ h_1]$.

The information corresponding to the transition ρ to $\hat{U}_\varrho \rho$ is $\mathcal{I} = K ln(\mathcal{P}'_\varrho / \mathcal{P}_\varrho)$ (Kullback 1958, Brillouin 1956), where $K = const.$

We shall call a pair $V_{i,i+1} = \{\hat{U}_{\rho_i}\rho_i, \hat{U}_{\rho_{i+1}}\rho_{i+1}\}$ **VERTEX** corresponding to two neigbor relations $\rho_i \prec \rho_{i+1}$. Let us consider the case (we shall call it **case A**) when $(\forall(\rho_j \subset \mathbf{J}_n) \wedge (\forall(\mathcal{H}_{\rho_{i+1}}^{(l)} \subset \mathcal{H})))$ $[(\mathcal{H}_{\rho_{i+1}}^{(l)} \prec \mathcal{H}_{\rho_{i+1}}) \wedge (\mathcal{H}_{\rho_{i+1}}^{(l)} \bigcap \mathcal{H}_{\rho_{i+1}} = \emptyset) \wedge ((\hat{U}_{\varrho_{i+1}}\rho_{i+1}, \mathcal{H}_{\rho_{i+1}}^{(l)}) = (\hat{I}_{\varrho_{i+1}}\rho_{i+1}, \mathcal{H}_{\rho_{i+1}}^{(l)})) \wedge (\hat{U}_{\varrho_i}\rho_i, \mathcal{H}_{\rho_i}) \neq (\hat{I}_{\varrho_i}\rho_i, \mathcal{H}_{\rho_i}))] \Rightarrow [(\hat{U}_{\varrho_{i+1}}\rho_{i+1}, \mathcal{H}_{\rho_{i+1}}) \neq (\hat{I}_{\varrho_{i+1}}\rho_{i+1}, \mathcal{H}_{\varrho_{i+1}})]$.

Let be also $(\forall(\rho_j \subset \mathbf{J}_n) \wedge (\forall(\mathcal{H}_{\rho_{i+1}}^{(l)} \subset \mathcal{H})))$ $[\mathcal{H}_{\rho_{i+1}}^{(l)} \prec \mathcal{H}_{\rho_{i+1}} \wedge \mathcal{H}_{\rho_{i+1}}^{(l)} \bigcap \mathcal{H}_{\rho_{i+1}} = \emptyset \wedge (\hat{U}_{\varrho_{i+1}}\rho_{i+1}, \mathcal{H}_{\rho_{i+1}}^{(l)}) = (\hat{I}_{\varrho_{i+1}}\rho_{i+1}, \mathcal{H}_{\rho_{i+1}}^{(l)}) \wedge (\hat{U}_{\varrho_i}\rho_i, \mathcal{H}_{\rho_i}) \neq (\hat{I}_{\varrho_i}\rho_i, \mathcal{H}_{\rho_i})] \Rightarrow [(\mathcal{P}_{\varrho_{i+1}}(\hat{U}_{\varrho_{i+1}}\rho_{i+1}), \mathcal{H}_{\rho_{i+1}}) \neq (\mathcal{P}_{\varrho_{i+1}}(\rho_{i+1}), \mathcal{H}_{\varrho_{i+1}})]$ (notice that this is not the general case).

This means, the change of the probability $\mathcal{P}_{\varrho_{i+1}}(\rho_{i+1})$ to $\mathcal{P}'_{\varrho_{i+1}}(\rho_{i+1}) = \mathcal{P}_{\varrho_{i+1}}(\hat{U}_{\varrho_{i+1}}\rho_{i+1})$ occurs under the condition that a change occured in the pair $(\hat{U}_{\varrho_i}\rho_i, \mathcal{H}_{\rho_i})$.

Introduce the conditional probability $\mathcal{P'}_{\varrho_{i+1}}(\mathcal{H}_{i+1}; \hat{U}_{\varrho_i}; \mathcal{H}_i)$ of the change in the pair $(\hat{U}_{\varrho_{i+1}}\rho_{i+1}, \mathcal{H}_{\rho_{i+1}})$ under the condition that the change occurred in the pair $(\hat{U}_{\varrho_i}\rho_i, \mathcal{H}_{\rho_i})$. Then the information corresponding to the vertex $V_{i,i+1}$ will be $\mathcal{I}_{i,i+1} = K ln[\mathcal{P}'_{\varrho_{i+1}}(\mathcal{H}_{i+1}; \hat{U}_{\varrho_i}\rho_i; \mathcal{H}_i) / \mathcal{P}_{\varrho_{i+1}}(\mathcal{H}_i)]$. This means, the *amount* of the information emerged at the transition ρ_i to $\hat{U}_{\varrho_i}\rho_i$ is $\mathcal{I}$, but, in addition, this transition provokes the emergence of the information $\mathcal{I}_{i,i+1}$, which increases the *value* (Eigen 1971, Volkenstein 1977, Packel *et al.* 1992) of the information emerged at this transition. The information obtained as a result of the n-th-order CR activation under the condition that the transition ρ_1 to $\hat{U}_{\varrho_1}\rho_1$ has occured will be as follows: $\mathcal{I}_{1,n} = K ln[\mathcal{P}'_{\varrho_n}(\mathcal{H}_n; \hat{U}_{\varrho_1}\rho_1; \mathcal{H}_1) / \mathcal{P}_{\varrho_n}(\mathcal{H}_{n-1})]$, where $\mathcal{P}'_{\varrho_n}(\mathcal{H}_n; \hat{U}_{\varrho_1}\rho_1; \mathcal{H}_1)$ is determined

as a result of the subsequent transitions at verices $V_{1,2}, V_{2,3}, \ldots V_{n-1,n}$. Then $\mathcal{I}_{1,n}$ is emerged as a result of this sequence of transitions and the corresponding negentropy (Brillouin 1956) is the
whole entropy change at the CR activation. $\mathcal{I}_{1,n}$ $\rho_{i\leq n}$ determines that part of the *value* of the information (Eigen 1971, Volkenstein 1977, Packel *et al.* 1992) emerged at the ρ_1 activation, which corresponds to the n-th-order CR activation. What provokes the ρ_1 activation, in other words, the initiation of the CR activation, depends on concrete system processing the information. In particular, it may be provoked by internal processes in the considered system (that cannot be considered in the present chapter), by an external source or may be included to the computing program.

The meaning of the written above (case **A**) becomes clear, if the time is chosen as the set $\mathcal{H}$ and one considers the propagation of a pulse through a CR constructed of units of a neural network. Then the consideration made above means that the activation of a relation (belonging to a CR) induces the activation (in a certain time) of its neighbor next one. The activation of a CR is, in this example, a process because the concept of time is introduced. In the **case A** this statement is correct also when the time does not exists, and a set $\mathcal{H}$ is used to define the activation of CRs .

Two relations ρ_i and $\rho_{i+1} \succ \rho_i$ themselves are different because a) the subsets $c^{b^{(i)}}$ and $c'^{b^{(i)}}$ are different from those $c^{b^{(i+1)}}$ and $c'^{b^{(i+1)}}$, and b) these relations are built on the grounds of different properties of the considered subsets: $\rho_i = \Phi_i(\mathcal{V}_{c^{b(i)}}, \mathcal{V}_{c'^{b(i)}})$, while
$\rho_{i+1} = \Phi_{i+1}(\mathcal{V}_{c^{b(i+1)}}, \mathcal{V}_{c'^{b(i+1)}})$. In other words, ρ_i and ρ_{i+1} have different *set theoretical sense.* Notice, it is principally important that $\mathcal{V}_{c^{b(i)}}$ *etc.* are determined by $\mathcal{V}_{a_u}$ of all $a_u = \{a_{u'}\} = a \in c^{b^{(i)}}$, and, therefore, generally speaking, are changed when operator $\hat{U}_{\varrho_i}$ acts upon ρ_i, which can be described, for example, in terms of probabilities $\mathcal{P}_{\varrho}$ and $\mathcal{P}'_{\varrho}$ defined above.

Another kind of sense (besides of the set theoretical one), *e. g.*, a proposition (Church 1956), can be assigned to a relation so that rules are defined connecting the relation structure with the assigned proposition. Then each vertex will correspond to a transition from one proposition to another, which means that the proposition assigned to $\hat{U}_{\varrho_i}\rho_i$ creates the new one assigned to $\hat{U}_{\varrho_{i+1}}\rho_{i+1}$, and therefore $\mathbf{T}_n$ will correspond to a sequence of propositions, where each proposition is created by the foregoing one. This means, at a convenient choice of senses assigned to relations in conformity with their structures, $\mathbf{T}_n$ processes the information and can be called **information processor** . Notice that unlike the set theoretical information (corresponding to the set theoretical meaning of relations) the amount of this information cannot be found in the general case, but only for each concrete case separately. At such calculations it must be taken into account that this information may have different VALUE (Eigen 1971, Volkenstein 1977, Packel *et al.* 1992) in different cases that complicates calculations of its amount.

EXAMPLE. Let $\mathcal{A} = \{a^{(1)},\ a^{(2)},\ a^{(3)},\ a^{(4)}\}$, where $a^{(1)} = \{a_1^{(1)},\ a_2^{(1)}\}$, $a^{(2)} = \{a_1^{(2)},\ a_2^{(2)}\}$, $a^{(3)} = \{a_1^{(3)},\ a_2^{(3)}\}$, $a^{(4)} = \{a_1^{(4)},\ a_2^{(4)}\}$. Let be $f = f(a^{(i)})$ the value of a bounded continuous function $f(\xi)$ of the real variable ξ at $\xi = a^{(i)}$, where $i = 1,\ 2,\ 3,\ 4$. Define two relations:

$$\langle a^{(1)} \mid \rho_1 \mid a^{(2)} \rangle = \eta(f(a^{(1)}) - f(a^{(2)}))$$

and

$$\langle a^{(3)} \mid \rho_2 \mid a^{(4)} \rangle = \eta(f(a^{(3)}) - f(a^{(4)})),$$

where $\rho_1 \prec \rho_2$ in the considered CR, and $\eta(z)$ is Heavyside function: $\eta(z) = 0$ *when* $z < 0$, $\eta(z) = 1$ *when* $z > 0$. The meaning of the relations ρ_1 and ρ_2 can be explained as follows: $\langle a^{(1)}, a^{(2)} \rangle \in \rho_1$, iff **1)** to each set of numeric values of $a_1^{(1)}, a_2^{(1)}, a_1^{(2)}, a_2^{(2)}$ correspond values $f(a^{(1)})$ and $f(a^{(2)})$ of the function $f(\xi)$, **2)** the difference between these values of f is, the argument of a bounded function (Heavyside function in the considered example). The same is correct also for $\langle a^{(1)}, a^{(2)} \rangle \in \rho_1$. For example, $a^{(i)}$ can be two-state neurons of a neural network and $f(a^{(i)})$ values of the potential on the neuron $a^{(i)}$ (Hopfield 1982).

Define now that $(\forall\alpha)[\langle a_2^{(i)} \mid \rho_\alpha \mid a_2^{(i')} \rangle = 1] \Rightarrow (\exists x)[xy > 0]$ and $(\forall\alpha)[\langle a_2^{(i)} \mid \rho_\alpha \mid a_2^{(i')} \rangle = 0] \Rightarrow (\forall x)[xy < 0]$, where $\alpha = 1,\ 2$, while x and y are real numbers and $i, i' = 1,\ 2,\ 3,\ 4$. Then, if at the subsequent realization of ρ_1 and ρ_2 is obtained $[\langle a_2^{(1)} \mid \rho_1 \mid a_2^{(2)} \rangle = 1; \mathcal{H}(\rho_1)] \Rightarrow [\langle a_2^{(3)} \mid \rho_2 \mid a_2^{(4)} \rangle = 0; \mathcal{H}(\rho_2)]$, this means that $(\exists x)[xy > 0 \mid \mathcal{H}(\rho_1)] \Rightarrow (\forall x)[xy < 0 \mid \mathcal{H}(\rho_2)]$, i.e., the first proposition creates the second one at the next subset of $\mathcal{H}$ (*e.g.*, the next time interval, if the time is chosen as the set $\mathcal{H}$). This result can be easily generalized to the case when *any* meaning is assigned to relations, but not specially propositions. Indeed, if two considered propositions are replaced by two subsets $\mathcal{Z}_{\rho_i} \subset \mathcal{Z} = \{z\}$ $(i = 1, 2)$ assigned *according the established rules* to the same relations ρ_1 and ρ_2, then instead the last statement one will obtain $[\mathcal{Z}_{\rho_1}; \mathcal{H}(\rho_1)] \Rightarrow [\mathcal{Z}_{\rho_2}; \mathcal{H}(\rho_2)]$. The generalization to the case of more than two subsequent relations and more than two elements of each set $\{a_u\}$ is evident.

Notice that the last result obtained without use of any language indicates that ACRs process the information without the language use. A language, *e.g.*, a formal one (Salomaa 1973), can be constructed from CRs and used in the information processing. With this purpose the alphabet should be constructed from relations so that each letter (or hieroglyph) is to be assigned to a relation, thereupon the grammar should be formulated and so on. A proposition expressed in a language is, of course, assigned not to a relation, but to a CR (or its part). This means, a proposition assigned to a relation must be now assign to a CR (or its part), if we transit to the language-used representation of the information obtained by ACRs' information processing. The information will not be lost or distorted at this transition, iff an isomorphism exists between ACRs representing propositions in non-language form and those in language form (*i. e,* by letters). If the number of all possible ACRs be unlimited, this condition may be satisfied in some special cases (even it is not evident and must be proved). But in real situations when the number of all possible ACRs is limited because properties generating relations (see §1.2) could be exhausted, as well as because the effect of ACRs' intersections (that will be considered in our third article on this subject), this condition, generally speaking, will not be satisfied. Thus, the information obtained by the ACRs information processing may be lost in part or/and distorted by the transition to language form of the information representation. If such a transition occurs at the output writing in language form and this output is input to continue the information processing, the final output obtained by use of a number of such pairs "output - input" may be erroneous.

The transition from $\mathcal{Z}_{\rho_1}$ to $\mathcal{Z}_{\rho_2}$ considered above may be logical, but may be not logical because processes in $\mathcal{A}$ occur according their own laws that, in general, have nothing to do with CRs activation. Indeed, besides the probabilities $\mathcal{P}_{\varrho}((\forall a \in \rho)[a_u \in \{a_{u'}\} = a])$ and operators $\hat{U}_{\varrho}$, probabilities $\mathcal{P}_{\mathcal{B}\subset\mathcal{A}}((\forall a \in \mathcal{B})[a_u \in \{a_{u'}\} = a])$ can be obtained from $\mathcal{P}_{\mathcal{A}}$ and operators $\hat{U}_{\mathcal{B}\subset\mathcal{A}}$ acting upon $\mathcal{B} \subset \mathcal{A}$ can be defined. Thus, really the "activation" of different $\mathcal{B} \subset \mathcal{A}$ occurs, and only in particular cases these subsets coincide with a CR, but even in such "successful" cases transitions at vertices are not obligatory logical. It is seen from the case when operator $\hat{U}_{\mathcal{A}}$ is expressed in terms of one-element operators and *small* two-element ones (perturbations). Then the considered process may be stochastic and the probability of a CR activation and the corresponding amount of information can be calculated by the theory of stochastic processes. If one wants to make these transitions logical, it must include (for example, to the software) corresponding constraints, which is a simple method to govern the information processing. This is a particular case of the general problem, how the information processing by ACRs is governed in computing by computers or neural networks, in human thinking *etc.*.

1.4 CASE: a_u ARE QUANTUM STATES OF a

Let us consider here physical systems accepting time t as the set $\mathcal{H}$. Then physical objects forming this system will be identified with elements $a \in \mathcal{A}$, or, exactly, an isomorphism will be established between these physical and mathematical objects. We shall limit ourselves with the case when the positions of these physical objects, *e. g.,* atoms, can be described in the framework of the classical mechanics. In the following consideration we shall mean that these physical objects are atoms with electronic spin 1/2 each. Then a_u will be the possible spin states ($u = 1,\ 2$) of such an atom a. Of course, it is only an example of physical systems, for which our consideration is valid.

If these electron spins do not interact with the system of atoms, they are described by the wave function $\psi_{\mathcal{A}}((\forall(a \in \mathcal{A}))[a_u \in \{a_{u'}\} = a]; \{\vec{r}_a\})$. In more real case, when the interaction of electron spins with the system of atoms (*e. g.,* spin - orbit interaction) cannot be neglected, the ψ - function does not exists, and , instead of it, the density matrix (operator) $\hat{w}_{\mathcal{A}}((\forall(a \in \mathcal{A}))[a_u \in \{a_{u'}\} = a]; \{\vec{r}_a\})$. This density matrix is the solution of the equation

$$\hat{\dot{w}} = \hbar^{-1}(\hat{w}_{\mathcal{A}}\hat{H}_{\mathcal{A}} - \hat{H}_{\mathcal{A}}\hat{w}_{\mathcal{A}}),$$

where $\hat{H}_{\mathcal{A}}$ is the Hamiltonian of the system $\mathcal{A}$.

For a subsystem of $\mathcal{A}$, *e. g.,* $\varrho \subset \mathcal{A}$ only density matrix description is valid, in exception of the case when there is not an interaction between spins of the considered subsystem and the rest of the whole system, and therefore, the wave function description is valid.

In the considered case operators $\hat{U}_{\mathcal{A}}$ and $\hat{U}_{\varrho}$ are quantum mechanical operator s acting upon spins. The activation of a relation ρ means the excitation of spin states of $a \in \varrho$.

The theory developped in previous sections of this chapter, as well as in Chs. 2 and 3, can be rewritten for the considered quantum case. However, here we limit ourselves with this short indication how it can be done.

1.5 CONCLUSIONS

It was shown that an ordered set $\mathcal{A} = \{a\}$ can serve as a system processing the information by information processors (ACR) obtained from certain combinations (CR) of its elements a, if $\mathcal{A}$ possesses properties necessary to construct relations between its different subsets. This processing of the information by this system *does not demand the use of any language*, however, a language can be constructed from CRs and used in the information processing. The translation of the information expressed in terms of CRs into the one expressed by a language is accompanied by an inevitable loss of the information.

The considered method of the information processing by the system $\mathcal{A}$ can be used for computations by computers as well as by neural networks. In the last case the neural net (or each of its subregions separately) must be ordered using its relevant properties, and then it (or each its subregion) can be considered as the source set $\mathcal{A}_S$. The level of the information processing by ACRs is higher than the one by neurons themselves. Moreover, CRs can be used to obtain the expanded set $\mathcal{A}^{(1)}$ that will play the role of the set $\mathcal{A}$ in our consideration to create new CRs which, in their turn, can be used to obtain the second expansion $\mathcal{A}^{(2)}$ of the source set *etc.* The number of such expansions of the source set is limited because the properties (see §1.2) necessary to create relations could be exhausted at a certain step, as well as because of the effect of ACRs' intersection that will be considered in our other paper. Thus, one will obtain different levels of the information processing by the neural network. Perhaps to model successfully the human brain by a neural network is impossible, if different levels of the information processing by ACRs are not taken into account (Ch. 4).

1.6 REFERENCES TO CHAPTER 1.

Abian, *Alexander*: 1965, *THE THEORY OF SETS AND TRANSFINITE ARITHMETIC*, Chapter 4, §5, p.p. 308 - 310. W. B. Saunders Company, Philadelphia and London.

Bachman, *George* & Narici, *Lawrence*: 1966, FUNCTIONAL ANALYSIS. Academic Press, New York & London.

Brillouin, *Leon*: 1956, *Science and Information Theory*. Acad. Press, Inc. Publishers, New York.

Čech, *Edward*: 1966, *Topological Spaces*. Interscience Publishers, A Division of John Willey & Sons, London-New York-Sydney.

Church, *Alonso*: 1956, *Introduction to Mathematical Logic*. Volume 1. Princeton University Press.

Eigen, *Manfred*: 1971, *Selforganization of Matter and the Evolution of Biological Macromolecules*. Naturwiss. **58**, 465-523.

Enderton, *Herbert B.*: 1977, *ELEMENTS OF SET THEORY*. Acad. Press, New York - San Francisco - London.

Gries, *David* & Schneider, *Fred B.*: 1993, *A Logical Approach to Discrete Math*. Springer-Verlag, New York, Inc..

Hopfield, *J. J.*: 1982, *Neural Networks and Physical Systems with Emergent Computational Abilities*. Proc. Nat'l Acad. Sci. (USA) **79**, 2554-2558.

Kolmogorov, *A.N.*& Fomin,*S.V.*: 1968, *Elementy Theorii Funktsiy i Functional'nogo Analysa*. 2-nd Edition. Nauka, Moskva.

Kullback, *Salomon*: 1958, *INFORMATION THEORY AND STATISTICS*. New York-John Wiley & Sons, Inc., London-Chapman & Hall, Limited.

Landau, *L. D.* & Lifshiz, *E. M*: 1977, *QUANTUM MECHANICS: NON-RELATIVISTIC THEORY*. Pergamon Press, Oxford.

Packel, *Edward W.*, Traub, *J. F.*, Woźniakowski, *Henryk*: 1992, *Measures of Uncertainty and Information in Computation*, Inf. Sci. **65**, 253-273.

Prigogine, *Ilya*: 1996, *LA FIN DES CERTITUDES*. Édition Odile Jacob, Paris.

Volkenstein, *M.V*: 1977, *The Amount and Value of Information in Biology*. Found. Phys. **7**, 97-109.

Chapter 2

ON THE MEMORY CONSTRUCTION FOR INFORMATION PROCESSING BY CHAINS OF RELATIONS

2.1 INTRODUCTION

In Ch. 1 was found that chains of relations (CRs) between different non-empty non-intersected single-connected subsets of an non-empty ordered set $\mathcal{A} = \{a\}$ of elements $a = \{a_u\}$, each of which is a set of elements a_u, can be transformed into information processors that were called activated chains of relations (ACRs). Properties of elements a as well as of a_u for each a were introduced as subsets of a given set. Using these properties, various relations $\langle c^b, c'^b \rangle \subset \rho^b_\alpha$ (Čech 1966, Gries & Schneider 1993), or, in our notations, $\langle c^b \mid \rho^b_\alpha \mid c'^b \rangle$ were defined between different ordered non-empty single-connected (Ch. 1) non-intersected subsets $c \subset \mathcal{A}$ and $c' \subset \mathcal{A}$, were $b \subset \mathcal{A}$ is a non-empty ordered single connected, and α denotes the type of relation. Thereupon chains of relations $\mathbf{J}_n$ on different neighbor (Ch. 1) non-intersected subsets $b^{(i)} \subset \mathcal{A}$ ($i = 1, \ldots, n$, n is the order of the chain equal to the number of relations forming it), were defined. The probability $\mathcal{P}_\mathcal{A}(\forall(a \in \mathcal{A})[a_u \in \{a_{u'}\} = a])$ was introduced that may be changed if the operator $\hat{U}_\mathcal{A}$ defined upon the set $\mathcal{A}$ affects elements a_u of sets $a = \{a_u\}$. The operator $\hat{U}_\varrho$ analogous to $\hat{U}_{\mathcal{A}}$, but defined upon the subset $\varrho \subset \mathcal{A}$ denoting the set of all elements $a \in \mathcal{A}$ included in the relation ρ, was introduced, and the probability $\mathcal{P}_\varrho(\forall(a \in \varrho)[a_u \in \{a_{u'}\} = a])$ was obtained from $\mathcal{P}_{\mathcal{A}}(\forall(a \in \mathcal{A})[a_u \in \{a_{u'}\} = a])$. A well ordered unbounded single-connected subset $\mathcal{H} \subset \mathcal{R}$ of a complete metric space $\mathcal{R}$ was introduced. The activation of a CR consists of the subsequent applications of operators $\hat{U}_\varrho$ to corresponding relations forming this CR and mapping of the results to subsets of the set $\mathcal{H}$ (Ch. 1). It was shown that the obtained ACR processes the information (Ch. 1).

The aim of this chapter is to find set-theoretical constructions of memories for the storage of the information obtained at different stages of the information processing by ACRs.

2.2 DEFINITION OF MEMORIES p.

In the present chapter the procedure similar to the CR activation (Ch. 1) is used to construct memories of different types. Its main difference from the CR activation procedure is that it must replace the well ordered unbounded single-connected subset $\mathcal{H} \subset \mathcal{R}$ of a complete metric space $\mathcal{R}$ (*cf.* Ch. 1, §3) by one of well ordered unbounded single-connected subsets $\mathcal{H}_{q,p} \subset \mathcal{R}_q$ such that $(\forall(\mathcal{H}_{q,p}))[m(\mathcal{H}_{q,p}) = m(\mathcal{H})]$, $(\forall(\mathcal{H}_{q,p}))[\mathcal{H}_{q,p} \bigcap \mathcal{A} = \emptyset]$, $(\forall \mathcal{H}_{q,p})[\mathcal{H}_{q,p} \bigcap \mathcal{H} = \emptyset]$ and $(\forall(\mathcal{H}_{q,p}, \mathcal{H}_{q',p'}))[\mathcal{H}_{q,p} \bigcap \mathcal{H}_{q',p' \neq p} = \emptyset]$, where all $\mathcal{R}_q$ are complete metric spaces. $\mathcal{R}_q$ may be different for different q, but may be identical for some or for all q, however, $(\forall(\mathcal{R}_q))[\mathcal{R}_q \bigcap \mathcal{R} = \emptyset]$.

Using the homomorphisms $\mathcal{H}^{(i)}_{\rho_i,q,p}$ of $\hat{U}_{\varrho i}\rho_i$ to well ordered single-connected bounded subsets of $\mathcal{H}_{q,p}$ instead the homomorphism to well ordered single-connected subsets of $\mathcal{H}$, one obtains instead Eqn. (1-8) of (Ch. 1) the following formula:

$$\mathbf{T}_{n,q,p} \stackrel{def}{=} \bigcup\nolimits_{i=1}^{n} \mathbf{t}^{(i)}_{\rho_i,q,p} \equiv \bigcup\nolimits_{i=1}^{n} \{\hat{U}_{\varrho i}\rho_i, \mathcal{H}^{(i)}_{\rho_i,q,p}\}, \tag{2-1}$$

Here and in the following text we write for short $\rho_i \equiv \rho_i^{b(i)}$ for relations belonging to a CR.

$\mathbf{T}_{n,q,p}$ is called n**-th-order information processor stored in memory** p, iff a)$\mathbf{t}^{(i)}_{\rho_i}$ $(i = 1, 2, \ldots, n)$ keeps the order of ρ_i in $\mathbf{J}_n$, b) ordered sum $\mathcal{H}_{q,p}(\mathbf{J}^*_n) \stackrel{def}{=} \bigcup_{i=1}^{n} \mathcal{H}^{(i)}_{\rho_i,q,p}$ is a single-connected subset of $\mathcal{H}_{q,p}$, where $\mathbf{J}^*_n$ means $\mathbf{J}_n$, in which $(\forall\rho)[\rho$ *is replaced by* $\hat{U}_\varrho\rho]$.

The recall of an ACR from a memory p is performed by the isomorphic mapping $\mathcal{H}_p(\mathbf{J}^*)$ to a subset of $\mathcal{H}$ that follows maps of ACRs, which fore-run the recalled ACR in the current information processing.

The storage of an ACR in a memory p means its "freezing". Indeed, if time is used as the set $\mathcal{H}$, the considered n-th-order ACR is the corresponding CR "labeled" by a time-interval (exactly, by n subsequent time-intervals (Ch. 1)), or, in general, by n subsequent subsets of the set $\mathcal{H}$. When these time-intervals or subsets of $\mathcal{H}$ are replaced by n subsequent subsets of $\mathcal{H}_{q,p}$, the ACR stops to participate in the information processing because the corresponding CR became to be constantly "labeled" by the same n subsets of $\mathcal{H}_{q,p}$, in other words, being "frozen".

2.3 DEFINITION OF MEMORIES (α, p).

One more type of memory can be defined, other than memories p. Let ordered sets $\mathcal{A}_\alpha = \{a^{(\alpha)}\}$ $(\alpha = 1, 2, 3, \ldots, \alpha_{max})$ exist such that each $a^{(\alpha)} = \{a_u^{(\alpha)}\}$, $(\forall\alpha)[\mathcal{A}_\alpha \bigcap \mathcal{A} = \emptyset]$, $(\forall\alpha)[\mathcal{A}_\alpha \bigcap \mathcal{H} = \emptyset]$, $(\forall(\alpha; q, p))[\mathcal{A}_\alpha \bigcap \mathcal{H}_{q,p} = \emptyset]$, $(\forall(\mathcal{A}_\alpha))[m(\mathcal{A}_\alpha) = m(\mathcal{A})]$. Let $(\forall(\mathcal{A}_\alpha))[\exists(\mathcal{P}_{\mathcal{A}_\alpha}(\forall(a^{(\alpha)} \in \mathcal{A}_\alpha)[a_u^{(\alpha)} \in \{a_{u'}^{(\alpha)}\} = a^{(\alpha)}]) > 0]$ and

$$\mathcal{P}_{\varrho^{(\alpha)}}(\forall(a^{(\alpha)} \in \varrho^{(\alpha)})[a_u^{(\alpha)} \in \{a_{u'}^{(\alpha)}\} = a^{(\alpha)}]) \stackrel{def}{=} \sum_{a^{(\alpha)} \in (\mathcal{A}_\alpha \setminus \varrho^{(\alpha)})} \mathcal{P}_{\mathcal{A}_{(\alpha)}}(\forall(a^{(\alpha)} \in \mathcal{A}_{(\alpha)})[a_u^{(\alpha)} \in \{a_{u'}^{(\alpha)}\} = a^{(\alpha)}]) \qquad (2\text{-}2)$$

(if $m(\mathcal{A}_{(\alpha)}) = \aleph$, the sum must be replaced by an integral). As distinct from the set $\mathcal{A}$, the sets $\mathcal{A}_\alpha$, as well as their elements and subsets, do not possess properties (Ch. 1) allowing to form relations.

Now establish an isomorphism between the sets $\mathbf{J}_n^*$ and subset $\mathbf{A}_\alpha(\mathbf{J}_n^*) \subset \mathcal{A}_\alpha \bigotimes \mathcal{A}_\alpha \stackrel{def}{=} \mathbf{A}_\alpha$, and denote $\mathbf{J}_n^{*(\alpha)}$ the isomorphism of $\mathbf{J}_n^*$ to $\mathbf{A}_\alpha(\mathbf{J}_n^*) \subset \mathbf{A}_\alpha$, or, in other words, $\mathbf{J}_n^*$, in which $(\forall(a \in \mathbf{J}_n^*))[a \in \mathcal{A}\ \textit{is replaced by}\ a^{(\alpha)} \in \mathcal{A}_\alpha]$ under the condition

$$(\forall(\rho \subset \mathbf{J}_n))[\mathcal{P}_{\varrho^{(\alpha)}}((\forall(a^{(\alpha)} \in \varrho^{(\alpha)})[a_u^{(\alpha)} \in \{a_{u'}^{(\alpha)}\} = a^{(\alpha)}]) \equiv \mathcal{P}_\varrho(\hat{U}_\varrho(\forall(a \in \rho)))[a_u \in \{a_{u'}\} = a])] \qquad (2\text{-}3)$$

Thereupon establish a homomorphism between $\mathcal{A}_\alpha(\mathbf{J}_n^*)$ and a $\mathcal{H}_{q,p}(\mathbf{J}_n^{*(\alpha)}) \subset \mathcal{H}_{q,p}$. The pair $\mathbf{J}_n^{*(\alpha)}$ and $\mathcal{H}_{q,p}(\mathbf{J}_n^{*(\alpha)})$ we shall call **n-th-order information processor stored in the memory** (α, p):

$$\mathbf{T}_{n,p}^{(\alpha)} = \{\mathbf{J}_n^{*(\alpha)}, \mathcal{H}_{q,p}(\mathbf{J}_n^{*(\alpha)})\} \qquad (2\text{-}4)$$

We shall call the memories p and (α, p) **memories of the first and second types** correspondingly.

The recall of an ACR from a memory (α, p) is more complicated than that from a memory p because in addition to the described (§2) procedure of the mapping into a subset of $\mathcal{H}$, it is to perform the isomorphic mapping of the $\mathbf{J}_n^{*(\alpha)}$ back to the set $\mathbf{A}$. When both operations have been performed, the recalled ACR can participate in current information processing.

2.4 DISCUSSIONS AND CONCLUSIONS

In the present work it was shown that two different types of the memory can be defined when the information is processed by ACRs. The use of these two types of the memory is different. Memories p are used for the storage of *completed ACRs* (Ch. 1) that are set aside for the participation in the following information processing. The sending of a complete ACR to a memory and its recall for the use in the information processing, this is the only way for its multiple use because, according the definition of completed ACR (Ch. 1) $(\forall(h \in \mathcal{H}))[(\not\exists(h)[h \succ h_1) \wedge (h \in \mathcal{H}(\mathbf{J}_n^*))]]$. Memories of both types can be used with this purpose. Memories p are preferable when this completed ACR should be recalled often because the procedure of the recall from a memory p is simpler and shorter than that from a memory $\mathcal{A}_\alpha$. It must be taken into account that the content of a memory of the first type may be affected *during its storage in the memory* by changes of the set $\mathcal{A}$ or its properties (Ch. 1, §2) because the ACRs stored in memories p are built from relations between subsets of the set $\mathcal{A}$ on the grounds of its properties, while those stored in memories (α, p) are built from elements of the corresponding set $\mathcal{A}_\alpha$ and, naturally, do not depend on the structure of the set $\mathcal{A}$. Therefore, they are unaffected by $\mathcal{A}$'s changes *during their storage in memories* (α, p).

An ACR recalled from a memory p must be identical to the one sent to this memory, which limits the distance $\mathbf{r}_{s,r} \stackrel{def}{=} \mathbf{r}(\mathcal{H}(\mathbf{J}_n^*) \subset \mathcal{H}, \mathcal{H}(\mathcal{H}_{q,p}(\mathbf{J}_n^*)) \subset \mathcal{H})$ (s and r mean "stored" and "recalled" correspondingly), if $\mathcal{A}$ is changed, by the condition $\mathbf{r}_{s,r} < \mathbf{r}_{ch}$, where $\mathbf{r}_{ch}$ is the characteristic distance in the set $\mathcal{H}$ when $\mathcal{A}$ can be still considered unchanged. In the case when the time serves as the set $\mathcal{H}$, this means that the information can be stored in a memory p only during limited time. Probably memories p should be used as short term memories, while the memories (α, p) should be used as long term memories.

As it was written above, the storage in a memory (α, p) means also the substitution of elements $a \in \mathcal{A}$ by elements $a^{(\alpha)} \in \mathcal{A}_\alpha$, which permits to keep the stored ACR unaffected by possible changes of the set $\mathcal{A}$ *during its storage.* Nevertheless, despite this fact, $\mathcal{A}$'s change may affect an ACR stored in a memory (α, p), but only *at its recall.* Indeed, the isomorphic mapping of the $\mathbf{J}_n^{*(\alpha)}$ back to the set $\mathcal{A}$, which is already not the same as it was at the ACR sending to the memory (α, p), leads to a difference between the recalled and original ACRs. For example, the learning (Hopfield 1982, Steinbuch 1961, Grossberg 1968) changes interneuron connections in a neural network, or, generally speaking, its properties. This means, a recalled ACR would be built from the same elements $a \in \mathcal{A}$ than the original one, but because the change of $\mathcal{A}$'s properties some of relations may be changed or even destroyed. As a result, the recalled ACR will differ from the original one, or even will not be an ACR. This phenomenon is not desirable at calculations by use ACRs, it makes them less reliable and exact, but in the artificial intelligence and brain modeling by neural networks it can be used as an important part of the learning that by this way influences not only the current information processing, but also ACRs recalled from long term memories. In the case of the brain modeling by neural networks this means that the recollection of the same event (or statement *etc.*) made by a child, by the same person after the school and after the university studies may be different.

The considered memories' realization depends on concrete system where the information processing by ACRs occurs. For example, in computing by computers the source set $\mathcal{A}_S$ (Ch. 1), the sets $\mathcal{H}$, $\mathcal{H}_{q,p}$ and $\mathcal{A}_\alpha$ can be built from elements of computer's hardware, however, $\mathcal{A}_S$ and $\mathcal{H}$ can optionally be created in the software. The second option is preferable when $\mathcal{H}$ is an infinite set.

Though the realization of these two types of the memory in neural networks, in the and other systems processing the information by ACRs may be done by other ways than the described above for the computing by computers, the common is the necessity to search for sets of elements or systems (in neural network, in brain etc.) isomorphic to each of the abovementioned sets defined here and in (Ch. 1) as the abstract mathematical ones. Notice that in the case of human brain this problem is none other than the mind - brain relationship problem (Ch. 4).

2.5 REFERENCES TO CHAPTER 2.

Čech, *Edward*: 1966, *Topological Spaces.* A Division of John Wiley & Sons, London - New York Sydney.

Gries, *David* & Schneider, *Fred B.*: 1993, *A LOGICAL APPROACH TO DISCRETE MATH.* Springer-Verlag, New York, Inc.

Grossberg, *Stephen*: 1968, *Some Nonlinear Networks Capable of Learning; A Spatial Patterns of Arbitrary Complexity*, Proc. Nat'l Acad. Sci (USA) **59**, 368 - 372.

Hopfield, *J.J.*: 1982, *Neural Networks And Physical Systems with Emergent Collective Computational Abilities*, Proc. Nat'l Acad. Sci. (USA) **79**, 2554 - 2558.

Steinbuch, *K.*: 1961, *Die Lernmatrix*, Kybernetik **1**, 36 -45.

Chapter 3

ON A POSSIBILITY OF THE INFORMATION PROCESSING MEASURING, MORE ON THE SOURCE SET EXPANSION AND DIFFERENT LEVELS OF INFORMATION PROCESSING

3.1 INTRODUCTION

In Ch. 1 the information processing by activated chains of (binary) relations (Čech 1966, Gries & Schneider 1993) (ACRs) was considered. In the present chapter the intersection of ACRs and its influence on the information processing are considered. It is shown that this phenomenon can be used for the information processing measuring, as well as for the information transfer to ACRs (e. g., from the operator or an outside automatic system) with the purpose to govern the information processing.

We keep here notations of Ch. 1 and refer the reader to Ch.1 for explanations. We also suppose in this chapter that **case A** (§1.3) is considered.

3.2 OPERATOR $\hat{U}_{\mathcal{B}\subset\mathcal{A}}$

As in (Ch. 1) we consider a finite or infinite (countable or continuum) ordered set $\mathcal{A} = \{a\}$ of elements $a = \{a_u\}$, each of which, in its turn, is a set of elements a_u. The probability $\mathcal{P}_{\mathcal{A}}((\forall(a \in \mathcal{A}))[a_u \in \{a_{u'}\} = a])$ and the operator $\hat{U}_{\mathcal{A}}$ over the set $\mathcal{A}$ acting upon elements a_u at each a were introduced in (Ch. 1, §3). In the present work we limit ourselves with the case of linear operators only. The probability $\mathcal{P}_{\mathcal{A}}$ may be changed as a result of operator $\hat{U}_{\mathcal{A}}$ action upon elements a_u. Let us consider now the operator $\hat{U}_{\mathcal{B}\subset\mathcal{A}}$ over a subset $\mathcal{B} \subset \mathcal{A}$ acting upon elements a_u of each $a \in \mathcal{B}$.

Let $\mathcal{H} = \{h\}$ ($\mathcal{H} \bigcap \mathcal{A} = \emptyset$) be a well ordered unbounded single-connected subset of a complete metric space (Kolmogorov & Fomin 1968, Bachman & Narici 1966), where the distance $\mathbf{r}(h, h')$ between two points h and h' is defined. Denote $\mathcal{H}^{(k)}_{\mathcal{Y}}$ homomorphism of a certain well ordered single-connected set $\mathcal{Y}$, e. g., $\mathcal{Y} \subset \mathcal{A}$, to a certain well ordered single-connected subset $\mathcal{H}^{(k)} \subset \mathcal{H}$, where k is a natural number. Let be $\mathcal{B} \subset \mathcal{A}$, $\mathcal{C} \subset \mathcal{A}$, $\mathcal{C} \bigcap \mathcal{B} = \emptyset$, $\mathcal{C} \prec \mathcal{B}$. Let be $(\nexists(\mathcal{C}' \subset \mathcal{A}))[(\mathcal{C} \prec \mathcal{C}' \prec \mathcal{B}) \wedge (\mathcal{H}(\mathcal{C}) \prec \mathcal{H}(\mathcal{C}') \prec \mathcal{H}(\mathcal{B}))$.

Now one can write

$$\begin{aligned}\mathcal{P}_{\mathcal{A}}(\hat{U}_{\mathcal{A}}((\forall(a \in \mathcal{A}))[a_u \in \{a_{u'}\} = a])) &= \\ \mathcal{P}_{\mathcal{A}}(\hat{U}_{\mathcal{A}}((\forall(a \in (\mathcal{A} \setminus \mathcal{B})))[a_u \in \{a_{u'}\} = a]) &+ \\ \hat{U}_{\mathcal{A}}((\forall(a \in \mathcal{B})[a_u \in \{a_{u'}\} = a]; \mathcal{P}'_{\mathcal{C}})),\end{aligned} \tag{3-1}$$

where $\mathcal{P}'_{\mathcal{C}} = \mathcal{P}_{\mathcal{C}}(\hat{U}_{\mathcal{A}}((\forall(a \in \mathcal{C} \subseteq (\mathcal{A} \setminus \mathcal{B})))[a_u \in \{a_{u'}\} = a])$ and $(...; \mathcal{P}'_{\mathcal{C}})$ means that the result of the operator $\hat{U}_{\mathcal{B}}$ action upon $\mathcal{B}$ depends on $\mathcal{P}'_{\mathcal{C}}$. The choice of the subset $\mathcal{C}$ depends on concrete system. Principally, in some cases may $\mathcal{C} = \mathcal{A} \setminus \mathcal{B}$, but, probably, $\mathcal{C}$ is a small part of the set $\mathcal{A} \setminus \mathcal{B}$ for the majority of practically interesting systems.

We have

$$\begin{aligned}\sum_{\forall a \in (\mathcal{A}\setminus\mathcal{B})} \mathcal{P}_{\mathcal{A}}(\hat{U}_{\mathcal{A}}((\forall(a \in \mathcal{A}))[a_u \in \{a_{u'}\} = a])) &= \\ \sum_{\forall a \in (\mathcal{A}\setminus\mathcal{B})} \mathcal{P}_{\mathcal{A}}(\hat{U}_{\mathcal{A}}((\forall(a \in (\mathcal{A} \setminus \mathcal{B})))[a_u \in \{a_{u'}\} = a]) &+ \\ \hat{U}_{\mathcal{A}}((\forall(a \in \mathcal{B}))[[a_u \in \{a_{u'}\} = a]; \mathcal{P}'_{\mathcal{C}}]))) &= \\ \mathcal{P}_{\mathcal{B}}(\hat{U}_{\mathcal{B}}((\forall a \in \mathcal{B}))[a_u \in \{a_{u'}\} = a]; \mathcal{P}'_{C}])))\end{aligned} \tag{3-2}$$

Eqn. (3-2) defines operator $\hat{U}_{\mathcal{B}}$.

3.3 TWO ACTIVATED RELATIONS INTERSECTION

Let us consider firstly two neighbor (Ch. 1) activated relations ρ_I and ρ_{II} such that $\varrho_I \bigcap \varrho_{II} \neq \emptyset$ and $\mathcal{H}(\hat{U}_{\varrho_I}\rho_I) \bigcap \mathcal{H}(\hat{U}_{\varrho_{II}}\rho_{II}) \neq \emptyset$, where ϱ **denotes the set of all elements** $a \in \mathcal{A}$ **forming a relation** ρ. Denote $[\varrho_I \bigcap \varrho_{II}]$ the original of the map $\mathcal{H}(\hat{U}_{\varrho_I}\rho_I) \bigcap \mathcal{H}(\hat{U}_{\varrho_{II}}\rho_{II})$. It is evident that $[\varrho_I \bigcap \varrho_{II}] \subseteq \varrho_I \bigcap \varrho_{II}$. Let us consider the case when $\Delta\varrho_I \stackrel{def}{=} \varrho_I \setminus [\varrho_I \bigcap \varrho_{II}] \neq \emptyset$ and $\Delta\varrho_{II} \stackrel{def}{=} \varrho_{II} \setminus [\varrho_I \bigcap \varrho_{II}] \neq \emptyset$, where $\Delta_{\varrho_I} = \Delta_+\varrho_I \bigcup \Delta_-\varrho_I$, $\Delta_+\varrho_I \subset \varrho_I$, $\Delta_-\varrho_I \subset \varrho_I$, $\Delta_-\varrho_I \prec [\varrho_I \bigcap \varrho_{II}]$, $\Delta_+\varrho_I \succ [\varrho_I \bigcap \varrho_{II}]$, and the similar formulæ for ϱ_{II}. Let us consider subsets $\mathcal{C}_{\varrho_I} \subseteq \varrho_I \setminus \Delta_+\varrho_I$ and $\mathcal{C}_{\varrho_{II}} \subseteq \varrho_{II} \setminus \Delta_+\varrho_{II}$ that play role of the subset $\mathcal{C}$ (introduced in §2) for ϱ_I and ϱ_{II}. Denote for short $\mathcal{C}_I \stackrel{def}{=} \mathcal{C}_{\varrho_I}$ and $\mathcal{C}_{II} \stackrel{def}{=} \mathcal{C}_{\varrho_{II}}$.

Let us rewrite Eqn. (3-1) for ρ_I as well as for ρ_{II} and thereupon to sum up the probabilities with respect to $(\forall(a \in (\varrho_I \setminus \Delta_+\varrho_I)))$ and $(\forall(a \in (\rho_{II} \setminus \Delta_+\varrho_{II})))$ correspondingly. Then Eqn. (3-2) can be written for each of relations ρ_I and ρ_{II} as follows:

$$\begin{aligned} \sum_{\forall a \in (\varrho_I \setminus \Delta_+\varrho_I)} \mathcal{P}_{\varrho_I}(\hat{U}_{\varrho_I}(\forall(a \in (\varrho_I \setminus \Delta_+\varrho_I))[a_u \in \{a_{u'}\} = a]) &\quad + \\ \hat{U}_{\varrho_I}(\forall(a \in \Delta_+\varrho_I)[a_u \in \{a_{u'}\} = a]; \mathcal{P}'_{\mathcal{C}_I})) &\quad = \\ \mathcal{P}'_{\Delta_+\varrho_I}(\forall(a \in \Delta_+\varrho_I)[a_u \in \{a_{u'}\} = a]; \mathcal{P}'_{\mathcal{C}_I}) &\quad = \\ \mathcal{P}_{\Delta_+\varrho_I}(\hat{U}_{\Delta_+\varrho_I}(\forall(a \in \Delta_+\varrho_I)[a_u \in \{a_{u'}\} = a]); \mathcal{P}'_{\mathcal{C}_I}) & \end{aligned} \tag{3-3}$$

and

$$\begin{aligned} \sum_{\forall a \in (\varrho_{II} \setminus \Delta_+\varrho_{II})} \mathcal{P}_{\varrho_{II}}(\hat{U}_{\varrho_{II}}(\forall(a \in (\varrho_{II} \setminus \Delta_+\varrho_{II}))[a_u \in \{a_{u'}\} = a]) &\quad + \\ \hat{U}_{\varrho_{II}}(\forall(a \in \Delta_+\varrho_{II})[a_u \in \{a_{u'}\} = a]; \mathcal{P}'_{\mathcal{C}_{II}})) &\quad = \\ \mathcal{P}'_{\Delta_+\varrho_{II}}(\forall(a \in \Delta_+\varrho_{II})[a_u \in \{a_{u'}\} = a]; \mathcal{P}'_{\mathcal{C}_{II}}) &\quad = \\ \mathcal{P}_{\Delta_+\varrho_{II}}(\hat{U}_{\Delta_+\varrho_{II}}(\forall(a \in \Delta_+\varrho_{II})[a_u \in \{a_{u'}\} = a]; \mathcal{P}'_{\mathcal{C}_{II}})) & \end{aligned} \tag{3-4}$$

The sums in Eqns. (3-3–3-4) can be rewritten as follows:

$$\sum_{\forall a \in (\varrho_I \setminus \Delta_+\varrho_I)} \mathcal{P}_{\varrho_I}(\hat{U}_{\varrho_I}(\forall(a \in (\varrho_I \setminus \Delta_+\varrho_I))[a_u \in \{a_{u'}\} = a]) \quad +$$

$$\begin{aligned}
\hat{U}_{\varrho_I}(\forall(a \in \Delta_+\varrho_I)[a_u \in \{a_{u'}\} = a]; \mathcal{P}^{'}_{\mathcal{C}_I})) &= \\
\sum_{\forall a \in \Delta_-\varrho_I} \mathcal{P}_{\varrho_I}(\hat{U}_{\varrho_I}(\forall(a \in \Delta_-\varrho_I))[a_u \in \{a_{u'}\} = a]) &+ \\
\hat{U}_{\varrho_I}(\forall(a \in \Delta_+\varrho_I)[a_u \in \{a_{u'}\} = a]; \mathcal{P}^{'}_{\mathcal{C}_I})) &+ \\
\sum_{\forall a \in [\varrho_I \bigcap \varrho_{II}]} \mathcal{P}_{\varrho_I}(\hat{U}_{\varrho_I}(\forall(a \in [\varrho_I \bigcap \varrho_{II}])[a_u \in \{a_{u'}\} = a]) &+ \\
\hat{U}_{\varrho_I}(\forall(a \in \Delta_+\varrho_I)[a_u \in \{a_{u'}\} = a]; \mathcal{P}^{'}_{\mathcal{C}_I})) & \qquad \text{(3-5)}
\end{aligned}$$

and

$$\begin{aligned}
\sum_{\forall a \in (\varrho_{II} \setminus \Delta_+\varrho_{II})} \mathcal{P}_{\varrho_{II}}(\hat{U}_{\varrho_{II}}(\forall(a \in (\varrho_{II} \setminus \Delta_+\varrho_{II}))[a_u \in \{a_{u'}\} = a]) &+ \\
\hat{U}_{\varrho_{II}}(\forall(a \in \Delta_+\varrho_{II})[a_u \in \{a_{u'}\} = a]; \mathcal{P}^{'}_{\mathcal{C}_{II}})) &= \\
\sum_{\forall a \in \Delta_-\varrho_{II}} \mathcal{P}_{\varrho_{II}}(\hat{U}_{\varrho_{II}}(\forall(a \in \Delta_-\varrho_{II}))[a_u \in \{a_{u'}\} = a]) &+ \\
\hat{U}_{\varrho_{II}}(\forall(a \in \Delta_+\varrho_{II})[a_u \in \{a_{u'}\} = a]; \mathcal{P}^{'}_{\mathcal{C}_{II}})) &+ \\
\sum_{\forall a \in [\varrho_I \bigcap \varrho_{II}]} \mathcal{P}_{\varrho_{II}}(\hat{U}_{\varrho_{II}}(\forall(a \in [\varrho_I \bigcap \varrho_{II}])[a_u \in \{a_{u'}\} = a]) &+ \\
\hat{U}_{\varrho_{II}}(\forall(a \in \Delta_+\varrho_{II})[a_u \in \{a_{u'}\} = a]; \mathcal{P}^{'}_{\mathcal{C}_{II}})) & \qquad \text{(3-6)}
\end{aligned}$$

Really, in $[\varrho_I \bigcap \varrho_{II}]$ both operators $\hat{U}_{\varrho_I}$ and $\hat{U}_{\varrho_{II}}$ affect the probabilities of $a_u \in \{a_{u'}\} = a$ with different u. Indeed, we have

$$\begin{aligned}
\mathcal{P}^{'}_{[\varrho_I \bigcap \varrho_{II}]}(\forall(a \in [\varrho_I \bigcap \varrho_{II}])[a_u \in \{a_{u'}\} = a]; \mathcal{P}^{'}_{\mathcal{C}_I}, \mathcal{P}^{'}_{\mathcal{C}_{II}}) &= \\
\sum_{\forall a \in (\varrho_I \setminus [\varrho_I \bigcap \varrho_{II}])} \mathcal{P}_{\varrho_I}(\hat{U}_{\varrho_I}(\forall(a \in [\varrho_I \bigcap \varrho_{II}])[a_u \in \{a_{u'}\} = a]; \mathcal{P}_{\mathcal{C}_I}) &\times \\
\sum_{\forall a \in (\varrho_{II} \setminus [\varrho_I \bigcap \varrho_{II}])} \mathcal{P}_{\varrho_{II}}(\hat{U}_{\varrho_{II}}(\forall(a \in [\varrho_I \bigcap \varrho_{II}])[a_u \in \{a_{u'}\} = a]; \mathcal{P}_{\mathcal{C}_{II}}) &\stackrel{def}{=} \\
\mathcal{P}_{[\varrho_I \bigcap \varrho_{II}]}(\hat{U}_{I\ II}(\forall(a \in [\varrho_I \bigcap \varrho_{II}])[a_u \in \{a_{u'}\} = a]; \mathcal{P}^{'}_{\mathcal{C}_I}, \mathcal{P}^{'}_{\mathcal{C}_{II}})) & \qquad \text{(3-7)}
\end{aligned}$$

The Eqn. (3-7) is the definition of the operator $\hat{U}_{I\ II}$ affecting $a_u \in \{a_{u'}\} = a \in [\varrho_I \bigcap \varrho_{II}]$. $\hat{U}_{I\ II}$ is function of $\hat{U}_{\varrho_I}$ and $\hat{U}_{\varrho_{II}}$.

The members with $\sum_{\forall a \in [\varrho_I \bigcap \varrho_{II}]}$ in Eqns. (3-5) and (3-6) must be replaced by the expression (3-7) to take into account the effect of relations' intersection , which, really, was not taken into account in Eqns. (3-5) and (3-6). Then it will be seen that $\mathcal{P}^{'}_{\Delta_+\varrho_I}$ depends not only on $\mathcal{P}^{'}_{\mathcal{C}_I}$, but also on $\mathcal{P}'_{\mathcal{C}_{II}}$, while $\mathcal{P}'_{\Delta_+\varrho_{II}}$ depends not only on $\mathcal{P}'_{\mathcal{C}_{II}}$, but also on $\mathcal{P}'_{\mathcal{C}_I}$. In other words, the change of each $\Delta_+\varrho_I$ and $\Delta_+\varrho_{II}$, produced by the intersection, carriers an information on the activation of ρ_{II} and ρ_I correspondingly before the intersection.

If propositions are put in correspondence to the activated relations ρ_I and ρ_{II} (Ch. 1), these propositions are destroyed by the relation intersection. If these activated relations belong to two ACRs, and each of these ACRs is carrying a progressed chain of propositions (Ch. 1), their continuations after the considered intersected relations, *in the general case*, do not continue these progressed chains of propositions, but begin to develop the new ones starting from relations following ρ_I and ρ_{II} correspondingly.

Let us consider now the case when $\| \mathcal{P}_{[\varrho_I \bigcap \varrho_{II}]}(\forall(a \in [\varrho_I \bigcap \varrho_{II}])[a_u \in \{a_{u'}\} = a]) - \mathcal{P}_{[\varrho_I \bigcap \varrho_{II}]}(\hat{U}_{\varrho_{II}}(\forall(a \in [\varrho_I \bigcap \varrho_{II}])[a_u \in \{a_{u'}\} = a])) \| \ll \| \mathcal{P}_{[\varrho_I \bigcap \varrho_{II}]}(\forall(a \in [\varrho_I \bigcap \varrho_{II}])[a_u \in \{a_{u'}\} = a]) - \mathcal{P}_{[\varrho_I \bigcap \varrho_{II}]}(\hat{U}_{\varrho_I}(\forall(a \in [\varrho_I \bigcap \varrho_{II}]) [a_u \in \{a_{u'}\} = a])) \|$, and the operator $\hat{U}_{I\ II}$ can be written as follows: $\hat{U}_{I\ II} = \hat{U}_{\varrho_I} + \Delta\hat{U}_{I\ II}$, where $\Delta\hat{U}_{I\ II}$ is a small perturbation, and it will be $q_I \stackrel{def}{=} \| \Delta_+\varrho_I^{(0)} - \Delta_+\varrho_I \| \ / \ \| \Delta_+\varrho_I^{(0)} \| \ll 1$, where $\Delta_+\varrho_I^{(0)}$ is defined as $\Delta_+\varrho_I$, but in absence of the intersection. The norm is defined in conformity with the type of space, to which the considered probabilities belong as functions of a_u for all elements a. As opposed to the first inequality, we have $q_{II} \stackrel{def}{=} \| \Delta_+\varrho_{II}^{(0)} - \Delta_+\varrho_{II} \| \ / \ \| \Delta_+\varrho_{II}^{(0)} \| \gg 1$. In accordance with the written abo e, the change of $\Delta_+\varrho_{II}$ carriers an information on the first activated relation and, therefore, on the proposition carried by this relation. q_{II} is one of characteristics of this change. Thus, principally, it is possible to measure activated relations with the purpose to obtain an information on their activation and thereby on the information carried by them, e. g., on propositions.

The change of $\Delta_+\varrho_I$ by such a measuring can be done small in comparison with $\Delta_+\varrho_I^{(0)}$, but never be equal to the zero, i. e., an uncontrolled error of measurement is inevitable. Moreover, even if this error is small for the considered *relation*, it is not obligatory small for the *information* carried by this relation, e. g., a proposition, because the connection between the relation structure and this information (Ch. 1), generally speaking, is not obligatory a continuous function. For example, two relations possessing very close structures may carry an information on two types of the symmetry. In such a case a measuring may destroy completely the information carried by relation ϱ_I, even if the change of this relation itself is small (see above). Therefore, a measurement has meaning, iff a)the change of the measured relation structure is small, and b)the change of the information carried by the measured relation is small. The meaning of "*small change of the information*" must be established in each concrete case because not only the amount of the information (Kullback 1958) is considered, but also its content and value (Eigen 1971, Volkenstein 1977, Packel *et al.* 1992).

The determination of the measured relation structure and the information corresponding to this structure (Ch. 1), is a very difficult and very complicated *inverse problem*. A realistic way to solve it could be as follows. It must select such an activated relation that does not destroy the measured one and the carried information as well, and to find (analytically or by computations) the dependence of the change of this selected measuring relation (as a result of the intersection with the measured relation) on the structure of the measured activated relation as well as on the content of the carried information. Thereupon it is to make a measurement and to obtain an information on the measured relation structure and carried information using measurement results and the dependence obtained beforehand. Perhaps, other methods exist to solve this inverse problem. For example, it is worth checking about the application of the maximum entropy principle that is successfully applied to the solution of many other inverse problems.

The demand that the measuring relation must not destroy the content of the information carried by the measured one, has very important consequences. Let us return to the example when the carried information is the one about an object possessing a certain symmetry. Then different measuring relations are necessary to obtain an information (carried by the measured relation) in two cases corresponding to two different groups of symmetry . In each of these cases the used measuring activated relation must not produce such kind of changes (even small) of the measured activated relation structure, which corresponds to a transition from one symmetry group to another in the carried information. Probably, in general, the information that principally can be carried by an activated relation should be classified into a number of different types. Measurements of a pair of such types of the carried information may be made by one kind of measuring activated relations, but may demand the use of two different types of them. In other words, they may be compatible or incompatible. This means, measuring relations must be classified into classes corresponding to the classes of information chosen so that measurements of the information of two types belonging to the same class would be compatible, while those of the ones belonging to two different classes would be incompatible.

3.4 TWO ACRs INTERSECTION

TWO ACRS ARE CALLED INTERSECTED, IFF AT LEAST THEIR TWO RELATIONS (ONE OF EACH ACR) ARE INTERSECTED. Notice that in this case $\mathcal{C}_I$ and $\mathcal{C}_{II}$ may include subsets of the corresponding foregoing relations, and the intersection of two ACRs may consist of any number of relations. Despite of these two distinctions from the case of two activated relations' intersection, the consideration of two ACRs intersection repeats the one made above. For example, two conditions of ACRs $\mathbf{T_n}^{(I)}$ and $\mathbf{T_m}^{(II)}$ (consisted of $\mathbf{n}$ and $\mathbf{m}$ activated relations, correspondingly) intersection can be written as follows: (A) $\mathbf{T_n}^{(I)} \bigcap \mathbf{T_m}^{(II)} = \mathcal{R}_I = \mathcal{R}_{II} \neq \emptyset$ and (B) $\mathcal{H}(\hat{U}_{\mathcal{R}_I}\mathcal{R}_I) \bigcap \mathcal{H}(\hat{U}_{\mathcal{R}_{II}}\mathcal{R}_{II}) \neq \emptyset$, where $\mathcal{R}_I \subset \mathbf{T_n}^{(I)}$ and $\mathcal{R}_{II} \subset \mathbf{T_m}^{(II)}$. If the source set $\mathcal{A}_S$ (Ch. 1) is a neural network and the time is chosen as $\mathcal{H}$, the condition (B) means that ACRs intersect only if pulses activating them, pass across their CRs intersection simultaneously. As in the case of two intersected relations, the intersection of two ACRs can be used for measuring ACRs with the purpose to obtain an information on them and on the information carried by them.

The consideration of an isolated activated relation structure and carried information measuring made by another relation (§3) can be applied to ACRs. In particular, measuring ACRs must be classified into classes corresponding to compatible measurements within each class, as in the case of the measuring of activated relations. Measurements of a number of activated relations belonging to an ACR, made by a number of measuring ACRs, provide an information on the development of the information processing by the measured ACR. On the other hand, measuring ACRs can be intentionally used *to change this information processing development* with the purpose to govern it. In this case it is not demanded that an uncontrolled change of measured ACR would be small: the aim is to stop the ACR development at the intersection with a measuring ACR, and to let new ACR be created. If the measuring ACR produces such a change of the measured ACR that determines what will be the new ACR (after the intersection), the information processing will be completely controlled (e. g., by an operator or an automatic equipment). More realistic is when the type of the ACR created after the intersection is chosen statistically from an ensemble of possible types corresponding to the obtained intersection.

The amount and the complexity of the information processed by an ACR depends on the number of activated relations forming this ACR, they increase when this number increases. This number is not obligatory coincides with the one of the corresponding CR. Indeed, if this ACR intersects with other ACRs, it is turned to a number of new ACRs : from the beginning of its CR up to the first intersection , between each pair of neighbor intersections, and from the last intersection up to the end of CR. The numbers of activated relations forming these ACRs are evidently less than the one of the CR. In consequence of the condition (B) an intersection of two CRs may be an intersection of two corresponding ACRs at one activation of this CRs, but may not be an intersection of them at another activation. This means, if we need an output containing reach, complex and sophisticated information, ACRs must contain as much as possible activated relations. At a given source set $\mathcal{A}_S$, i. e. for a given system processing the information by ACRs, it can be achieved by a decrease of the information processing rate. Then intervals between acts of each CR activation would be long enough to reduce noticeably the number of ACRs' intersections. If such a decrease of the information processing rate is not desirable, it is to replace the system, i. e. $\mathcal{A}_S$, by another, such that on its bases much more relations could be constructed so that the ratio of their intersections' number and the total number of relations would be reduced in comparison with the first system. Probably, in the majority of cases it demands the increase of the number of elements in $\mathcal{A}_S$, if it is a finite set.

In (Ch. 1, §1.2) the possibility of the source set $\mathcal{A}_S$ expansion was considered. It was indicated that the procedure of this expansion can be repeated N times, in other words, N steps of such an expansion can be performed. It leads naturally to the definition of *different levels* of the information processing: **the information processing by ACRs built from elements of a set $\mathcal{A}^{(K)}$ is called $(K+1)$-th level information processing**. Of course, the mixing of different levels of the information processing is possible when CR corresponding to an ACR is built of relations containing elements of sets $\mathcal{A}^{(K)}$ with different values of K. In the case when the source set $\mathcal{A}_S$ is a neural network, the information processing by its hardware itself, without use of ACRs, we shall call **basic level information processing**.

There are three factors limiting the possible number of such steps of the source set expansion:

a) It is evident that possible number K is limited by the value $N^{(1)} \stackrel{def}{=} K^{(1)}_{max}$ because the set of properties (Ch. 1) necessary for the construction of relations may be exhausted at a certain value $K = N^{(1)}$, and, therefore, the next step $(K > N^{(1)})$ will be impossible.

b) The second cause of K limitation is that the set of properties necessary for *ordering* set $\mathcal{A}^{(K)}$ may be exhausted at a certain step $K = N^{(2)}$. Notice that the ordering of sets $\mathcal{A}^{(K)} = \{a^{(K)}\}$ can be done as follows:

1) $(\forall(a^{(K)} \in (\mathcal{A}^{(K)} \setminus \mathcal{A}^{(K-1)})), \forall(a^{(K-1)} \in \mathcal{A}^{(K-1)}))[a^{(K)} \succ a^{(K-1)}]$; **2)** $(\forall((\mathbf{J_n^K}, \mathbf{J_{n'<n}}^K)) \in (\mathcal{A}^{(K)} \setminus \mathcal{A}^{(K-1)})))[(\mathbf{J_n^K} \succ \mathbf{J_{n'<n}}^K)]$; **3)** Two CRs of the same order belonging to the same set $\mathcal{A}^{(K)} \setminus \mathcal{A}^{(K-1)}$ must be ordered on the grounds of properties of the set $\mathcal{A}^{(K)} \setminus \mathcal{A}^{(K-1)}$; **4)** The order in the set $\mathcal{A}_S$ is kept.

c) The possible number of these steps is limited also by the third value $K = N^{(3)}$ because the existence of the effect of ACR's intersections. Indeed, each step of $\mathcal{A}_S$ expansion leads to an increase of the number of CR's intersections (relatively to the total number of relations) and to a corresponding decrease of possible length of ACRs. The possible length of ACRs at the given length of CRs depends on the rate of the information processing so that it increases when this rate decreases.

Therefore, $N^{(3)}$ depends on the information processing rate. In particular, if one wants to use high level information processing, it is to decrease its rate. If the human brain processes the information by ACRs (*this is a hypothesis needed to be checked*), it can be expected that the highest level intellectual activity occurs slowly than the lower level one.

Thus, taking into account these three possible causes of limitations of K, one obtains that it must be $K \le min(N^{(1)}, N^{(2)}, N^{(3)}) \stackrel{def}{=} N$.

Define the topology ϑ_K on each set $\mathcal{A}^{(K)}$. Then $(\mathcal{A}^{(K)}, \vartheta_K)$ will be a topological space.

3.5 CONCLUSIONS

In Ch. 1 the method of the information processing by activated chains of binary relations (ACRs) was proposed. In the present paper the intersection of activated relations as well as ACRs is studied with the purpose to clarify its rôle in the information processing. The conclusions can be formulated briefly as follows:

I. The intersection of ACRs can provide an information on one of these ACRs. It opens a way to obtain information on the information processing by use of relevant types of ACRs generated by a special system.

II. The intersection of ACRs allows one to govern the information processing leaning upon the fact that an intersection can stop the information processing by the corresponding ACR and a new ACR begins new information processing after the intersection.

III. The intersection of ACRs can be used for the transfer of the information carrying by ACRs to corresponding sets $\mathcal{H}_{q,p}$ and $\mathcal{A}_\alpha$ to store these ACRs to memories, as well as for their recall from memories, *e. i.*, for the realization of corresponding mappings (Ch. 2).

IV. Intersections limit length of ACRs and thereby the complexity and level of the information processed by it. This limitation can be weakened by a certain reduction of the information processing rate, so high rate of the information processing is not always desirable. In particular, because of this phenomenon it is necessary to reduce (in the given system) the rate of the information processing to obtain in output information of high level and of high complexity. high rate of the information processing is not always desirable.

3.6 REFERENCES TO CHAPTER 3.

Bachman, *George* & Narici, *Lawrence*: 1966, *FUNCTIONAL ANALYSIS.* Academic Press, New York & London.

Čech, *Edward*: 1966, *Topological Spaces.* Interscience Publishers, A Division of John Willey & Sons, London-New York-Sydney.

Eigen, *Manfred*: 1971, *Selforganization of Matter and the Evolution of Biological Macromolecules.* Naturwiss. **58**, 465-523.

Gries, *David* & Schneider, *Fred B.*: 1993, *A Logical Approach to Discrete Math.* Springer-Verlag, New York, Inc.

Kullback, *Salomon*: 1958, *INFORMATION THEORY AND STATISTICS.* New York-John Wiley & Sons, Inc., London-Chapman & Hall, Limited.

Packel, *Edward W.*, Traub *J. F.*, Woźniakowski, *Henrik*: 1992, *Measures of Uncertainty and Information in Computation*, Inf. Sci. **65**, 253 - 273.

Volkenstein, *M.V*: 1977, *The Amount and Value of Information in Biology.* Found. Phys. **7**, 97-109.

Chapter 4

AN APPROACH TO THE MIND AND CONSCIOUSNESS STUDY

4.1 INTRODUCTION

In Chs. 1 - 3 the information processing by ACRs was considered and its theory was developped as a pure mathematical one. If there is an object consisting of physical, chemical, biological or other kinds of elements that can be ordered *on the grounds of natural properties of the system*, they can be identified with elements of the source set $\mathcal{A}_S$. If the set of these elements as well as its subsets possess properties necessary to create CRs (Ch. 1), and physical, chemical, biological or other processes exist that are able to activate them, the considered object is able to process the information by ACRs , and the proposed theory is valid in this case. It would be interesting to check about whether the human brain, sets of stars in the Universe (the Universe itself, galaxies), inside of a star, crystals and polymer molecules, e. g., DNA and RNA, are such objects. In the present chapter it is assumed that the human (maybe also animal's) brain is such an object, which processes the information by ACRs, and consequences of this hypothesis are studied. The verification of the abovementioned hypothesis can be obtained by the comparison of these and other its consequences with experimental results. The information processing by the brain we identify with the **thinking** and an ACR with a **thought**. Of course, this identification is not necessary for the mathematical theory of the information processing by the brain developped here. In Ch. 3 the set $\mathcal{A}^{(N)}$ was defined as the maximum possible expansion of the set $\mathcal{A}_S$. This set, as well as sets $\mathcal{A}^1$, $\mathcal{A}^2$, ..., $\mathcal{A}^{(N-1)}$, is a very important concept of the theory of the information processing by the brain, i. e., of the thinking. We shall call $\mathcal{A}^{(N)}$ **mind** indicating by this that for a given brain it is the set of all potentially possible thoughts. The use of the word "mind" is not necessary for the developped mathematical theory of the thinking and can be replaced by "set $\mathcal{A}^{(N)}$" in the following text by somebody who prefers not to use the word "mind" as a term in a mathematical theory. The problem of the mind - brain relationship never was formulated clearly and definitely mainly because the uncertainty of the concept of the mind. The identification of the mind with the set $\mathcal{A}^{(N)}$ allows one to formulate this problem as follows:

DEFINE THE MIND-BRAIN RELATIONSHIP PROBLEM AS THE ONE CONSISTING OF THE ATTRIBUTION TO EACH ELEMENT OF SETS FIGURING IN THE PROPOSED THEORY (CHS. 1 -3), A CERTAIN SUITABLE BIOLOGICAL SYSTEM IN THE BRAIN (§4.4). In that way the mind, i. e., the set $\mathcal{A}^{(N)}$, is connected with the real brain. The second aspect of the thinking, to what this chapter is dedicated, is the **consciousness**. Try to define it in the most general form.

We DEFINE CONSCIOUSNESS AS THE AWARENESS OF A PERSON OF ITS OWN THINKING PROCESSES AND THE ABILITY TO GOVERN THEM. It can be realized by the use of mind self-measurements (§4.2). In Ch. 3 the mechanism of mind self-measuring is found and in §4.2 it is clarified that it is used also to govern thinking . If neural network (NNW) be the relevant model of the brain activity, this mechanism assumes clear biological meaning, being identified with processes occurring with suitably defined combinations of neurons.

§4.5 - §4.8 are dedicated to applications of the proposed theory to NNWs. Among the results obtained in these sections are the following: 1)the elucidation of the synergetic character of human thinking that, in particular, allows genetic information transfer up to the highest intellectual level of thinking, 2)the comparison of the "electronic brain" (obtained if one replaces all information processors of the brain by electronic devices) with the real human brain, which was found to have essential advances comparable with the electronic one, 3)the revelation of limitations of the intensity of thinking that lead to the necessity to concentrate thinking to a certain subject, not to think on two or more subjects simultaneously.

4.2 CONSCIOUSNESS AND SUBCONSCIOUSNESS

In §4.1 the definition of the general concept of the consciousness was formulated. In this paragraph we shall consider how it is realized. Thoughts, i. e., ACRs, appear and develop in the mind, i. e., in the set $\mathcal{A}^{(N)}$, by CRs activation. There are also thoughts stored in memories of two types (Ch. 2). Those stored in memories p (§2.2) are in the mind because they are constructed from elements of the set $\mathcal{A}$ as CRs, while those stored in memories (α, p) (§2.3) are outside the mind. Thoughts that are in the mind can be measured by use of ACRs intersections (Ch. 3), while thoughts stored in memories (α, p) should be recalled from memories (§2.3) to the mind to be measured. To be aware of thinking processes means to obtain information on them. It can be done by measuring ACRs (thoughts) in the mind by use of the ACRs intersections (Ch. 3). As it was indicated in Ch. 3, the transfer of the information to ACRs (thoughts) with the purpose to govern the thinking can be done also by use of ACRs intersections. Therefore, the definitions of conscious and subconscious thinking can be formulated as follows:

DEFINITION: *CONSCIOUS THINKING IS SUCH THINKING WHICH IS ACCOMPANIED BY MEASUREMENTS OF THOUGHTS ARISING AND DEVELOPPING IN THE MIND AND BY THE TRANSFER TO THOUGHTS INFORMATION GOVERNING THINKING.*

DEFINITION: *SUBCONSCIOUS THINKING IS SUCH THINKING WHICH IS NOT ACCOMPANIED BY MEASUREMENTS OF THOUGHTS ARISING IN THE MIND AND BY THE TRANSFER TO THOUGHTS INFORMATION GOVERNING THINKING.* Thus, conscious thinking on a certain subject occurs when the mind is concentrated on this subject, which means namely that it performs corresponding self-measurements, while subconscious thinking occurs in the opposite case. However, results (final or intermediate) of subconscious thinking may be detected when the mind transits to the state corresponding to its concentration on this subject of the thinking. Such a phenomenon is well known.

This definition of conscious thinking is very general and allows to be filled with different content corresponding, for example, to different theories of consciousness. Indeed, results of measurements of thoughts must be interpreted by the mind to provide an information. This interpretation can be performed, in particular, on the grounds of the information obtained in previous experience and stored in the memory. Taylor (1996b) writes: "The main thesis of the Relational Mind model is that *The conscious content of a mental experience is determined by the evocation and intermingling of suitable past memories evoked (sometimes unconsciously) by the input rise to the experience*". The processes mentioned in this citation can be realized by means of recall of corresponding thoughts from memories that initiates new thinking processes as result of the interaction between all thoughts (ACRs) existing in the mind, including those recalled from the memories. The "mental experience" is contained in memories, mainly those of the type (α, p), therefore, by this way it will be involved to the thinking. Therefore, measurings of ACRs participating in these thinking processes realize the task formulated in the abovementioned citation and in our definition of the conscious thinking.

Notice that the proposed theory naturally leads to the existence of different levels of consciousness (see §4.7).

If two subjects of thinking are considered, then two options exist: 1) trial sets of thoughts about one of them do not collide with thoughts about the second one or, if they collide, do not produce remarkable uncontrollable changes in them, and, 2) do collide and do produce such changes. The first option corresponds to *two compatible subjects* of the thinking, while the second one corresponds to *two incompatible subjects* of the thinking. In the first case the mind is able to obtain information on thinking about both subjects and to govern them both, while in the second case it is possible with one of the two subjects only and therefore the mind cannot think on them simultaneously, or, at least, the simultaneous *CONSCIOUS* thinking on them is impossible. Therefore the subjects can be classified into groups, each of which contains only compatible measurements. Naturally, some kinds of uncertainty and complementarity (Bohr 1928, 1935, Lindenberg and Oppenheim 1974) principles must exist between self-measurements of the mind, made by trial sets of thoughts relevant to different incompatible subjects. In other words, *concentration of the mind on different incompatible subjects of the thinking cannot be achieved.* An adequate mathematical formalism for the descriptions of such systems is based on an algebra of non-commuting operators acting upon elements of an abstract metric space representing states of the mind. The use of a metric space in the quantum theory of the mind is dictated by the fact that there is no grounds to use a normalized space that exists in quantum mechanics (Dirac 1958). This formalism provides response to a very important question: how human thinking (including operations with memories) is governed? This response is as follows: the human thinking is governed not directly on the level of the topological space $(\mathcal{A}^{(N)}, \vartheta_N)$ (§3.3), *i. e.*, on the level of mind, but indirectly on the level of the metric space of states of the mind by probabilities of its different states (not thoughts or sets of thoughts!). It will be considered in detail in Ch. 5.

4.3 ACRs AND LANGUAGES

The existence of a language is not assumed, but a language, for example, a formal language can be constructed on the grounds of the definition of the notion of ACR (§1.3). An ACR fit for language-using thinking must itself be a letter or a combination of letters satisfying the language rules. ACRs (thoughts) of other types must be neglected and all the information contained in such ACRs will be lost in transition to the language-using thinking (§1.3). It was never proved that thinking is possible only on the grounds of a language, moreover, it is very probable that our real thinking includes thoughts that cannot be expressed by a language. The definition (1-8) of the concept of ACR (thought) allows one to consider both the language-using thinking as well as the one occurring without the use of a language. In fact, we think mainly without use of a language and only at certain stages, especially at the last stage, we formulate our thoughts in a language neglecting those ("obscure" thoughts, as we feel them) that cannot be expressed so. The proposed theory covers the whole thinking process no matter whether or not a language is used; it permits also to consider the transition from one of these kinds of thinking to the other. Thus, the proposed theory is occupied with more fundamental aspects of the human thinking than a language and the thinking by its use. Probably a new-born baby thinks entirely without use a language (he does not know any!) and during the early period of his life not only studies the language itself, but also studies to translate his thoughts into language. Perhaps speech development troubles of children as well as adults are sometimes caused by difficulties of this translation, but not by ones of the language study or by mental under- development. On the other hand, our definition of thought allows the consideration of languages using hieroglyphs without representing each hieroglyph by letters: a hieroglyph can be defined as a relation of a certain type while in this case letters will not be defined, in general. Possibly such an approach will permit to compare (in the framework of a mathematical theory) thinking using a language based on an alphabet with the one using a language based on hieroglyphs.

4.4 ON THE MIND - BRAIN RELATIONSHIP AND LIBET EFFECT

To connect the mind with the human brain or with any other system, means to indicate what mathematical objects and operations introduced above must be realized there as concrete physical, chemical, biological or other objects and processes, and how it is done. This means, it must find 1) the nature (physical, physiological etc.) of elements of the source set $\mathcal{A}_S$ because all CRs can be constructed from them, 2) the nature of the set $\mathcal{H}$ necessary to construct ACRs from their CRs, and 3) the nature of the sets $\mathcal{H}_p$ and $\mathcal{A}_\alpha$ necessary to the both types of the memory.

If somebody's brain is empty of thoughts, even if all its biological structures remain unharmed, this person is dead because the brain cannot rule such vital functions of the organism as breathing, heart beating etc. are, and cannot process the information obtained from receptors (eyes, ears, skin, nose etc.). Is it possible to create thoughts in such a brain and to start thinking? Perhaps the effect of Libet (Libet *at al.*1979, Libet 1985) serves as an indication that a way exists to create thoughts in a brain that before it was empty of thoughts. The interpretation of Libet of his results can be expressed in our terms as follows: pulses created in his experiments in the nervous system may realize CRs (the physical time used at the generation of electrical pulses forwarded to nerves serves as the set $\mathcal{H}$), i.e. to create thoughts (ACRs) . This means, the electrical pulses may start a thinking process in the brain that provokes the reaction of the patient to them before the physical excitation of the nervous system reaches a certain point. This thinking can be conscious or subconscious. If the results of the Libet experiments are not the same for both cases, it suggests one more way of the use this effect to study consciousness.

1)If the proposed interpretation of the Libet effect is correct, this effect can be used to create thoughts in a brain empty of them, i.e. to reanimate the brain. If the thinking processes created by electrical pulses are continued after the pulses termination, the reanimation will be successful. Therefore, attempts of the reanimation could/must be continued up the moment when an irreversible destruction of vitally important biological structure of the brain will occur.

2) If the proposed interpretation that the Libet effect is based on the creation of thoughts in the brain by electrical pulses is correct, the time delay measured by Libet and *collab.* apparently contains information on high-level functions of the brain . It suggest the idea that this effect can be used to study and control (in particular, at neurosurgical operations) of these functions of the brain.

4.5 ACRs IN NEURAL NETWORK (NNW): GENERAL APPROACH

Consider now a neural network consisting of units (neurons) connected by synapses (see, for example,Amit 1989). Suppose that this net is divided into some regions, and consider one of them. **NOW DEFINE** *THAT THE SET OF UNITS OF THIS REGION IS THE SOURCE SET, IF IT IS ORDERED PHYSICALLY*, but not only mathematically. It can be naturally done, if, for example, some physical properties are asymmetric: for example, if the probability of the excitation transmission from a neuron i to its neighbor $i+1$ through the synapse depends on the direction, i.e. the probability of $i \to i+1$ is not equal to the probability of $i+1 \to i$. Then from units of the considered region it is possible to construct a set of CRs existing, of course, only virtually, at least in the considered model. If the units are not (or cannot be) ordered throughout the whole net, CRs can be constructed only inside each ordered region (if such regions exist!) separately, no CR can contain units of different regions.

This consideration remains valid also when $\mathcal{A}_S$ is not a NNW and is not able to process the information, but CRs can be constructed and can be realized into ACRs. In this case only ACRs can process the information.

Choose the time t as the set $\mathcal{H}$. Suppose that at a time moment t a subset of neurons (in the considered region) were fired (Hopfield 1982), no matter what was the cause of it (pulses from an outside source, spontaneous internal processes etc.). If these fired units form a relation, it may be the start of an ACR creation. The other possibility is that the set of fired units at a time moment $t' > t$ obtained as a result of excitation propagation, will make up a relation which may start the creation of a ACR. Thereupon the natural propagation of the state of fired neurons throughout this region of the network may create a new relation. If the conditions contained in the CR and ACR definitions are satisfied for the first and second relations, then the first order ACR will be created. The creation of the first and second relations can be also done artificially by pulses from an outside source. The last option could be used for neural computing and also for reanimation when the brain is already empty of thoughts.

Our consideration can be continued and the creation of higher orders

ACRs can be considered analogously. As it is seen from the description of the ACR creation process, *IN THE CONSIDERED MODEL THE MAPPING OF A CR TO A SUBSET OF THE SET $\mathcal{H}$ MEANS THE REALIZATION OF THE SUBSET OF NNW UNITS FORMING THIS CR.* The mapping is a physical process of firing of units at different time moments, and not only an abstract mathematical operation.

An important subject of future research should be the study of the information content and amount carried by ACRs.

Let us discuss this problem in general outline. First of all it is possible to define the notion of the **preinformation** contained in a CR. As is indicated in APPENDIX 1, the probability (1-4) can be defined from pure set-theoretical combinatorial reasons (**proper probability**). This probability can be used to define the information as it is usually done. The result will be called **proper preinformation** (i.e. obtained from proper probability). Why this "pre"? It indicates the fact that this information is not displayed itself, but only at the transformation of a CR into the corresponding ACR. Notice that the last statement remains valid for any way of defining the CR probability. The same method can be applied to ACRs to define the PROPER INFORMATION carried by ACR that is obtained from the proper probability (Kullback 1958, Brillouin 1956) of each state of the considered ACR. This proper probability is equal to the proper probability of the corresponding CR (i.e., the probability to find this CR) multiplied to the probability of a certain state of the obtained ACR (more detailed see in APPENDIX 1). As it is seen from the consideration contained in APPENDIX 1, the proper probability (and therefore, the proper information) of an ACR depends on the probability of the excitation transfer from one unit of NNW to another. This means, in the case of human thinking the neural activity is included to the proposed theory already at the stage of the proper probability and information calculation. However, it is not enough to calculate only the proper information because this definition would say nothing on the meaning of this information, i.e. what subject is the considered thought about: about a certain human being, or about nuclear fission, or about a dog, or about the Schrödinger equation, or it is the order to create a new thought and on its meaning etc.. It could be expected that such information cannot be defined in terms of abstract mathematical set theory only, but the definition must include certain properties of the considered "hardware", i.e. of the brain, or of an artificial neural network, or something else. Notice that important information carried by an ACR may be the order to create a new ACR. In this case it could be expected that under certain conditions the information processing can be a self-sustained process. It would be interesting to check what biological and medical, e. g., psychiatric, consequences it may lead to, especially when this process is "explosive" (i.e. self-accelerating). The information really carried by an ACR may not be the same for different physical, biological or other information content. Indeed, the proper information carried by an ACR is like the information carried by a text when it is determined by the calculation of letters and their combinations such as words, phrases etc.. From this point of view the prominent letter of Albert Einstein to USA President Franklin D. Rooswelt, which started work on the nuclear weapon, contains no more (proper) information than any other letter of the same length and text structure. But, if to take into account *what* was written in Einstein's letter and to what consequences it led, the information contained there will be much larger. By analogy, if, for example, an ACR starts a chain of other ACRs that represents the proof of an important mathematical theorem, the amount of information carried by this ACR would be much larger than the amount of its proper information. These examples reveal the existence of a very important characteristic of information called the **value of information** (Eigen 1971, Volkenstein 1977, Packel *et al.* 1992). The notion of the value of information can be illustrated by the following non-biological example. The neutron flux from a source penetrated into the rock at neutron well-logging (a method of bore hole examination) carries information about the rock structure which is more rich qualitatively and larger quantitatively (= has larger value) than the information carried by the free neutron flux. Neutron flux penetrated into the supercritical mass of U-235 initiates the chain reaction of fission and explosion with well known consequences. In this case the same neutron flux has the value information much bigger than in the case of neutron well - logging. An interesting question (for future research) arises: whether the amount of information carried by an ACR can be obtained from the probability that is the product of its proper probability and the probability of a certain effect produced by this ACR? For the consideration of this problem it should be taken into account that an ACR may produce more than one effect and this makes the problem complicated. The consideration of this problem is not a subject of the present work. If each of the considered regions of the network is ordered separately from the other ones, different regions can play different rôles and accomplish different tasks. Perhaps this is a reasonable explanation of the origin of different regions of the (human) brain responsible for different functions. An influence of thinking processes occurring in one region of the neural network, e.g., of the brain, on those occurring in other regions may be a result of the neural excitation transfer throughout the net. Its different regions are only ordered differently, but they are not isolated. The "borders" between them do not exist for neuronal excitation propagation, therefore, a set of such excitations can enter into a certain region from another one and may realize there a prethought, as was described above, i.e. create a thought. If this model can be applied to the human brain, it could explain why, for example, the nervousness influences the heart beating, blood pressure, ability to be concentrated on a certain work *etc.*. Contrary to an excitation propagation through a neural network, which is localized at each moment of time, a thought (ACR) is evidently not localized because its CR occupies a part of the considered region. Perhaps this fact can explain volume transmission in the brain (Agnati *et al.* 1992 and references there). Consider it in more detail.

In the cited article the authors write: "Just as electrons flow along wires in a circuit, the neurons in the brain relay information along structured pathways, passing messages across specific points of contact called synapses. Information can no more leave the neuronal circuitry than a train can safely leave its tracks. But there is increasing evidence that neurons can communicate without making an intimate contact. The relaying of messages across synapses may be the fastest means of processing information, but it is quite likely that information often leaves the track." A CR is not localized in a certain point of the brain being a combination of many neurons filling up a certain *region*. Therefore, the picture that the neurons in the brain relay information along structured pathways, does not correspond to the information processing by ACRs, but to the one without ACRs' participation, to the basic level information processing, as we call it. Thus, the effect of volume transmission not only is naturally explained in the framework of the ACR based information processing by the brain, but the existence of this effect confirms that at least a part of the information processing by the brain is done by ACRs. Complicated thoughts can be represented only by ACRs of different levels, or, in other words, the human thinking corresponds to the information processing by ACRs, but not to the basic level of the information processing.

4.6 ACRs IN NNW: SOURCE SET EXPANSION AND ORDERING

In §4.5 we have explained in general terms how the proposed theory can be applied to NNWs. Now consider it in detail. The mathematical theory developed above makes it clear that the considered in Chs. 1 and 3 an expansion of the given set $\mathcal{A}$, e. g., $\mathcal{A}_S$, creates new possibilities to construct

CRs and therefore ACRs, which means an increase of the NNW capacity for information processing. Consider now an NNW consisting of a finite number of interconnected units, e.g., neurons, T_{ij} being the strength of the connection between units i and j, and define the source set $\mathcal{A}_S$ as the set of all units. In this case we shall call **BASIC LEVEL INFORMATION PROCESSING** the one performed by the set of connected units of the NNW, i.e. by the source set itself without ACRs participation (this means, without mind participation), such that each unit forwards its output to other ones inputting them.

The general set theoretical definitions of CRs and ACRs for a NNW introduces new elements able to process the information, which are not elements of the source set $\mathcal{A}_S$,e.g., units (neurons) of a NNW, but their combinations. What is the second order (i.e. the simplest) CR? This is a combination of NNW units having 4 states: the state when only the first relation is excited, the state when only the second relation is excited, the states when both relations are excited and when neither are excited. The realization of such a CR by excitation propagation throughout the units forming it (keeping the order!), i.e. its transformation into a ACR, means the transition from the first state to the second one, as occurring by the firing of a unit in the McCullough&Pitts (1943) and Hopfield (1982) model of the NNW. In other words, such an ACR processes the information as a neuron does in the considered model. By analogy, a CR of the order n represents a system with $2n$ possible states participating in its realization, and its realization means transitions between these states ordered from the first relation to the n-th one. Therefore it is like a unit having $2n$ states. NNW consisting of such units was considered by Nakamura *et al.* (1995). The first step of the set $\mathcal{A}_S$ expansion (§1.2) is a) to construct from NNW units all possible combinations satisfying the CR definition, b) to consider each CR as an element of the set $\mathcal{M}^{(1)}$, and c) to add them to the set $\mathcal{A}_S$. Then we shall obtain the set $\mathcal{A}^{(1)}_{\mathcal{M}^{(1)}} \supset \mathcal{A}_S$. The second step is a) to construct all possible CRs from elements of the set $\mathcal{A}^{(1)}_{\mathcal{M}^{(1)}}$, b) to consider each CR as an element of the set $\mathcal{M}^{(2)}$, and c) to add them to the set $\mathcal{A}^{(1)}_{\mathcal{M}^{(1)}}$. Then we shall obtain the set $\mathcal{A}^{(2)}$. This procedure can be continued. This description of the source set expansion is rough, but allows one to understand better its meaning in the case of a NNW. The strict mathematical procedure is described in §1.2. If the source set (units of the NNW) is a finite one and the procedure of its expansion (described above) principally can be continued infinitely, the set $\mathcal{A}^{(K)}_{\mathcal{M}^{(K)}}$ at $K \to \infty$ will be an infinite countable set in the case when this limit exists. However, in a really existing NNW, as well as in the general case (*cf.* 3.4), this process may be stopped at a finite value of $K = N$, in particular, because all possible relations necessary to order the set and to construct CRs, will be exhausted as a result that the corresponding properties of the NNW will be exhausted. To understand this statement it is to be reminded that in a *real* NNW all relations are based on physical, chemical and other laws of the nature, but cannot be implemented arbitrarily as it can be done in an abstract mathematical theory. For example, a 1-D NNW can be ordered by defining that for all units unit $(i) \prec$ unit $(i+1)$, iff $T_{i,i+1} > T_{i+1,i}$, the unit with $i = 1$ being at the left end of the NNW. Then it can serve as the source set $\mathcal{A}_S$. The ordering of sets $\mathcal{A}^{(1)}_{\mathcal{M}^{(1)}}, \mathcal{A}^{(2)}_{\mathcal{M}^{(2)}}, \ldots, \mathcal{A}^{(K)}_{\mathcal{M}^{(K)}} \ldots$ can be done as follows (see §3.4): 1) All elements of a set $\mathcal{A}^{(K)}_{\mathcal{M}^{(K)}} \setminus \mathcal{A}^{(K-1)}_{\mathcal{M}^{(K-1)}}$ follow all elements of the set $\mathcal{A}^{(K-1)}_{\mathcal{M}^{(K-1)}}$. 2)In the framework of the same set $\mathcal{A}^{(K)}_{\mathcal{M}^{(K)}}$ each CR of higher order follows all CRs of lower orders. 3) Two CRs of the same order belonging to the same set $\mathcal{A}^{(K)}_{\mathcal{M}^{(K)}} \setminus \mathcal{A}^{(K-1)}_{\mathcal{M}^{(K-1)}}$ can be ordered, for example, as follows: that one of them follows the other one, which has the larger sum of all its connections $T_{i,j}$ with the NNW units (if a unit enters $l > 1$ times into the CR, the sum of its connections with other units of the net is multiplied to l).

The ordering of the source set $\mathcal{A}_S$ and its expansions may be done not only on the grounds of relations between interunit couplings, but also on the grounds of differences between units (e.g., neurons) and between CRs. The difference between units may arise, in particular, from the difference between their states. It is possible, for example, in the Nakamura *et al.* (1995) generalization of the Hopfield (1982) model of the NNW consisting of units possessing more than two possible states. Excited states usually have a finite life-time, therefore, only such CRs have meaning, i.e. can be transformed into ACRs, for which the time of the excitation propagation throughout the CR is less than the smallest among life times of its excitations. According to the n-th order CR definition it contains n different relations between subsets of the corresponding set $\mathcal{A}^{(K)}_{\mathcal{M}^{(K)}}$. These relations also may be the ones between combinations of interunit connections of certain subsets, as well as between subsets of units themselves, if they are different. This "if" arises only in connection with NNW units, but not in connection with CRs because any two CRs are different, being built from different sequences of relations, which corresponds to the case of different units, if to consider each CR as a supplementary unit.

What is the difference between the use of a CR as an element of the set $\mathcal{A} \setminus \mathcal{A}_S$ and the use of a corresponding thought (ACR) recalled from memory? The use of a thought recalled from memory is exactly as the use of a new thought, while in the first case the content of the CR is not important, it simply represents one more combination of NNW units serving a new element a of the set $\mathcal{A}$. We considered here different-level information processing based on the realization of different-order CRs, i.e., their transformation to ACRs of corresponding orders. As it is explained in APPENDIX 1, this transformation is based on neuronal activity in the case of human thinking or on physical processes occuring with units of an artificial NNW. It evidently remains correct for CRs of any order when they are transformed into ACRs.

4.7 SYNERGETIC CHARACTER OF HUMAN THINKING

We shall call N-th *LEVEL INFORMATION PROCESSING* the one performed by use of elements of the set $\mathcal{A}^{(K)} \setminus \mathcal{A}^{(K-1)}$ and only by them. The different levels of information processing may interact, and this interaction may be strong, intermediate or weak dependent on the degree of the involvement of two kinds of CRs to this processing: those constructed only from elements of a set $\mathcal{A}^{(I)} \setminus \mathcal{A}^{(I-1)}$ and those constructed only from elements of a set $\mathcal{A}^{(J)} \setminus \mathcal{A}^{(J-1)}$ $(J \neq I,\ J \neq I \pm 1)$. This means the information processing by a NNW has the synergetic character because its different levels (different values of K) correspond to different levels of the NNW organization. Of course, the simultaneous participation of different levels of information processing in thinking is also possible and may produce non-trivial effects. Their study would be very interesting, especially to understand some important aspects of scientific thinking. The K-th level of information processing (thinking) includes different types of this level thinking, in particular, **K-th level conscious thinking**, if it can be defined there according to its general definition in §4.2. Thus, *the proposed theory naturally leads to the existence of different levels of consciousness.* Indeed, in this case all ACRs (thoughts) including trial sets of thoughts serving for self-measurements, are those of K-th level and because of this consciousness must be defined separately for different levels of thinking. The exception is the basic level because basic level information processing is performed without use of ACRs. Therefore, there are no self-measurements, and *the basic level consciousness does not exist.* Perhaps, researches into awareness, *e.g.*, sensory awareness, (see, for example, (Taylor 1996a)) *really* deal with information processing of levels higher than the basic one. It can be expected that the explicit use of the theory proposed in the present work will be useful for such researches. Notice that an interesting subject of research would be the effect of the simultaneous participation of different levels of consciousness that is possible as a consequence of the simultaneous participation of different levels of information processing in thinking.

The present mathematical theory can be applied also to information storage and processing on sub-cellular level of organization, e.g., to DNA (Ch. 7), which means that, at least from the mathematical point of view, the brain is a synergetic system where similar processes occur with information at different scales: from the sub-cellular one up to the whole brain. However, the synergetic character of human thinking is expressed also in the fact that NNW *of each scale* (microscopic or macroscopic) has the set of levels of information processing (thinking) considered above. In particular, it can help to understand how genetic information may influence high-level human thinking . The genetic information evidently influences the structure and properties of neurons and interneuronal connections in the brain , and thereby it influences basic-level information processing, which, in its turn, may influence high-level thinking, as it is established below in §4.8. Reflexes, talent for music or for mathematics etc. "written" in DNA molecules can be transferred to the mind in this way.

4.8 COMPARISON OF THE HUMAN BRAIN AND ARTIFICIAL NNW

The fact that CRs really play the rôle of supplementary units, as was described above, leads to a drastic increase in the number of elements processing information and therefore of the NNW capacity for information processing at a given number of its units. *IT WOULD BE NATURAL TO SUPPOSE THAT IT EXPLAINS THE ENORMOUS CAPACITY OF THE HUMAN BRAIN FOR INFORMATION PROCESSING IN COMPARISON WITH COMPUTERS DESPITE (MAY BE BECAUSE) NEURONS AND INTERNEURONS CONNECTIONS WORK INCOMPARABLY MORE SLOWLY THAN SEMICONDUCTOR DEVICES IN COMPUTERS.* Let τ_s be the time of life of a unit (e.g., neuron) excited state with respect to spontaneous transitions, and τ be that with respect to the excitation transfer to another unit. Then the time of a CR transformation into a ACR would be $n_1\tau$, where n_1 is the number of neurons in this CR. In continuation of this rough consideration assume that each relation contains the same number μ of NNW units. Therefore the order of a CR $n = n_1/\mu$.

Denote $w_s = 1/\tau_s$ the probability of a unit (neuron) excited state to decay spontaneously. If there are n_1 units and if spontaneous decays of their excitations are independent, the probability of such a decay in a CR of the order n would be

$$W_n = \mu n w_s = \mu n/\tau_s, \tag{4-1}$$

and

$$\theta_n = 1/W_n = \tau_s/\mu n \tag{4-2}$$

For the normal functioning of the NNW it is necessary that

$$\theta_n \gg \mu n \tau, \tag{4-3}$$

i.e.

$$\tau_s \mu^{-1} n^{-1} \gg \mu n \tau, \tag{4-4}$$

and therefore it must be true that

$$n \ll \mu^{-1} \tau_s^{1/2} \tau^{-1/2} \tag{4-5}$$

The last inequality limits the length of ACR expressed in the number of relations. Its generalization to the case when relations may consist of different numbers of units is evident. The τ_s of neurons in the brain can be very large in comparison with τ, and because of it ACRs of very large orders n can be created. It is very doubtful that it is possible to obtain $\tau_s \gg \tau$ in semiconductor devices. The time-energy uncertainty principle will lead to the overlapping of levels, if it be reached by the diminishing of τ. From this very rough consideration one can conclude that the possibility of the creation of high-order ACRs by an artificial NNW built of semiconductor devices is very questionable, while it is possible in the case of the brain. This means, the Hertz *et al.* (1991) idea that an artificial NNW constructed exactly as the human brain, but from semiconductors ("electronic brain"), may have the much higher (than the brain) capacity for the information processing, seems at least questionable. Notice that our conclusion probably is not valid, if an artificial NNW is built of superconducting devices, because the time τ_s connected with the dissipation of the excitation energy in the NNW (including radiation processes) is very short in this case. Now return to the concept of "collisions between thoughts (ACRs)" (considered in Ch. 3) that becomes especially clear and concrete in the case of NNWs. Suppose two CRs have one common unit. Let the excitations transforming them into ACRs (thoughts) reach it simultaneously. It does not mean that they arrive there *exactly* at the same time, but that the difference between times of their "arrivals" must be less than the time of life of a unit excitation (τ in our rough consideration). Then both ACRs interact changing the following excitation propagation through the NNW (it is possible that after this time moment only one excitation propagates instead of two). Therefore the resulting ACRs (or ACR) may differ from those that should be created, if both excitations have not reached the considered unit simultaneously. This is the collision between thoughts within a NNW. It can be expected that the probability of such a collision increases when the excitation life-time τ increases. Therefore the use of fast semiconductor devices in the same NNW instead of slow neurons-interneuronal-connections "devices" must diminish essentially the probability of the collisions of thoughts and, as a consequence, the capacity of the NNW to perform self-measurements to be aware of its own thinking and to govern it. Thus, once again we see that the low rate of processes in the brain has important advantages, and cannot be considered as its imperfection in comparison with the "electronic brain" . If such a common element of two ACRs is not a unit (neuron), but an element of a set $\mathcal{A} \setminus \mathcal{A}_S$, the situation is the same. It remains the same even if two elements of the set $\mathcal{A} \setminus \mathcal{A}_S$ have only one common unit of the NNW. In this case two thoughts collide, if the excitations transforming the corresponding prethoughts into thoughts reach this common NNW unit simultaneously. Warning: if two CRs have more than one common elements (units or elements of the set $\mathcal{A} \setminus \mathcal{A}_S$), it does not mean that the corresponding ACRs collide more than once because, as was noted above, the first collision changes them and therefore their following propagation cannot be considered as the realization of the same CRs which existed before the collision. In other words, two thoughts can collide only once, while the second collision (if it occurs) will be between other thoughts. The probability that two or more CRs have a number of common units increases when the order of CRs increases and when the number of units decreases. Therefore in a NNW having a small number of units, very long CRs cannot be transformed into ACRs, in other words, they cannot be virtual thoughts. Thus, only NNWs consisting of very large number of neurons are able to create long and complicated ACRs. This statement is clarified by the consideration of some simple examples (APPENDIX 2). Information processing, or thinking, may change the NNW hardware consisting of units and interunit connections (see, for example, Hopfield (1982), Cooper *et al.* (1979), Willmacher (1976), Anderson (1977)), and this phenomenon underlies the NNWs learning mechanism. This means that the set of relations is changed by learning: a part of them stop to exist, while new relations appear. It causes changes of the set of CRs and, as a consequence, of corresponding ACRs. If the characteristic time of the learning is much larger than the time of the longest CR realization, one can use the quasi-stationary approximation: to consider at first the realization of a CR occurring under stationary conditions supposing that the hardware properties are fixed, and thereafter to take into account these changes and their influence on the CRs realization using iterations or the theory of perturbations. As is seen from the above, these changes of the NNW hardware properties influence the thinking of all levels including the highest ones. This conclusion is not trivial. This means the learning performed only in the framework of the basic level of information processing changes all higher levels of information processing. Notice that the possibility of high-level thinking creation by low-level ones completes and clarifies our interpretation of the effect of Libet (Libet *at al.* 1979, Libet 1985). At the same time, analogically, the learning performing in the framework of a high level $K > 1$ information processing causes changes of couplings between elements of the corresponding expansion of the set $\mathcal{A}^{(K)}_{\mathcal{M}^{(K)}}$ and therefore between units (because elements of the set $\mathcal{A}^{(K)}_{\mathcal{M}^{(K)}} \setminus \mathcal{A}_S$ are connected by NNW units), which returns us to the previous situation. Therefore learning performed in the framework of any level of information processing, including all highest levels, i.e. by use of high order very sophisticated thoughts (ACRs) , scientific theories etc., influences, in its turn, all levels of information processing (thinking) beginning from the basic level one, and provokes changes of the brain structure influencing its *physiological* development. This means, it would be *incorrect* to think that the brain is developed only by biological, biochemical processes and so on, while learning only fills it in of more and more sophisticated programs. In different systems the density of CRs may be different and they may form a "gas" as well as a "condensed ensemble". In the first case the concentration of pairs of CRs having more than one common unit is small, as well as of "clusters" of few CRs having one or more common units. Following this analogy with gases it is possible to consider CR gases of different densities, and therefore with different contributions of binary, ternary and so on collisions of ACRs. Then the existence of CR pairs (or clusters) having two or more common units will limit the achievable length of ACRs, making questionable the use of the ACR concept in the limiting case of CRs condensed ensemble. However, it is to be remembered that a unit common to two or more CRs influences the corresponding thoughts only when the excitations realizing these crossed prethoughts reach this unit simultaneously. The probability of this event increases at the increase of the excitation pulses repetition frequency, i.e. of the thinking intensity. *The proposed model can, therefore, remain valid also in the case of the very dense CRs ensemble, if the intensity of thinking is* *not too high.* Thus, the following conclusion can be made concerning artificial NNWs: it must not try to increase without bound the number of CRs (by increasing the number of relations existing in the considered NNW) to promote the NNW capacity for information processing, because beginning from a certain stage of this process it may demand to reduce the intensity of the information processing. Following the analogy with gases, solids and liquids, one can suppose that under certain conditions in the case of very dense CRs ensemble ACRs can be considered as an analogy of elementary excitations in solids (quasi-ACRs play the similar rôle than quasi-particles, *e.g.*, phonons) forming not too dense gas, but something like exciton liquids. However, in those cases when such situations are impossible, how does the NNW process information, and how, in general, is it able to do it? This is a very interesting question and also very important because the choice of the way of promoting the capacity of a NNW for information processing depends on the answer to this question.

The concentration of the human mind on a certain subject of thinking , instead of its occupation with thinking on all possible subjects, is a way to reduce the intensity of thinking (therefore also the density of the ensemble of thoughts) and the number of ACRs' collisions. Conscious thinking can be performed only at very low densities of thoughts corresponding to the "gas of thoughts with only binary collisions" to make possible self-measuring of the mind by trial sets of thoughts. However, if thinking on a certain selected subject becomes too intensive (the ensemble of thoughts would become too dense) it is necessary to divide the considered subject of the thinking into some "sub-subjects" and to be occupied with them subsequently, but not simultaneously to reduce the density of ACRs and to make thinking possible.

Thus, the limitation of permissible thoughts' density (especially in the case of conscious thinking when the mind measures itself by use of trial sets of thoughts) demands from the human being to concentrate the thinking on a certain subject. Then it obtains the maximum of information on this subject and the minimum on other ones. It leads to the quantum theory of the mind, when, in particular, the information processing by a NNW, e. g., by the human brain, is governed on the level of the metric space of states of the mind according quantum probabilities. The quantum theory of the mind is a subject of Ch. 5.

4.9 CONCLUSIONS

It was supposed that the human brain processes the information (= thinks) by activated chains of relations and mathematical theory developed in Chs. 1 - 3 was applied to the human thinking. This application demands the "biologization" of this theory, which is formulated as the mind-brain relationship problem consisting of definitions of certain biological systems in the brain as elements of sets figuring in the proposed theory. These sets are: 1)source set $\mathcal{A}_S$ (ordered) necessary to construct combinations of its elements called CRs, 2)well ordered set $\mathcal{H}$ necessary to transform CRs into ACRs, or thoughts, sets $\mathcal{A}_\alpha$ (ordered) and $\mathcal{H}_p$ (well ordered) necessary to define memories of two types. The case of neural networks is considered. In this case the source set is a NNW. ACRs that are themselves information processors (Ch. 1) are added to the NNW and may essentially promote its ability for the information processing without an increase of the number of units forming the NNW hardware. It is important that the information processing by ACRs possesses the ability for the creation of very complicated and sophisticated statements. It leads to a very important conclusion that the intellectual development of a person occurs mainly because more and more longer CRs are created in its brain, and only in a small degree because the increase of the number of neurons. Consider it in more detail. If to assume that NNW principally could be a relevant model of the human brain, then the proposed approach helps to clarify why the intellectual development of an individual can occur without an increase of the number of neurons in the same measure that the intellectual capacity and level increase. For example, the brain of a man who was never occupied with any intellectual activity, never even studied in school, contains on average the same number of neurons as the brain of a prominent scientist. However, at the same time the proposed theory does not consider these two brains as identical, but indicates why and how learning and the intellectual activity, in general, produce changes (and what kind of changes) in the brain rising its ability to create more and more sophisticated thoughts (ACRs) , without affecting the number of neurons in the brain.

If the brain thinks using ACRs, it explains the effect of volume transmission in the brain discovered by Agnati et *al.* (1992): an ACR is not localized at the place of one neuron because it includes a certain set of neurons placed in a region of the brain, which means that the propagation of the information expressed in thoughts (ACRs) cannot be identified with the propagation of nervous pulses, but with the volume transmission. Usually the NNWs theory is, in our terms, the study of the basic level information processing only, while human thinking creating sophisticated statements occurs on higher levels of the information processing using ACRs. Apparently the brain modeling by NNWs is impossible, if, as usual, we limit ourselves with only basic level information processing. *Perhaps the theory proposed in this chapter allows the brain modeling by NNWs by taking into account the information processing by ACRs, i.e. on its higher (than basic) levels.*

The consideration made in §1.3 allows one to come to one more conclusion concerning the human thinking. If the brain processes the information by ACRs (this is a *hypothesis* needed to be checked), one or more sets $\mathcal{H}$ can exist and be used for CRs activation, which can be called **thinking time(s)**. Indeed, it is not yet proved that namely the physical time serves as the only time for the thinking processes, and, therefore, it would be logically to check all possibilities.

4.10 REFERENCES TO CHAPTER 4.

Agnati, *Luigi F.*, Bjelke, *Borie*, Fuxe, *Kjell*: 1992, *Volume Transmission in the Brain.* Am. Scientist **80**, 362-373.

Amit, *Daniel J.*: 1989, *MODELING BRAIN FUNCTION. The World of Attractor Neural Networks.* Cambridge University Press.

Anderson, *J.A.*, Silverstein, *W.*, Ritz, *A.*, Jones, *Randal S.*: 1977, *Distinctive features, categorical perception, and probability learning: some applications of a neural model.* Psych. Rev. **84**, 413-451.

Bohr, *Nils*: 1928, *The Quantum Postulate and the Recent Development of Atomic Theory.* Nature **121**, 580-590.

Bohr, *Nils*: 1935, *Can Quantum Mechanical Description of Physical Reality be Considered Complete?* Phys. Rev. **48**, 696-702.

Brillouin, *Leon*: 1956, *Science and Information Theory.* Acad. Press, Inc. Publishers, New York

Čech, *Edward*: 1966, Topological Spaces. Interscience Publishers, A Division of John Willey & Sons, London-New York-Sydney.

Cooper, *L.N.*, Liberman, *F.*, Oja, *E.*: 1979, *A theory for the acquisition and loss of neuron specifity in visual cortex.* Biol. Cybern. **33**, 9-28.

Dirac, *P.A.M.*: 1958, *The Principles of Quantum Mechanics.* Oxford at Clarendon Press.

Eigen, *Manfred*: 1971, *Selforganization of Matter and the Evolution of Biological Macromolecules.* Naturwiss. **58**, 465-523.

Hertz, *John*, Krogh, *Anders*, Palmer, *Richard G.*: 1991, *INTRODUCTION TO THE THEORY OF NEURAL COMPUTATION.* Addison-Wesley Publishing Company, Redwood City, USA.

Hopfield, *J.J.*:1982, *Neural Networks and Physical Systems With Emergent Collective Computational Abilities.* Proc. Nat'l Acad. Sci. (USA) **79**, 2554-2558.

Kelley, *G.*: 1955, General Topology. New York.

Kolmogorov, *A.N.*& Fomin,*S.V.*: 1963, *Elements of the Theory of Functions and Functional Analysis.* Rochester, N.Y., Gray Lock Press.

Kullback, *Salomon*: 1958, *INFORMATION THEORY AND STATISTICS.* New York-John Wiley & Sons, Inc., London-Chapman & Hall, Limited

Libet, *B.*, Wright, *E.W., Jr.*, Feinstein, *B.*, Pearl, *D.K.*: 1979, *Subjective Referral of the Timing for a Conscious Sensory Experience. Brain*, **102**, 193-224.

Libet, *Benjamin*: 1985, *Subjective Antedating of a Sensory Experience and Mind-Brain Theories: Reply to Honderich (1984).* J. Theor. Biol.**114**, 563-570.

Lindenberg, *Siegwart*, Oppenheim, *Paul*: 1974, *Generalization of Complementarity.* Synthése **28**, 117-139.

McCullough, *W.S.* & Pitts, *W.*: 1943, *A logical calculus of the ideas immanent in nervous activity*, Bull. Math. Biophys. **5**, 115-133.

Nakamura, *Y.*, Torii, *K.*, Munakata, *T.*: 1995, *NEURAL-NETWORK MODEL COMPOSED OF MULTIDIMENSIONAL SPIN NEURONS*, Phys. Rev. E**51**, 1538-1546.

Packel, *Edward W.*, Traub, *J. F.*, Woźniakowski, *Henryk*: 1992, *Measures of Uncertainty and Information in Computation*, Inf. Sci. **65**, 253-273.

Salomaa, *Arto*: 1973, *Formal Languages.* Acad. Press, New York and London.

Taylor, *J. G.*: 1996a, *A competition for consciousness?.* Neurocomputing **11**, 271 - 296.

Taylor, *J. G.*: 1996b, *The Emergence of Mind.* In: Proc. Int. Workshop "Brain, Computer, Evolution." Kobe, Japan, December 9-10.

Volkenstein, *M.V*: 1977, *The Amount and Value of Information in Biology.* Found. Phys. **7**, 97-109.

Willwacher, *G.*: 1976, *CAPABILITIES OF AN ASSOCIATIVE STORAGE-SYSTEM COMPARED WITH FUNCTION OF BRAIN*, Biol. Cybern. **24**, 181-198.

Chapter 5

THEORY OF STATES OF MIND AND ITS APPLICATIONS

5.1 INTRODUCTION

One important problem was not considered in Chs. 1-4: how the information processing, in particular, thinking is governed? In this chapter this problem is considered, and it was found that the human thinking is governed on the level of states of mind, but not on the level of the mind itself. In other words, the thinking is governed indirectly that influences essentially its laws, e.g., the character of the logic used by human beings, if namely the logical thinking is considered (in Chs. 1-4, as well as in the present chapter, any kind of thinking is considered, not obligatory the logical one). The study of human thinking naturally leads to the use for this purpose of *general ideas* of the quantum theory (see, for example, Temkin (1982) and Jahn & Dunne (1987)) originated from the physics of the micro-world that however are meaningful for a much wider field of the science. Our theory is built so that at first *the mind* is defined as a set theoretical concept (Ch. 4) and thereupon, in the present work we find that *under certain conditions* its states and behavior possess such properties that demand to describe them in the *spirit* of quantum theory, though *not obligatory by use of exactly the same mathematical formalism.* In other words, the proposed new theory, being not an application of the quantum mechanics itself to the human thinking, is based on the same fundamental principles as the quantum mechanics, especially all those concerned with the connection between incompatibility of different types of measurements and the structure of mathematical formalism. Notice that discussions between physicists about the validity of the Copenhagen interpretation of quantum mechanics are not concerned with this theory namely because of the fact that it is not the quantum mechanics. The author considers this interpretation as a principally new approach opening the way of science (not only physics) development, no matter whether it is the only possible interpretation of quantum mechanics itself.

In the previous work of the author (1982) (see also Ch. 6) self-measurements of thinking processes and physical, geometrical and other quantities characterizing the state of a person A were considered and compared with measurements performed by another person B on A. It was found out that these measurements create two different reciprocally complementary realities. We postpone the detailed consideration of this phenomenon to Ch. 6.

In this chapter we continue the analysis, which was begun in our work (1982), focusing now our attention on different *self-measurements* of the mind. In this case different incompatible realities are created by different types of mind *self-measurements* when only one person is involved, but his thinking may be concentrated on different subjects.

Let us consider in brief some basic aspects of measurements and their role in the theory, with the purpose of understanding how to construct a theory of human thinking, taking into account the peculiarities of self-measurements of the human mind. The point of view of modern physics is that measurements and their properties play a fundamental role in physical theory (Einstein 1905, 1953, Dirac 1958, Bohr 1928, Heisenberg 1930). Nils Bohr (1933, 1937) gave arguments that this statement is also valid in microbiology. There are arguments that it is also valid in psychology and human thinking, in general (see, for example, Temkin 1982, Snyder 1983a,b, Penrose 1989). The fundamental role of measurement in the theory comes from the fact that measurements may change uncontrollably the state of the measured system, which leads to the impossibility of simultaneous measurements of different quantities and thereby affects directly the structure of the mathematical formalism. For example, the system of Newtonian differential equations for a system of material points was replaced by the quantum mechanical formalism of algebra of non-commuting operators in the case of atomic systems just because of the incompatibility of measurements of conjugate variables. A measurement is supposed to be performed by a system consisting of measuring instruments and an observer. The task of the observer is to interpret results of the measurements. *Without this interpretation the measurements provide no information.* However, this task of the observer is not usually considered and not analyzed explicitly in physical theories. Only the collapse of the state vector in quantum mechanics reminds us of the *EXISTENCE* of the observer supposed in the quantum mechanics. But, the work of Schmidt (1982) on this subject hints that *PROPERTIES* of the observer are important and should be an essential part of the physical theory (*cf.* §5.6).

In the relativity and quantum mechanics, in exception to the theory of the quantum Universe (Hartle & Hawking 1983, Fukuda 1989, 1991, Mensky 1991, Zeh 1986, 1988), an observer equipped with measuring instruments studies physical bodies *which can be only objects of such study* because they are not able to measure their own physical quantities and to interpret results of these measurements.

In contrast to such primitive systems, a human being is able to measure characteristics of his own state including his own thinking processes (Temkin 1982) by use of the interaction between ACRs. (Chs. 3-4). The concentration on a certain subject of the thinking means that the content of measuring thoughts corresponds to this subject. Under this condition the mind obtains the maximum of information on its thinking processes about the chosen subject. As it was shown (Chs. 3-4), the set of all possible self-measurements of a mind can be classified as a number of subsets (corresponding to the concentration of mind on different subjects of thinking) such that two measurements are compatible, if they both belong to the same subset, and incompatible, if they belong to two different subsets. In the latter case uncertainty principles exist between different kinds of measurements made by a person measuring his own mind. Therefore the relevant mathematical description of the human mind should be based on algebra of non-commuting operators. In other words, the theory of the human mind should be quantum in nature. However, as we shall see in §5.2, it cannot be identical to the mathematical formalism of the quantum mechanics of atomic particles.

When human thinking is compared with information processing by computers, the computer seems to be a symbol of certainty, reliability, exactness and perfection as opposed to the human brain that functions imperfectly, uncertainly, unreliably and not exactly. However, when in Ch. 4 a computer was compared with the human brain, it was unexpectedly clarified that the extremely high operation rate of computer's electronic devices (which seems to be computer's very important advantage) when compared with the operation rates of neuronal, synaptic, etc. processes of the human brain, does not lead to the computer's superiority over the brain, but, rather, to the brain superiority over the computer with regard to some important aspects of high level information processing. Could the uncertainty of our thinking also not be a shortcoming of the human brain, but its advantage over computers? In the present work we try to answer this question as well as find the origin of the uncertainty of human thinking and how it affects the theory of thinking.

5.2 METRIC SPACE OF STATES

What is the main difference between the quantum theory of states of mind and quantum mechanics? The representation of micro-system states by elements ψ of normalized spaces in quantum mechanics is based on the interpretation of the $\mid \psi^* \psi \mid$ as the probability density and on conservation laws of mass and charge of a particle. Such arguments do not exist in our quantum theory of states of mind, and therefore there is no reason to use normalized spaces. Hence, we shall use a metric space to represent states of the mind. In each metric space the distance $\rho(\psi_0, \psi) = \rho(\psi, \psi_0)$ between each two points ψ_0 and ψ exists, is positive for two different points, is equal to zero, iff these points coincide, and satisfies the triangle inequality $\rho(\psi, \psi') \leq \rho(\psi, \psi_0) + \rho(\psi_0, \psi')$ (Kolmogorov & Fomin 1963, Čech 1966). Normalized space is a particular case of metric space because in such a space the distance can be defined by use of norm. Hilbert space used in the quantum mechanics is, in its turn, a particular case of normalized spaces: in Hilbert space the scalar product of two vectors is defined, then the norm of a vector is defined as its scalar product with himself in degree 1/2. To construct the theory of states of mind the concept of probability of a state of mind must be defined as it is done in quantum mechanics for states of micro-systems. The existence of the distance ρ between two states of mind allows us to define the notion of the probability of states represented by points ψ of a metric space relative to a point ψ_0 of the same space. This probability is defined and normalized differently in the following three cases having the analogies in the quantum mechanics of atomic systems:
1)ψ *IS AN ISOLATED POINT OF A COUNTABLE SET*. Then the minimum distance $R_{min}(\psi) \leq \rho(\psi_0, \psi)$, exists between the considered point and other points of this set (ψ_0 is a selected point of this space). The relative probability (*i.e.* depending on the choice of ψ_0) $w(\psi_0, \psi)$ of the state ψ is defined by the relation:

$$w(\psi_0, \psi) = Q^{-1} R_{\min}(\psi) \rho^{-1}(\psi_0, \psi) \ , \tag{5-1}$$

where Q is the normalization constant. If all permissible states of the mind are isolated points of the considered countable set, Q is defined by the relation ($\psi \neq \psi_0$):

$$Q = \sum_{\psi \neq \psi_0} R_{min}(\psi) \rho^{-1}(\psi_0, \psi) \tag{5-2}$$

With this choice of Q the probability is normalized as follows:

$$\sum_{\psi \neq \psi_0} w(\psi_0, \psi) = 1 \tag{5-3}$$

2)ψ *IS A POINT (BUT NOT AN ISOLATED ONE) OF A COUNTABLE SET.*

Consider the neighborhood of the point ψ having the radius $R(\psi)$. It contains an infinite countable set of points ψ'. Let $\Gamma_R(\psi)$ be the maximum linear density of states along lines connecting ψ_0 and ψ, $F(\psi) = \lim_{R \to 0} [\Gamma_R(\psi)]^{-1}$, when $\lim_{R \to 0} [\Gamma_R(\psi)]^{-1} \geq \rho(\psi_0, \psi)$, and $F(\psi) = \rho(\psi_0, \psi)$, when $\lim_{R \to 0} [\Gamma_R(\psi)]^{-1} < \rho(\psi_0, \psi)$. Now define the relative probability of a state $\psi \neq \psi_0$ by the expression:

$$w(\psi_0, \psi) = Q^{-1} \, F(\psi) \rho^{-1}(\psi_0, \psi) \ , \tag{5-4}$$

where the normalization constant Q is determined as follows:

$$Q = \sum_{\psi_0 \neq \psi} F(\psi) \rho^{-1}(\psi_0, \psi) + \sum_{\psi \neq \psi_0} R_{min}(\psi) \rho^{-1}(\psi_0, \psi) \tag{5-5}$$

to normalize the total probability to 1, if all permissible states consist of a countable set (the second summation is done with respect to all isolated points of this set). 3) ψ *IS A POINT OF A CONTINUUM SET.* Let $\mathcal{M}$ be a closed measurable subset of this set and the point $\psi_0 \notin \mathcal{M}$. Then the relative probability of the subset can be defined as follows:

$$w(\psi_0, \mathcal{M}) = Q^{-1} q_{\mathcal{M}} F(\mathcal{M}) \rho^{-1}(\psi_0, \mathcal{M}) \ , \tag{5-6}$$

where $\rho(\psi_0, \mathcal{M}) \neq 0$ is the distance between point ψ_0 and subset $\mathcal{M}$ (Kolmogorov & Fomin 1963),

$$F(\mathcal{M}) = \begin{cases} \lim\limits_{R \to 0} \Gamma_R^{-1}(\mathcal{M}), \text{ if } \lim\limits_{R \to 0} \Gamma_R^{-1}(\mathcal{M}) \, \rho^{-1} \, (\psi_0, \mathcal{M}) \leq 1 \\ \rho(\psi_0, \mathcal{M}), \text{ if } \lim\limits_{R \to 0} \Gamma_R^{-1}(\mathcal{M}) \, \rho^{-1} \, (\psi_0, \mathcal{M}) > 1 \ , \end{cases} \tag{5-7}$$

$$R = \rho(\mathcal{M}, \psi') \ , \tag{5-8}$$

$\psi' \notin \mathcal{M}$, but can be any point in the neighborhood of $\mathcal{M}, q \neq 0$ for any $\mathcal{M}$ is the measure of the subset. Thus, in the general case of the set of all possible states containing countable and continuum subsets, as well, the formula (5-5) must be generalized as follows:

$$Q = \sum_{\mathcal{M}\not\ni\psi_0} Q_{\mathcal{M}} F(\mathcal{M})\rho^{-1}(\psi_0,\mathcal{M}) + \sum_{\psi\neq\psi_0} F(\psi)\ \rho^{-1}\ (\psi_0,\psi) + + \sum_{\psi\neq\psi_0} R_{min}(\psi)\rho^{-1}(\psi_0,\psi) \tag{5-9}$$

The summation with respect to subsets $\mathcal{M}$ in (5-9) should be made only over a system of reciprocally non-intersecting subsets, which means that for any two subsets of this system $\mathcal{M}'$ and $\mathcal{M}$" would be $\mathcal{M}'\bigcap\mathcal{M}" = \emptyset$. The mind was defined as a certain set of CRs only, without ACRs . Therefore, according this definition, the mind has only one state. Let us now to change the terminology and keep the term *mind* also for the same set of CRs when a certain part of CRs is realized, *i. e.*, when there are not only CRs, but also sets of ACRs. The mind that does not contain ACRs we shall call **mind in its ground state**, while the mind containing sets of ACRs we shall call **mind in its excited states**. Therefore, the state of the mind, as well as ψ, the point of the metric space of states representing it, is function of ACRs' distribution like ψ-function of an electron is function of its co-ordinate or linear momentum or, better to say, as Fock's column is function of particles' configuration (Fock 1932). The meaning of the relative probability becomes clear: $w(\psi_0,\psi)$ means the probability of such a distribution at a chosen state ψ_0. The three considered cases have the analogy in the quantum mechanics of atomic systems. In the quantum mechanics a countable set of states corresponds to bound states, while the continuous spectrum corresponds to an infinite motion of parts of the considered system. What could this mean in our theory? An analogue of bound states, e.g., hydrogen atom, would be stable systems of thoughts (ACRs) , so to say, "atoms" and "molecules" (even "polymer molecules") of thinking. To clarify whether such states exist, how they influence the thinking (e.g., the logic), to search for such states and to study them, represent an extremely interesting and attractive field of research of human thinking. Represent each observable quantity A by an operator $\hat{A}$ acting on points of the metric space of states of the mind. Notice that there is no reason to demand that operators used in the quantum theory of mind would be Hermitian ones. Their eigenvalues therefore may be complex numbers. The definition of the relative probability by formulæ(5-1), (5-4) and (5-6) allows us to define the observed value of the observable A as follows:

$$\bar{\rho}(\psi,\hat{A}\psi) \stackrel{def}{=} \mathbf{S}_\psi\ w(\psi_0,\psi)\rho(\psi,\hat{A}\psi)\ , \tag{5-10}$$

where symbol **S** is written to be concise and means the three types of summation appearing in the formula (5-9). The summation is supposed to be done with respect to all $\psi \neq \psi_0$.

The general expression (5-10) of the observed value is different from the quantum mechanical one because in quantum mechanics the Hilbert space is used, in which the scalar product exists. While the quantum theory of the mind deals with the metric space where the scalar product is not defined in the general case. The expression (5-10) defines the observed value of an observable as the average value of the distance to where the points of the metric space are displaced by the operator $\hat{A}$, but not the average value of the operator $\hat{A}$ itself, contrary to the quantum mechanics rule. Operators $\hat{A}_1$ and $\hat{A}_2$ commute, iff the corresponding observables are measurable simultaneously, and they do not commute in the opposite case. Despite points ψ of the metric space of states of the mind depend on the set of ACRs (thoughts) as the electron wave function depends on its co-ordinates or linear momenta, as it was mentioned above, it is impossible to use points ψ of this metric space to find the probability of a certain set of thoughts, contrary to the quantum mechanics of the atomic particles where the probability distribution of co-ordinates (or linear momenta) is expressed as $\mid \psi^* \psi \mid$. Only the probability of a point ψ of a countable set or of a subset of continuum can be defined, *but of point or subset of the metric space itself, not of arguments of these functions, i.e., not of sets of CRs.* Thus, dealing with the necessity of the *metric space* it must be remembered that the thinking is governed by relative probabilities of states of the mind, i.e.more indirectly than the behavior of an electron is governed by its wave function. The recollection of thoughts from the memory is a good demonstration how the metric space of states of the mind acts.

In Ch. 2 two types of the memory were defined. Let us consider now how the recollection process is represented in terms of states of the mind. When the mind performs the recollection of an ACR (thought) or a set of them stored in a memory, the state of the mind is changed as a result of the appearance of a new thought (or thoughts) and will be represented by a point ψ_1 of the metric space of states. Generally speaking, this thought (or thoughts) is not obligatory an exact copy of the memory content. Let us now repeat this recollection process using different trial sets of thoughts. Each time the act of the recollection creates a certain state ψ_n of the mind. If at least one Cauchy sequence exists in the set $\{\psi_n\}$, then the recollection by use of the considered set of trial sets of thoughts is possible. If there is a number of Cauchy sequences in the set $\{\psi_n\}$ *having the same limit*, the result of the recollection would be independent of the choice of Cauchy sequence.

Otherwise it would not be known whether the result of the recollection has to do with the stored thought.

5.3 RELATIVE PROBABILITIES AND THINKING PROCESS; THE ORIGIN OF THE QUANTUM LOGIC

If two different points ψ_1 and ψ_2 representing two different states of the mind have the equal relative probabilities $w(\psi_0, \psi_1) = w(\psi_0, \psi_2)$, how does it influence the thinking process? Let ψ_0 represents a state of the mind created at a certain step of the thinking process. Let one of these two states of the mind ψ_1 and ψ_2 can be created as a result of the next step, i.e. that there are two and only two possible issues of the next step of the reasoning. Both these issues are equally probable because $w(\psi_0, \psi_1) = w(\psi_0, \psi_2)$. The states ψ_1 and ψ_2 correspond, generally speaking, to two different distributions of sets of thoughts that can be reached at the next step of the reasoning. This situation is like the one in the probabilistic quantum logic, but not exactly. As we have just seen, the thinking process development depends on relative probabilities **OF STATES OF THE MIND**, but not on the probabilities of sets of thoughts themselves. This is a very new situation which leads to a "subjectivisation" of the logic: different minds have, generally speaking, different pairs of the considered probabilities $w(\psi_0, \psi_1)$ and $w(\psi_0, \psi_2)$ corresponding to the distributions of possible results of the same step of the reasoning. Therefore the development of the thinking process could be different for different persons. This is a very important distinction between *statistical inferences of the quantum mind* and those usually considered in the theory of probability and quantum mechanics, where probabilities of inferences are the same for all persons. We return now to the considered example and add one more statement (or statements) that inserts an intermediate step of the reasoning creating a state ψ_{01} of the mind so that from the state ψ_0 the mind transits to the state ψ_{01}, and only thereupon to one of the states ψ_1 and ψ_2. Let $w(\psi_{01}, \psi_1) \neq w(\psi_{01}, \psi_2)$. Then that issue will be preferable, which corresponds to the state of the mind with the largest probability relatively to ψ_{01}. Thus, a way must be found to make considered relative quantum probabilities of different issues at each step of the reasoning different as much as possible with the purpose to reduce the indeterminacy of the reasoning. The quantum logic was studied by Birkhoff & Neuman(1936), Bergmann (1947), Chari (1977), Heelan (1970), Orlov (1982), Roman & Rumbos (1991) a. o., but it was not clarified that it originated from the nature of the human mind. The conclusions made above remain valid also when the neighborhood of ψ_0 contains more than two points representing states of the mind corresponding to distributions of possible issues of the next step of the reasoning. If the set of these points possesses a symmetry, *i.e.* they have the same probabilities relatively to ψ_0, it should be broken (as in the case of two points) to reduce the indeterminacy of the reasoning. Let us mention one more situation leading to uncertainty of the reasoning. It is possible that two (or more) different distributions of ICs correspond to the same state ψ. If this state is to be created at the next step of the reasoning, then these two (or more) inferences have the equal probabilities. To eliminate this uncertainty is possible by changing the reasoning using a new knowledge or to change the structure of the mind by learning (*cf.* Ch. 4) so that these two (or more) distributions of ICs correspond to different ψ. This means, one of purposes of the development of the scientific theories and learning should be the elimination of such situations when one state of the mind corresponds to more than one distribution of ICs.

5.4 REPRESENTATIONS

We shall say that the *mind serving as the measuring equipment+observer is in a certain representation , if it performs self-measurings when it is concentrated upon a certain subject of the thinking.* This concept of representation is the analogy of the representations in quantum mechanics, *e.g.*, co-ordinate and linear momentum ones. The principle difference between the representations in the quantum mechanics of the micro-world and in the quantum theory of the mind is that in the first case the observer is the same for all representations, only measuring devices are different. While in the second case there are *different observers for different representations* because the change of the concentration of the mind means also the change of its state, i.e. the mind that interprets measurements made in one representation is not the same as the mind that did it being in another representation. Therefore, one cannot be sure that all the information accepted and processed by the mind in the 1st representation would be translated without changes and losses into terms of another, the 2nd representation, and would be kept by the mind being in this new state. The considered information may be lost and distorted once again at the inverse transformation $2 \to 1$, and so possibly it will not be reproduced exactly and completely after these two subsequent transformations $1 \to 2 \to 1$. This means the product of a transformation and its inverse one, generally speaking, is not equal to the unit transformation. Therefore transformations between different representations of the mind do not form a group, at the best they may form a semi-group because not each transformation has the inverse one.

5.5 PERSONALITY

DEFINITION: *THE PERSONALITY OF AN INDIVIDUAL IN A CERTAIN REPRESENTATION OF HIS OWN MIND IS A SUBSET OF HIS metric space OF STATES REPRESENTING ALL POSSIBLE STATES OF HIS MIND AT A GIVEN SOURCE SET* $\mathcal{A}_S$ *WHEN THE MIND IS CONCENTRATED IN ACCORDANCE WITH THE CONSIDERED REPRESENTATION.* According to the definition of relative probability , the structure of this subset determines relative probabilities of all possible states of the mind (at a chosen ψ_0) and therefore it determines the thinking because it is ruled by means of these probabilities. However, another person, e.g. a psychologist trying to determine the personality of the examinée principally is really able to determine something else: **DEFINITION**: *THE PERSONALITY OF A PERSON* A *FROM THE POINT OF VIEW OF ANOTHER PERSON* B, i.e. the personality of A in a certain representation of B, *IS A SUBSET OF* B's *metric space OF STATES* (at a certain concentration of B's mind corresponding to the chosen representation) *REPRESENTING ALL POSSIBLE STATES OF* B's *MIND CREATED BY THE INFORMATION PROVIDED BY MEASUREMENTS PERFORMED BY* B *ON* A. The results of these measurements are input to B's mind and processed by him. Thoughts of B arising as a result of these operations create certain states of B's mind. It is clear that the thinking and behavior of A are determined more completely by his self-dicovered personality (see the first definition above), than by his personality discovered by the person B (see the second definition above), because the second one contains much less information, *e.g.*, B cannot measure A's thinking processes. Our definitions allow us to study mathematically this difference in the following way: to map A's personality found by B into that determined by A himself and to find what part of the set (A's self-discovered personality) is not covered by this map and what information on A's thinking is contained in this part, In other words, what information is lost at this mapping. The mathematical solution of this problem is very complicated and difficult, but when it will be solved, the proposed way should become a solid basis for the elaboration of adequate psychological methods of the human thinking and behavior study.

Introducing a basis of the metric space (see, for example, Kolmogorov & Fomin 1963) of states, each open subset of this space can be represented as a sum of a number of basic subsets. The personality is evidently an open subset and therefore it can be represented as a sum of a number of basic subsets, which can be called *BASIC PERSONALITIES*. Each of them is also a subset of all possible states of the mind under certain constraints, other than those used above to define the personality of an individual. Notice that it is necessary to suppose the existence of constraints because in the opposite case the subset of all possible states of the mind may coincide with the whole metric space of states. This quantum idea that the personality of an individual can be represented as a superposition of some personalities was suggested first by Pascual Jordan (1960). Pascual Jordan's idea was based on the analogy with the superposition of wave functions in quantum mechanics. Our approach is not connected with this analogy, but based on general properties of metric spaces. According to formula (5-10) observed effects are non-linear functions of ψ, so there is the interaction of effects arising on the grounds of different personalities of the same individual. Consider the representation when an individual is concentrated on thinking about his everyday life problems. Usually in this representation the most important effects produced by only one dominating basic personality have the largest relative probabilities. In other words, *in everyday life his psychology is determined practically by only one dominating basic personality* (*cf.* below and in our work (1982): in the case when there are two or more dominating personalities). Relative contributions of observable effects produced on the grounds of different basic personalities are determined by relative probabilities and therefore depend on the choice of ψ_0. Thus, one can state that to the same personality, generally speaking, corresponds a manifold of types of the thinking and behavior determined by the choice of ψ_0. However, it would be natural to suppose the existence of some invariance principles, as in the physics. Such a principle would establish that for the choice of ψ_0 within a certain distinguished sub-set $\mathcal{D}$ of the metric space of states of the mind, sub-sets of this space exist possessing the property that $w(\psi_0, \psi)$ does not depend on ψ being within one of these subsets. Thus, the existence of an invariance principle means that the personality possesses a kind of symmetry. The influence of the symmetry on the thinking was demonstrated above by the use of an example when only two equivalent points existed. This means the symmetry of the personality is an important psychological characteristic of the individual determining to a certain degree the type of his thinking and behavior, as well as other manifestations of the personality. The fact that it is defined here as a mathematical concept allows the study of it using mathematical methods. The symmetry of a human personality arises as a result of the heredity, as well as of the creation of some principles of thinking by the intellectual activity of the individual, of the religion, ideology, professional education and experience etc., which may create a distinguished subset $\mathcal{D}$ of states of the mind. If such a subset was not created, the thinking, its logic (if logical thinking occurs) and therefore the behavior of the individual are very uncertain because ψ_0 can be chosen arbitrarily, no preferable choice exists. However, it must be remembered that a preferable choice of ψ_0 does not prohibit absolutely another choice of ψ_0, but only makes it not typical for the individual. For example, he may get rid of the ideology that created the set $\mathcal{D}$, which in our terms means that he has chosen the point $\psi_0 \notin \mathcal{D}$. If an individual has two or more dominating personalities, the influence of this "split of personality" on his thinking, and therefore on his behavior, depends on representation in what this situation exists. If it is the representation corresponding to his concentration on everyday life problems and tasks, his behavior may seem strange or irrelevant, so his adaptation in the society would be very difficult. He even may be (sometimes erroneously, sometimes correctly) considered mentally ill because the majority (now not all) psychiatrists consider the split of personality as a symptom of mental diseases. But if this effect exists only in a representation corresponding to the concentration, for example, on abstract mathematical problems, it can be detected only by analysis of his scientific works and his way of the scientific thinking. Perhaps the interaction of different basic personalities of a scientist may help the creation of principally new ideas because to different personalities may correspond different approaches and styles of scientific thinking. If the mind of an individual cannot be brought to a certain representation commonly existing in the human society, or if the information that his mind is able to accept and to process when it is in this representation is very poor, it does not yet mean that his personality in other representations is also damaged and his intellectual level is low. It is probable that he possesses developed personalities in some other representations, i.e. he is different from the majority of human beings, but not mentally handicapped. Individuals suffering from serious limitations of their communications with the outside world seem to be an example of such disturbances. It is known that a part of them have a rich internal world and are able to express it by drawing pictures and by some other ways. However, if to take into account that the information processing (Ch. 1) contributes to the development of human brain during the life, it is to be expected that the abovementioned limitations may limit the content and amount ofthe information that the brain of such a person processes during his life, and, therefore, its contribution to the brain development. It is especially harmful during first years of the life when the development of the brain determines the intellectual level of the adult human being. Possibly the percent of babies born with such disturbances, but *potentially able to develop their intellect up to the normal (or close to the normal) level*, is essentially higher than among children of the kindergarten age. Perhaps, education programs (from the zero age, if possible) based on the principle of the intensification as much as possible of the information processing by the brain (in unharmed representations) can prevent the brain underdevelopment of such persons, e.g., autistic.

5.6 SYMMETRY OF PHYSICIST'S PERSONALITY AND IN PHYSICAL THEORIES

The connection between the human mind and laws of physics was discussed in the book of Penrose (1989). We shall discuss here an aspect of it based on symmetry properties of the human personality. As it was explained above, the symmetry of a person's personality directly influences the structure of the quantum logic and therefore his reasoning ways. Therefore, it would be very natural to expect that the symmetry of a physicist's personality influences the structure of physical theories elaborated by him. It would be very interesting to explore whether a connection exists between symmetry properties of elementary particles appearing in physical theories, and the symmetry of the common professional personality of modern theoretical physicists, i.e. to check whether homomorphisms exist between symmetry groups (or semi-groups) of this common personality and those of the theory of elementary particles. It would be interesting to clarify whether symmetry properties of this common professional personality exist *only* in the representation corresponding to the scientist's concentration on his research or also in other representations and these properties are not lost completely in transformations from one representation to another. In other words: the scientist's profession does or does not influence, for example, his thinking and behavior in everyday life? To study this problem and other ones connected with transformations of the mind from one representation to another, it would be desirable to develop projection operator formalism in the framework of our theory. This is a task of future researches. However, at the present time a psychological study of this problem would be interesting and useful. Symmetry properties of the observer's personality may be important for the study of observer reactions upon the observed considered by Schmidt (1982) and Costa de Beauregard (1980). For example, it can be expected that the interaction of the mind with the wave function of a particle depends on the symmetry properties of this wave function and those of the observer's personality. Thus, it can be expected that the psychokinetic effect as produced, according to Schmidt (1982), by the observation provoking the collapse of the particle wave function, should depend on symmetry properties of the observer's personality and particle wave function. On the other hand, there is no reason to expect its dependence on the symmetry properties of the particle wave function, if no connection exists between them and symmetry properties of the observer's personality. Therefore, the existence of this connection can be checked experimentally, if we study this effect for scalar, spinor, vector a.o. particles possessing various types of the symmetry. If the obtained results are different for various types of particles, it would be a serious argument in favor of the existence of a connection between symmetry properties of the particle wave function and those of the observer's personality.

5.7 CONCLUSIONS

This chapter is dedicated, first of all, to the clarification how our thinking is governed. Without knowledge of this all the theory of the human thinking developped in Chs. 1-4 hangs posed in mid air. Unexpectedly the consideration of mind self-measurings has led us to the answer to this question. The development of the approach of our work (1982) in combination with results of Chs. 1-4 allowed us to conclude that the mind is a system described by an algebra of non-commuting operators acting upon its states representing by points ψ of the metric space of states.Then the incompatibility of self-measurements corresponding to concentration of the thinking on different subjects (its microscopic mechanism was found in Chs. 3-4 means the existence of uncertainty principles that leads to the conclusion that the mind behavior should be described by an algebra of non-commuting operators acting on points of a metric space representing states of the mind. In this space the notion of the probability of a state relative to another one was defined. Thinking, as information processing occurs on the level of mind, i.e., on the level of the set $\mathcal{A}^{(N)}_{\mathcal{M}^{(N)}}$. However, it is not governed directly on the same level, but only indirectly on the level of the metric space of states of this mind by means of relative probabilities. It leads, in particular, to a kind of quantum logic as the logic inherent in the human reasoning, when logical thinking is considered. Notice once again that *the proposed theory considers all kinds of thinking*, no matter whether it is logical or not, meaningful or not *etc.*.

The formalism developed in this work allowed us to define the concept of the personality as a certain subset of the metric space of states of the mind. It opens the way to study the personality by mathematical methods, e.g., by the study of its symmetry properties influencing essentially the logic of the thinking, as it was demonstrated in §5.3. The conclusion concerning the possible connection between the structure of the physicist's personality and the structure of physical theory possibly indicates the way how the observer can be included explicitly to future physical theories.

Some conclusions made in the present work on the grounds of the proposed formalism hint of possible applications of this theory to the psychology, medicine and creative, e.g., scientific, thinking . On the other hand, the general character of the proposed formalism may lead to its applications to objects other than the human mind, which also are able to perform self-measurements. For example, according to Mensky (1991), Halliwell (1989) and Zeh (1986, 1988) the Universe is able to measure itself, if it is considered as a quantum system (see, for example, Hartle & Hawking 1983, Fukuda 1989, 1991). It is possible that because of this some mathematical definitions (e.g., of the concept, of CR, ACR and the set $\mathcal{A}^{(N)}$), considerations and conclusions made in Chs. 1-5 are also valid for the quantum Universe. If it is correct, it would be interesting to check about the possible existence of the thinking (as the information processing by ACRs) on the Universe scale and the possible existence of communication between the Universe and the human mind on the grounds of different level thinkings' interaction (Chs. 3-4). *Maybe the Mach's principle, but more sophisticated than in mechanics, exists also for the human thinking* ? The following mechanisms of this communication are possible: 1) the information processing by ACRs, if it indeed occurs in the quantum Universe, may influence the human thinking by the telepathy because the consideration of telepathy between two minds made in our work (1982) (see also Ch. 6) remains valid for the Universe - mind system, 2) modulation of gravitation and electromagnetic fields by stars' motion, explosions a. o. cosmic processes may realize CRs, i.e. create ACRs in the Universe, which influence cells of brain initiating new ACRs (thoughts) creation in the brain as follows from our interpretation (§4.4) of Libet effect (Libet *at al.* 1979, Libet 1985). Of course, this hypothesis needs to be checked theoretically and maybe experimentally. It seems the astrology at least hints that such influence exists. Then the very rich collection of facts accumulated during thousands of years of astrology existence can help to check this hypothesis. The author is not specialist in astrology, and can say only that without the considered connection astrology would be nonsense because the information processing by the Universe and its connection with human thinking on the Earth are necessary to make possible the influence of the occurring in the Universe on Earth's events. Thus, if the proposed hypothesis be confirmed, it may, in particular, serve as the starting point of a scientific approach to the astrology. On the other hand, it could extend the synergetic character of thinking (§4.7) to the Universe's scale that opens the way for information transfer from micro-world to the Universe and *vice versa* as described in Ch. 4 for subcellular level information transfer to the brain and *vice versa*.

Possibly in the proposed theory of the mind, principles of extremum exist on the level of the metric space of states of the mind (like in quantum mechanics on the level of the Hilbert space). If it is discovered that they really exist, it would be interesting to clarify whether *EMOTIONS* represent simply the expression in psychological terms of the mathematical events that are deviations from an extremum. In particular, a deviation from an extremum may correspond to such a state of the mind that we customarily call feelings of anxiety, dissatisfaction etc., while the achievement of an extremum brings the mind to a state of contentment and calmness. This is an interesting matter for future researches. It would be interesting to check whether the process of the achievement of a certain aim is guided by a principle of extremum. The experimental checking is possible, for example, by study of corresponding processes in vision.

5.8 REFERENCES TO CHAPTER 5.

Bergmann, *Gustav*: 1947, *The Logic of Quanta*. Am. J. Phys. **15**, 397-408; 497-508.

Birkhoff, *Garrett*, Neuman, *John von*: 1936, *The Logic of Quantum Mechanics*. Ann. Math. **37**, 823-843.

Bohr, *Nils*: 1928, *The Quantum Postulate and the Recent Development of Atomic Theory*. Nature **121**, 580-590.

Bohr, *Nils*: 1933, *Light and Life*. Nature **131**, 421-423.

Bohr, *Nils*: 1937, *Biology and Atomic Physics*. Physical and Biological Memorial Congress of Louigi Galvani, Bologne, November; in Physics and Human Knowledge. John Willey & Sons, New York 1958, p.p. 13-22.

Čech, *Edward*: 1966, *Topological Spaces*. Interscience Publishers, A Division of John Willey & Sons, London-New York-Sydney.

Chari, *C.T.K.*: 1977, *Quantenmechanischer Meßprozeß, nichtboolesche Logik und "Psi-Paradigmen"*. Zeitschrift für Parapsychologie und Grenzgebiete der Psychologie **19**, 49-75.

Costa de Beauregard, *O.*: 1980, *CTP Invariance and Interpretation of Quantum Mechanics*. Found. Phys. **10**, 513-530.

Dirac, *P.A.M.*: 1958, *The Principles of Quantum Mechanics*. Oxford at Clarendon Press.

Einstein, *Albert*: 1905, *Zur Elektrodynamik der bewegter Körper*. Ann. der Physik **17**, 891-921.

Einstein, *Albert*: 1953, *The Meaning of Relativity*. Princeton.

Fock, *V.*: 1932, *Konfigurationsraum und zweite Quantelung*. Z. für Phys. **75**, 622-647.

Fukuda, *Reijiro*: 1989, *Implications of the Proposed Theory of Measurement*. Prog. Theor. Phys. **81**, 34-46.

Fukuda, *Reijiro*: 1991, *Wave Function of Macrosystem - A Functional Approach*. Prog. Theor. Phys. **85**, 441-462.

Halliwell, *Jonathan J.*: 1989, *Decoherence in Quantum Cosmology.* Phys. Rev. (D) **39**, 2912-2923.

Hartle, *J.B.*, Hawking, *S.W.*: 1983, *Wave Function of the Universe.*Phys. Rev. (D) **28**, 2960-2975.

Heelan, *Patric*: 1970, *Quantum and Classical Logic: Their Respective Roles.* Synthése **21**, 2-23.

Heisenberg, *Werner*: 1930, *The Physical Principles of the Quantum Theory*, Chicago.

Jahn, *Robert G.* & Dunne, *Brenda J.*: 1987, *MARGINS OF REALITY. The Role of Consciousness in the Physical World*, Brace Jovanovich, Publishers, San Diego-New York-London.

Jordan, *Pascual*: 1960, *Parapsychological Implications of Research in Quantum Physics.* Int. J. Parapsychology, Autumn, 5-21.

Kolmogorov, *A.N.*& Fomin,*S.V.*: 1963, *Elements of the Theory of Functions and Functional Analysis.* Rochester, N.Y., Gray Lock Press.

Leek, *Sybil*: 1971, *TELEPATHY*, Collier Books, New york.

Libet, *B.*, Wright, *E.W., Jr.*, Feinstein, *B.*, Pearl, *D.K.*: 1979, *Subjective Referral of the Timing for a Conscious Sensory Experience.* Brain **102**, 193-224.

Libet, *Benjamin*: 1985, *Subjective Antedating of a Sensory Experience and Mind-Brain Theories: Reply to Honderich (1984).* J. Theor. Biol.**114**, 563-570.

Mensky, *Michael B.*: 1991, *Time in Quantum Cosmology from the Self-measuring of the Universe.* Gen. Relativity and Gravitaton **23**, 123-127.

Orlov, *Yuri F.*: 1982, *The Wave Logic of Consciousness: A Hypothesis.*Int. J. Theor. Phys. **21**, 37-53.

Penrose, *Roger*: 1989, *The Emperor's New Mind: Concerning Computers, Mind and the Laws of Physics.* Oxford University Press, Oxford.

Roman, *L.*, Rumbos, *B.*: 1991, *Quantum Logic Revisited.* Found. Phys. **21**, 727-734.

Schmidt, *Helmut*: 1982, *Collapse of the State Vector and Psychokinetic Effect*. Found. Phys. **12**, 565-581.

Snyder, *Douglas M.*: 1983a, *The Relativity of Psychological Phenomena*. J. Mind and Behavior **4**, 75-80.

Snyder, *Douglas M.*: 1983b, *On the Nature of Relationships Involving the Observer and the Observed Phenomenon in Psychology and Physics*. J. Mind and Behavior **4**, 389-400.

Temkin, *A. Ya.*: 1982, *Parapsychology from the Point of View of Modern Physics*. European J. Parapsychology **4**, 257-280.

Zeh,*H.D.*: 1986, *Emergence of Classical Time from a Universal Wave Function*. Phys. Lett. (A) **116**, 9-12.

Zeh, *H.D.*: 1988, Time in Quantum Gravity. Phys. Lett. (A) **126**, 311-316.

Chapter 6

ESP AS A NATURAL, BUT NOT SUPERNATURAL PHENOMENON

6.1 INTRODUCTION

In Ch. 5 the concentration of **one person** on different subjects of his thinking was considered. In this chapter we shall consider the situation when **one person** A can be concentrated or on the processing of the information on the surrounding world provided by his organs of sense (maybe with the help of measuring instruments) or on the study of his own thinking processes, while **another person** B is occupied all the time with the receipt of the information on the person A and surrounding world, using with this purpose observations and measurings. Our approach corresponds to the one of the modern physics that is based on the recognition that 1) the description of physical phenomena principally depends upon the nature and state of measuring instruments and observers interpreting the results of measurements; 2) the set of all possible measuring instruments can be divided into reciprocally complementary sub-sets such that it is impossible to perform simultaneously measurements by instruments belonging to different sub-sets; 3) for instruments belonging to each of these sub-sets their own reality exists; there is no reality independent of the kind of measuring instruments (see, for example, Einstein 1905 and 1953, Bergman 1942, Bohr 1928, 1934 and 1935, Dirac 1958, Heitler 1956, Heisenberg 1930, Shiff 1955, Messiah 1961). For example, an electron has a co-ordinate, but not the corresponding linear momentum for one class of measurements, but for the other class of measurements it has linear momentum, but not the corresponding co-ordinate. To consider measurements performed on human beings with the purpose of providing information on their states, thinking processes, *etc.*, it must be taken into account that a person A can himself measure his state as well as his thinking processes and interpret the results of these measurements, i. e., he is at the same time a measuring instrument and an observer of himself, which is impossible in the world of elementary particles. An elementary particle is too primitive, and so it can only be an object of measurements.

Thus, the set of measuring instruments (together with observers) necessary to measure the state of a man A consists of the man A himself and all other men B_i. A man B_i can measure time, all co-ordinates, configurations a. o. geometrical and mechanical parameters of A, as well as some physical, chemical and physiological quantities of A. He can also obtain some information on the thinking processes of A from speaking with A, from psychological tests, from EEG, *etc.*, but such information is very limited and not exact. Maximum information on his thinking processes can be provided by A himself to A himself, **if he is concentrated on them**. But at the same time he deprives himself of information about the time, co-ordinates, his own configurations and other geometrical, physical and physiological quantities, which are measurable by all B_i. A similar situation occurs when A is sleeping (and dreaming) or is in a hypnotic state. For short, we shall call *meditation states* all such states of A in which he is able to obtain maximum information about his own thinking processes. We see that in our case, as well as in quantum mechanics, all measuring instruments are divided into two incompatible classes: 1) the man A himself, and 2) all other men B_i. In quantum mechanics, for example, they are 1) instruments measuring co-ordinates and 2) those measuring the corresponding linear momenta. These two classes (or sub-sets) of measuring instruments are reciprocally complementary. This principle of complementarity in quantum mechanics was formulated by Nils Bohr. In his lectures (Bohr 1933, 1937), Bohr mentioned arguments that this principle and the uncertainty principle of Heisenberg are also valid for biological systems. An uncertainty principle represents relations between errors of measurements of the same object, performed simultaneously by two reciprocally complementary measuring instruments: for example, measurements of the co-ordinate and the corresponding linear momentum of an electron (in quantum mechanics) or measurements of the state of a person A performed simultaneously by A and by B_i in the considered case. If A is in a state of meditation, his reality does not contain his localization in space and time, but it contains, for example, his dreams and other things produced by his brain. It is not less real than for all B_i the localization of A in space and time as well as other parameters measurable by B_i are real.

This means that for A his own reality exists and for a B_i his own reality exists. Any discussion about which of these realities **is more real** is nonsense, like the discussion about what is more real: that an electron has a co-ordinate or the corresponding linear momentum. If being in a meditation state A "sees" that he is in another place (maybe in another country) in an epoch other than the one determined by a B_i by means his measurements, it is still the reality for A, the data forming the reality of B_i do not exist for him. This means that the clairvoyance, the "memory" of events of hundreds years ago, meetings with persons who are in other towns or even other countries, *etc.*, represents consequences of uncertainty and complementarity as properties of the human thinking. For example, it is possible that in B_i's reality A is in Paris at noon on June 30, 1996, while in A's reality he is in London in Shakespeare's time, or, on the contrary, in London in the year 2100. It may seem that the person B_i is superfluous because the uncertainties responsible for ESP phenomena arise as a consequence of A concentrating on his thinking processes. However, this opinion would be not correct because A's "travel" in space and time has meaning only relative to B's measurements of A's position in space and time, while from A's point of view he does not "travel", in general, but really in those places and epochs. The fact that the thinking of only one person produces different realities depending on its concentration on different subjects of the thinking (Ch. 5) means that the considered creation of different realities *when two persons A and B_i are involved* (that is the mechanism of ESP) loses its exclusiveness and becomes a particular case of more general phenomenon. This in its turn means that in particular the *parapsychology becomes simply an aspect of psychology characterized by a certain concentration of the mind*, losing its character as something special, existing separately from natural, or may be even something supernatural, mystic, esoteric, as many people think.

6.2 ON OBSERVER

In the classical mechanics it was supposed that a) errors of measurements are results of the imperfection of our measuring apparatus and *principally* can be reduced to the zero by the subsequent, step by step improvement of the measuring techniques, and b) properties of the observer and even his existence itself are not important. The theory built on the grounds of these principles did not take into account errors of the measurements, the observer existence and his properties as well as the measurement as the source of the information on the examinated object. It reflects the intention to create the (not an!) *objective* picture of the World as a perfect one, independent of human beings with their imperfect measuring equipment and brain. The World was considered perfect, and it was unaxeptable to spoil its perfection.

The relativity and quantum mechanics have rejected this point of view and the scientific approach to the physical World study based on it. Simply because it was impossible to build on this grounds a physical theory able to explain new experimental facts.

It was rejected the oversimplified concept of the objectivity of physical theory created by the absolutization of the classical mechanics which, really, is no more than *one model* for the approximate description of a certain class of physical phenomena. There was (and still is) a very difficult psychological problem: our personality is created mainly by our every-day-life experience. The information on the surrounding World is provided by our organs of senses. Such an experience continues during the whole life confirming and reinforcing this personality structure (*cf.* §5.5). All that is in the framework of this personality structure, is (often) unwillingly interpreted by us as natural, correct and objective. The whole "great" philosophy (the materialistic philosophy) was created on these grounds. This philosophy **really** is not so great, but simply expresses in never-ending fluxes of high-flown words and phrases the point of view that only such a theory can be considered as acceptable that can be squeezed into the framework of concepts and views engendered by our every-day life. No more. The materialistic philosophy is now the main obstacle in the scientific progress. It influences the thinking of scientists limiting it artificially because its demands and conditions seem very natural and fundamental, even unquestionable. In addition, even in the Free World any theory contradicting to the materialistic philosophy meets serious objections in the community of scientists, not to mention communist countries where it is considered as a heavy crime (ideological diversion) that merits a cruel punishment.

The modern physics recognizes the fundamental role of measurements in physical theory and introduced the concept of observer to the theory. However, only the fact of its existence is taken into account, but not his/its properties. Consider this problem in more detail. The observer can be a human being or a computer. His tasks are to plan Measurements, to perform them by means of measuring instruments and to interpret their results on the grounds of theories (models) that he has. They can be theories already existed or a new one that needs checking by measurements. If no of such theories is fit for the interpretation of new measurements made by (the observer + measuring equipment), a new theory should be created for this purpose. It is clear that without interpretation made by the observer measurements' results provide no information.

In physics, however, an observer is considered simply as a physical body, its/his own properties and activity are not considered. However, taking into account the observer's properties and activity can lead to changes of physical laws and, generally speaking, of those in other fields of science. Indeed, an observer-human being or an observer -automaton have an enormous number of states. Their activity in the interpretation of measurements' results means an enormous number of all kinds of transitions between these states. Such a transition has, maybe small, but finite duration in time. This means, the information provided by the observer refers not to the time when we have gotten its output, but to the past, maybe close past, but past. Moreover, if the transfer of this information from one observer to another is considered, not only the time of the signal propagation (with the light velocity) between these two observers must be taken into account, but also the time necessary to emit the detailed information on all interstate transfers of the first observer, to accept and decode it by the second observer . It is a very important point because transformation laws in physics are based on the consideration of the information transfer from one reference system to another. There is one way to shorten the time necessary to forward, accept and decode the information: instead to transfer the whole information from the first observer to the second one, to limit it by an incomplete information. Then an inequality is expected to be between the error in information obtained and decoded by the second observer, and the time delay, in other words, an uncertainty principle between the transferred information and time delay. Thus, for example, the validity of Lorentz transformations in the case of living systems becomes questionable, and, therefore, the Twin Paradox must be reconsidered.

6.3 HUMAN WAVES OF DE BROGLIE

In Ch. 5 it was argued that the behavior of the mind is described by an algebra of non-commuting operators acting upon points of the metric space of states of the mind, in other words, that the mind is a quantum system. As it was written there, such a point ψ depends on the set of ACRs (thoughts) existing in the mind. When A is in a meditation state, among these thoughts are those on his location in the space and time. Then the point ψ is his wave function in space and time (as function of the corresponding variables), i.

e., his De Broglie wave, and we shall call it **human wave of De Broglie**. Now the mechanisme of the telepathy and other ESP phenomena can be expressed in terms of human waves of De Broglie: this function is delocalized in space and time (when A is in a meditation state!) and may be overlapped with the De Broglie wave of another person A' that may lead to their interaction being resulted of the initiation of thoughts (ACRs) in the mind of A' by those existing in the mind of A, and vice versa. Why there are so much "may"? This situation is like the overlapping of wave functions of two fields in the quantum theory of fields. But they interact only if the interaction constant is non-zero. Thus, to get rid off of these "may" it is to check theoretically or experimentally whether something corresponding in the considered case to the fields' interaction constant is non-zero. To understand why the overlapping of A's and A''s wave functions may lead to ESP phenomena, e. g., telepathy, it must take into account that the wave function depends not only on space co-ordinates and time , but also on all other sets of ACRs (thoughts). There is a principle difference between the considered case and the case of two-particle (e. g., two electrons) system in quantum mechanics. In the considered case the set of variables corresponds to that measured by A **or** by A', while in the case of two electrons (or other quantum particles) the set of variables includes the linear momenta (or co-ordinates) and spins of both particles. This difference is a consequence of the fact that measurements upon the system of two electron are made by an external observer (by his measuring instruments), while those made upon the system $A + A'$ are performed by A **or** by A'. The delocalization of the wave function of A_1 and/or A_2 can lead to their overlapping in a certain region of space and time. In this region the wave function of A_1 and A_2 can interact as two overlapped quantum fields interact, *if their interaction constant is non-zero.* If this interaction exists, the thinking processes of A_1 can influence the thinking of A_2 and vice versa. Indeed, as it was explained in Ch. 5, the point ψ of the metric space of states of the mind is a function of the set of thoughts (ACRs) existing in the mind, therefore, inside the region of the overlapping of the wave functions of two persons ACRs existing in one mind can initiate ACRs in the second mind, in other words, to realize the telepathic communication between A_1 and A_2. Thus, **the telepathy is realized by human waves of De Broglie** represented by the above mentioned ψ-functions, but not any kind of radiation and, therefore, 1)the velocity of the telepathem propagation is not limited with the light velocity, and 2)screens shielding electromagnetic waves do not prevent the telepathem propagation. These two consequences of the proposed theory allows one to check it experimentally: a)telepathy between persons separated by cosmic distances can be used to determine the telepathem propagation velocity and whether it is really not limited with the light velocity; b)experiments with to see screens can show whether or not they prevent the telepathy (a layer of water between sender of telepathems being on the earth surface and recipient being in a submarine deep in the water is such a screen).

6.4 ESP, PERSONALITY AND STATES OF MIND

If two atoms are considered, the ability of one of them to absorb photons emitted by the second one depends on the quantum level set structures of the both atoms and on their state at the moment of photon emission. By the analogy it can be expected that the telepathic communication (Leek 1971, Murphy 1961, Rogo 1975, Rhine 1975, Sinclair 1971, Hunt 1964) between two persons A and B depends on structures of their personalities and the actual states of their minds. Consider it more in detail by taking into account that the personality is defined for a given representation of the mind, i.e. for a given concentration of the thinking. Firstly, the both communicated minds (or at least one of them) must be concentrated each on its own thinking processes to achieve the delocalization in space and time, which makes the telepathy possible (Temkin 1982). However, in the framework of such concentration, each mind can be concentrated on various subjects of the thinking . If the sender and the recipient are concentrated on the same subject of the thinking , i.e. are in the same representation, then telepathems are able to influence the conscious processes of the recipient. It can be experimentally checked in the following way. The recipient must be instructed that at a certain time interval he must think of a given subject chosen so that there is a difficulty at a certain point of the reasoning and the recipient does not know how to advance beyond this point. If, for example, both persons know the mathematics, the chosen subject may be the proof of a theorem. During the first trial the recipient works without help of the sender. During the second trial the sender performs the same work as the recipient, but the sender knows how to advance at this difficult point. In this case, then his telepathems may complete the knowledge of the recipient and the last will perform the reasoning up to the experiment termination. In fact, even without this telepathic help some probability exists that the recipient will cope with his task. Because of this a large number of such trials is necessary to compare probabilities of recipient success with and without the telepathic help. We have discussed the telepathic communication between two minds occupied with conscious thinking. Consider now the telepathy when the sender is occupied with conscious thinking on the same subject as in the previous series of trials, e.g., he is proving the same mathematical theorem, while the recipient begins to think about quite another subject, e.g., his forthcoming weekend, *since he unsuccessfully attempted to cope with the abovementioned difficulty at the given step of the reasoning.* According to our work he may continue to think, *but subconsciously*, about the subject of the first series of trials, and may detect the results of this subconscious thinking when he returns to the conscious thinking about the previous subject. Therefore, if the telepathem is accepted when he thinks subconsciously on this subject, it could help the recipient to accomplish his task. Thus, two parallel series of trials can be performed to compare the probabilities of the recipient's success with and without the telepathic help. Of course, each trial must include the change of his representation (concentration) at the two certain stages mentioned. By this way the existence of the telepathic communication when the recipient thinks subconsciously, could be checked. The comparison of the probabilities obtained in this experiment and in the first one could reveal the connection between the consciousness and telepathy. These probabilities are calculated as repetition frequencies of corresponding issues. If to continue the analogy with two atoms emitting and absorbing photons, it could be expected that telepathy is more probable between two persons with the same (or, exactly, similar) personalities. However in the case where dominating personality of the recipient is quite different from the one of the sender, another basic personality of the recipient may have the structure close to the one of the dominating personality of the sender. Telepathems can then be received by means of this basic personality (Temkin 1982). Of course, as it is seen from this reasoning, it is not obligatory that at least one of personalities (of the sender or recipient) would be dominating one. The telepathic communication can be realized by basic, but not obligatory by dominating personalities of both persons. Telepathic experiments with pairs of twins compared with those when sender and recipient are not relatives, would help to establish connection between telepathy and personalities. Notice that sometimes twins may have quite different personalities, and therefore the similarity (exact identity evidently does not exist) of their personalities must be checked before the beginning of the proposed experiments.

Notice that the telepathem can be received not obligatory by the dominant personality (Ch. 5) of the recipient, but also by one of his other basic personalities (Ch. 5). In this case the reasoning of this Section are referred to the likeness of the sender personality "responsible" for the sending the telepathem (it also can be not his dominating one) and that of recipient's basic personalities which accepts the telepathem. In view of this it would be reasonable to suppose that individuals like Wolf Messing in the USSR, who are able to "read thoughts" of different persons having different personalities, have comparable probabilities of their basic personalities, possibly, none of them (*defined in the representation when such man is concentrated on the "reading of thoughts"*) is the dominating one. For such a man "voices" that he hears can be produced by the interference of his different basic personalities and be a symptom of a mental disease, if he is not able to establish that this is their source, but not the external world. But "voices" can also be produced by telepathems sent by different external sources, and in this case his talking about "stories" that he "heard" cannot be considered as a symptom of mental disease, even if these stories seemed very strange. Just as a non-stationary perturbation of a quantum mechanical system can provoke its transitions from one state to others, the telepatic influence on a person, depending on time (non-stationary), can provoke transition from a state with one dominating personality to a state with another dominating personality, in other words, the change of his personality. This means, the brainwashing can be accomplished by the telepathy.

6.5 SOUL AND ESP

The concept of mind (Ch. 4) includes CRs as well as ACRs (thoughts) as realized CRs. It is evident that when the mind consists only of CRs, the human being is dead. Thus, ACRs (thoughts) form an especially important subset of the mind that merits to be identified with a very important attribute of human beings such that without it life is impossible. To reflect this fact the following definition is introduced:

DEFINITION: *SOUL-t IS THE SET OF ALL ACRs (THOUGHTS) EXISTING IN THE BRAIN OF A PERSON AT A GIVEN MOMENT t OF TIME.*

Without the soul-t a human being is dead because then his mind consists only of CRs. It is clear that the soul-t defined above depends on time.

Perhaps a "massive" telepathy is possible when all thoughts of a person (existing at a given moment of time) are accepted by a recipient. In our terms this means that the recipient got the soul-t of the sender. Perhaps, the phenomenon of **reincarnation** (Rogo 1975, Rhine 1975, Hunt 1964, Parker 1975) can be explained on these grounds, if we take into consideration also "travels" in space and time to include the reincarnation when two participating persons are separated in time and/or space. However, it must remember that soul-t must not be identified with the *soul* used in the poetry, religion *etc.*. The latter is apparently something characterizing a human being very profoundly, almost independently of the time, a characteristic existing constantly, may be only weakly depending on the time.

At the death of a person the realization of CRs is stopped irreversibly which, according to the definition of soul-t, means that "the soul-t leaves him". With this connection it would be interesting to think about the possibility of soul-t transfer to another person just during the dying process because this process provokes the rapid change of the ACRs set. If at a certain stage of dying the human being looses his contact with the outside world and is able to be concentrated only on his thinking processes, then in his reality he may be at a time and at a place occupied by another person. For this second human being this rapid change of the ACRs set could create a rapidly changed perturbation of his mind, which increases the probability of thoughts transfer. This last conclusion was made by the *analogy* with the quantum mechanical perturbation theory and so is only a hypothesis needed for scientific proof. It would be interesting to check whether the telepathy , including the "massive" telepathy, i. e., the transfer of a set of thoughts (that may be, in particular, the soul-t) can be described in terms of thoughts' radiation and absorption, and to try to construct with this purpose an analogue of the second quantization and Fock columns (Heitler 1954, Fock 1932) in the proposed quantum theory of states of mind, which, in particular, can be applied to processes of the thoughts and their combinations emission and absorption by mind. If future researches confirm that it is possible, the following processes should be considered: a) a thought (or thoughts) emitted by a person A is absorbed by another person B, b) a thought (or thoughts) emitted by A is absorbed by A himself (virtual emission), c) the structure of A's mind was changed abruptly after the thought (or thoughts) emission so that it already is not able to absorb this thought (or these thoughts) and there is no other person able to do it, then it (they) remains free. The option c) may be a result of the death of A, and if the emitted thoughts form his soul-t, it remains free in the space at least for some time. However, one must be extremely careful in that what concerns hypotheses in the ESP field, not forgetting that they are only a subject of future researches, and not yet results of a theory. This caution is necessary to remain in the framework of the science, but not to replace it carelessly by science-fiction.

6.6 ON THE TELEPATHIC BRAINWASHING

If A receives telepathems from B who emits them with the purpose to thrust his opinion onto A , or even to thrust onto A that all fundamental ways of thinking of A are nonsense and must be replaced by those thrusted by B (brainwashing), it is important whether A is concentrated on the subject of telepathems or not. If he is concentrated on the subject(s) of the telepathem, he can check thoghts induced in his mind by the telepathems and to reject those of them that he considers as incorrect.

Thus, in this case the attempt of B can be rejected. This means, the attempt of B is expected to be successful, if A is in a state when trial sets of thoughts content is other than the content of telepathems, *i. e.,* when A is not concentrated on the telepathem subject area. Then telepathems can create in A's mind thoughts that cannot be checked by trial sets of thoughts existing in A's mind in the considered representation. From these "injected" thoughts new trial sets of thoughts can be constructed, and, as a consequence, criterions of A's thoughts correctness will be checked by these new, originated from B, trial sets of thoughts.

6.7 CONCLUSIONS

The principal result of the present work is to show that the telepathy is realized by the human waves of De Broglie rather than by a kind of radiation. This mechanism was expressed, in other terms, so that the existence of the telepathy is a result of uncertainties of time and space location of a person from his own point of view when he is concentrated on his thinking processes. It must be emphasized that that we did not yet prove that just this mechanism is responsible for the telepathy and other ESP phenomena. Strictly speaking, it was indicated that such an ESP mechanism exist which is not supernatural, esoteric, but, on the other hand, is not based on the use of a kind of radiation. The missing proof can be obtained by the comparison of consequences of our theory with experimental results. Some indications of possible experimental ways to check the proposed theory are contained in this chapter. Some of them are based on the use of the theory of quantum states of mind (Ch.5), as it is described in §6.4. Other experiments are not based on any theory as, for example, the examination the influence of screens or other obstacles preventing the electromagnetic or other kinds of radiation propagation, on the telepathy. According our theory the telepathy can exist even between two persons separated by metallic screens, layers of the earth, by water *etc.*. Good and unambigouos experiments on the telepathic communication between one person on the earth surface and the second in a submarine deep under water could be considered a serious text of the proposed theory. The second test could be telepathy experiments when the distance between two persons is extremely great, the best would be the use of cosmic distances, so that it would be impossible to explain the communication by electromagnetic or another radiation because even in the absence of the absorption (really, the absorption exists) the intensity if a radiation decreases with the distance from the source increase as r^{-2}, and the brain of the sender of telepathems could be a very powerfull radio station to send telepathems (by electromagnetic radiation) which could be accepted by a recipient separated from him by so big distance. The third text (admittedly very difficult to execute) could be the measurement of the time of the telepathic propagation between two persons. The velocity of the propagation of a radiation cannot be more than the the light velocity. Therefore, if the velocity of telepathem propagation is larger than the light velocity, it would be very serious argument in favour of our theory because the propagation of (human) waves of De Broglie is not connected with the transfer of the matter so its velocity is not limited by the light velocity.

The views presented and described in this chapter can be applied not only to human beings, but also to any system able to perform self-measurings that can be clasified into subsets so that self-measurements belonging to two different such subsets, are incompatible. Then complementarity and uncertainty principles exists for such a system, and it is expected that the proposed theory is valid. Possibly, animals, plants, some types of computers, as well as some kinds of cosmic objects are such systems. If it is correct, the telepathy can be expected between different object of such kind, e. g., between human beings and animals, human beings and plants, human beings and *quantum* Universe. Possibly, the psycho-kinetic effect can be understood in terms of the telepathy between human being and non-living body by human waves of De Broglie interaction with the quantum mechanical wave function of the non-living body. The Helmut Schmidt theory of psycho-kinetic effect based on the consideration of the collapse of the wave function, makes the proposed explanation of the psycho-kinetic effect reasonable. Perhaps the collapse of wave function can be described as a result of the information transfer from the human mind to this non-living object by the telepathy . But it is still only a hypothesis. It must build a theory of the considered information transfer by the telepathy to confirm or disprove it.

6.8 REFERENCES TO CHAPTER 6.

Bergmann, *Gustav*: 1947, *The Logic of Quanta*. Am. J. Phys. **15**, 397-408; 497-508.

Birkhoff, *Garrett*, Neuman, *John von*: 1936, *The Logic of Quantum Mechanics*. Ann. Math. **37**, 823-843.

Bohr, *Nils*: 1928, *The Quantum Postulate and the Recent Development of Atomic Theory*. Nature **121**, 580-590.

Bohr, *Nils*: 1933, *Light and Life*. Nature **131**, 421-423.

Bohr, *Nils*: 1934, *Atomic Theory and the Description of Nature*, Part 2, London.

Bohr, *Nils*: 1935, Phys. Rev. **48**, 696.

Bohr, *Nils*: 1937, *Biology and Atomic Physics*. Physical and Biological Memorial Congress of Louigi Galvani, Bologne, November; in Physics and Human Knowledge. John Willey & Sons, New York 1958, p.p. 13-22.

Dirac, *P.A.M.*: 1958, *The Principles of Quantum Mechanics*. Oxford at Clarendon Press.

Einstein, *Albert*: 1905, *Zur Elektrodynamik der bewegter Körper*. Ann. der Physik **17**, 891-921.

Einstein, *Albert*: 1953, *The Meaning of Relativity*. Princeton.

Fock, *V.*: 1932, *Konfigurationsraum und zweite Quantelung*. Z. für Phys. **75**, 622-647.

Heisenberg, *Werner*: 1930, *The Physical Principles of the Quantum Theory*, Chicago.

Heitler, *W.*: 1954, *THE QUANTUM THEORY OF RADIATION*. Oxford, At Clarendon Press.

Hunt, *Douglas*: 1964, *EXPLORING THE OCCULT*, Ballantin Books, New York.

Leek, *Sybil*: 1971, *TELEPATHY*, Collier Books, New york.

Messia, *A.*: 1961, *QUANTUM MECHANICS*, vol. 1 & 2, Amsterdam.

Murphy, *Gardner*: 1961, *CHALLENGE OF PSYCHICAL RESEARCH. A PRIMER OF PARAPSYCHOLOGY*. Harper Colophon Books, Harper & Row, Publishers, New York.

Parker, *Adrian*: 1975, *STATES OF MIND. ESP AND ALTERED STATES OF CONSCIOUSNESS*, Malaby Press, London.

Rhine, *Louisa E.*: 1975, *PSI, WHAT IS THIS?*, Perrenial Library, Harper & Row, Publishers, New York.

Rogo, *Scott D.*: 1975, *PARAPSYCHOLOGY. A Century of Inquiry*, Dell Publishing Co., Inc..

Sinclair, *Upton*: 1971, *MENTAL RADIO*, Collier Books, New York.

Schiff, *Leonard I.*: 1955, *QUANTUM MECHANICS*, McGraw-Hill Book Company, Inc., New York - Toronto - London.

Temkin, *A. Ya.*: 1982, *Parapsychology from the Point of View of Modern Physics*. European J. Parapsychology **4**, 257-280.

Chapter 7

CRs AND ACRs THEORY AS AN APPROACH TO POLYMER MOLECULE AND GENETIC INFORMATION STUDY

7.1 INTRODUCTION

Polymer molecule of DNA consists of a number of chemical groups connected with each other (Watson 1970, Drlica 1992), such that each group has its rotational, vibrational and electronic states. These groups can play rôle of multistate units ("neurons") (see, for example, Nakamura *et al.* 1995) forming a neural network (NNW) that is, in this case, the considered polymer molecule, if excited states of one of these chemical groups can be transferred to other chemical groups. Thus, the connections of each group with other ones must be weak enough that quantum states of this group would make sense and at the same time strong enough to do possible the excitation transfer. Then intramolecular excitation transfer, a.o. processes in such a molecule can be treated by theories developped for NNWs. It permits to deal directly with the information processing and storage that is fit for molecular genetic problem study. *This approach allows one to consider explicitly the genetic information "written" not only by means of DNA molecule chemical composition (genetic code), but also by means of its nuclear and electronic* *motion.* In the present work we use for this purpose the method proposed in Ch. 1.

Following Ch. 1, we call the set of chemical groups in a polymer molecule, SOURCE SET $\mathcal{A}_S$, *iff it is ordered*, and construct such combinations of subsets of this source set that are CRs between them. Relations and the ordering of the source set must be based on physical, chemical a. o. natural properties of units and intergroups' connections (*cf.*Ch. 4), as distinct from the case of an abstract pure mathematical problem where they could be introduced artificially. In Ch. 4 is shown that CRs do carry a potential (virtual) information.

If units cannot be ordered throughout the considered polymer molecule, but it can be divided into a number of micro-regions so that inside each of them the ordering is possible, then the written above can be applied to each such micro-region separately, and, therefore, the considered polymer molecule will be represented by a number of different source sets.

As it is seen from Ch. 1, if to change the order of a source set, the corresponding set of all possible CRs will be changed and, therefore, the pre-information carried by them also will be changed. In the case of a DNA molecule this means that the genetic information will be changed. It suggests an idea that possibly a relevant selective change of the order of a virus DNA molecule micro-region may stop its harmful activity. Perhaps this indicate the right way to cure diseases caused by viruses. The said seems to be valid also for diseases caused by microbes.

CRs do not reveal new properties of polymer molecules, in particular, of DNA molecule, but express those of molecular nuclear and electronic motion in terms of information. Therefore, the genetic information contained in CRs is none other than the one contained in DNA molecule nuclear and electronic motion. CRs contain only the potential information (that can be called also virtual information), i. e., such an information that cannot be displaied directly, but is revealed when a CR is transformed to an ACR. This transformation can occur, for example, if an excitation runs through a CR, which was considered in detail in Ch. 4.

It may be that $\mathcal{A}_S$ is not able itself to process the information, but CRs can be constructed. Then the corresponding ACRs will do it, and by this way such a source set is enabled to process the information not directly, but by means of ACRs. For example, a polymer molecule may be represented as one or few of neural networks. In this case it can process the information by the system of its units, but not only by ACRs, which means that the zeroth-order of the information processing exists in this case. But in the case when a polymer molecule cannot be represented as one or few of NNWs and, therefore, it cannot process information directly by use of its structure, only higher-order, i. e., by means of ACRs, information processing is possible. Notice that in the case when $\mathcal{A}_S$ itself is a *NNW and CRs can be constructed*, ACRs created from CRs will increase essentially its ability for the information processing. The addition of CRs to the source set as new elements expands the source set (see Chs. 1, 3 and 4) and increases the number of CRs which can be constructed. These new CRs also can be added to the obtained set, and it will be the second step of the expansion, *etc.* as it is described in Chs. 1,3 and 4.

7.2 C-GENE AND S-GENE

The following consideration is relevant to all polymer molecules, but to make the explanation concrete and clear it is written on DNA molecule and molecular genetics. As it is seen from the definition of concepts introduced in this chapter, they are not connected only with the DNA molecule despite terms of the molecular genetics are used.

Suppose that DNA molecule contains a number of ordered sets of chemical groups such that elements of each set are connected with each other (for example, by chemical bonds). Then under certain conditions each such set is a source set $\mathcal{A}_{S,\varrho}$ number ϱ that can be used to create CRs . The set $\mathcal{G}_\varrho$ of all possible CRs constructed on the grounds of $\mathcal{A}_{S,\varrho}$ determines all information that can be obtained from $\mathcal{A}_{S,\varrho}$ at the realization of all CRs, *i. e.*, their transformation into ACRs. Taking it into account, one can conclude that from each set $\mathcal{A}_{S,\varrho} \bigcup \mathcal{G}_\varrho$ is possible to obtain 1)the information corresponding to that written by the genetic code, *i.e.*, to $\mathcal{A}_{S,\varrho}$ structure, 2)the information released by the functioning $\mathcal{A}_{S,\varrho}$ as a NNW (*basic level information processing*, if the source set is a NNW, and 3)the information released by the transformation of CRs into ACRs. Consider firstly the case when each such micro-region of DNA molecule coincides with a gene. Then with the purpose to include to a gene all this information, WE DEFINE C-GENE (COMPLETE GENE) AS $\mathcal{A}_{S,\varrho} \bigcup \mathcal{G}_\varrho$. However, the chemist cannot see CRs, and because of this he considers only $\mathcal{A}_{S,\varrho}$ structure as a gene. It would be natural to call $\mathcal{A}_{S,\varrho}$ C-GENE HARDWARE. If the c-gene hardware itself is a NNW, then the programs for the information processing by this NNW (*basic level information processing*) plus the set of all possible CRs can be called C-GENE SOFTWARE. If the hardware is not a NNW, then only the set of all possible CRs is the c-gene software. Really c-gene software expresses in terms of the NNW theory the part of genetic information contained in electronic and nuclear motion states of the gene and in their possible permanent or temporary changes while the "ordinary" genetic information written by the genetic code is contained in c-gene hardware $\mathcal{A}_{S,\varrho}$ structure.

As it was mentioned above, a polymer molecule of DNA consists of a number of chemical groups so that for some types of vibrations they can be represented as internal vibrations of these groups perturbed by intergroup weak couplings, then the vibration state transfer between groups occurs just as the one in a chain of weakly coupled oscillators. In terms of NNW this vibration state transfer means the interunit *information transfer* (Hopfield (1982), Nakamura et al. (1995)), if each such chemical group is identified as a NNW unit. The same can be said on the intergroup transfer of their internal rotations. If electronic excitations can be transferred between chemical groups, the corresponding CRs must be constructed and included into the gene software, but they can be transformed into ACRs only when some factors (e.g., ionizing radiation, light, excited molecules or other chemical additions etc.) create electronic excitations. Then the "frozen" under normal conditions genetic information is "defrosted", and virus, microbe or a cell of an organism reveals the "non-conventional" behavior. It may be useful, but may be harmful for human beings, animals and plants. Notice that this "frozen" genetic information must include also CRs constructed on the grounds of vibrotational states of electronically excited molecules. If the order cannot be established throughout a gene, it cannot be a source set $\mathcal{A}_{S,\varrho}$. If, however, this gene can be divided into two or more ordered micro-regions, the source set can be defined and CRs can be constructed for each of these micro-regions separately. In this case the C-GENE is to be defined as the sum $\bigcup_\varrho \mathcal{A}_{S,\varrho} \bigcup \mathcal{G}_\varrho$ with respect to all such micro-regions (index ϱ) covering the considered gene. Then the c-gene hardware is defined as $\bigcup_\varrho \mathcal{A}_{S,\varrho}$, and its software is defined as $\bigcup_\varrho \mathcal{G}_\varrho$ + the sum of basic level information processing software by all NNWs forming the considered gene. In the case when micro-regions *that can be ordered* cover only a part of the gene, the summation must be performed with respect only to these ordered micro-regions. It is evident that it does not contain the genetic information written by the genetic code because some parts of the gene are not included into the sum. By this reason we shall call this sum S-GENE (soft gene). In this case it is impossible to define c-gene joining together all kinds of genetical information, but it is necessary to consider separately s-gene and the information written by genetic code.

It may be that an ordered micro-region of one gene covers also a neighbor gene or a part of it, or even an ordered micro-region covers a number of genes, perhaps, the whole DNA molecule. In this case the s-gene can be defined without a connection with genes. To what consequences may lead this situation? Rate constants of the protein's synthesis depend on vibrotational and electronic states of the gene. In our theory these states and transitions between them are expressed in terms of CRs and ACRs correspondingly. In the case when a source set covers partially or completelly two or more genes, processes with nuclear and electronic motion (*i.e.*, with corresponding ACRs) influence reactions produced by all genes covered by this source set. If, for example, reactions occuring with one of these genes lead to vibrotational states' excitation (in our terms, to the appearance of corresponding ACRs) , it may influence reaction rates of other genes covered by this source set. In other words, the existence of gene software may create interactions between genes.

The interaction of genes may be caused also by the following effect, analogue of which was considered in Ch 4. If an excitation propagates throughout hardware of the c-gene number ϱ_1 realizing its CRs (i.e. producing ACRs) , this excitation *may* transit to the hardware of another c-gene ϱ_2 and *may* realize there its CRs . This means that the reveal of original genetic properties of the c-gene ϱ_2 is influenced by the c-gene ϱ_1, and possibly leads to the appearance of a new genetic information referred to this second c-gene. The transition of an excitation from one c-gene hardware to another may be produced mainly by the intramolecular interaction between source set s $\mathcal{A}_{S,\varrho}$ with different values of ϱ. If c-genes are defined correctly, the probability of such transitions must be very small. If it is not small, this means that really all interacting c-genes together are one c-gene or one s-gene covering a number of genes. Possibly such a rearrangement of their elements exists that leads to new set of source sets, this time almost not interacting, which are new *real* c-genes.

Up to this place the c-gene software were considered only as the source of genetic information complementing the one written by genetic code, i. e., determined by the chemical structure of the gene. However, this software has one more function issued from the fact that, at the end, it is determined by the source set that, in its turn, is determined by the gene chemical structure. This means, *the creation of ACRs from CRs serves as a channel for the first step of genetic information (written by genetic code!) realization.*

Whether a c-gene can be changed? Suppose in the beginning that there is no mutagen factors such as ionizing radiation, chemical mutagenes a. o. able to change the c-gene hardware. If the c-gene hardware is a NNW, it might be able to learn. The learning, as it is well known in the theory of NNWs, changes inter-units connections [see,for example, Hopfield (1982)]. Such changes may lead to changes of relations necessary to construct CRs and therefore they affect the structure of the set of all possible CRs of this hardware, in other words, in our case the genetic information might be changed. The said evidently is remained valid also if the c-gene hardware itself is not a NNW, because it functions as a NNW by use ACRs. However, might is not must, and it is questionable whether a c-gene can be learned. Indeed, connections between units, i.e. between elements of the source set $\mathcal{A}_{S,\varrho}$ are chemical couplings. The electronic structure of these couplings or vibrotational states of chemical groups included into the gene cannot be changed irreversibly or, at least, for long time by any factor, if there is no mutagen mentioned above. Therefore one must conclude that under this condition *the change of genetic information contained in c-gene by learning is impossible.* At the same time a *temporary* change of the genetic information seems to be possible . For example, the electronic state of the source set $\mathcal{A}_{S,\varrho}$ can be changed *temporary* as consequence of photon(s) absorption or spin states can be changed by magnetic field action on electronic and nuclear spins - all these effects may *temporary* create new relations and therefore new CRs changing by this way the set $\mathcal{G}_{\varrho}$ determined before these factors appeared. If during the time-of-life of the considered change of the electronic structure excitations propagate throughout the source set $\mathcal{A}_{S,\varrho}$ and realize those CRs that could not be realized before this change, it will provoke "non conventional" influence of this c-gene on the cell or virus. It may change *temporary* the microbe or virus as well as of a cell of an organism behavior and reproduction. In particular, the "perverted" reproduction of healthy cells may create cells of cancerous tumor, which will continue to breed already without any external stimulation. However, it is possible that, on the contrary, this change will stop the reproduction of a cancerous cell of organism or a virus. If to find what kinds of electronic, vibrotational or nuclear spin state excitations lead to the stopping of cancerous cells or viruses reproduction, it would indicate a possible way to treat corresponding diseases. The possible existence of self-accelerating processes of the ACRs creation as well as the possible existence of the information (contained in ACRs) possessing the large VALUE (Eigen (1971), Volkenstein (1977)), possibly makes certain weak excitations, such as those of nuclear spin state, to be effective for this purpose.

Acceptors of electronic excitations that are outside a DNA molecule, may accept such an excitation propagating throughout a gene and realizing its CRs. It may prevent the creation of some undesirable ACRs or stop completely the ACRs creation, i.e., it may change the genetic information realization from the potential one. It is desirable to study this effect and possibilities of its use in the medicine and genetic engineering.

7.3 CONCLUSIONS

The information contained in intramolecular motion of a gene is a part of genetic information. In the present work is proposed to treat this information using the representation of a gene as one or few NNWs. The theory developped in Chs. 1-4 was applied to these nets that allows one to deal with different types of genetic information.

For this purpose a molecule of DNA is considered as one or few of source sets $\mathcal{A}_{S,\varrho}$, if it is possible to order chemical groups in this molecule throughout. In particular, some of these source sets can be NNWs. More then one source set appears when is impossible to establish the necessary ordering throughout the whole polymer molecule. In this case the molecule could be divided into a number of micro-regions such that each of them can be ordered. It is desirable to choose genes as such micro-regions, as it was proposed in Ch. 4 where the application of the proposed theory to the human thinking was considered. If it is possible the theory of Chs. 1-4 is to be applied to each gene separately. If a gene cannot be ordered throughout, it could be, in its turn, divided into few micro-regions so that each of them can be ordered. In the first case, when a gene is one ordered micro-region, all kinds of genetic information are contained in c-gene: namely those represented by the gene chemical structure, in particular, by the NNW ability to process the information, and by CRs. The last two types of the information are connected with the nuclear and electronic motion of the gene. Taking into account this information allows one to consider chemically nondestructive genetic changes and their possible consequences. On the other hand, the transformation of CRs to ACRs can be a channel for the first stage of the genetic information release, i. e., the transformation of the potential (virtual) genetic information written by genetic code into real acting information. Indeed, at the end, the chemical structure of the gene determines the structure of the corresponding source set s processing the information (which, in particular, can be NNWs) and the set of all possible CRs. Therefore, we come to the statement written above that the information carried by ACRs is the realized part of the information written by genetic code. It can hope that at this stage of the virtual genetic information realization its amount (Kullback 1958) and value (Eigen 1971, Volkenstein 1977) can be calculated. However, it must remember that following transformations of this genetic information can change essentially its amount and value (*cf.* Ch. 4) so that they cannot be calculated in the general case because the *biological meaning* of an ACR and the information that it contains depends on physical, biological, chemical and other factors existing at the moment of this ACR creation. The mathematical determination of the amount of this potential information and especially its value in each concrete case represents an interesting and important problem. This approach opens the way to influence the genetic information without chemical changes of the c-gene hardware, changing only the set of all its possible CRs by, for example, excitations of electronic, vibrotational or nuclear spin states. Thus, the genetic engineering as well as the medical treatment of cancer and diseases provoking by microbes and viruses can use such "light" changes of c-genes (even temporary) instead "heavy" changes (i.e. of its chemical structure). Notice that among such light changes is the change or destroy of the order of the c-gene hardware without a change of its chemical structure. According to the CR definition the destroy of the c-gene hardware order means the killing of the c-gene (but not the gene because the information written by genetic code remains unaffected), if its hardware is not a NNW, or the drastic decrease of the gene ability for the information processing, if its hardware is a NNW. It is important that in the framework of the proposed theory (Chs. 1-4) the net can process the information by use of ACRs as elementary information processors, even if the net itself is not a NNW. In other words, an ordered set such that its elements are connected with each other may process information as NNW, if there are a) relations allowing the construction of CRs, b) excitations propagating through the net and c) transformation of CRs into ACRs by these excitations. It expands the field of possible use of the proposed theory and perhaps is especially important for its applications to ordered sets of chemical groups contained in DNA even when some of them are not NNWs. Then c-genes are identified each with such net of chemical groups contained in a DNA molecule + the set of all CRs that is possible to construct in this net.

7.4 REFERENCES TO CHAPTER 7.

Čech, *Edward*: 1966, *Topological Spaces.*Interscience Publishers, A Division of John Willey and Sons, London-New York-Sydney.

Eigen, *Manfred*: 1971, *Selforganization of Matter and the Evolution of Biological Macromolecules.* Naturwiss. **58**, 465-523.

Drlica, *Karl*:1992, *UNDERSTANDING DNA AND GENE CLONING.* John Wiley & Sons, Inc., New York-Chichester-Brisbane-Toronto-Singapore.

Hertz, *John*, Krogh, *Anders*, Palmer, *Richard G.*: 1991, *Introduction to the Theory of Neural Computation.* Addison-Wesley Publishing Company, Redwood City, USA.

Hopfield, *J.J*: 1982, *Neural Networks and Physical Systems with Emergent Collective Computational Abilities.* Proc. Nat'l Acad. Sci.(USA)**79**, 2554-2558.

Kolmogorov, *A.N.*& Fomin, *S.V*: 1963, *Elements of the Theory of Functions and Functional Analysis.* Rochester, N.Y., Gray Lock Press.

Kullback, *Salomon*: 1958, *INFORMATION THEORY AND STATISTICS.* New York-John Wiley & Sons, Inc., London-Chapman & Hall, Limited.

Nakamura, *Y.*, Torii, *K.*, Munakata, *T*: 1995, *Neural-Network Model Composed of Multidimensional Spin Neurons.* Phys.Rev.E **51**, 1538-1546.

Trifonov, *E.N.*: 1993, *DNA AS A LANGUAGE*; in "The Second International Conference on Bioinformatics, Supercomputing and Complex Genome Analysis", Eds.: Hwa A. Lim, James W. Fickett, Charles R. Cantor, Robert J. Roberts. World Scientific, Singapore-New Jersey-London-Hong-Kong; p.p. 103-110.

Volkenstein,*M.V.*: 1977, *The Amount and Value of Information in Biology.* Found. Phys. **7**, 97-109.

Watson, *J.D.*: 1970, *MOLECULAR BIOLOGY OF THE GENE.* W.A. Benjamin, Inc., New York, 2nd Edition

Chapter 8

APPENDICES

8.1 APPENDIX 1. CRs AND ACRs IN NNWs

Let us consider a NNW consisting of a finite number of units. Order this assembly $\mathcal{A}'$ of units. Then define that this set is the source set, i. e., that $\mathcal{A}' \stackrel{\text{def}}{=} \mathcal{A}_S$. Consider two subsets of this source set $b \subset \mathcal{A}_S$ and $b' \subset \mathcal{A}_S$ such that they would have common units, i. e., $b \bigcap b' \neq \emptyset$. Possibly it would be enough to demand that in the case when the intersection is empty, at least one unit of b must exist that is connected by interunits' connections with at least one unit of b'. However, here we shall limit ourselves with the first, more limiting demand not to complicate our consideration.

Now define a relation

$$\langle c^b \mid \rho_\alpha^b \mid c'^b \rangle$$

on the subset b and a relation

$$\langle c^{b'} \mid \rho'^{b'}_\alpha \mid c'^{b'} \rangle$$

on the set b'. They can be relations between individual units as well as between assemblies of them. Some simple examples of relations between NNW's units and their assemblies are contained in APPENDIX 2. It is important that in a pure mathematical consideration, e. g., at a modeling of a NNW by a computer program, we can define interunits connections, properties of units etc. by our will and to use them to create relations, while in the case of a real NNW all this is given by its construction. For a NNW the condition (1.3) means that there is one and only one unit which belongs to the both relations written above. It remains correct also in the intersection of b and b' where each unit belongs to both *subsets* b and b', but only one unit can belong to the both *relations*. To understand better the described situation it is useful to picture it in the case of 1-D NNW.

The definition (1.1) of the simplest CR in the case of a NNW means that this CR is the assembly of all pairs of units forming the both relations. One way to define the probability $\mathbf{P}(\mathbf{J}_2)$ as well as $\mathbf{P}(\mathbf{J}_n)$, is to calculate the number of units' configurations included in the right hand side of the Eqn. (1.1) and to divide it to the integral number of possible configurations of units. The result will be the considered probability that we shall call PROPER PROBABILITY.

Let us consider a simple example. Let n be the number of units of the considered NNW, $n_{\mu,\mathbf{J}}$ be the number of units in an $\mathbf{J}$-th-order CR of a certain type μ (the number of units may be different in CRs of the same order, but different types), N_μ be the number of all possible *combinations of* $n_{\mu,\mathbf{J}}$ *units forming the considered CR*, and $M_{\mu,\mathbf{J}}$ be the number of all possible combinations of $n_{\mu,\mathbf{J}}$ units, but without the condition that they form the considered CR. Then the proper probability of the considered CR is as follows:

$$\mathbf{P}_{\mu,\mathbf{J}} = \frac{n_{\mu,\mathbf{J}}}{n} \times \frac{N_{\mu,\mathbf{J}}}{M_{\mu,\mathbf{J}}} \tag{A1-1}$$

The fact that $N_{\mu,\mathbf{J}}$ is calculated under the condition that each combination forms the considered CR is very important: relations are based on physical, chemical a.o. natural properties of an NNW (or the brain), as it was explained above and demonstrated in APPENDIX 2, therefore this condition introduces these properties to the proposed theory.

Now it is clear how this procedure of CRs' construction can be continued in the case of a NNW (*cf.* Ch. 1). Notice that in the case of a NNW we have naturally begun from the source set $\mathcal{A}_S$ because it is given by the NNW construction, while in §4.2 we have begun from any ordered set $\mathcal{A}$ that includes the source one, but may not coincide with it, i.e. $\mathcal{A} \supseteq \mathcal{A}_S$. To understand how the transformation of a CR to an ACR occurs, let us consider a NNW consisting of units having only two possible states 0 and 1 each. If an excitation (created, for example, by electric pulses) propagates through the net, it is possible that during a certain time interval all units forming a relation will be in state 1. Then one can say that the considered relation is realized during this time interval. It must be emphasized that a relation is realized, iff *all* units forming it are excited. This time interval labels the considered excited relation, or, in other words, *the relation is mapped to this time interval.* Now one can speak on two states of a relation, i.e., on two states of an assembly of NNW's units forming this relation. One state is not excited (ground state) and one state is excited.

In the continuation of the excitation propagation it may excite another relation having one common unit with the first one. There are two options: 1)during the time necessary to excite all units forming the second relation the first relation remains in its excited state, and 2) during this time at least one unit of the first relation transits to the state 0, which means that the first relation transits to its ground state. The probabilities of the realization of the first and second options determined by the velocity of the excitation propagation and time-of-life of the unit excited state. This means that the described combination of two relations (a first-order CR) has 4 possible states: both relations are not excited, both relations are excited, the first relation is excited while the second one is in its ground state, and the first relation is in its ground state while the second one is excited.

These states are revealed only at the realization of a CR and, therefore, really they are the states of an ACR. Principally it is possible that the second relation will be excited not as a result of the excitation propagation throughout the first relation and its transfer to the second relation, but independently, e.g., because another excitation propagation through the net that accidentally excited the second relation after the first excitation has passed through the first relation. In such cases when the excitation of the second relation is not a consequence of the first relation excitation, the process is not the realization (transformation into an ACR) of a 2nd-order CR. To be transformed into a 2nd-order ACR a 2nd-order CR is labeled by the time-interval of the excitation propagation throughout its two relations, no matter at what states will be the relations after this. The generalization of this picture to n-th-order thoughts (ACRs) is trivial.

The proper probability of an ACR state can be calculated by multiplication of the proper probability $\mathbf{P}_{\mu,\mathbf{J}}$ of the corresponding CR to the probability of each relation to be in the excited or ground state during the corresponding time-interval at the realization of this CR by an excitation propagation.

This calculation is based on physical properties of the considered NNW. A unit (neuron) in the excited state may transfer its excitation to one of other units, no matter whether it is included to the considered CR or not (neuron "does not know" on the existence of CRs). It may be also de-excited by, for example, a radiative or radiationless transition. To each such elementary process corresponds its probability determined by physical properties of the considered NNW, i.e., its units, interunit connections and the NNW structure. Therefore, the excitation propagation through the NNW, in particular, through a CR , is of probabilistic character and can be described, for example, as random walks. The said means that in the proposed theory the neural activity (change of neuron state, excitation transfer between neurons, de-excitation of neuron) is the physical basis of the CR's realization, i.e., of the thinking.

If each relation has two states, the n-th-order ACR has $2n$ states. If to assume that they have equal probabilities of realization, the probability of each of them to be realized is equal to $(2n)^{-1}$. This probability must be multiplied to the proper probability of the considered CR. If one of these states is realized by the excitation propagation throughout the considered CR, its probability becomes equal to 1 multiplied to the proper probability of this CR. The amount of corresponding (proper) information can be calculated from these two probabilities as usually.

This very simple example demonstrates how the proper information carried by an ACR can be calculated. However, it must remember that the most important information carried by an ACR is not the proper one, but contained in transitions from each relation to the next one during the excitation propagation through a CR .

8.2 APPENDIX 2. CRs IN NNWs. EXAMPLES

Let us consider a simple example of a 1-D NNW consisting of 4 "on-off" units ordered from left to right by use of interunits connections as described above. Notice that this example is used only to demonstrate how CRs could be constructed and how the source set could be expanded. 4 units is a too small number, because,as it will be seen, each two CRs contain common units that make their realization (i.e. their transformation to the corresponding ACRs) impossible, according to what is said in the connection with thoughts collisions. Let the following relations exist *between units*:

$$(1 \mid \rho_1 \mid 2) = \eta(V_1 - V_2), \tag{A2-2}$$

$$(3 \mid \rho_2 \mid 4) = \eta(V_3 - V_4), \tag{A2-3}$$

$$(1 \mid \rho_3 \mid 2) = \eta(V_2 - V_1), \tag{A2-4}$$

$$(3 \mid \rho_4 \mid 4) = \eta(V_4 - V_3), \tag{A2-5}$$

$$(1\ 2 \mid \rho_5 \mid 3\ 4) = \eta(V_1 + V_2 - V_3 - V_4), \tag{A2-6}$$

$$(1\ 2 \mid \rho_6 \mid 3\ 4) = \eta(V_3 + V_4 - V_1 - V_2),\ etc., \tag{A2-7}$$

where

$$\eta(x) = 0 \, at \, x < 0 \tag{A2-8}$$

$$\eta(x) = 1 \, at \, x > 0 \tag{A2-9}$$

is the Heavyside function and V_i is the potential on unit i. It is clear that other kinds of relations are possible. The 2nd - order CR consists of two relations, therefore only the first 4 relations can be used to construct CRs.There are CRs that can be built from them: $\mathbf{J}^{(0)}_{2,1,2} = (1010), \mathbf{J}^{(0)}_{2,1,4} = (1001), \mathbf{J}^{(0)}_{2,3,2} = (0110), \mathbf{J}^{(0)}_{2,3,4} = (0101)$, and the set $\mathcal{A}^{(1)}$ is as follows: $\mathcal{A}^{(1)} = \{1, 2, 3, 4, (1010), (1001), (0110), (0101)\}$. In this example we have supposed that the CRs $\mathbf{J}^{(0)}_{2,i,k}$ are ordered according to their numbers by use relations, as it was described above. Now the relations ρ_5 and ρ_6 can be used to construct the second-order CRs such as $\mathbf{J}^{(1)}_{2,5,7} = (1110(1010)(1001))$ etc.. It is to be reminded that each bracket inside the outer ones of this expression represents *ONE* element of $\mathcal{A}^{(1)}$. In this example the relation between (1010) and (1001) is as follows:

$$((1010) \mid \rho_7 \mid (1001)) = \eta(V_1 + V_3 - V_2 - V_3). \tag{A2-10}$$

This is only an example. Some other CRs can be constructed from elements of the set $\mathcal{A}^{(1)}$, if there is necessary relations. We shall limit ourselves with one example of the third-order CR

$$\mathbf{J}^{(1)}_{3,1,2,7} = 1010 \; (1010) \; (1001)), \tag{A2-11}$$

which can be written also as follows:

$$\mathbf{J}^{(1)}_{3,1,2,7} = (1 \mid \rho^{(0)}_1 \mid 2) \bigcup (3 \mid \rho^{(0)}_2 \mid 4) \bigcup ((1010) \mid \rho^{(0)}_7 \mid (1001)). \tag{A2-12}$$

The 4 "on-off" neurons of the considered NNW have 8 possible states. Each CR like $\mathbf{J}^{(1)}_{2,5,7}$ adds 2 possible states, each CR like $\mathbf{J}^{(1)}_{3,1,2,7}$ adds 6 possible states etc. Thus, we can see how the number of possible states of the NNW and therefore its computational capacity increases without change of the number of neurons. But there is one more cause of the increase of the NNW capacity for the information processing related, first of all, to its qualitative aspect. High - order thoughts (ACRs) may contain very sophisticated information, e.g. scientific statements, and because of this they are very important, even if the amount of this information is relatively small in comparison with the one carried by shorter and simplest thoughts. Notice that really a NNW consisting of a small number of units cannot produce long ACRs in view of what is written above in connection with ACRs collisions: if there is only a small number of units, two high-order CRs must have more than one common unit, and the corresponding ACRs cannot be realized. The case of 10-units NNW is a little bit better than the considered one of 4-units NNW. Let the following relations between units exist:

$$(i \mid \rho_{i,i+1} \mid i+1) = \eta(V_i - V_{i+1}), \tag{A2-13}$$

$$(i \mid \rho'_{i,i+1} \mid i+1) = \eta(V_{i+1} - V_i). \tag{A2-14}$$

Of course, other relations are possible.

Define:

$$\mathbf{J}^{(0)}_{2,1,2;3,4} = (1 \mid \rho_{1,2} \mid 2) \bigcup (3 \mid \rho_{3,4} \mid 4), \tag{A2-15}$$

$$\mathbf{J}^{(0)}_{2,5,6;7,8} = (5 \mid \rho_{5,6} \mid 6) \bigcup (7 \mid \rho_{7,8} \mid 8). \tag{A2-16}$$

The ACRs corresponding to these two CRs never collide because the CRs have no common unit. But one can define another CR:

$$\mathbf{J}^{(0)}_{2,4,5;6,7} = (4 \mid \rho_{4,5} \mid 5) \bigcup (6 \mid \rho_{6,7} \mid 7). \tag{A2-17}$$

The ACRs corresponding to $\mathbf{J}^{(0)}_{2,5,6;7,8}$ and $\mathbf{J}^{(0)}_{2,4,5;6,7}$ may collide because they have a common unit 5.

Index