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1979
THE IMPLICATIONS OF BRAIN FUNCTIONING
FOR LEARNING AND THE PROCESS OF EDUCATING

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
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The Ohio State University
1979

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Donnal. Sanders
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This study is dedicated
to all women
who struggle for knowledge and freedom
against ignorance and prejudice

Throughout this study I use the pronouns he/his for both sexes
to avoid awkward grammatical constructions.
ACKNOWLEDGEMENTS

Goethe once said: "People are always talking about originality; but what do they mean? As soon as we are born, the world begins to work upon us, and keeps on to the end. What can we call ours, except energy, strength, will? If I could give an account of what I owe to great predecessors and contemporaries, there would be but a small remainder".

My account of the persons who actively contributed to my personal growth begins with my parents, Nikos and Chrysi, who, early in life inspired me the zeal for knowledge and worked hard to make my education possible. It farther extends to my husband, Aristidis, and my children, Katerina, Vassos, and Nikos, who greatly contributed to the accomplishment of the present study by creating a warm and harmonious family environment. I especially want to express my gratitude to my husband. His medical training and his deep knowledge of the nervous system, as well as his participation in reviewing and evaluating the extensive literature on brain functioning were centrally important.

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INTRODUCTION

This is a doctoral dissertation in the general field of educational development. Its purpose is to generate propositions concerning the nature of the educational processes that are required for effective education. These propositions will be based upon a selective review and interpretation of the current knowledge about brain functioning. The reason for evaluating current facts on brain functions is the assumption that learning takes place in the nervous system and especially in the brain. On the other hand, it is widely accepted that the learning process per se is the primary concern of, and directly related to the process of education. Thus, the propositions about educational processes will be based on an understanding of learning that has its basis in brain function.

The role of the brain is central in the processes by which we "learn". The brain learns in an interaction of the individual with his environment. Which exactly are the processes and/or functions of the brain participating in learning is a rather debated area. Scientific knowledge about the functioning of the human brain, in respect to learning, is still in its dawn. Nevertheless, if learning is realized by the brain it will be dependent on a normal brain functioning in general.
Normal brain functioning depends on several factors. Anatomical integrity, for instance, is necessary. Non-arrested development of the brain is also necessary. This will give rise to an anatomically and physiologically normal brain. Conversely, hereditary, congenital, or adverse environmental factors may influence the development of the brain and give rise to pathological brains. These individuals usually have learning disabilities and are characterized as mentally retarded. The defect that may make the brain function abnormally may be in the brain itself or it may involve other organs or functions of the body which affect the normal development and/or function of the brain indirectly. For instance, some typical mental retardations result from pituitary and thyroid gland deficiencies (cretinism). The environmental factors which may influence the normal development of the brain (and which are also indispensable for the normal function of the brain) may be separated grossly on biochemical factors (many of which depend on adequate and appropriate nutrition) and on other factors which will be discussed later. Perhaps the common denominator of all these other factors is adequate in quantity and appropriate in time stimulation. Some of the biochemical factors are adequate blood levels of glucose, O₂, proteins, tryptophan and choline and perhaps many others (Wurtman et al., 1976; Rawls, 1978).

The cerebral development has an irreversible character. Deprivation of nutritional elements in the course of its development
would seem to lead to irreversible consequences.¹

The low intelligence of the mentally retarded individuals is socially accepted as a misfortune. The individuals themselves are not considered responsible for their impaired ability for learning and for their defective behavior. Special efforts to educate them are undertaken by society. However, the possible low intelligence and the subsequent educational problems² which are probably created by the lack of nutritional factors do not receive by society the same wide understanding and acceptance. This may be a result of the fact that the recognition of the existence of such possibilities is too recent to become widely accepted knowledge. In any case, the point that I want to make is the following: "Society could adopt efficient nutritional measures which would improve the performance of its educational system" (Faure et al., 1972, p.108), as a preventive measure instead of designing special educational programs after the brain development of these individuals is impaired.

From the above it is apparent that environmental factors which appear unrelated to education in the first place influence

¹The baby-carrying and nursing mother and the child should be supplemented with adequate and appropriate food to ascertain normal brain development. (Strategy statement on Action to Avert the Protein Crisis in the Developing Countries, New York, N.Y., United Nations, May, 1971).

²Longitudinal development studies carried out in various countries, especially in central Africa and Central America, show that malnutrition during the first four years of life leads to a mediocre intellectual performance when children reach school age. (Faure et al., 1972, pp.107-108)
educational processes. Thus, educational policies must seriously take into account the advancement of knowledge in several fields and especially in the fields which are related to the brain, its development, and its function.

In this dissertation I am not concerned with the nutritional problems which are related to education. It take it for granted that these problems will be solved sooner or later, since they are recognized. However, I want to emphasize that such a recognition could not occur without adequate knowledge of brain functioning, its impact on learning, and the relationship of the brain's function with adequate and appropriate nutritional factors.

There are other environmental factors influencing learning which are of concern to this dissertation for the same reason: their relation to brain functioning through learning.

The wrong kind of education and, worse, the lack of education, even among children living in comfortable material conditions, may have disastrous consequences for cerebral development. It has been established that "educational deficiency" has a prejudicial effect on growth of the cortex. (Faure et al., 1972, p.108)

The purpose of this dissertation, then, will be to analyze the relations of brain functioning to learning which is considered as the basis of education and to formulate propositions about educational processes that will take into account these relations. Such
propositions will be in accordance not only with the goal of education - but also with the conditions that promote normal brain and mental development.

For the analysis of learning and its implications for education, concepts from "General System Theory" will be used. It is assumed that man is an open, adaptive system. He is studied in "General System Theory" (GTS) terms as an organism which receives inputs of mass, energy, and information from his external environment, and by his throughputs breaks down and transforms them into outputs. In the analysis of "learning" as information processing by the brain, information is viewed as input processed by the throughputs of the human brain and as the basis for learning.

In my assumptions of man and the human brain as systems, I stand very close to the works of Ashby (1940, 1960), Mooney (1955, 1956, 1963, 1967) and Miller (1978). They have all influenced my way of theorizing and analyzing the complex behavior of human beings.

Ashby perceived the brain as an adaptive system and has concerned himself with the question of how the brain produces adaptive behavior. He tried to reconcile the views that the brain is both mechanistic in nature and yet produces purposeful, adaptive behavior.

Mooney has developed the notion that life-serving systems must operate as systems which are: (1) open to their environment, (2) integrative of their being, (3) in transactional give-and-take of
energies across their borders, and, (4) selectively forming fresh
fittings in creative transformations as time passes (adaptations,
creations).

Miller has developed a general theory of living systems. His
central thesis is that all living systems composed of several sub-
systems are open systems that operate in a continuous interchange
with their environment. He maintains that complex structures which
carry out living processes, i.e. living systems, can be identified
at seven hierarchical levels - cell, organ, organism, group, organ-
ization, society, and supranational system. Living systems at each
of the seven levels have the same 19 critical subsystems. Each of
these subsystems carries on for the living system the same processes
at all levels. This is why it is possible to discover, observe,
and measure cross-level formal identities or isomorphisms.

The learner, as a living system, is viewed through systems.
Learning is a property of living matter (Korzybski, 1933). The
result of the learning process - knowledge - constitutes the basis
of adaptive behavior for an individual, be it man or animal.
Accumulated and organized knowledge constitutes the basis of all
progress in human society, and it is the basis for the sciences,
technology and social evolution.

In conclusion, in this work I am concerned with these inputs,
these "educational" factors which, in a continuous interplay with
the developing brain, may affect cerebral development and ultimately
the intelligence and/or the character of an individual. It has been established that impaired cerebral development leads to impaired learning abilities. Environmental factors, including the type of education offered to the developing brain, influence brain development and brain functions which, in turn, affect the learning abilities of an individual. Because there is a continuous interplay between brain functions and learning and between learning abilities and education, the education offered to a learner (for instance, special education for defective learners), should be determined by the stage of development of the maturing brain or by the development an already-developed brain has achieved. Speaking practically, this may not be feasible but there should be a trend in this direction.

Thus, it becomes obvious that knowledge of brain function is the *sine qua non* for a comprehensive understanding of the learning processes. And knowledge of the learning processes is the *sine qua non* for a comprehensive study of educational processes. These ideas will receive further elaboration in the chapters that follow. At the moment, I will provide a general overview of the study and its organization.

The first chapter focuses on an analysis and a review of some basic concepts from GST. I consider it indispensable to clear up concepts of systems, because they constitute the basis for the analysis of brain functioning.
It is widely assumed that the central aim of education is to facilitate the learning process of a learner. This takes place at a certain time-space, through information processed by the brain. Therefore, the concepts of time-space and mass-energy are briefly analyzed in order to establish meaning for these concepts. Information processing is discussed rather extensively because it is central to learning. "Open, "concrete", "goal-oriented" systems are described and several of their properties are discussed. Finally, the levels of organization of systems are briefly mentioned as are the properties of systems that are due to their organization.

The brain relates to its environment through information. Therefore, learning cannot take place unless there exists a brain that learns, and an environment that provides the information. Learning represents the relation of these two existences. What I want to scrutinize is the relation itself. The following chapters are organized in ascending levels of organization: First, the processing of information at the cellular and organic level of the brain. Then, learning on the level of the individual interacting with his environment. In terms of systems, an individual is viewed as a system by himself. All the environmental factors that we consider in relation with the individual constitute a system, and the individual in this case is a subsystem of this larger system. Therefore, propositions concerning education, which is always realized by the individual within a certain environment, cannot
attend only to the level of the individual, but must deal with higher levels as well.

The second chapter deals with the nature of the human brain and the functions that are basic to the learning process. I discuss recent findings on brain functioning that are connected with learning. Synaptic learning and memory theories are reviewed and developed in conjunction with the concept of information processing. Using language as an example, I try to illustrate how information is processed "as a whole" by the brain, working "as a whole" also. Mandler's theory of learning is also presented after a brief review of some aspects of theories of learning.

To further elucidate the process of learning and connect it with an individual's environment, I use, in the third chapter, comparisons of the brain with artificial intelligence machines (computers). The way that learning is related to brain functioning is still a debated area. Relation of the brain with the environment (i.e. the way reality is represented in the brain or interpreted by the brain) is a more debatable area. I try to establish a useful view of this relation for several concepts: (1) "understanding" of concepts on the part of an individual, (2) the development of his cognitive tree, abstract thinking, and creativity. These discussions are based on certain basic explanatory assumptions about the nature of thinking, consciousness, subconsciousness, emotions, and, more generally, brain functions in connection with
representation or interpretation of the environment. Then, a theory of learning on which I will base by propositions is presented.

In the fourth chapter the connection of education with learning is established, as I understand it. I demonstrate that the conditions for learning are "thinking" and "adaptation". Through an elaboration of how "meaningful learning" can be realized, I conclude that two conditions - thinking and adaptation to a new situation - facilitate meaningful learning.

When this proposition is analyzed we see that there are two determining factors that enable a person to adapt effectively to a new situation:

(a) The amount of pre-existing knowledge, relevant to a given situation the person possesses. This helps the individual to eliminate some trial-and-error behaviors through estimation based on prior knowledge about whether these behaviors will or will not work. This reduction of potential behaviors can happen only when previous experience exists and if the experienced person has the ability to recognize similarities with the new situation, which brings us to the second factor.

(b) The ability to make suggestions, hypotheses about new situations. Forming hypotheses is purely a mental
process. In this case, it refers to the ability to form new ideal models which, because of the nature of the functions of the brain, means to think creatively.

That this is the real meaning of learning becomes self-evident. If the situation presented to the individual is known, he does not have to hypothesize, adapt, etc., he already knows. If the situation is "unknown", a successful suggestion to confront it will provide him, together with the successful confrontation, the "knowledge" of how to act in similar future situations. This constitutes "learning:. Thus, "learning" in humans is determined by the ability of the brain to think creatively. This ability, innate in the brain, is, I believe, partly genetically determined and partly acquired. To the extent that "thinking creatively" can be taught, education must undertake the necessary steps to help the learners cultivate this ability. Due to the way the brain functions while thinking, all kinds of thinking include some sort of creative resynthesis and, from this point of view, it could be considered as creative thinking. Since this is the case, I could speak only about thinking and not about creative thinking. However, I add this adjective in most occasions when I refer to thinking because usually this faculty of the human brain is forgotten and I want to emphasize it. Besides, it has important implications in the way that educational processes which facilitate it will be perceived.
In the last chapter of this study, I formulate a number of propositions about educational processes based on the "inner necessity" of the learner. Einstein's theory of Relativity implies an image of the world in which we act under external compulsion and inner necessities. In the case of the learner, the inner necessity of learning is considered the axis of creative thinking-adaptation. Based on this and on the assumption that human systems will be successful if we take care not to violate the inner necessity of their subsystems, I formulate propositions in which the ultimate criterion is not to violate the learner's inner necessity. Man should be the ultimate criterion for any educational propositions.
A Brief History

Traditionally, the layman has treated groups of entities (parts) interrelated by specific relationships or just by the fact that they happen to be contiguous in a certain time-space, as systems, as wholes. Science, also, has done the same for a long time without developing any theory or giving further explanations. Therefore, perception of a system as a whole of interrelated parts, is not at all new. The idea was standing in the twilight "inhabited by shadow concepts from the past" (Silvern, 1975, p.3).

One of the first philosophers to deal with concepts involved in systems -albeit indirectly - was Leibnitz. He believed that a part of a system expresses the whole and that it is dynamically involved in the whole. Later, Herbart developed a way of thinking which can be viewed as immediately related to systems theory, and as the immediate predecessor of the "systems approach" (Silvern, 1975).

However, what brought about the ideas expressed in General System Theory (GST) as we know them today, is briefly as follows.
Post World War II societies were seriously influenced by a tremendously rapid development of the sciences and of their applications during the war. With scientific applications rendering life easier, more technology and further development of the sciences were demanded. Society was willing to pay for it. This brought about new, elaborate, and complex methodologies, specialized complex technology, an increased number of scientists, an increased number of publications, and a "breakdown of science as an integral realm" (Bertalanffy, 1956, p.1). Theoretical structures within every field increased. The situation is not unfamiliar today:

The ever rising flood of literature will soon overwhelm us....We have been living in an era of exponential growth of information for several decades now.... (Relman, 1978, p.197)

On the other hand, similar conceptions of reality, giving rise to similar general points of view, began to appear in fields which were not related at all. Physics, chemistry, biology, psychology, the behavioral sciences, and all their branches were faced with a common problem: the problem of wholeness, of organization, and of dynamic interaction of the parts. People from all these fields started toying with the idea of more general theories.
Today our main problem is that of organized complexity. Concepts like those of organization, wholeness, directiveness, teleology, control, self-regulation, differentiation, and the like are alien to conventional physics. However, they pop up everywhere in the biological and social sciences, and are, in fact, indispensable for dealing with living or social groups. Thus, a basic problem posed to modern science is a general theory of organization. General system theory is in principle capable of giving exact definitions for such concepts and, in suitable cases, of putting them to quantitative analysis. (Bertalanffy, 1955, p.2)

At the same time, Norbert Wiener (1956, 1961), as early as the twenties and thirties, had already given shape to a number of concepts which today are in the core of GST. He is considered by many as the person who has contributed the most to the development of GST, although he never concerned himself with systems theory as such (Sadovsky, 1972).

Ludwig von Bertalanffy (1951, 1952, 1955) was working with the concepts of "wholeness" and "systems" since the thirties. He had described "open systems", "dynamic equilibria", and "irreversible processes". By the early fifties, he had pretty much given shape to the concepts of GST as we know them today. In 1956, a group of scientists organized into the "Society for General System Research". The central figure in this group was Bertalanffy. The group gave the name "General Systems" to its yearbook and made the name, "General System Theory" official:
Thus, there exist models, principles and laws that apply to generalized systems or their subsystems...
In this way we come to postulate a new discipline called General System Theory. (Bertalanffy, 1956, p.2)

The aims of GST are summarized by Bertalanffy (1956) as follows:

(a) There is a general tendency towards integration in the various sciences, natural and social.

(b) Such integration seems to be centered in a general theory of systems.

(c) Such theory may be an important means for aiming at exact theory in the non-physical fields of sciences.

(d) Developing unifying principles running "vertically" through the universeries of the individual sciences, this theory brings us nearer to the goal of the unity of science.

(e) This can lead to a much-needed integration in scientific education (p.2)

As a result of "open systems" organization in wholes,
Bertalanffy brought together or introduced the concepts of finality, equifinality, centralization, differentiation, leading part, and many others. It became clear to many scientists that principles such as these were operating in more than one instance, more than one phenomena, more than one discipline. So, many began looking for isomorphies, analogies, and models.³

³ Analogic models are transplanted examples that operate as theories in the discipline to which they are transferred and they usually are most productive.
Some scientists believe that GST holds true only for the applied sciences and that it necessarily involves the use of high technology and computers. This is an erroneous assumption that has fostered the confusion which exists between GST and "systems analysis". This misconception has its roots in the fact that the industrial, technological, and "practically oriented" people, in general, embraced systems analysis as soon as it was adequately shaped because it is such a formidable tool. As a result,

To many people the systems movement suggests only the military and industrial applications of systems concepts in such applied technologies as systems engineering, systems analysis, and systems design. (Baker, 1973 p.1)

For these reasons many people who were oriented toward a theoretical (as opposed to practical) approach to educational or social problems, people who were interested in the human aspects of man and of social organizations (and not only in successful results, disregarding man, as are industry and the Army) moved away from "systems". I, personally, also oppose a "corporate spirit approach" to education; but I believe that we should not reject "systems" merely because the technocrats use them. This does not characterize "systems" as good or bad. It only characterizes the spirit with which systems may be used.
"Systems analysis" is a thinking device which proposes the application: (1) of an analytic-synthetic process, (2) modeling and, (3) simulation, as the tools for the analysis of any system and/or situation. But GST is not only "systems analysis". The total platform for the scientific work of GST implies that one perceives things as systems - open, closed, goal-oriented, with feedback mechanisms, homeostasis, dynamic equilibria - accepts the rules under which such systems operate, and embraces the properties and features of the systems that are derived from their very nature of systems. GST is, in essence, an intellectual movement.

One of the best ways to deal theoretically with organization and complexity is by GST. This is so because GST - or "systems" - originated from research in "dynamic equilibria" - a complex situation - and dealt from the beginning with organized complexity. By drawing elements from many mathematical and probabilistic theories, systems became able to deal efficiently with almost all complex situations.

The subject dealt with in this study has to do directly with an extreme complexity which is, in addition, extremely well-organized: The human brain, its organization and function, and its interrelation with learning. I thought that such a subject would be best analyzed by the use of GST.
Basic Concepts

As a first approach to systems understanding, I will use the definition of a system. There is more than one definition of "system". The reason for that will become immediately apparent. Let us examine two known definitions of a system. One is Bertalanffy's definition: "systems are complexes of elements standing in interaction" (Bertalanffy, 1956, p.2). Another is Rapoport's, who separates all possible systems into "hard" - used in the "hard" sciences - and "soft" - used in all other cases. According to the definition of Rapoport:

....a (soft) system is a portion of the world that is perceived as a unit that is able to maintain its "identity" in spite of changes going on in it. (Rapoport, 1970, p.22)

There are so many "complexes of elements standing in inter-relation", there are so many "portions of the world" that can be perceived as systems, that someone who is preoccupied with the description or the definition of a specific system may use a definition that describes more appropriately the "portion of the world" that he scrutinizes. Thus, there are many definitions of a system, and they are all legitimate within a large framework of possibilities.

Due to the above and to the diversity and the plethora of existing systems, it is not enough to know what the definition of a system is in order to "understand" it. One should describe and
analyze the different types of systems as well. There are open and closed systems, concrete and abstract (or conceptual) systems, human systems, etc. In order to examine all of them effectively, I should define them and clarify several basic concepts that hold for all types of systems and several specific features that apply only to specific types of systems. To accomplish this goal would probably require writing a book only on systems because systems have by now a long history that has produced a lot of information. For everyone who wants to use "systems" today in a work that does not concern "systems" theory itself, I believe that there are no other ways to deal with it except to consider the concepts which have been developed by "systems" as well known and not define their meaning at all, or to present selectively the concepts that are related to one's subject of analysis.

Of the two I will take the latter approach because I believe that in any discussion it is appropriate to agree on the basics before one gets to the core of the arguments. The systems that I will examine are concrete, open, goal-oriented systems (the human brain, man, groups, organizations). They exist in some time-space and they have inputs and outputs of mass, energy, and information. Therefore, I will first discuss these basic concepts.
Time-Space

At present, space is perceived as a three-dimensional, multidirectional entity and time is perceived as a special unidirectional fourth dimension of space. The two of them form one entity which I will refer to as time-space. This concept is based on a Riemannian geometry which is based on uniformly curved dimensions, three of space and one of time, and which has been accepted by scientists with the establishment of the Theory of Relativity (Miller, 1978). Although they form a unit, time and space may be treated separately. However, since they are in reality one unit, defining each of them separately presents difficulties.

I usually refer to space with its conventional meaning, as understood by Euclidean geometry. In this sense, concrete systems exist in a space. Description of the spatial relations of the parts of any system is the means by which one understands the structure of the system. It is also the basis for other relations that may also exist in a system. For instance, the parts that are close to each other interact more than the parts that are away from each other. Also, the place and the position of a system among other systems indicates which is the system's more immediate, and which is its more remote environment. Since an exchange among systems always exists when they are open, spatial relations contribute greatly in understanding the probable origin of the inputs to a system; or which elements of the environment will most probably be
influenced by the outputs of a system. Of course, this does not exclude interrelations among systems or subsystems that are spatially remote, but it means that the possibility of such interrelations is more remote than for systems in close spatial proximity.

Time can be conceived as a measurable period during which an observable process occurs on a set of structures. This is a complicated way of defining time, but we cannot really appreciate time except if and when at two different instances we observe a certain structure on which a change has been realized during the period that the observations were made. Thus, time can be understood as a change in the spatial relations of a certain system (see, for instance, the hands of your watch), and space can only be understood within the framework of time.

Due to the unity of time and space, it is conceivable that the spatial relations of the parts of a system will also depend on time. Spatial relationships alone do not really exist. They may not be the same for all of time, therefore, they are not "real" unless they are understood within the framework of time. Thus, structure, in an absolute sense, does not exist.

When I refer to a concrete system in time-space, I understand it as a changeable unit, the structure of which depends on the time at which it is observed. This conception of a system is close to

4Nevertheless, concrete systems in the Euclidean space do have a more or less well-defined structure. We may call a structure of a system the spatial relationships existing within a system in a slice of time. Although this does not represent reality, it is helpful in understanding a reality which is constantly changing.
reality. Today, after the influence that the theory of relativity has had on the thinking of all sciences, it is widely accepted that processes are more stable than structures. The sense of stability of structures that we as observers have is due to the fact that some of them may change by very slow processes. On the other hand, processes may be repeated over and over in time. This is due to stable laws whose continuous influence on structures is perceived as a process which is repeated.

Unidirectionality of time is related to entropy and, through entropy to information. 5 We are almost certain now, through the work of Penzias et al. (1967), that a central event happened some time ago in the universe (Big Bang). As long as we are traveling away from this event - which movement is time - the temperature in all parts of the system of our galaxie tends toward equal distribution (entropy). Thus, time and entropy are interrelated and all systems in our galaxie tend to increase in entropy with time. 6 Without inputs of negentropy, i.e. information, this process is irreversible for any concrete system. "Information" as the opposite of entropy is related to time by a relation negative to that of time and entropy. Since entropy increases as time passes, information decreases. The relationship of the amount of information

5 Entropy, negentropy and information are discussed on pp.28-31.
6 For a further discussion of the relation of time to entropy seen within the framework of systems see Miller (1978).
available to the human brain and the reaction time of the neuron system is very interesting. It has been shown that there is a "linear dependence between reaction time (of humans to a light stimulus) and the amount of information" (Rahmani, 1973, p.184; experiments of Leontev and Krinchlik, 1961 and 1964). This fact is probably related to the basic relationship of information and time. Also, when entropy in the brain cells increases, it becomes difficult for the neurons to accomplish the functions which would help the individual memorize, therefore learn.

Experiments studying ways and means of reducing entropy in brain cells and guaranteeing a permanent consolidation of protein for memory-functions support.........(Faure et al., 1972, p.107)

Thus, understanding of the basic relationships of the entities of information - entropy and time - provides us with a deeper understanding of the properties of the human brain which are of importance for this study.

The relation of time-space to the observer,\(^7\) is an important one. I will try to illustrate it through the following example.

Suppose a fire is moving towards a place where a monocellular organism and a man exist together at time \(X\). At a visible distance

\(^7\)An observer may be understood as a certain brain, processing the concepts of time and space as information inputs. The interesting thing is to see (through its outputs) how this brain translates this information.
the man sees the fire and runs away from it just **three minutes**
before the fire gets to where he was. What he did from the point
of view of time-space was to schedule his existence in space within
his future. He was able to do this because the visual information
about the fire reached him quicker than the fire. The information
was quicker in **running the distance** between him and the fire. If
he had seen, i.e. been informed about the fire only **half way** from
where he saw it in the first example, he would have left just **one
minute, 30 seconds** before the fire got there. I underlined the
words which clearly show that information relates the observer to
time-space, and not only to time or only to space. The human brain
has obviously no difficulty in instantly understanding the relations
of time with space, or in understanding time-space as a whole.

Let us now see what happens with the monocellular organism. It
appears that for this organism time does not exist. The truth is
that for it time is very short. The cytoplasm reacts to stimuli
but because this organism does not have the same sensoria for visual
information we have, it can only feel and react when the fire has
reached it. So it gets burned.

This demonstrates that although time-space exists independently
of the observer, we can relate to it only through information which
is carried to our brain by an information carrier for which we have
the appropriately developed sensoria, and concepts with which to
analyze and understand it. Whether the concepts of time-space are
related to the size and structure of the organism itself, and how
and why we developed the sensoria and the concepts of time-space
that we have, is not of concern to us here. What I want to empha­
size is that, despite the interdependent existence of time-space
and information, we can only understand time-space through our
sensoria and our brain, our information receivers. Therefore, what
is crucial to understand is the relation of the observer with time-
space.

The brain is, in a way, a differential analyzer. This becomes
more understandable when we observe how the brain performs a lan­
guage analysis. Let us suppose that a person hears a sentence that
has a subject, a verb, and an object, and that the subject is pro­
nounced first in time; then comes the verb and, finally, the object.
If you ask this person to write what he has heard, he will first
write the subject, then the verb in the middle, and the object at
the end of a sentence. Time is translated into space as opposed to
the previous example. In this case, because dimensions in space
are bidirectional, we also have to have an agreement in our writing.
We translate the time factor from left to right. The Arabs do it
from the right to the left. The brain generally has no difficulty
understanding time as space or space as time, or perhaps space-time
as a unit, as a whole.

Then, why do we traditionally separate these concepts? I
believe that this depends on the specific conditions under which
the brain finds itself. For instance, when traveling the brain will understand space as time. But when stationary, it will understand only space, or it will require other information to understand time. For instance, when it becomes dark at night we say that time has passed; in reality, this is the way we understand the earth's movement which, by definition, is a change of position (space) with time. Eventually we developed separate words for time and space in order to communicate and subsequently, due to language habits, we became culturally conditioned in understanding time and space as separate entities.

In conclusion, time-space should be understood as a unit, a whole, although there is no doubt that separation in time and space are helpful in many instances for our understanding.\(^8\)

**Mass-Energy**

The main purpose for analyzing mass-energy in this dissertation is to allow me to present, later on, a current understanding of how information flows, because information flow is inseparable from changes in mass-energy. Matter has mass and measurable spatial dimension. It also has energy, which is the ability to work. Mass and energy are also (as are time-space) interrelated into a unit

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\(^8\)An extensive discussion on the concepts of time-space and the practical inseparability of these entities is to be found in the discussion of Relativity (pp.267-277).
which, in turn, is related with time-space and information in a larger unit. The total mass-energy in the universe can be neither created nor destroyed. But it can be converted from the one to the other. What form matter will manifest at a certain time-space (i.e. whether it will be expressed as mass or as energy) will depend on its speed (speed=space divided by time) as compared to the speed of light - the ultimate speed of which we are aware. We can quantitatively measure this state by the use of the equation \( E=mc^2 \) in which "E" stands for energy, "m" for mass, and "c" for the speed of light. The amount of energy a certain quantity of mass possesses is the rest mass energy. In mechanical physics, mass has also kinetic energy because it is moving and potential energy because of gravity. All living systems (and social groups in education) process some forms of mass-energy and transform them into others. Movement of mass-energy (by processing or in a physical space) is action.

Information

Information is of special interest for the purposes of this dissertation. The basic works of Gibbs (1902), Wiener (1961), Ashby (1960), Hartley (1928), Shannon (1948), Szilard (1929), and Brillouin (1951) represent an innovation probably equal to relativity for the sciences and philosophy of science. I say this because I believe that the computer, a byproduct of this line of
thinking, is changing our life (problem-solving, programming, scientific approaches, etc.) much faster and more dramatically than anything else. The literature in this field is very extensive and I read it selectively. For my purposes, the following are important ideas.

To begin with, I will briefly review the concepts of entropy and negentropy. Entropy is related to the second principle of thermodynamics which states that in a closed system entropy - which is the tendency for equal distribution of temperature in this system - must increase to the maximum, the process coming to an end when the system reaches equilibrium. This means that a closed system, as we think the universe is, tends toward an equal temperature in all its parts. This was the only understanding of entropy that we had until Norbert Wiener (1956). He gave us a new insight of entropy using Gibbs' concept of the probable existence of many universes.

If we move to the many universes of Gibbs, the previous situation may change: while entropy is probably operating in one of those universes, it might not be operating in another. Therefore, in our universe as well, there may be local enclaves whose direction runs opposite to entropy.

**Entropy as a Probability**

Let us then examine entropy from the view of probabilities as in the following example: As it is known, temperature means
movement of molecules. Higher temperature means faster movement (no movement can exist only in the temperature of absolute zero, i.e. minus 273°C). If the molecules are replaced by beads of different colors, say white and blue in a closed system (a box), their most probable distribution will be a mixture of blue and white beads, all mixed here and there; it is most improbable that all the whites would be on one side and all the blues on the other. Disorder is most probable. The same is true for molecules. To have all of the fast ones in the one side (high temperature) and all of the slow ones in the other side (low temperature) is most improbable. Disorder is most probable. Therefore, entropy, which was previously understood only as the tendency of temperature to equalization, is now understood also as the tendency by which we will obtain the most probable distribution of molecules in the universe.

Chaos Versus Organization: Entropy Versus Information

Since disorder is the most probable distribution, entropy is the tendency to disorder, to chaos. Imagine the universe at absolute zero which, by the way, is the only possible equilibrium state thermodynamically: everything will be equalized; no movement will exist; everything will lose its distinctiveness, its organization and differentiation and will be complete sameness. Instead, organization, shape, distinctiveness, and differentiation are the results of a force opposite to entropy. This opposite force is
termed negentropy. According to the Information Theory (Miller, 1978), "negentropy" is equal to information. Hence, only by information can one bring organization; even out of chaos. In "our system", our universe, life has found its home in some of these enclaves in which information runs opposite to entropy (Wiener, 1956).

In relation to entropy, information is equal to negentropy. In relation to probability, information is equal to the degree by which one moves away from uncertainty or approximates certainty. On the next page is a table (Table I) about information and entropy which, I think, points up the importance in recalling all the negative relations between those two factors.

**Measurement of Information**

Expressed in a more sophisticated way, information is the number of degrees of freedom one has in a given situation to choose from among alternatives. This concept indicates that information can be measured in terms of decisions.

Consider, for example, the game of Twenty Questions. We are supposed to find out an object by getting answers to twenty questions with yes or no. The amount of information contained in an answer can be viewed as a decision between two alternatives: Yes or no. For instance, is this a living or a non-living thing? Then, is it a plant or an animal, etc. With the second answer that we receive
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which represents a second decision, we have decided about one out of four possibilities. The amount of information we receive is increasing exponentially to the number of decisions made between two possibilities (yes or no) in one question. Based on this, the amount of information is measured by the logarithm to the base 2 (yes-no) of the number of patterns or messages available. The smallest amount will be the amount of information that is necessary to relieve uncertainty in a situation where two equal possibilities exist and the outcome is known. This is the unit of information and it is called a bit of information.\(^9\)

The minimum amount of energy required to transmit a bit of information is what Szilard and Brillouin calculated. Thus, certain information we received can be thought of as being composed of so many bits of information, and it can be transmitted by spending so much energy. But this is not all. Information cannot be transmitted but via a material holder. And, perhaps, this is where the whole subject-matter becomes more complicated.

Communication and Marker

Transmission of information from one system to another is called "communication". The information which is transmitted from a system to another must be ultimately represented in the receiver system itself by an entity that is also mass-energy. This entity

\(^9\)In the language of the computers it is called a "bite".
has been named the marker. By marker, von Neuman (1958) refers to those observable (by any means) objects or changes of mass-energy whose patterning bears the informational symbols of the information the entity has received and now has in it, e.g. the notches on a key and the key itself or smoke signals and the smoke itself, or the arrangement of the nucleotides in the RNA and the type of RNA itself, or the pattern of the impulses forming circuits and the circuit itself, etc.

The mass-energy of a written paper is not the same as the mass-energy of the same paper when there is no writing on it. When an information was transmitted to the paper (in written letters) a change occurred in the mass-energy of this paper. In other words, communication is simultaneous with some action (I have already said that action represents some transmission of mass-energy). On the other hand, the paper constitutes now a new marker as shaped by the letters. That is, the information transferred onto the paper in the form of letters and by the expenditure of energy has changed the shape of the paper into a new shape, a fact that makes it able to transmit the information that it received. This makes the written paper a new marker.

Perhaps the change in the shape and/or amount of the mass which occurs during marker formation would be more obvious if instead of a paper we had engraved letters on a blank stone. The result of the transmission of the information to the stone would be grooves
of a certain shape. Thus, the overall shape of the stone would be different.

In most instances, information changes the shape of the receiving system by arranging basic units existing in the receiving system according to the information that is received, so that the new pattern of the system carries the information. To better understand this, one needs to understand also the notion of the "value of a marker" which is, simply, the amount of information a marker carries in bits of information. The smallest material representation of information, the smallest marker, can answer only one question by a yes or no answer. Obviously, this is one bit of information, but because it answers to a yes-or-no question it is called a two-valued or double-valued marker.

Now, imagine a physical system that has double-valued markers, the most common type of marker found in nature. Let us say "an electrical impulse on a preassigned line" or a nucleotide on a DNA chain. The presence or absence of these entities conveys information about "the marker's value" (Neuman, 1958). It answers positively or negatively the question whether the electrical impulse exists or not on the preassigned line. The nucleotide arrangement in the DNA chain enables the DNA to bear the information which the DNA carries with it. But the shape of the chain depends on the presence or absence of the individual nucleotides. Thus, each nucleotide-marker, by its presence or absence, conveys information
which is equivalent to the marker's value.

Let me present the whole idea graphically. Suppose that a double-valued marker would look like this \( \bullet \). Suppose, also, that its presence \( \bullet \), and the absence, \( \bigcirc \), could be represented so. Let us say that I want to represent eight things by these markers, eight numbers - the number from one to eight of the decimal system. I can use as many of these markers I want, but I cannot change markers. By a quantity of three double-valued markers, we can make eight (8) combinations, as shown in Figure 1, and we can assign a digit to each one of these combinations.

\[ 1 \text{ is } \bigcirc, \quad 2 \text{ is } \bigcirc, \quad 3 \text{ is } \bigcirc, \quad 4 \text{ is } \bigcirc, \quad 5 \text{ is } \bigcirc, \quad 6 \text{ is } \bigcirc, \quad 7 \text{ is } \bigcirc, \quad 8 \text{ is } \bigcirc \]

Figure 1. Arrangements of double-valued markers

We see, then, that by the use of the same basic markers we can represent a whole host of information simply by changing the arrangement of these markers according to the information. Furthermore, what I have done in this figure, by changing the spatiotemporal relations of pre-existing markers into new arrangements, is to formulate new markers which now carry the information in their arrangements. This type of information transfer is the most economic, because little energy is spent in creating new basic markers. Simple rearrangement of existing markers forms new ones. This
process is used by nature. By a certain amount of the same basic, double-valued markers, we can express several messages. Thus, several different units of information can be transmitted by changing the fact of the presence or absence of these markers in a predetermined time-space, giving shape to accumulations of basic markers.

The cases of paper and stone presented previously may be considered as subcases of the general case of marker formation; they may be considered as rearrangements of existing markers, in different compartments of time-space.

The example gives me the opportunity to discuss some preliminary concepts of "meaning". From now on, for you and for me it is the same if we see either 1 or $\Box$. We know that this $\Box$ is one. This combination of markers (in the case of 1, total absence of all markers) carries a certain information which we have agreed represents the number 1. And this is the "meaning" of this marker.

In respect to "meaning", understanding of a marker's message requires not only that the information transmitted gave shape to a marker, but it also requires that a relationship is established between this marker and another marker which is known (or is considered as known) to the observer.
There are some points I would like to make out of these examples.

(a) Some sort of energy is needed to bring about the change in the shape of mass-energy that will carry an information in the new system. The minimum energy needed for the transmission of an information is the energy needed for the transmission of a bit of information (yes or no); i.e., it is the energy needed for a rearrangement of the minimum marker of the new system, a double-valued marker.

(b) The new shapes of mass-energy that will be formed in the receiver system, i.e. the new markers, are not random arrangements of mass-energy. They are the result of the probable interactions of the kind of receiver system's mass-energy itself (paper, stone), and the information (letters, painting, sculpture, etc.). As the result of these interactions groups of markers can assume different shapes. The information which is transmitted from one system to another may be different or it may be the same. However, because the kind of the material of the
system receiving the same information is determined by the relations of its molecules, this transmission of information may result in different markers. Thus, the outcome, the new marker, as an overall appearance (shape), substance, energy, etc., is an arrangement of mass-energy through information.

Stated differently, information can only exist on markers. During flow of information from one system to another, the relations already existing in the receiver system at a certain time-space, give different shape to the same information; or the same information shapes different materials in different shapes. Briefly, the same information can result in different markers.

(c) Any kind of shape (configuration, structure) can be viewed as a marker. We only may be unable to understand it, as insects cannot read the Bible. They eat it. In fact, everything can be viewed as a marker that has been, and continues to be, shaped by the information, constantly carried out from all existences via the information mediators (light, sound, etc.) and transferred to all systems that receive the information.
For an understanding of meaning, additional information about some properties of the observer is required.

Depending on the nature of the human brain and especially on its function, called attention (Hilgard, et al., 1975), only one information can be appreciated at a time on a marker for any observer. In other words, the observer can relate himself to the marker with only one information at a time out of the multiple units of information that a marker can carry. This, though, does not mean that other units of information do not exist on the same marker. It follows that,

(d) A marker can, supposedly, represent \( n \) bits of information.

Since absence of a bit of information from one unit represents a negative answer to a possible yes-or-no question concerning the presence of this bit of information, absence of a marker is, also, a bit of information, although negative. Because the possible absences of such negative information are infinite, the shape that constitutes a marker is attributed to a certain number of positive information (\( n \) bits of information) and an infinite number of negative information bits which, because they are infinite, are also omni-present and, thus, not taken into account. Therefore, at any certain point in time a marker will bear \( n \) bits of positive
information and,

(e) when the marker is observed by an observer, \( n-I \) bits of information will be carried by the marker, but they will not be appreciated by the observer.

(f) The meaning of the information carried out by a marker is related to both the marker and the observer.

From the point of view of the marker itself the meaning of a bit of information carried by this marker is probably related to the amount of positive information that a marker carries, and that is not appreciated by the observer at the time at which he is busy observing the one bit of information that the physiology of his brain allows him to observe. For the observer, the meaning of information conveyed is related to his brain function and development. This will be examined later in this chapter.

In relation to meaning, Miller comments as follows:

Meaning is the significance of information to a system that processes it: it constitutes a change in that system's processes elicited by the information, often resulting from associations made to it on previous experiences with it. (Miller, 1978, p.11)
Let me describe a marker using concepts that were developed out of this discussion on information and markers. I will use the example of a famous marker: the smile of Mona Lisa - La Gioconda. To begin with, the painting of Gioconda as a whole, as well as her smile, can both be perceived as markers. Da Vinci was receiving a message from Gioconda through a marker (her smiling face), and he tried to transfer to the canvas the message as he perceived it. By the use of certain materials he transferred the message on the canvas. The message was first on the lips of Gioconda. Then, it was put on the canvas. Let us say that the information is more or less the same: a smile. But, the materials that shaped it in markers are different; muscles, mouth, and flesh at one time, and canvas and colors at the other. Energy was spent in both cases. The markers are different. The difference exists mainly because of the material. The information is more or less the same.

However, the "meaning" of this information depends on who is looking at it. We do not know exactly what the model Gioconda meant by smiling. We have no way of knowing what Da Vinci understood by this smile. And, furthermore, what is understood now from it depends on us, the observers.

When I was a young girl, and viewed the painting, I paid no attention to the "smile", even though I had seen many reproductions of Gioconda. In my thoughts it was a face like other faces of the Holy Virgin that I had seen expressing kindness and acceptance.
When I grew up and heard all the discussions about the "smile", I understood that it could also mean a "look of shame" or "a call for love". The same marker caused me to understand different things. It conveyed to me different "meanings". And not because the smiling Gioconda herself was saying one thing when I was ten and something else when I was twenty. So, even the same observer in different stages of his development may attribute different meanings to the same information-marker. To that extent then, meaning depends on the observer. However, the discussion would be different if Gioconda were not smiling but crying. To that extent, meaning depends on the marker.

To demonstrate how powerful the concept of information flow through marker formation is, I will provide another example. As we now know, information passes from one system to another printing markers (through energy expenditure) on the new system. "Information is the patterning of matter-energy in systems" (Miller, 1978, p.1030). I will try to demonstrate that this same general rule is followed by all the subsystems of our body which receive information. They all "print" markers. Any shape of mass-energy entering the body can be viewed as a marker carrying information with it. Thus, microbes, viruses or generally antigens are information carriers. They carry with them the information of their own shape. This shape for another system is information.
The immune system as a receiver of this information is a major marker printer. One of the major functions of the immune system is to manufacture antibodies. Antibodies are proteins of a shape representing the exact negative of the shapes of the foreign invading substances (mass-energy) that enter the body. These proteins (the antibodies) are not manufactured before the new shapes (the antigen) arrive. They can be synthesized only if the information about the shape of the invaders is transmitted. After this transmission the new information shapes the DNA of the host receiver in accordance with the message that was transmitted by the foreign substances. This DNA represents a new arrangement of pre-existing nucleotides and so is a new marker. After the new arrangement of the nucleotides is realized, the new DNA stays in our body permanently. It is now a constant part of our body. What should be emphasized is that this part of our body has been shaped by information from the environment - the foreign substances that entered our body. Also, following the pattern of this DNA, new proteins, the antibodies, are produced. As you can see, the whole process of immunization is responding by printing new markers to the information about the shape of the entering foreign substances. That this is so, is indicated by the shape of the

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antibodies. Also, that printing of the information on our markers permanently shapes a part of our body is proven by the immunity most microbial or viral diseases leave behind when they pass (lifelong immunity in many instances, e.g. measles, smallpox, etc.). Individuals who have experienced these shapes, this information, do not get sick again because they now have these antibodies - or the ability to form them - permanently.

This is an example of how our environment has shaped and is continuously shaping us by making us form markers, as a response to information. Projecting these mechanisms in our understanding of evolution we may say that our whole existence can be perceived as a pile of markers that have been formed during the biological history of the human race through an interaction of the materials that gave genesis to life initially, and information from the environment shaping them.

Information received by the brain, as well as other body parts, shapes the brain by causing it to print markers on which to inscribe the incoming information. If we admit the proposition that our sensoria carry "information" (visual, acoustic, etc.) to our brain and that this information can relate to our brain only by markers, and since all information can be carried only on mass-energy through markers, we understand that information, by being inscribed in our receiver system, the brain, is shaping it.
Information carriers for the human brain are, usually, electrical impulses but they may also be other substances such as chemicals, etc. These represent inheritance. Information received from the environment interacts with these materials (chemicals, neurons, etc.) and gives shape to markers. The arrangement of them by information depends, of course, on the type of information which, in turn, depends on the realities existing in the environment at the time of the interaction, and on the kind of materials the brain is made from. Since inheritance cannot change, the important message for the educator is that the development of the brain depends on the type of information that the brain will receive during its development.

Concluding with basic concepts, I will proceed now to a further description of other aspects of GST.

**Systems Analysis**

"Systems analysis" which has also been termed "systems thinking" or "systems approach" is an integral part of GST. It constitutes a natural result of the acceptance of the other concepts of GST. It represents a model of thinking and it is said to reflect the way the brain functions when thinking naturally, without any preconceived pattern of thinking. As such, it will be better understood and criticized after an analysis of the brain's nature and function. I will develop the concepts that are more closely related with systems
analysis in the next chapters. However, for the sake of completeness of this chapter, I will briefly mention the steps of the mental process that systems analysis implies. These steps are:


Supposedly, the brain, while perceiving things, is "analyzing" them in parts retaining at the same time the pattern of the relationships of the parts that it separates. Therefore, in an analysis we are not only separating an entity into parts but we are at the same time forming "models" of the structure of this entity. These models are perceived as separate parts of the analysandum, while, at the same time, they do not constitute anything more than the relationships of the real parts of the analysandum. A "resynthesis" of the analyzed parts must take place in order to understand the analysandum as a whole. This synthesis can take place either according to the model of relationships the analysandum itself has provided or according to a slightly or greatly different model. This new model is chosen by us through "simulation" of the model the analysandum has provided to other models previously inscribed in the brain (or previously given to a computer). If we keep this in mind we can probably understand how the brain perceives entities as wholes while performing an analysis and a resynthesis of the whole.

As "whole" we can understand a part of the world which, as I said, can be perceived as a system. According to Silvern (1975)

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[1] Analysandum is called an entity, system, or situation which is being analyzed.
systems analysis is:

...the application of ANALYSIS, SYNTHESIS, MODELING, and SIMULATION to a SYSTEM. The iterative, high speed process of ANALYSIS...SYNTHESIS...ANALYSIS...SYNTHESIS followed by MODELING and SIMULATION may be termed ANASYNTHESIS and this is, in fact, the real meaning of systems approach....(Silvern, 1975, p.1)

GST proposes the above approach to any problem: Analysis-synthesis-modeling and simulation to all levels and/or subsystems of the system under investigation.

Whether this is true or false for the brain, acceptable or rejectable as a thinking tool, and whether it really reflects the mental process of thinking itself, can better be criticized after developing a number of other concepts related to GST and the nature and function of the brain.

Concrete Systems and Some of Their Properties

Concrete or real or veridical systems are complexes of elements consisting of mass-energy, interrelated in a time-space. Energy is spent to keep the parts of a system interacting, organized. The complexes of elements that constitute the parts of the system are systems themselves. Any sort of connections among the parts of the system constitutes their relations. These relations are spatial, temporal, spatiotemporal, information flow, or mass-energy flow. Properties or relations of the parts of a system are its variables. Usual variables of a system are:
1. The number of its parts. 2. Its size. 3. Its rate of movement in space. 4. Its rate of growth. 5. Its rate of information flow. And, 6. Its different thresholds (threshold of response to light, sound, smell, etc.). These variables are intrasystemic and should not be confused with external variations.

The spatial relationships of a system in the Euclidean space determine its structure. The structure (or state) of its parts always changes over time. The concrete systems have boundaries which are more or less well-defined (a living creature - a water fountain).

Open Systems and Some of Their Properties

Depending on the permeability of the boundaries, concrete systems are closed when the boundaries are impermeable, and open when the boundaries are semipermeable. Mass-energy and information are processed by the system and products or waste are extended across the boundaries. Thus, there are inputs, throughputs, and outputs. The following model described by Bertalanffy (1973) for living organisms is used as a prototype for dealing with open systems:

![Figure 2. Schematic representation of an open system](image-url)
The component "A" is introduced into a system (direction of the arrow $\frac{k_1}{k_2}$) and is transformed in a reversible reaction ($\frac{k_1}{k_2}$) into B. It is also catabolized in an irreversible, unidirectional reaction ($\frac{k_3}{k_2}$) into C and eventually the product of this reaction is excreted (direction of the arrow $\frac{k_2}{k_3}$). $K_1$ and $K_2$ are constants of import and export. The symbols $k_1$, $k_2$, and $k_3$ are constants of internal reactions. As $k_1$, $k_2$, and $k_3$ are variables by which the rate of the throughput is regulated, it is understood that $K_2$ (the rate of output) will depend on the rates of $k_1$, $k_2$, and $k_3$. These considerations illuminate why a static perception of an open system, i.e. of any part of the concrete world, is erroneous. It is obvious that open systems are constantly changing. As their structure then I consider the arrangement of their parts in the three-dimensional space in a time slice; as their processes, the change of mass-energy or information over time. Of course, structure and process are related in time-space:

The antithesis between structure and function, morphology and physiology is based upon a static conception of the organism...What is described in morphology as organic forms and structure, is in reality a momentary cross-section through a spatio-temporal pattern. What are called structures are slow processes of long duration, functions are quick processes of short duration. (Bertalanffy, 1952, p.134)

A living creature is "the typical" example of a concrete, open system: it grows and then it declines, but the parts are intercon- nected and the organism keeps its identity throughout life despite the changes.
Closed Systems and Entropy

Closed systems can be viewed as a case of open systems without inputs and outputs. No actual concrete system we can imagine is completely closed except, perhaps, the universe. So, closed systems are relatively closed. The big difference between open and closed systems is entropy. While open systems remain in steady state or even grow by inputs in mass-energy and information (entropy equal to negentropy) and eventually decline (as entropy increases), closed systems, having a fixed amount of energy within the system, eventually become unable to keep even their own household.

Conceptual Versus Concrete Systems

Conceptual or abstract systems are constructed of abstract entities which practically are terms. Their elements are words, numbers, or other symbols such as computer simulations and computer programs. The relations of such systems are expressed again by words (usually verbs) or by the symbols of calculus or the symbols of computers that represent operations.

In my opinion, it should not be forgotten that whatever language symbols or computer programs are used, they all exist in one (or more) concrete systems - living or non-living, the man or the computer.

At any rate, the subject of my dissertation does not require the use of conceptual systems. Instead, it is mandatory to always
look back and get in touch with reality, consider where education is applied, and the societies that use it.

Some behavioral scientists consider "human" systems as patterns of behavior (roles). In this sense, they form either conceptual systems, or a mixture of concrete and conceptual elements, the so-called "abstracted" systems. GST allows for such mixture. In the present study I will treat educational systems as concrete, open systems.

**Goal-Oriented Systems, Feedback Mechanisms and Dynamic Interactions**

Living systems are also considered as goal-oriented organisms or systems. Goals are related to learned or intentional behavior. Learning does not only mean that behavior changes subsequently to an experience (e.g., approach a fire, be burned, and not approach it again), but that the behavior changes also for the "better". The meaning of better in the above example is that the once-burned "system" now behaves in a way by which it has less chance to be burned again. This pattern of behavior, in the last analysis, promotes survival. This constitutes the real meaning of "better". Living organisms survive by the process of adaptation to the challenges of the environment through learning (Ashby, 1960).

Ashby, in an excellent analysis of the problems of adaptive behavior, proceeds from goals to values and from values to behavior. He shows that any subsystem of the body has its own values that may influence its own goals. Although survival of the whole organism
does not represent a value for a neuron for instance, or groups of neurons, or even parts of the body, as these have other values in their immediate environments, however, when these parts are connected to each other, they acquire additional values.

These considerations reveal the main peculiarity of the problem. When the nervous system learns, its behavior changes for the better. When we consider its various parts, however, we find that the value of one part's behavior cannot be judged until the behavior of the other parts is known; and the values of their behaviors cannot be known until the first part's behavior is known. All the valuations are thus conditional, each depending on the others. Thus, there is no criterion for "better" that can be given absolutely, i.e., unconditionally. (Ashby, 1960, p.7).

Since all valuations are conditional and the behavior of the individual changes for the better, there should be a condition to which this "better" should match. Ashby, by a discussion through the whole book, proves that this condition is the stability of the system that is necessary for its survival (its continuation in existence as a system).

The fact that the stability of a system is a property of the system as a whole is related to the fact that the presence of stability always implies some co-ordination of the actions between the parts. (Ashby, 1960, p.57)

Opposing variables in a system are either in balance - the system
is in equilibrium - or unbalanced - disequilibrium. The equilibrium in an open system is maintained unchanged in the middle of a continuous change: Flux equilibria or steady state. There is a range of stability for each of the essential or critical variables in all living systems. When the variables are within such range, need for correction of their deviation is zero or minimal. This situation is homeostasis and the open systems acquire by adaptation that form of behavior which maintains the essential variables within physiological limits. This is effectuated through feedback mechanisms or dynamic equilibria. Bertalanffy has shown that the primary regulations in living systems, those regulations that are most fundamental and primitive in embryonic development as well as in evolution - the regulations that show equafinality\textsuperscript{12} - are governed by mechanisms other than feedback. In these stages, open systems depend more upon system constants than upon environment - in the condition that the environment has abundant essential inputs. This means that their steady state can vary within a wide range and still allow the composition of the living tissue to remain relatively constant. Later in development or evolution, secondary regulations are superimposed. These are mainly of the feedback type. These regulations develop in more fixed environmental factors than do the primary regulations. This is due to the general principle of organization

\textsuperscript{12}Equafinality means that a final state of any living system may be reached from different initial conditions and in different ways.
or progressive mechanization.

Bertalanffy maintains that in its beginnings the open system (of any kind, biological or social) is governed by "dynamic interaction" of its components. Then, conditions of constraint are established which render the system more efficient but also more differentiated. It is not any more pluri- or multi- or equipotential. Bertalanffy does not make clear what happens with inputs that are beyond the wide but still "normal range". Miller has worked on systems overloads and he shows that they become either destroyed or abnormal (Miller, 1978).

In systems, a measure of the sum of the individual parts of a system is larger than the sum of the measures of its individual parts. This can be presented as follows: \( \Phi (x + \psi) > \Phi x + \Phi \psi \) where \( \Phi \) represents measurement and \( x \) and \( \psi \) the parts of a system \((x + \psi)\). This is so because the components or subsystems join in coalition (systems) in which the interacting elements follow a superadditive composition rule (Foester, 1962). The larger system has its own stability to find, which is conditional on its own inner and outer environment, and which represents an additional value orientation for the whole system, which did not exist before the parts coalesced into a system. This new value-goal has "emerged" as a result of the parts now being connected in a system. This new property which is apparent only on the "whole" of a system is called "emergent" and constitutes one of the most characteristic features
of the systems. It should be mentioned that this is another formulation of the classical view that a system must be viewed as a "Gestalt" or a "total configuration".

Systems Hierarchy

A very important feature of systems is the existence of levels of them or of hierarchy. If we consider the universe as a system, it is easy to understand that everything else is comprised in it, i.e. is a subsystem of the universe. Galaxies comprise planetarian and solar systems. Our earth can be conceived as a system; continents, nations, societies, man, other animal species, microbia, viruses, molecules, proton and electrons - can also be considered as systems. If we take a look at the generalizations humans created, we see that some of them concern actually a whole hierarchy of systems: plants and animals are such types of generalizations.

...some of the essential characteristics which every hierarchy has....(are) vertical arrangement of subsystems which comprise the overall system, priority of action or right of intervention, of the higher level subsystems, and dependence of the higher subsystems upon actual performance of the lower levels. (Mesarovic, 1970, p.34)
A representation of the vertical arrangement may be demonstrated in Figure 3:

Although this representation concerns primarily human organizations, it contains all the main characteristics of any open systems. In combination with Bertalanffy's representation (see p. 49), one can understand that any point of mass-energy processing in Bertalanffy's representation, here is presented as a subsystem, which, of course,
is by itself another system. In this respect, any system or subsystem is conceived as a transformer of inputs to outputs. Obviously, the functions that a subsystem fulfills constitute variables for the next higher in the hierarchy system. Thus, the subsystem of a hierarchy, conceived as a variable of the higher level, must contribute to the homeostasis of the higher level. The operations of a system or a subsystem are obviously influenced directly and explicitly from the higher levels, most probably from the immediately supracing system or level. There is, however, a performance interdependence and the successful processing of inputs depends on good performance of all the subsystems in spite of the fact that there is priority of action whose direction is oriented in a command fashion from the higher levels downwards (Mesarovic, 1970). Inputs and outputs come, go, or pass through the immediately higher levels that constitute the immediate environment of the lower level.

Levels of Living Systems and Some of Their Properties

Miller has distinguished seven levels of living systems which he analyzed as: Cell-Organ-Organism-Group-Organization-Society- and Supranational System. He does not argue that there might be other types of division. Gerard, for instance (Rapoport, 1970), proposes six levels: cell-organ-individual-small group-institution-society. Miller's division is convenient for my purposes and I will follow it when I need to refer to hierarchical levels of living
organisms.

Miller describes 19 subsystems (processes) in the living organisms which exist in all seven levels—but which have a different structure in each level. They are named according to the process they are performing. I will not describe them in detail. For the purposes of this dissertation it suffices to emphasize at this point that organs of man, man himself, organizations or society, with their subsystems and their suprasystem, are perceived by many authors as concrete, open, goal-oriented, living systems. It follows that the brain, man, and educational entities which are all of concern in this study, may be perceived as living systems having their subsystems and their hierarchy.

An important property of the living systems as compared to non-living ones has been pointed out by Gerard (Rapoport, 1970). According to his organismic theory living systems have "being", "acting", and "becoming". "Being" corresponds to the structure which has been described above, "acting" to function or process, which has also been described, and "becoming" corresponds to the history or the evolution of the system. Organisms, ecological systems, institutions all have these three attributes. "Non-material" systems, like language, have "being" and "becoming", but they have no "acting". For the action that their becoming requires they depend on living systems who perform changes on them.
Another thing to keep in mind is that subsystems and processes do not have a one-to-one relationship. In fact, subsystems because they are interconnected, are performing as the beginning of their main process some of the processes that other subsystems finish. In fact, most of the time, in order to function, they need as inputs several outputs of other subsystems. This explains why anything which is processed by a system is processed by it as a whole, by another whole. This understanding, also, lies on the basis of the concept of "network causality (Weiss, 1974) and is opposed to the notion of "linear causality". Network causality means that an effect in one part of a system causes a series of reactions as it is processed by the whole system. It does not result in a simple cause-and-effect relationship between some elements of a system only.

Also, inherent to systems properties is the so-called progressive segregation. This is the process by which all systems display a division into a functional and hierarchical ordering of subsystems. It is due to the systems' evolutionary development during the continuous movement of the universe that is also a continuous movement from randomness and chaos into order and complexity.

Summary on Systems

"A system is an entity composed of a number of parts, the relationships of these parts, and the attributes of both the parts and the relationships." (Immegart, et al., 1973, p.30). I am
interested in the concrete, open, goal-oriented systems into which living systems are classified. These systems exist in time-space, consist of mass-energy and continuously receive inputs of mass-energy and information which they process (throughputs). This results in the excretion out of their boundaries of mass-energy and information (outputs). Mass-energy processing constitutes action. Information flow (= communication) is always born on a mass-energy basis (marker). Marker is a concept which means "a portion of mass-energy which carries information". The placement of the parts of a system represents a non-random, organized distribution of mass-energy (structure). Due to the continuous movement in time structures are actually slow processes.

The whole universe is a hierarchy of systems. Thus, when examining a system, we must examine it in relation to its higher levels - suprasystems - and its lower levels - subsystems. Suprasystems interfere with their subsystems in a command fashion, while a system's performance depends on the overall performance of all the subsystems.

Again, due to the continuous movement of the universe, there is a continuous becoming. Due to the interrelation of the systems among themselves this continuous "becoming" becomes evolution. So, systems move, evolve, develop spontaneously and continuously. Systems tend to maintain a steady state, a condition which because it is happening in the middle of a continuous flux of mass-energy
and information, requires self-regulation (homeostasis). This they obtain either through feedback mechanisms or by dynamic interaction. Due to all these mechanisms and the fact of movement forward of time, they show progressive segregation (differentiation) with progressive mechanization. They obtain this through information struggling against entropy (through negentropy=information). The living systems in their becoming – which supposes of them being and acting – assume several phases of which the more characteristic is growth and decline. This process is their individual evolution.

Somewhere, among all these "living" but also "social" systems is education. If education is perceived as a concrete system, then it is composed of living and non-living parts, of material and immaterial parts. The overall estimation of Miller and other behavioral scientists is that these types of social systems are "living systems" in which there is a "vertical" projection of all the subsystems of the living organisms. Of course, there is a group of behavioral scientists who prefer to see social institutions as systems of "roles", "behaviors", etc., and have formed for this purpose "abstracted" systems. I follow, in this study, the position of Miller (1978) who rather strongly argues against the "abstracted" systems.

If education is perceived as a concrete, open, and goal-oriented system and society is perceived as a system composed of subsystems such as education, then education will be at the same time a
subsystem and a variable of society, contributing together with other variables or subsystems to society's stability.
CHAPTER II

THE BRAIN AS PROCESSOR OF INFORMATION

THE PHYSIOLOGICAL BASIS OF LEARNING

The subject matter of this dissertation is interdisciplinary, but it is mainly addressed to educators who might not be familiar with some of the terminology biologists use. I feel, therefore, that I have to insert here a brief, selective, informative section about the concepts we are to be confronted with in the following sections.

Elements of the Cellular Anatomy and the Physio-biology of the Nervous System

The neuron - the cell of the nervous system - is a mass of living substance which is composed of three main parts (Fig.4). The membrane outside, the cytoplasm inside the membrane, and the nucleus in the center of the cytoplasm. From the cytoplasm emanate two kinds of processes: the axon (one) and the dendrites (many). The axon is the way by which an electric impulse generated in or trans­crossing the cell is transmitted out of the cell. The dendrites receive impulses and transmit them inwards (Fig.5).
Figure 4. A neuron

Figure 5. A neuron usually synapses with many other neurons. At the side of the synapse the axons are forming end buttons or synaptic knobs.

All neurons are connected to one another. They are also connected with many kinds of other cells (muscle fibers, neuroepithelial cells, etc.). The sides of their connections are called synapses (Figure 5 and Figure 6). Between two neurons or a neuron and any other kind of receptor cell that form a synapse, there is a slight physical separation which is called the synaptic cleft (Figure 6).

Figure 6. Synaptic junction

Figure 7. Spine synapse.
At the sites of the synapses the dendrites might develop specific structures called spines (Figure 7). The axons come to the synapse by their tip which becomes enlarged and is called a synaptic button or synaptic knob (Figure 5 and Figure 6). Synapses are formed not only on dendrites and the body of neurons as it was believed up to now but along the axon also (Peters, 1970; Bodian, 1972). The synaptic knob is the site at which specific chemical substances, called neurotransmitters are formed in the synaptic vesicles (Figure 6). When an electrical impulse running through the cell reaches the synaptic button the synaptic vesicles open into the synaptic cleft (Figure 6) and the neurotransmitters are secreted and come into contact with the membrane of the receptor cell.

Information Processing by the Neurons: Impulses and Neurotransmitters

Learning cannot be realized without being preceded by information processed by the brain. Information processing by the nervous system means the generation of an electrical impulse at a site of the nervous system which is then transmitted from neuron to neuron by running through all the cell's body and processes and by being transformed at the synapses into neurotransmitters. Information is received as light, sound, etc., at the sensoria. There it is transformed usually through chemicals (e.g. rhodopsin) into electricity by specific neuroepithelial cells and it is transmitted from cell to cell to the brain as electrical "impulse". Or an electrical impulse generated in some neurons of the brain goes out from the brain to the muscles. Again, it is transmitted from neuron to neuron until
it reaches the muscle fiber. While passing from one neuron to the
other the impulse is transformed into chemicals - the neurotrans-
mitters - in the synaptic knobs. On the membrane of the receiver
cell the neurotransmitter generates an electrical potential differ-
ence which is transmitted as electrical impulse throughout the other
cell and when it reaches the end of its axon is again transformed
into neurotransmitter and so on and so forth.

There are several kinds of neurotransmitters and several kinds
of synapses. According to the post-synaptic action that is produced
the synapses have been termed either excitatory or inhibitory. This
quality of the synapses may be determined by the kind of the neuro-
transmitters and/or by specific mechanisms at the particular post-
synaptic sites (e.g. acetylcholine may mediate either excitatory or
inhibitory actions). In the brain, glutamic and aspartic acids
(aminoacids acting as neurotransmitters) have been implicated at
excitatory synapses whereas gamma-aminobutyric acid (GABA) and gly-
cine (other neurotransmitters) have been implicated in inhibitory
synapses.

Elements From Nervous System Gross Anatomy and Physiology

The human brain contains approximately 10.000 million of
neurons. Towards its lower part the brain is gradually changing
into the spinal cord (Figure 11). The brain and the spinal cord
form the Central Nervous System (CNS). The nerves and several
other structures (ganglia, plexuses, etc.) form the Peripheral Nervous System (PNS).

Nerves process information either from the periphery to the center (sensory nerves) or from the center to the periphery (motor nerves). The same in or out directions have messages from the so-called autonomic system (sympathetic and parasympathetic). These messages regulate functions in which the "will" of man is, usually, not participating (for instance, the heart beat, the body temperature, the respiration rate, etc.). All messages are processed in successively repeated rows of neurons in the CNS. As one can understand, there are hundreds of thousands of millions of synapses among the thousands of millions of neurons, firing impulses continuously from all the parts of the body: all muscles, skin, sensoria, the inner environment of vessels, organs, the brain itself, and so on. Through these, all kinds of information originating in the inner and outer environment of the individual reach the brain and are processed simultaneously, in a parallel fashion, analyzed and resynthesized. Then, the CNS formulates motor images and reacts according to the "information" received and sends messages to the effector cells or organs.

Often more than one name is given to the same anatomical areas of the brain. One type of nomenclature takes into consideration mostly physiological principles—functions—of parts of the brain; another is purely topographical—anatomical. However,
one or the other has dominated in the everyday use of terms, and I will here mention those terms that will be needed for an understanding of information processing by the brain.

The hemispheres of the brain (Figure 8 and Figure 9) are interconnected by a bridge of white substance (Figure 8) which is called corpus callosum (Figure 9 and Figure 11). The left hemisphere is, usually, slightly bigger and different from the right and it is called the major hemisphere. The other is the minor hemisphere. The neuronal bodies are found in the brain in the area which is in the outer part of the organ and it is called the cortex (Figure 8). Local collections of neurons in the cortex may serve a specific function and they may take a name according to this function, i.e. the visual cortex, the acoustic cortex, the motor cortex, etc.

From the point of view of evolution, the brain is divided into three concentric layers: (1) a primitive central core, (2) the limbic system which evolved later upon this core, and (3) the cerebrum, the latest evolutionary development which is composed of the two hemispheres (Figure 10 and Figure 11). Figure 11 provides a more detailed illustration of the hierarchical structure of the human brain. The hemispheres are divided into lobes (Figure 8): the frontal, parietal, temporal, and occipital lobes. The major
Figure 8. A: Cross section of the hemispheres. The white substance is mainly composed of neuronal processes (axons) while the gray substance is composed of the neuronal bodies. B. The hemispheres from above. C. Lateral aspect of the left hemisphere: The lobes. Psychology and Life, 7th Edition by Floyd L. Ruch. Copyright 1967 by Scott, Foresman and Company. Reprinted by permission.
Figure 9. Biological basis of Psychology: Sensory inputs to the two hemispheres

Introduction to Psychology, 6th Edition by Ernest R. Hilgard et al.
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Figure 10. The three concentric layers of the human brain.

Introduction to Psychology, 6th Edition by Ernest R. Hilgard et al.
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Figure 11. Hierarchical structure of the human brain.

hemisphere is the hemisphere that processes language, and specific centers have developed for this function in areas of the parietal and the temporal lobes.

Functional Units of the Brain

There are three functional units of the brain (Figure 12 and Figure 13).

The first unit "regulates the energy level and tone of the cortex, providing it with a stable basis for the organization of its various processes" (Luria, 1970, p.66). The systems of the second unit have highly specific assignments. They receive, elaborate, and store the incoming information; they also perform the basic mechanisms of cognition.

We can easily identify areas in the second block that are respectively responsible for the analysis of optic, acoustic, cutaneous and kinesthetic stimuli. Each of these cortical areas has a hierarchical organization: a primary zone that sorts and records the sensory information, a secondary zone that organizes the information further and codes it and a tertiary zone where data from different sources overlap and are combined to lay the groundwork for the organization of behavior. (Luria, 1970, p.67)

The third unit represents the functional apparatus of the brain for intentions and programs, regulating and controlling our actions. Neuronal fibers descending from here regulate vigilance and attention, coordinating behavior and conscious goals and motives.
Figure 12. A. The gray area indicates the first functional unit of the brain. B. The gray area indicates the second functional unit of the brain. From "The Functional Organization of the Brain" by A.R. Luria. Copyright (c) 1970 by Scientific American, Inc. All rights reserved. Reprinted by permission.
The brain normally has an electric potential which is created by the firing of its approximately ten billion neurons. Each individual neuron has a firing time and a resting time, but the created electrical field from the combination of these firings is continuous. This forms the basis for the electrical threshold of the brain: if the impulse caused by a stimulus is weaker than the threshold, it cannot be appreciated by the brain, as a whole, even though the information is being processed by its subsystems. The threshold forms the basis for "the rule of force" (Pavlov, 1927): strong stimuli evoke strong response, weak stimuli, weak responses. These two features provide for the brain a very high selectivity; in a way
the brain "chooses" the most strongly evoked impulse among the numerous impulse patterns always running throughout the brain in a low potential.

I. P. Pavlov observed that when the normal tone of the cortex is lowered, the "law of force" is lost and much of the brain's ability to discriminate among stimuli suffers. Normally the cortex reacts powerfully to strong or significant stimuli and responds hardly at all to feeble or insignificant stimuli, which are easily suppressed. (Luria, 1970, p.66)

Finally, on the basis of the existence of the "inhibitory" circuits evoked by inhibitory synapses, the brain acquires the tremendous plasticity which is indispensable for its work. Plasticity in this instance means that the brain can quickly and fluently block a pattern in use and transit to another. A certain state of excitation that the brain reaches because it is dominated for a certain period of time by a certain pattern of impulses, will dominate only for a while the electrical potential of the brain. Very quickly, because of the inhibitory circuits, in other words, because of its plasticity, the brain will switch to another state of excitation. It cannot remain for a long time in a fixed state of excitation except in pathological cases (Luria, 1972).
Considerations on the Physiological and the Psychological Basis of Learning

Most of the experiments that psychologists and physiologists perform in order to delineate which of the functions of the brain are related to learning make use of some kind of information coming from the environment to the brain, which is processed by the brain and is learned. The results of these experiments are then examined to determine what are the effects of such a processing. Thus, learning is definitively related to information processing. While this is true, the opposite may not be true. That is, information may be processed by the brain but it may not be learned. This depends on the normal function and condition of the brain while processing a certain unit of information, and it does not constitute evidence that learning can be realized without information processing by the brain. For this reason, I am not interested in examining this alternative for the present.

What I want to point out at this moment is that information processing by the brain is the basis of learning. This implies that an interaction between the environment and the individual takes place and learning is realized exactly during this interaction. Thus, to find out how learning is realized, one should know the functions of the brain that participate in this process. However, this "how" is not well known at the level of the brain's physiology because learning involves higher mental processes, the physiology of which cannot be studied since they are realized in humans, not
amenable to the kind of experimentation that is necessary to solve these problems.

...as has repeatedly been stressed, we do not know anything about the physical basis, within the brain, of higher mental function. (Dobbing, 1975, p.11)

However, abundant indirect experimental evidence about the ways by which learning is realized comes from psychological experiments. Of course, these experiments do not answer the problem of the physiology of learning but they constitute the best approximation that is available. All of them are based on some basic assumptions about the physiology of learning. This means that propositions concerning educational processes, because they are based on these assumptions, cannot be directly based on the physiology of learning but they have to be based on some theory of learning. Therefore, the validity of the propositions will depend on the truth and the strength of such a theory.

Approximation of such a theory to the truth will depend on how much it makes use of experimental and observational evidence, and by which basic assumptions it relates in a logical and consistent way the physiological to the psychological basis of learning.

In this respect, when discussing the theory of learning on which I will base my propositions, I will try to correlate it first with as much experimental evidence as possible, and secondly, I will
try to use those assumptions which do not disregard whatever we know about the physiology of the nervous system in general (the physiology of learning will obviously depend on the physiology of the brain). If the learning theory is somehow different from the brain's physiology, this can only be of a super-additive type; that is, the differences that may exist between the physiology of learning and the overall physiology of the brain cannot lead me to adopt an assumption about the physiology of learning that denies the facts that we know about the physiology of the brain in general. All the assumptions I will accept in this area must first explain and/or incorporate what we know about the physiology of the brain and then, perhaps, proceed even further, proposing additional mechanisms in order to explain phenomena not understandable by the physiology of the brain alone.

Most of the physiology of the nervous system that we know of comes from experiments with animals. Thus, another difficulty, in-built in the area of theories of learning, is that one has not only to speculate from experimental evidence; he has, also, to extrapolate from animal experiments. Since humans are not animals, this extrapolation should be done very carefully. However,

...there is no great difference between mammalian species in the pattern of brain development...Even the individual unit structures of which the brain is composed, such as the nerve cells, glia and myelin sheaths are remarkably similar both in composition and function from one species to another. (Dobbing, 1975, p.9)
The basic assumption that I follow in the theory of learning I adopt coincides with the basic assumptions that modern psychology has adopted:

"Modern psychology takes completely for granted that behavior and neural function are perfectly correlated, that one is completely caused by the other. There is no separate soul or life force to stick a finger into the brain now and then and make neural cells do what they would not otherwise". (Hebb, 1949, p.XIII)

I follow this assumption throughout my dissertation:

"Actually, of course, this is a working assumption only as long as there are unexplained aspects of behavior". (Hebb, 1949, p.XIII)

The reader may choose to follow another assumption.

"But it is important also to see... (that) the working assumption is a necessary one, and there is no real evidence opposed to it. Our failure to solve a problem so far does not make it insoluble. One cannot logically be a determinist in physics and chemistry and biology, and a mystic in psychology". (Hebb, 1949, p.XIII)

In this respect I will try to stay close to physiology as much as possible. In this chapter, I will treat the problem of learning mainly from its physiological aspects, although one understands that
since basic ignorance exists in this area, there will be instances in which logical inferences about the basis of learning will interfere. In the next chapter, I refer mostly to psychological experiments based on the assumptions formulated in the present chapter.

**Information Processing and Learning**

The several functions of information processing by the brain which result in learning can be most vividly and comprehensively presented through the demonstration of the processing of one type of information. As such, I will use language. In areas where there are more adequate experiments on other types of information processed by the brain than language, such as purely visual information, I will use this type of information.

Language is viewed as a system of signals through which humans communicate. These signals are of acoustic nature when we are dealing with spoken language and of visual nature when we are dealing with written language. This is their initial nature and it corresponds to an initial step of information processing by the nervous system and the brain, i.e. to the step at which information is transferred from the corresponding sensoria (ear, eye) to the appropriate areas of the brain (in this case, acoustic or visual cortex). From this level, through appropriate interconnections of neurons of the several centers, all incoming information is processed in a similar fashion (though perhaps in different centers) in all
other levels of the brain.

Therefore, I will take the case in which language, as a processor of information to the brain (Eccles, 1977 and Chomsky, 1975), is related to the process of learning (Luria, 1970). Recent research has shown that processed information is learned by being related to long-term memory (Luria, 1974) which, in turn, is related to synaptic growth (Brown, 1976), and to the production of ribonucleic acid (RNA) - one of the genetic substances controlling protein synthesis (Shashoua, 1976), and to "ongoing protein synthesis" in the neuron (Shashoua, 1977).

Other researchers have found that learning is also related to attention (Rubenstein, 1973) which depends, among other things, on at least two hormones (Sandman et al., 1972; Miller, et al. 1974). One of them, melanocyte stimulating hormone (MSH) is regulated through the pineal organ and is related to exposure to light (Wurtman et al., 1977). The other, adrenocorticotropic hormone (ACTH) is intimately related to stress (Sandman et al., 1973). Thus, learning may be related through attention to an appropriate balance of these hormones. Learning is also related to a number of nutritional factors (Rawls, 1978) including those which, acting as precursors of neurotransmitters, influence learning by improving the transmission of impulses at the level of the synapses (Wurtman et al., 1976; Ulus et al., 1976).
The close relation of learning to nutritional factors that improve impulse transmission in the synapses may be understood on the basis of the function of the nervous system. Information processed by the nervous system generates an electrical impulse which is transmitted from neuron to neuron through neurotransmitters. Normal synthesis of neurotransmitters requires the presence in the blood of substances dependent on appropriate and adequate nutrition. Also, protein synthesis which is related to memory, requires the presence in the blood of amino acids which are precursors of the proteins. The level of them in the blood depends on nutrition. We see then that improvement of transmission of impulses and of memory improves learning. But, through the interconnection of the nutritional factors with the neurotransmitters or the memory we may say that improvement of nutrition improves learning. Finally, it has been found that when some substances found in the synapses (as yet unidentified) are blocked by an antibody, learning patterns change significantly (Rapport, et al., 1978).

From all the above findings it becomes evident learning is realized in the brain, and through functions of the brain.

The brain, while learning, processes information by analyzing and resynthesizing it. This happens necessarily because the several physical entities that are processing information are different in nature. The brain, for instance, receiving information from another physical entity through light and sound, etc., does not have the
same nature that the other entities have, that is, to be able to process this information by forming the same type of markers that the other entities are composed of. Thus, on the basis of the universal law that information can only flow through markers, and on the basis of the nature of the brain, all information received by the brain has to be broken down, i.e. analyzed into bits of information that correspond to the nature of the least markers that the brain can generate. Subsequently, appropriate arrangements of brain markers have to be formed that will represent the incoming information. This requires a synthesis of the bits into which the information has been analyzed. This synthesis will be done according to the pattern that the information itself dictates, and according to the possibilities of the brain.

So, the analyses and syntheses that take place are the result of the nature of the brain itself and of the only way by which information can flow. Analysis and synthesis take place on different levels of the brain: The cellular or even lower level, the level of the different centers of the brain, the level of groups or centers, or of functional units of the brain, and the level of the whole brain. Each of these levels can, of course, be viewed as a subsystem of the brain, the several subsystems each belonging to a specific suprasystem, and all together forming the system, the brain, the whole individual. In this sense the reader has to keep in mind that all these systems are functioning in a continuous interaction with each other,
their function influencing the function of the other systems, belonging to the same suprasystem.

In this respect, it will not be difficult to understand how a malfunction of nutrition, which is effectuated by other systems of the body than the nervous system, can affect the development of the brain in one or more of its levels. Or conversely, it can be understood how a malfunction of the brain, or of one of its subsystems, can affect the overall performance of the individual.

**Neurogenesis - Synaptic Learning**

I have already mentioned that several factors have been identified as influencing learning (long-term memory, for example). I will now discuss one of these factors which is called "synaptic learning".

The production of the ten billion neurons which make up the human brain begins in utero and continues after birth for various lengths of time. The periods of extramaternal production of new neurons differ from species to species (Dobbing, 1975). The whole period of brain cell production and initial organization of the neurons is called the period of neurogenesis and it is believed that in humans it ends at approximately the fourth year of life. During neurogenesis, the neuroblastic cells are not only dividing very actively but are also projecting their processes in several directions. The neuroblastic cells may even migrate from one place to
another.

All these activities during the period of neurogenesis help to shape the brain into more or less its adult form. Centers are formed and pathways of communication between neurons are established. After neurogenesis has finished, the only activities that are observed concern the processes of the cells. But if the cell itself is irreversibly injured and dies, there is no way it can be replaced. This gives the period of neurogenesis and generally to the brain's development an irreversible character.

It appears that except for heredity, the normal development of the brain during neurogenesis depends heavily on incoming information from the environment. Evidence of this has been obtained in recent years by experiments with kittens. As I have mentioned, synapses of the neurons are realized in many occasions through spines, structures that develop as little growths (see Figure 7), at the receptor side of the synapse. Therefore, the number of spines that we will find on the dendrites of the neurons may correspond to the actual number of connections of these neurons with other neurons. Several researchers, among them Valverde (Eccles, 1977) and Szentagothai (1971) have conducted the following experiments: They raised mice or kittens or immature monkeys in complete darkness. After the neurogenesis period for their species was completed they examined these animals. They were completely blind. Then, they examined the number of the spine synapses grown
on the dendrites of the cells of their visual cortex. There was either no growth of spines on these cells or there was very defective growth as compared to normally raised animals (Figure 14).

Figure 14. The drawings demonstrate differences in the spine synapses that are found on the dendrites of the neurons of kittens raised in normal light (A, B, C) and in darkness (D). In this last case, there was a regression in the number of spine synapses, i.e., in neuronal connections.

Other investigators have done experiments in which only one eye of the animals was closed. The animals became blind in this closed eye but not in the other. The blindness corresponded to the loss of synapses in the respective area of the visual cortex.

These experiments established the fact that even seeing, which is a characteristic that we consider to be inbuilt in a normal
individual is a learned behavior, the normal development of which depends on interaction of the developing brain with appropriate stimuli. Other experiments have shown that similar treatment of adult animals did not have the same results, and, further, that within the period of neurogenesis there was a specific period, sometimes only a few days, during which the animals were more susceptible to the deprivation of light (Kuffler et al., 1976). In a series of related studies kittens were raised in various abnormal environments and then were examined. For example, kittens were made to wear goggles marked by horizontal or vertical stripes (Hirsh et al., 1971) or were kept in an environment with striped walls, so that they were exposed to only one kind of orientation (Blakemore et al., 1970). On examination of the cortical neurons, the great majority of the cells could respond only to light that had an orientation similar to that prevalent in the environment; that is, they needed horizontal or vertical stimuli in order to see. Two interpretations of these observations have been proposed:

1. Cortical cells could change their orientation preference, and,

2. Only those cells responded specifically that had been appropriately stimulated; the remaining cells that had not received appropriate experience lost their orientation specificity.

The effects produced by these experiments in animals have not only a number of important implications for our understanding of the
nervous system, but also for our understanding of the behavior of individuals.

At the level of behavior, the demonstration of a critical period of vulnerability to deprivation or to abnormal experience has been shown. Dobbing (1975) extrapolating from animal experiments and from measurements of the brain weight and the number of neurons in human brains, discusses the issue of vulnerability to deprivation in humans.

The significance of the brain growth spurt for our present discussion is that this transient period of rapid growth seems to be one of particular vulnerability to growth restriction (Dobbing, 1975, p.5).

It follows that in order to obtain a normal development, the individual should not be exposed to adverse environments during these periods. Dobbing has studied in particular a special type of neuron in the cerebellum (the granular neurons). These neurons achieve their adult neuronal numbers before the brain growth spurt begins.

The cerebellar deficit and distortion is a particularly good example of the way in which the vulnerable period hypothesis is found to be justified. All depends on the timing of the growth restriction in relation to developmental events within the growth spurt period. It is also the only example so far discovered of a structural effect having definitely related functional consequences. The cerebellum has an important role in motor coordination and these animals are found to be permanently clumsy. Perhaps it is significant that there are very large numbers of clumsy human children
who are otherwise "normal", even in our society, and this disorder does have a correlation with previous social disadvantage. (Dobbing, 1975, p.8)

It is not known whether similar events in neurons take place during the organization of the neurons that are responsible for higher mental functions, but we can hypothesize that there may not be differences. If this is so, desirable behavior in an individual may be obtained by exposing the individual, during the critical periods of neurogenesis, to the appropriate environment. Development of neurons toward a certain orientation may induce individual responses toward desirable behavior in the same way as in the experiments in which the animals responded to light coming from a certain orientation.

Lorenz (1970) has shown that birds follow any moving object as if it were their mother if it is presented to them during the first day after hatching. In higher animals, in dogs for example, behavioral studies indicate that if they are handled by humans during a critical period of 4 to 8 weeks after birth, they are far more tractable and tame than animals that have been isolated from human contact (Fuller, 1967). The critical period in an animal's development may possibly represent a time during which a significant sharpening of senses or faculties occurs.

In light of such evidence, I think that it is appropriate to speculate that similar events are taking place in the neurons
responsible for higher functions in man: Acquisition and competence in language, for instance; socialization of individuals; intelligence and creativity. As Hubel (1967) said:

Perhaps the most exciting possibility for the future is the extension of this type of work to other systems besides sensory. Experimental psychologists and psychiatrists both emphasize the importance of early experience on subsequent behavior patterns—could it be that deprivation of social contacts or the existence of other abnormal emotional situations early in life may lead to a deterioration or distortion of connections in some yet unexplored parts of the brain? (pp.17-45)

To find a physiological basis for such behavioral problems seems a distant but not impossible goal. But as an educator, I have the following questions: Are we going to stay passive, in light of such overwhelming evidence that probably all the higher functions in man depend to a degree on an interplay with the environment during some critical periods of his development? Do we not have the responsibility to at least eliminate from the environment adverse or deprivating situations? I understand that such tasks are not simply educational tasks; they are, rather, social tasks. However, do we not have to establish desirable policies at least where we can, in day care centers, for example? And is it not our responsibility as educators to make parents aware of the possible impact their behavior will have on the development of mental abilities and the character of their children? Faure (1972) says that educational
policies should take into account nutritional policies if they want to improve the performance of the educational system. With the same logic I say that educational policies should take into account the already stated factors also if they want to improve the performance of the educational system.

In any case, I believe that the first step towards establishing any kind of policy is to emphasize the findings around synaptic learning. Everyone should understand that it does not suffice to possess eyes and brain in order to see. It takes interaction with the light coming from all possible directions in order for an individual to be able to see normally.

Memory at the Cellular and Subcellular Level

Synaptic learning, which presumably takes place during the development of all mechanisms of the brain that are related to sensory systems (Coss, 1978), is only one of the bases on which the future development of higher mental functions depends. Memory is another. The impact of a good function of memory in the development of our higher mental functions is well known. I will try next to present very briefly what we know at present about the cellular basis of memory.

Memory means that we remember previous experiences, activities, emotions, or feelings. We say that these experiences have been inscribed in our memory and this gives us the possibility to recall
them. So, what we call memory corresponds to some functions of the brain through which we can inscribe and recall our previous experiences. Let me first remind the reader that all experiences in the brain are processed as electrical impulses. Based on this notion, it was initially hypothesized that a certain experience would generate an impulse which according to its origin and the interconnections of neurons, would follow a certain pathway and would cause a change in brain cells that marks a memory trace; that is, the establishment of a certain neuronal pathway corresponding to the pattern of the electrical circuits that an experience generates, together with possible changes in RNA and protein within the neurons that participate in this pathway, forms the cellular and subcellular basis of memory. These pathways were termed engrams (Lasley, 1950).

An engram may not be permanently inscribed in the brain. In this case, we speak of short term memory. After repetition of an experience the engram becomes permanently inscribed in the brain: Long term memory. How this inscription is realized we do not really know. One clue about how this may be effected comes from the earlier discussion of synaptic learning. However, this mainly concerns the period of neurogenesis. Keeping in mind that alterations in the neuronal processes may continue during adult life (Spinelli, et al., 1979). I have reached the conclusion that while the impulses will largely follow the pre-established pathways and interconnections that have been created during neurogenesis, they might also create
slight deviations from the previous pathways. Such a thing has not been proven but neither can it be completely rejected. In any case, the experience, carried through the brain as an impulse, follows certain pathways and after repetition, these pathways are "inscribed" in the brain and the experience can be recalled thereafter.

A second clue about how these inscriptions and also about how recalling may be realized comes from other sets of experiments. These experiments have shown that long term memory involves production of RNA in the neurons of the brain. RNA is a genetic material transcribing DNA and it is responsible for the production of protein. The most recent experiments in this area have been done with fish by Shashoua (1976 and 1977). Some fish, in response to training, produced in their brain cells increased amounts of a specific protein which already existed in their cells. In terms of RNA, "specific" means that RNA which was responsible for the production of this protein, had coded a specific message in its molecules. This message, whose markers are the sequence of the nucleotides of the RNA molecule, represents the type of information transmitted to the cells of the brain of the fish while it was being trained - or having an experience. What this message could be we do not know. It may be different each time, changing with different experiences, or it may be the same for different kinds of experiences. It may be that any kind of experience may have as an end result production of the same kind of protein. In this case, the type of information
transferred through the experience to the brain cells cannot be anything more than an indication that another action is taking place in the environment. It is rather difficult to accept that the exact type of the action going on in the environment is printed on the markers of RNA (producing a specific type of RNA each time) because such a thing would presuppose that any kind of experience is capable of causing a specific mutation of the DNA, the primary genetic material from which RNA is derived. This would imply an easy way to cause mutation and it would also require to admit that an enormous number of specific RNA-DNA molecules exist in an experienced individual. What is the truth in this matter we do not know. The different theories about this can be found well reviewed in Mikulas (1974). In any event, the fact remains that, although we do not know exactly what is going on in the brain, RNA and protein are manufactured in excess in response to experiences.

For many years physiologists unsuccessfully searched for the engram. After many experiments Lasley concluded that memories had to be distributed throughout the brain because they could not be localized. Pribram (1971, 1978, 1979), a student of Lasley, has been intrigued for many years by the experimental evidence that specific memories are incredibly resistant to brain damage. Despite the removal of a hunk of brain tissue, or the injuring of several portions of the brain, a particular memory or a whole set of memories were not excised. Based on these findings Pribram challenged
the existence of engram. He hypothesized that remembering may be distributed in some general way in the brain. It may become spread over a sufficient expanse of the brain to render the memory of an experience resistant to brain damage. The formation of RNA-protein molecules following training could not account for these phenomena.

Then he hypothesized that the structure of the brain may be holographic in nature - analogous to the lensless photographic process. So according to Pribram:

The (holographic) theory reads that the brain at one stage of processing performs its analyses in the frequency domain. This is accomplished at the junctions between neurons....This distributed input must then, in some form, perhaps as changes in the conformation of proteins at membrane surfaces, become encoded into distributed memory traces. The protein molecules would serve the neural hologram in the same way as oxidized silver grains serve the photographic hologram. (Pribram, 1978, pp.14-18)

This hypothesis of Pribram is fascinating. It is based on sound experimental basis. It also adds to the previous theories the

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13 Holography is called a method of lensless photography in which the wave field of light scattered by some object is recorded on a plate as an interference pattern. Due to the lack of focusing lens, the plate appears as a meaningless pattern of swirls. When the photographic record - the hologram - is placed in a coherent light beam, like a laser, the original wave pattern is regenerated. A three dimensional image appears.

14 Pribram does not deny "synaptic learning" or RNA and protein production. However, in the framework of his hypothesis there is not a clear cut assigned role of these facts.
element which was missing: A holistic approach to the problem of memory. However, his theory explains only some observations that could not be explained by synaptic learning and RNA and protein increase alone; but it should incorporate more comprehensively "synaptic learning" - which is a fact during neurogenesis. It also needs to provide for a better explanation for the increased RNA-protein findings. The engram theory explains better both these findings but it fails to explain the distribution of memory in the brain. Thus, at this time, I am not inclined to completely reject the engram theory although I see its incompleteness. Therefore, while I discuss Pribram's theory to explain the fact of distribution of memory in the brain, I will keep the term "engram" with the reservations just mentioned.

The stated hypotheses represent only the basic facts and main theories existing at present in the area of memory. Lengthy discussions on long and short term memory and their interplay take place nowadays in conventions concerning "memory" (Re-vision, 1978). An explosion of experimental facts (accompanied by their interpretations) has occurred in recent years (partly reviewed by Coss, 1978). Taking into account the scope of the present dissertation, I cannot expand more on this specific matter. Anyone who is interested in more details is referred to the works of Eccles (1977), Pribram (1971, 1978), Luria (1973), Coss (1978) and Spinelli, et al.(1979).
Information Inscription in the Brain: A Condition For Learning

Let me try to speculate about a possible combination of the things we know. The stimulus (whatever it may be, visual or acoustic experiences of language, for instance) makes a trace which might be called an "engram". I prefer to call it a "marker", generally, or an "impulse pattern" more specifically. In early life this causes the synapses to acquire a certain number and a certain orientation. At the same time it causes a certain message to be inscribed on the RNA of the neurons and/or on molecules of the membrane of the cells, according to Pribram. The brain as a unit, together with neuronal synaptic pathways, RNA-protein and/or membrane protein, can respond to the "pattern of the specific experience" that was transmitted to the neurons. Perhaps the synaptic pathways - number of synapses, orientation, interconnections of pathways - provide the background on which memory can be realized. Having been developed through and because of the interplay of the environment with the brain, the experiences are in a way included in the structure of the brain. After the brain's development, however, the impulse patterns do not continue to include the exact, same original experience through which they were initially formed. They are now modified by new experiences which inscribed as markers later on, reshaped the original shape, acquired during neurogenesis (this will be discussed extensively later on). If this is true, we cannot know which part of the initial experience we recall when remembering,
because the whole complex (the initial experience as it is re-shaped by subsequent experiences) represents the potential for recalling it. Maybe Pribram's changes in the membrane protein represent the material basis of all these functions in the adult brain; maybe a combination of all the factors I mentioned is needed for the inscription in the memory of any information. In any case,

...there are in the brain, and particularly in the cerebral cortex, these immense numbers of patterns ready for replay so that impulse patterns can arise that are approximate copies of those involved in the original experience. (Eccles, 1977, p.186)

Further, we have to remember that although other functions of the brain may be involved in memory printing and recalling, synaptic learning and RNA-protein synthesis are, for certain, involved in memory and learning at this level.

Elements of Linguistics

Linguistics, traditional or empirical, which, over the period of the last 30 years has developed into a discipline almost as "hard" as the natural sciences (Luria, 1974), describe the system of language as having a subsystem of acoustic and articulation analysis and synthesis; this is the foundation of understanding and performing oral and written speech and constitutes what we call the phonology of language ("phonemes" correspond to sounds of letters or
combination of letters, symbols or other parts of the words or, generally, of speech); language also includes a subsystem for the designation of objects, actions, and their relations which constitutes what we call the **lexicon** of a language (mainly words); a subsystem for the designation of the structure of the words which constitutes what we call the **morphology** of a language; a subsystem of **semantics** which enables us not only to designate objects, actions, and relations but to include them in different systems of meanings and correlations; and finally, a subsystem of **syntax** which enables us to relate words which will formulate statements and thoughts.

According to the neurolinguistics, language is an **informational system** for communication which has had its own evolution within human societies. It has been developed socially by the same brain of *homo sapiens* who has remained relatively unchanged during the whole period since man's origin (Rivers, 1901; Leroy, 1927; Boas, 1911; Luria, 1974; Huxley, 1979). Thus, language is a system which is interdependent on man: it can exist independently from man (it has being) and it can change and evolve (it has becoming), but it cannot realize its becoming by itself (it has no acting).

Considering these statements one should not forget what the basic correlations between language and the brain are. Humans are the only species that possess a minor and a major hemisphere with anatomical differences between them (Geschwind, 1972). These differences in the human brain have developed as a result of language.
However, the history of evolution of the two systems - language and the brain - is different. The brain's development depends mainly on biological procedures, and language's development on social procedures. Language is a purely social product and has its own structure and logic.

Therefore, the relationship of the brain to language is indirect though interdependent. Another very important point to remember is the following: The history of the evolution of the brain in relation to language in the level of species (the human race), is different from the development of the individual's brain during a lifetime. Language, in this second case, is processed as any other entity of the environment by the brain of an individual, i.e. as a whole system of signs and symbols found as a ready-made product within a society that has already reached a high level of language development, no matter what is the stage of development of a certain individual's brain.

Language Processing by the Brain: Part I

The processing of language by the brain in terms of its physiological functions does not correspond to processing separately of one or two of the subsystems of the informational system of language - for instance, of the phonemes only - by one or two of the subsystems of the brain - for instance, by memory only. The "system brain" must always be viewed as a whole which is processing another whole (language) at all its organizational levels simultaneously.
Therefore, it should be understood that when I describe language as being processed at the level of memory, the whole of the brain is working, processing the whole language together, phonemes, semantics, morphology, etc., as it is spoken. That means that the brain is processing the interrelations of these parts, also. And not only this; together with language the brain is processing other incoming units of information, while at the same time it is processing all these units of information and their relations at other levels of its organization by analyzing and resynthesizing them.

Analysis is a term corresponding generally to the process of breaking down a whole into parts. Historically the term has been applied in chemistry and in the theoretical sciences. In the theoretical realm, the tool by which one analyzes is one's mind and the means used is observation. The term "analysis" is not descriptive of cases in which the observandum is physically separated into parts. During analysis, in addition to separating the objects into parts, the relationship of the parts to each other and to the whole ought to be carefully observed and described. For the theoretical sciences, then, analysis is a method by which one can mentally separate complex objects, entities, situations, or "states of affairs" of the present and the past, into parts and patterns of relationships.

The brain does exactly the same while analyzing information. It performs analysis obligatorily because of its nature and the nature of the other entities which it processes (see p.85). Each
type of information that it receives corresponds to a physical entity different in nature from its own nature. Thus, it must be broken down into bits of information which, when translated into the brain's marker arrangements can represent the external physical entity using materials of the brain. After the analysis the information is processed by the brain's subsystems and by the whole brain.

The fact that ultimately we understand the information in units that more or less represent reality, but which are different from the parts into which it was broken down initially, shows that the brain performs a resynthesis of the parts into which it has analyzed the incoming information. This also demonstrates that it has saved the pattern of the relationships of these parts.

Synthesis is a term describing the process of putting parts together. The tool by which one does this might be one's mind or some mechanical means. But again in the theoretical realm, we limit ourselves to the mind. There is an aspect in the meaning of "synthesis" which should be emphasized. The term is not descriptive of situations in which things are simply aggregated or put together. Any parts that will be synthesized must be put together in such a relationship as to cause them to be a functioning whole. Only then can it be called "synthesis". That is why "invention" or "creation" or "design" are used as synonyms of "synthesis" in some fields. If one puts together parts which formerly belonged together, and re-establishes among them exactly the same relationships that the parts
previously had, then one is simply performing a synthesis. If one puts together parts that did not belong together, or if one puts together parts in new relationships, in a new pattern, and one succeeds in forming a functioning whole, one is creating a new synthesis. The brain performs analysis and synthesis. Thus, there is the possibility of performing a "simple" synthesis or a "new" "creative" resynthesis. It appears that both these functions may take place in the brain.

Meaning

On these grounds let me elaborate on how the brain can "understand" language. As written or spoken information, language is processed as visual or acoustic information. But we say that words have some "meaning", and with this meaning or because of it, they are "understood" by the brain. How can this be comprehended at the level of brain function?

"A vocal noise, it is assumed, is associated with some notable feature of the environment and with an "idea" or "thought" of this feature. The word, then, "means" this feature in the sense that "its utterance can be caused by the feature in question, and the hearing of it can cause the "idea" of this feature. This is the simplest kind of "meaning" out of which other kinds are developed." (Chomsky, 1971, p.10)\textsuperscript{15}

\textsuperscript{15}In this passage Chomsky quotes B. Russel with whom he agrees.
The brain can be compared to both a parallel and also a serial type of information processing computer. This will be analyzed in more depth in the next chapter. The billions of neurons of the brain process simultaneously a number of units of information. The billions of pathways existing in the brain are interconnected either directly or through the physiological function of the brain as a whole. Therefore, information which is processed at a point in time is associated with many other units of information also being processed in parallel at that same time. Thus, it may potentially be associated with all other processed information. Associated experiences being inscribed in the memory together with all the other information, may provide the basis for the understanding of what can be conceived of as the "meaning" of a word at this level.

Let me, then, review some basic concepts that I want to put together:

1. Words are processed by the brain as are all other informational entities.

2. No information can be processed separately from mass-energy. The result of the information processing is marker formation.
3. The shape of the mass-energy of the final marker depends on the information itself and on the materials that are shaped by the information. The same information is carried by different markers: a picture and a painting show the same smiling face (p.42).

4. Words are processed by the brain simultaneously with other incoming information. This constitutes the basis of the associations of the markers of the words with other markers of other information.

5. This, together with other factors, like the situation of the brain while inscribing information, etc., can result in different markers for the same word, depending on how differentiated the material was on which the words have been inscribed. By "differentiated" I mean material reshaped by previous experiences forming markers.

An analysis of this last proposition is needed to make clear exactly what I mean by it. The materials on which words will be inscribed are the chemical substances of the cells and the cells themselves - the neurons. Their consistency and initial pathways depend
on inheritance, but their form at a certain point in time (shape, connections, etc.) depends also on the processes that continuously go on in the brain. One must not forget that structure is a moment of a process. Consequently, when an information passes, especially in the early years, it leaves behind it a trace. The traces that are formed in this way are:

1. Pathways that the impulses follow (synaptic learning) and
2. Probable "memory protein" increase.

With them and perhaps with other substances, information forms a marker. If a second unit of information passes, it does not have to shape the same neurons into neuronal pathways, as in the beginning. It has to shape the neurons in their new situation as they were shaped by the first information. Now, let us suppose that the same information passes twice through the brain. The marker that will be produced will most probably be different. Let us say that the first time it was like a photograph and the second something like a painting. The following analysis of the above process will make it more clear: A marker may carry more than one bit of information. Let us suppose that the sum total of information associated with a certain marker is n. We know that a man (brain) can see only what he has focused his attention on: Only one information at a time. The rest of the associated information which is not seen by the brain but exists on the marker is n-1 information. Let us now examine two different brains. In order to differentiate them in
terms of information we say that one has $a_n$ information on his markers, and the other $b_n$ information ($a$ and $b$ are indices which represent the difference, i.e. the quality of the markers).

According to what I have already said, this quality will be the result of:

1. The **material** on which the information was initially inscribed upon (inheritance)

2. The **kind** of information already inscribed.

3. The **number** of the units of information already inscribed on the marker and which have already reshaped the marker accordingly.

Now, the same information is going to be inscribed on $a_n$ brain and on $b_n$ brain. The $a_n$ brain will become $a_{n+1}$ and the $b_n$ marker will become $b_{n+1}$. But, when the man sees the new information he can see only one information at a time because that is the physiology of his brain. The rest of the information which is not seen by the brain will be $(a_{n+1})-1= a_n$ or $(b_{n+1})-1= b_n$. But $a_n$ and $b_n$ is how I described their brain in the first place. Therefore, viewed as associations, $a_n$ and $b_n$ are the factors which attribute meaning to the new information. On the other hand, they represent
the whole previous experience that an individual had plus his inheritance. Briefly they represent the whole brain at a certain point in time. So, we see that in the case of the brain it happens exactly like what happens to any other case during marker formation (p.40-43): The bit of information which is inscribed on two different materials may be the same but the result of the inscription of it on different materials will produce different markers. Then, this is the factor which makes the difference in the meaning of the information for different brains. That is, the material on which the information is inscribed is different although it may appear the same when examined by simple chemical or anatomophysiological approaches. The difference may be in the RNA (Mikulas, 1974) or in the shape of the neurons (Coss, 1978). The important thing in this case is to understand how this difference is built up:

The quality of \( a_n \) and \( b_n \) is determined, by and large, by previous experiences (quantity and quality of them) and by inheritance. A further analysis of these factors is necessary in order to attribute in each one of them their true impact. To reach a better evaluation of them it would probably be desirable to quantify them. But, as we know, this is not possible. Nevertheless,

...we know quite certainly that the non-physical post-natal environment of the growing child has an enormous part to play in shaping his personality and intellect. Human emotional and intellectual development is astonishingly plastic. Tremendous improvement even in the severely mentally handicapped can be
achieved through non-physical means, by increasing the child's experience of external stimulus. Presumably, similar alterations of achievement in normal children accompany comparable alterations of this environmental non-physical input. Indeed, the demonstrable effects of changes in the environment on the psychological development of the normal child are so great that there seems little need to attach much importance to the comparatively insignificant effects of genetic inheritance. (Dobbing, 1975, p.11)

Even if the case were not as Dobbings describes it, from the point of view of education, the impact of experience in attributing a certain quality to the brain is more important than any possible impact of inheritance; because we can influence the first while the second is something beyond our reach, at least for the present.

This discussion helped in establishing the crucial importance of associations to "meaning". Since while learning we must always attribute a meaning to what we learn, I believe that this discussion also helped in establishing the importance of associations or the amount of experience already undergone by the brain for further learning. Indeed, experimentally demonstrated facts in this area indicate that the meaning of the information that our brain processes depends on associations (Rubinstein, 1973; Mikulas, 1974). And Novak (1977) shows how important it is for "meaningful learning" to associate new concepts with those already learned. However, interpretation of associations through "markers" is my own interpretation, with all the shortcomings it may contain. The reader may understand associations and previous experiences in a different way.
I, personally, understand experience as reshaping and, thus, changing our brain with time; and this not only theoretically but in a concrete way, i.e. anatomically and/or biochemically.

At this point let us examine "meaning" from the point of view of associations of markers. As I have discussed in pp.40-43 a part of what we call "meaning" is attributed to it by the observandum itself and a part by the observer. An information which is inscribed on any marker (for instance, the smile in the painting of Mona Lisa) is associated with all the other details that exist in the same object. All these other details are of course potential bits of information and they constitute the n-1 information which exists on a marker-object; these cannot be appreciated by an observer at the time at which he is observing a specific bit of information. These associations give to the information observed part of its meaning (the meaning of the Mona Lisa painting would not have been the same if she was represented as crying instead of smiling). On the other hand, as I have just discussed, the meaning of the information observed - concerning the observer - is attributed to it by the associations that the observer will form in his brain. These associations will be generated in his brain at the time at which the observer will perform his observation, i.e. at the time at which he will form his marker, and will depend on his previous experience. From the point of view of associations then, the meaning is generated at the time at which two sets of associations (observandum -
observer) will come into interplay. These two sets of associations will be interrelated - at the time of the generation of meaning - by the same information which on the one hand is already inscribed on the one set (painting) and on the other hand is in the process of being inscribed on the other set (brain).

This understanding of meaning (being the result of the interplay of two sets of associations) implies an image of the brain functioning which requires two different types of information processing. One serial and one parallel. During serial processing one information is processed after another while during parallel processing one information is processed simultaneously with another. As it will be discussed more extensively in the next chapter it appears that the brain can work both ways (von Neuman, 1958).

Preliminarily I would say that in what we call "consciousness" the function of the brain appears to be serial in which case the brain can relate only to one bit of information at a time. Converesely, in what we call "subconsciousness" the function of the brain appears to be parallel, hence the ability for perceiving things as wholes, and the ability to absorb and process all the rest of the n-1 associations of one bit of information. This gives to this formidable organ the possibility to have an interplay of the whole of the two different sets of associations (the observandum and the observing brain) and creates the basis of what we call "meaning".
Now let me examine more closely the variation in "meaning" that words may have. If associations give meaning to words it is important to realize in what tremendous variations in "meaning" the functions of the brain can result. Since processing of the words generates a pattern of impulses, which is the marker of the word, consider what a variety of meanings can be produced for the same word depending on:

1. The different associations of the word itself in different environments (present during the time one individual is inscribing this word on his brain) and,

2. On the different associations that will be formed for the same word in two different brains simply because they differ in previous experiences.

However, consider also,

3. What tremendous potential for refinement of the markers of the words can be achieved with the continuous "reshaping" of them with time. This is the basis on which, finally, by a continuous communication among us, we reach the point at
which most of us attribute the same or very similar "meaning" to the same words. The same word may be associated with different experiences the next time that it is processed but it is also evaluated against its own associations and the previous associations that the individual made for it. As long as the same word is attributed by the social environment of the developing individual to the same or similar circumstances, objects, situations, etc., the individual is reshaping his markers accordingly and finally reaches a point of mutual understanding with other people.

And yet, this is not all. This is only the raw material on which the cognitive process is built. To fully appreciate the extent of the complexity involved in the interaction of language with the brain, we need more knowledge; and we need to obtain this knowledge because there, in the brain, is where learning and "understanding" take place.

I will use the example of how an individual can learn and understand language in order to demonstrate how an individual uses his learning abilities or how he can develop them. Therefore, only after we become aware not only of the inbuilt variations of word markers or their meanings, but also of the processes that speech is
undergoing in the brain (due to the processing of language simultaneously in all of the brain's levels, lower and higher, local and general), only then will we be able to evaluate how closely a particular theory of learning may represent the truth, or what aspects of such a theory we should take into account in generating propositions about education based on the learning abilities of the brain.

Our "understanding" depends on the resynthesis that the brain performs. This resynthesis depends partly on the incoming information and partly on the brain. These are the limiting factors that contribute to the determination of the different probabilities existing for a certain resynthesis. The resynthesis that the brain obtains while "understanding" a newly processed information may be performed according to the pattern that the analysandum has provided or according to a slightly new pattern. However, since the information will contribute to the formation of a marker, it becomes immediately evident that the resynthesis can hardly be at any time a simple synthesis (except perhaps during the first inscription of information after birth). It will mostly be a resynthesis which will depend as much on the information as on the previous experiences of the brain. Because of these qualities of the brain we may consider the possibility that all resyntheses in the brain are "new" or "creative" resyntheses. Any small deviation from the original pattern results in a new synthesis which is slightly or greatly
different from the original. The markers of the previous patterns determine, in this sense, our understanding of the new patterns. This is the physiological basis of creative resynthesis.

With the brain's interchangeable function from digital to analog, with all the connections and interconnections of the neuronal circuits, the subsystems, and systems of the brain (which works as a whole while processing any kind of information), it may be surprising that most of us understand similar things in a similar way. However, I have shown how an "equalization" in meanings can be achieved through reshaping of the markers after reference to similar situations, experiences, etc. By extrapolating from the previous discussion to explain our understanding of the surrounding world we may say that we understand the world to the extent that previous experiences have shaped our brain. By extrapolating from this to explain concept formation, we may say that new concepts are understood better to the extent that they are associated to previous experiences. By extrapolating from this to explain creativity we may say that the nature and function of our brain presents us with a set of probabilities for resynthesis of information which depend, on the one hand, on the processor system itself (the brain) and, on the other, on the previous experiences already processed by the brain (which largely determine its present condition).
"Let us suppose", as Locke wrote, "the mind to be, as we say, white paper, void of all characters, without any ideas; how comes it to be furnished?..." (Locke, 1690, Essay II, 1, 2). If we substitute "ideas" with "words" and "mind" with "brain" and we perceive the paper to have some matrices due to the genetic code (Chomsky, 1975(a), we are about in the same situation as Locke. It is obvious from what we know about the physiological growth of the synapses that during neurogenesis and perhaps later on also, under the influence of language, synapses corresponding to language processing will develop in the respective areas of the brain's cortex to a certain number and direction to which they would not have developed if language were not there.

According to the "generative" theory of Chomsky, the ability for language in humans is transmitted together with other inherited characteristics. This theory explains several phenomena such as the use and/or understanding of sentences which were never before used by an individual and the tremendously quick acquisition of language by young children.

My position is that inheritance accounts only for the material of which the brain is formed. That is, we have inherited a brain with specific centers for language processing in which thousands of neurons are predisposed to accomplish the unique function of language. Nevertheless, this fact acts only as a facilitator of
language acquisition and it cannot realize its potential unless it comes into interaction with external environmental stimuli. I suppose that in respect to the development of the neurons in the speech areas of the brain, the same principles apply as in the development of the neurons in the visual cortex. The example of the children who have been raised by animals and who could not speak (Miller, 1978) supports such an assumption. Another example refers to children who in the past were characterized as deaf and mute. Some of them did not have any motor defects of the larynx and mouth muscles; but muteness was the result of the primary defect of deafness (whether this was localized in the ears or in the brain is not mentioned). Nowadays these children can be taught to speak. This may be explained by the fact that the language areas are connected not only to the acoustic analyzer but to the visual cortex also (Geschwind, 1972). Teaching a language to these children is therefore mediated by visual stimuli. However, we do not know the development and/or orientation of the neurons forming the speech areas in individuals who use both acoustic and visual stimuli in comparison to deaf individuals who can or cannot speak. Extrapolating from the animal experiments, I assume that there could be a difference in the development of these neurons. I suppose that everything else that takes place in the area of the visual cortex in the blind kitten takes place, also, in the area of the acoustic cortex (or acoustic analyzer according to the nomenclature of
systems) in deaf from birth individuals. As far as I know this as yet has not been investigated. Because the phenomenon of language is much more complex than the simple perception of visual or acoustic stimuli, no one can speculate at the present time what the condition of the neurons in such instances will be. At any rate, an initial proliferation of neurons and the establishment of pathways in the areas of speech in the brain in a way similar to the one that allows us to see (i.e. after interaction with acoustic and/or visual stimuli appropriate to facilitate development of neurons in these areas of the brain) may provide us with an anatomo-physiological basis for language processing by the brain. This by no means can provide a complete explanation of the physiological mechanisms underlying language "acquisition" and language "understanding" and "performance" because these faculties require the involvement of much more complex phenomena than synaptic memory, etc. These phenomena belong to the sphere of the higher mental processes whose anatomo-physiological basis is not known. For this reason Chomsky proposes:

It seems to me that the most hopeful approach today is to describe the phenomena of language and of mental activity as accurately as possible, to try to develop an abstract theoretical apparatus that will as far as possible account for these phenomena and reveal the principles of their organization and functioning, without attempting, for the present, to relate the postulated mental structures and processes to any physiological mechanisms or to interpret mental function in terms of "physical causes". (Chomsky, 1968, p.12)
However, for the elaboration of propositions for effective education based on learning as realized by the brain, we need to know as much as possible about the physiological interrelations of the mental processes with brain functioning. For this reason, I follow the propositions of Luria who speculated on some the physiological functions of the brain while processing language based on observations of patients with brain lesions.

Language is not only "understood" but also performed by an individual. And it is processed in many more areas of the brain than in the acoustic analyzer. We have come to know about these areas mainly from patients who had suffered injuries in certain areas of their brain and had as a result specific impairments in their understanding or their ability to perform language. Later on I will describe some characteristic cases. For the moment I need to emphasize that kinesthetic, motor, visual, and other higher coordinating centers or cortical areas of the brain are involved in language processing.

It is easily understood that the expression of language, (i.e. an individual who speaks) presupposes areas of the brain that not only "sense" and "understand" language, but can also "produce some action". Indeed, a pattern corresponding to the movements that the mouth and the throat muscles must perform in order to pronounce words is formulated in some of the centers of the brain. This pattern is called the "motor image" of the word and it depends on
the analysis of sounds and visual pictures of the words that the brain has already performed in its acoustic analyzer (the visual cortex is connected with the acoustic). The motor image dictates the movement that the muscles of the mouth and the throat should carry out in order for the appropriate sounds and words to be produced. Different pathways in the brain transfer the "motor image" of the language to motor centers whose coordination is being realized by higher centers, also. Finally, the order for the muscles to move is transmitted through nerves to muscles that will move and express language in one of its forms (oral or written). We see then that for someone to process language to the point that he can speak, i.e. to the point that he has learned it, many more brain processes are activated than the ones already described. To describe the brain functions that participate in learning a language, one has practically to describe all the functions of the brain.

This is not only for learning language, but for all mental activities related to learning. Mental activities taking place during learning require the coordination of all the functional units of the brain, while each one of them is playing its highly specific role in the organization of the activity. Initial data inserted in the brain - for instance, words or phrases - are processed locally and then reprocessed, and even re-reprocessed in all levels of organization. At this time the status of excitation of the brain must be in its normal state, otherwise an equalization of excitation
may cause selectivity to be lost, as when dreaming or in situations of deep exhaustion or in some pathological situations, i.e. patients with lesions (Luria, 1974). In such cases, some irrelevant observation may pop up in the middle of a logical process, representing the recalling of an irrelevant experience, because all excitations - not only the strong ones - have the same probability of being picked up by the brain. Conversely, other pathological situations will bring about the loss of plasticity. These patients say some words and then stop because they cannot switch from the existing excitatory pattern and make the transition to the next (Luria, 1974). From this we see that in order to learn at least a language, the faculties of the brain that contribute to the establishment of the "rule of force" and of "plasticity" should be intact and well-functioning.

To more deeply understand these brain functions, let us examine them from the beginning. In order to process language, the brain has to:

1. Perform an analysis of the codes of language, and translate them into its own markers. This, indeed, the brain does by the coordinated work of its functional units under the auspices of its physiological mechanisms.
2. Obtain a resynthesis of these. This the brain does by the same means. Analysis and synthesis take place almost simultaneously in the brain and they are practically inseparable.

Analysis - Synthesis of Language

According to the classical approach to aphasias, the idea that isolated parts of the speech area in the left hemisphere are "centers" for complicated speech functions was widely accepted and has dominated classical neurology for about a century. Nevertheless, some controversies existed as, for instance, patients characterized as having "motor aphasia" were not found, at autopsy, to have lesions of the Brocca zone as they should (Luria, 1972). For this reason, aphasias have been reconsidered in the framework of neuropsychology (Luria, 1970, 1974). This approach takes into account that, while specific areas of the brain may process specific stimuli (acoustic or visual) which contribute to speech, the function of speech is performed by many areas of the brain acting simultaneously and in coordination with each other. The classical approach classified aphasias as sensory, motor, conduction, transcortical, etc. In neuropsychology, one began to deal with defect of phonemes or articulemes, "sequential" or "spatial" schemes and "programs" underlying speech process.
In this sense, the previously-classified as "motor", "sensory" etc. aphasias can be explained not only by destruction of a specific area of the brain but by other mechanisms as well.

"A neuropsychological approach was an important step towards a scientific analysis of aphasia and superceded the naive idea of the immediate localization of complex speech processes in circumscribed cortical areas." (Luria, 1972, p.37)

However, modern knowledge of neuromorphology strongly contradicts the idea that the brain is a homogeneous, undifferentiated mass of tissue parts (Luria, 1974).

"Psychologists of our time reject the idea that speech can be understood as an immediate "faculty". The acquisition of language and linguistic performances are in no way indivisible "functions" but have to be understood also as complex "functional systems", that they may not be "localized" in separate zones, but, rather, distributed in widespread cortical constellations or assemblies." (Luria, 1974, p.2-3)

According to this approach, the brain is organized as a system with subsystems, each one of them accomplishing its specific function, but all of them working within the framework of the whole system.

The "acoustic analyzer", which anatomically is located in the temporal lobe of the major hemisphere, has the task of providing an

analysis of sounds. That this is so has been found from patients with lesions of these areas of the cortex who suffer a breakdown in phonematic hearing with the resulting disturbances in all processes that need phonematic analysis: understanding of words, naming, writing. The processes that are not dependent upon the phonematic hearing remain mostly undisturbed: spatial analysis, written computation, relational thinking (Luria, 1972).

"Articulemes", the precise oral movements required to produce articulated speech sounds, are organized on the basis of the "phonemes", i.e. the phonematic components of speech. A system to provide a plastic transition from the one articuleme to the other is also required. Connections between three areas of the cortex: temporal—for the acoustic analysis—(the acoustic analyzer), parietal—for the kinesthetic regulation of the articulemes—, and premotor zones—for the regulation of the oral movements according to these patterns—are indispensable in order to produce the series of "kinetic melodies" which are required for articulated speech. Lesions in any one of these zones or in their interconnections result in aphasias which were termed previously as "motor aphasias". Their types are different according to where the lesion is located and that is how they are diagnosed and named. For instance, if a lesion is localized in the acoustic analyzer, this will result in a motor aphasia secondary to the sensory aphasia, i.e. lack of recognition of phonemes will produce secondary disturbances in the expression
of speech.

Morphological, Semantic, and Spatio-Temporal Analysis-Synthesis

Another type of analysis-synthesis that takes place in the brain is named according to the form or structure of speech fragments. This is called morphological analysis.

Analysis and resynthesis of the relations between speech units - or speech fragments - which have some meaning, is performed in the temporo-parieto-occipital areas of the brain (posterior parts of the hemispheres). Semantic units are the words themselves or complexes of words as, for instance, "the sister's mother" or "the mother's sister", or even more complex speech constructions, the meanings of which depend on their sequential or spatial relations (the one before the other in time-space). The areas of the brain responsible for this type of analysis-synthesis constitute the apparatus of the brain for spatial analysis. The analysis is performed by the brain in terms of the relations of the semantic units with each other. Obviously this relation depends on the grammar and the logic a language has. Simultaneously with the analysis of speech in its component parts, these zones of the brain provide a "quasi-spatial" synthesis of separate components.

Finally, the language is analyzed in terms of its syntax, also.

All these functions are realized almost simultaneously. At the same time, the components into which language has been analyzed and
resynthesized, are put, by the brain, into matrices from which a selection, based on the rule of force, is made according to the pattern of the impulses that are circulating in the brain at the time one hears or reads speech or when one is speaking himself.

**Understanding Language Processing**

One may understand language processing only in terms of how the brain manages to make a combination of phonemes, articulemes, etc., that result in speech; or how it is that this speech is meaningful. Nowadays it is widely accepted that the first proposition is rather meaningless. However, trying to understand speech using the second proposition, one cannot stay strictly with only linguistics and brain physiology because the brain learns through interaction with the environment. These interactions are not examined by physiology but by psychology. So we see once more that the separation that we make between physiology and psychology is a technical one and that, in reality, such a separation can not be made.

Furthermore, all the physiological and psychological functions that take place during learning are not known. Therefore, a "theory of learning" has to be generated to interconnect, by speculation, into one unified process, the process of learning. Such a theory may belong to psychology but it will originate, I believe, in physiology. Furthermore, in the case of language, it will have to take into account anthropological and ethnological studies, also.
(Malinowsky, *In* Korzybski, 1933).\(^{17}\)

So, in this specific case, learning of a language should be examined at the broad level at which one lives and acts, and which is not only what one can observe at the present time; but it is also the result of an evolution which should be taken into account in order to prove an understanding of some situations. Nevertheless, for studying purposes, the level at which an individual lives and acts and the level of his brain's physiology may be examined separately while keeping in mind that they are interconnected. In fact, the level at which an individual exists may be considered to be a higher level in the hierarchy of systems than the level at which his brain works - and, of course, these levels are interrelated. There is no need of hard proof to accept such relations. No individual can exist without a nervous system and a brain; and no brain can exist outside of an individual. Nevertheless, in this chapter I will try to keep as close as possible to the brain's physiology, while in the next chapter some of the same processes will be examined in their relation with the higher level of the individual.

As it has probably become obvious from my discussion of the analysis and synthesis of language, one cannot describe only one main function of the brain which is related to learning, because

\(^{17}\)The authors just mentioned admit that the central nervous system is the system which processes language.
such a function simply does not exist. As I have demonstrated, during the process of learning a language a whole host of subsystems are working simultaneously: sensory, kinesthetic, motor and coordinating systems.

I appears that "understanding" is closely related to this cooperation. In the next few paragraphs I will try to demonstrate the interrelations of the "impulse pattern" that is the result of an experience processed by the brain with "plasticity", "selectivity", and "threshold", which are all physiological properties of the brain. Language will be used as a vehicle for this demonstration. What I will describe holds not only for language, but also for all "entities" which are learned.

At this point I would like to insert a note of reservation. In spite of the many animal experiments and the many observations of humans in the field of cognition (and how cognition is realized at the level of brain function), the explanations existing about it are still speculative. They are hypotheses. Personally, I do not want to tie myself with any specific theory, but in this case, there is no alternative but to adopt a theory, especially a theory of learning. For this reason, while presenting basic concepts that have been more or less ascertained, I want to warn the reader that other explanations may fit the facts that I will present. At the present there is no consensus with regard to concepts such as thought, consciousness, etc. Although I will not discuss all these concepts
in this chapter, what follows in the next paragraphs constitutes the basis on which I will develop these concepts in the following chapter.

Differences in state of excitation of the brain at the time when "understanding" of a concept or an entity is realized, or when performance of speech or another act is realized, may account for differences in the "understanding" or the "performance".

Due to the way they are initially inscribed in the brain, and the way they are processed and analyzed, words should be understood as multidimensional matrices of phonetic and semantic features. Every word, then, evokes a complex of associations that are partly phonetic ("mouse", "house", "cat", "hat"), partly morphological ("black-bird", "blue-tit"), and partly semantic ("mousè"-"cat"-"maze"; "dog"-"house"-"animal"). All these form dynamic mosaics of excitation. According to plasticity, change, when needed, happens with great rapidity and a shift from one matrix of excitation to another is readily achieved. Furthermore, all related but unwanted words are inhibited from reaching threshold. Under normal conditions of cortical excitation, the organism is absolutely able to focus on the targets of the matrices indicated by the pattern of impulses that hearing or reading of speech stimulates. "The rule of force" endows him with this high selectivity. The same is true when the organism freely attends to targets by recalling a pattern of impulses. On this basis, "acquisition", "understanding", and "performance" of a
language can be better understood than previously while providing us with an insight into the functions that participate in "meaningful learning" in general.

The Basis of Neurolinguistics

The previously-stated views on brain function and language processing relate to each other thus providing a basis for the physiological basis of language processing and constituting the foundation of the discipline which, according to propositions of Pribram and Luria, is called neuropsychology and neurolinguistics. The development of today's theories in this area followed experimental verifications of some of the hypotheses of Vygotsky (1934), initiator of this line of thinking. But they are mainly based on experience with patients with brain lesions or injuries.

Lesions in areas connected with the acoustic analyzer result in a spectrum of speech disturbances because patients fail to understand or name words. Lesions in other areas may result only in loss of understanding of the spatial relations of words, etc. In some lesions in the area of the acoustic analyzer, the speech is rapid, rhythmic and grammatically and articulatorily correct, but it is meaningless. An example that Geschwind (1972) refers to is of a patient with a lesion in the area of Wernicke's center: "Before I was in here, I was over in the other one. My sister had the department in the other one" (Geschwind, 1972, p.78). Failing to find the correct words, the patient uses empty words like "the here" or "the
other", etc. He also substitutes "apartment" with "department". In other instances patients use words from nearby "matrices" instead of the appropriate word. For example, the word "fork" instead of "knife" or "kench" for "wrench". A patient of Luria trying to find the word "preacher" replaced it initially with "feature" (phonetic similarity), then with "teacher" (both phonetic and semantic similarity), and, finally, by the words "school", "pupil", "blackboard", etc., which all rise in the frames of the "matrices of contextual associations" (Luria, 1972, p.38).

Other patients suffer severe loss of understanding of articulated speech, even though hearing of nonverbal sounds and music are fully normal.

If the lesion is located between the acoustic analyzer and the motor zone, the patients understand spoken language, can express their own ideas fluently, but they cannot repeat spoken language.

Comprehension of written language requires connections from the visual regions to the speech regions. But not only that; areas of the cortex in the secondary zones of the left temporal lobe in the acoustic region convert a visual stimulus into the appropriate auditory form. People with lesions in this region cannot distinguish, for instance, "b" from "p" and they may write "pull" instead of "bull" or "tome" instead of "dome" (Luria, 1970). However, Chinese patients with severe injury of the same regions "have no such difficulty because their writing is based on ideographs instead of words
that call for the coding of phonemes" (Luria, 1970, p.71). As a result, Chinese soldiers with wounds in the acoustic region of the major hemisphere have oral language disturbance but not written language disturbances.

All these examples demonstrate that while the brain is working at analyzing speech in its subsystems, at the same time it is working as a whole under the auspices of the rule of force, plasticity, etc., and that for a normal understanding of speech all functions are important. Substitution of phonemes (kench-wrench) or words (teacher-preacher) by the use of entities from nearby matrices, show exactly that for the understanding of language all the functions of the brain I have described are indispensable and not only the inscription of the experience. Furthermore, an interaction of the environment with the brain results in the modification of the processes of the brain in such a way that with the same functional units the brain can process the realities of the environment in the way that they are presenting themselves to it. In this respect the example of the Chinese soldiers (who understand written language while they have impairment in understanding spoken language) versus patients speaking languages based on a written alphabet (who have impairment in both spoken and written language) is very striking. Although in both cases the brain injuries are in the same areas and although in both cases we are speaking about language, because there is no interrelation of the coding of phonemes with written letters
in the Chinese language, the brain does not interrelate them, while in the other language it does interrelate them.

Furthermore, experiments of Luria and his co-workers have shown that the motor speech areas of the brain are also involved in the process of learning how to write because they are connected with the system. In early stages of learning how to write, children usually are busy mouthing the words. Luria and his co-workers instructed children to "hold their mouths open or to immobilize their tongues with their teeth while they wrote. In these circumstances, unable to articulate the words, the children made six times as many spelling mistakes....." (Luria, 1970, p.71).

This example shows that we cannot disassociate the functions of the brain that are responsible for action from the process of learning despite the fact that these last functions concerning purposeful movements appear, in the first place, remote from learning.

Although learning in the level of the brain cannot begin except by an information that has been processed by the brain and has been inscribed in memory, this is not the only step that takes place while learning. Learning is modified by subsequent behavior and behavior is modified by learning. In terms of brain function, this means that probably many other functions of the brain are involved between the step of the inscription of information and the step of making a decision that will modify previous behavior on the basis of what we have learned, processes which in return will modify our
initial learning.

The exact functions and areas of the human brain that participate in learning are largely unknown. In the process of learning a language we have seen several steps that were taking place between insertion of "an information" into the acoustic analyzer and the utterance of the speech by the movement of the appropriate muscles. It became possible to identify these steps largely because of the existence of patients with injuries in specific areas of the brain, who, because of that, acquired impairment of specific parts of the language or started performing language in specific unusual ways.

The association of learning with the brain's function has been studied in humans not only in language but in other learned behaviors, also. However, the conclusions of these studies are not able to bring about "proofs" for such associations at the level of the brain's physiology, because the injuries of the human brain in the performance of all learned behaviors perhaps involve other functions in addition to the ones concerned with learning and, thus, they are rather confusing.

Nevertheless, there are many studies performed on animals. Although extrapolation of animal experiments to explain human behavior has to be done with extreme caution, as I mentioned earlier, in the level of the neuronal organization of the brain there is a similarity among all mammalian brains; and such extrapolations have been made by many scientists (Dobbing, 1975). Using animal studies
and whatever findings on humans could be explained and/or satisfactorily identified, many scientists have formulated theories of learning. I will have to describe a theory of learning in spite of my preference not to extend into the realm of theories but rather to restrict my attention to the discussion of facts in the present study. The reason for this is that there are many steps of brain function, the relation of which with learning remains unknown. Therefore, if I did not utilize some type of theory, I would not be able to effectively use the facts that are known and to relate them to learning. My understanding of the process of learning will be presented in the third chapter. I can view learning only as an interaction of the environment (society) and the individual. Therefore, I do not want to separate the physiology from the psychology of learning. However, I will present later in this chapter the theory of learning of Mandler (1954) which will give us an example of a type of evolutionary theory that I also want to follow in my understanding of the learning mechanisms.

Theories of Learning

The brain, during its normal function, accomplishes several tasks among which is learning. One hypothesis may be that only some of the subsystems of the brain and/or only some of the functional subunits of it carry out such functions that by themselves could accomplish a certain task, such as learning. In this case, one of
our tasks should be to identify which of the functions that the brain carries out while working are immediately involved with learning, which are perhaps indirectly involved in learning, and which may not at all be involved in the learning process. Such a task would be very difficult to accomplish (even if it were the case that the functions of the brain can be separated from each other). This is so because, in order to test learning by itself in a living organism one can do so only judging from the results of learning, i.e. mainly behavior. If one admits that behavior does not constitute part of the learning process but is is only the result of it, it follows that one is forced to work always with assumptions. For instance, one takes an animal and teaches it "A". As a response, he gets behavior "a". Then he teaches it "B" and, as a result, he gets behavior "b". The assumption is that because "A" changed to "B", "a" changed to "b" also. But our task was to find what functions of the brain correspond to the learning of "A" or "B" and what functions correspond to behaviors "a" and "b". At what point did the learning process per se stop, and at what point did the process of decision making, or the process of putting to work the movements that constitute the changed behavior start?

We know, for instance, that there are sensory, kinesthetic, and motor centers in the brain. Their main function is to sense, to form a motor image according to patterns of sensation and to command or coordinate movements respectively. Is it, then, correct to say
that in the process of learning only sensory centers participate and to imply that beyond that point all the other functions which take place in the brain belong to the process of decision-making? Or to say that, in the process of learning, only sensory and kinesthetic centers participate but not motor centers?

It seems to me that any attempt to identify brain functions that will constitute "closed compartments" corresponding solely to the learning process is condemned to failure. We have seen that the brain works as a whole. There is not a single moment during the function of the normal brain in which all parts of the brain do not find themselves under the influence of a certain electric potential which, as we know, is the result of the firing of all the brain cells, from all its parts. "Threshold", "rule of force" and "plasticity" which constitute characteristics of its function, are the resultants of the function of the whole brain and not of one or two of its parts. Under the influence of extreme emotion a student cannot learn. Which part of his brain should be accused? Did the sensory areas fail, or the kinesthetic, that he cannot now learn? Or is this due to failure of the higher centers coordinating these functions? Or, if we say that he did not learn because he failed to concentrate his "attention", with which part or function of the brain should we identify the relation of "attention" and emotions? And if we, supposedly, find such a place, how does it affect the other functions of the brain, which we know take place during information processing, and which
should take place once the appropriate stimuli for learning existed in his environment?

I think that one should not forget that the brain functions as a whole, while at the same time its parts may be performing specific functions. In this sense, all of the brain's functions can be better understood in the framework of systems theory. The function of every part of a subsystem of a system influences the function of the whole, while the function of the whole influences the function of the subsystems. No matter how many subsystems of the brain are processing a specific learning process, if the whole malfunctions the process will be defective. On the other hand, if the subsystem which is carrying out a part of a learning process is malfunctioning, despite the fact that the rest of the brain may be in perfect shape, the learning process will be defective and the behavior of the whole individual will be affected.

Examples of both situations exist: In the first case, I described an emotionally disturbed individual. In the second case, the examples of the blind kittens or of the deaf from birth person who cannot speak are appropriate. Not only specific functions connected with malfunction of the brain's subsystem are impaired (vision-visual cortex, speech-probable defective acoustic cortex and perhaps acoustic analyzer, also), but these individuals will not behave as normal individuals. The blind cat cannot have the same behavior as a seeing cat, nor can a deaf person function like a hearing individual.
It is important to emphasize that the parts of the brain which are responsible for motion (the participation of which leads to action) are not exempted from this wholeness during the learning process despite the fact that they may seem remote from the learning process. If one accepts the fact that the brain works as a system and as a whole, they must be included, too. Such an acceptance provides a sound basis for the explanation of the experiments of Luria in which he prevented the children from "mouthing" the words while learning spelling. It appears that learning is promoted when the brain and the whole individual are allowed to participate in the learning process. This same explanation may apply to the observation that when we "act" while learning, we learn it better. This is close to the principle of Dewey which is "learning by doing". It is possible that this is due to "modification" of learning subsequently to acting, but the net result is that learning is affected through action - action that is either previous or subsequent to learning.

In conclusion we should not adopt a theory of learning that will not accept the interrelation of all the brain functions.

Let me, now, review very briefly the main tendencies according to which theories of learning have been formulated. There are two main schools of thought on this matter, the "associationists" and the "structuralists".

The basis of any behavior is the reflex. Learning leads to change in behavior, thus, the basis of any learning is also the
reflex. Through repetition of a stimulus a neuronal pathway is established which connects sensory fibers with motor fibers in such a way that a stimulus-response bond is established. This is the basis for a reflex. Accordingly, certain stimulus evokes a certain response. The neuronal pathways that underlie the presence of a reflex may be simple, connecting almost directly the sensory with the motor fibers or more complex, using many neuronal interconnections in between sensing and responding. The existence of simple or complex reflexes is not disputed by anyone. Also, the fact that we can provoke unconditioned or conditioned reflexes is established. Finally, that the establishment of such reflexes represents a form of learning is not disputed. The discussion begins from the point at which we try to explain the conditioned reflexes and with this explanation to build a theory of learning.

The associationist view holds that the establishment of a stimulus-response bond presupposes that the organism has an actual experience (stimulus) to which it responds. In many cases this has been demonstrated. Nevertheless, rats can learn an avoidance response by being moved in a transparent cage so that they can see the route to follow to avoid a punishment, "even without running it themselves". In this case, learning occurs without the repeated transmission of signals over the neuronal channels, which these theories assume to be necessary to establish the requisite synaptic connections.
After a rat has learned to run a maze it will use quite different motor components than the ones used during the learning trials, even crawling or rolling to the goal if for any reason it becomes incapable of running (Watson. In Miller, 1978, p.411)

Such behaviors then present the associationists with problems. Of course, we develop theories of learning because we do not know what are all the brain functions that participate in the learning process. What we know are the external entities that are to be learned (inputs). We also know the outputs (behavior). But we know very few of the processes that take place in the brain during learning (some of the throughputs). Therefore, what a theory of learning has to establish is interrelations of the inputs (stimuli, information) with the outputs (behavior) by a logical sequence which will include the known throughputs and may postulate the steps which will be necessary in order to lead from inputs to outputs. To begin from the aspect that in order to have answers to inputs one should establish neuronal pathways through synaptic connections, is logical from the physiological point of view and I think that it should not be abolished by any theory. What is wrong with some theorists is that they tend to deny facts when these facts cannot be explained by their basic postulates. This happens with some associationist theorists who try to explain everything on the basis of the formation of synaptic connections. Some observations clearly require additional
postulates in order to explain behaviors such as perceptive learning. These facts, then, cannot be easily explained by associationist theories which attach strictly to the requisite of synaptic connection.

In an effort to avoid the shortcomings of the associationists, the structuralists emphasize cognitive maps, schemata, Gestaltien, hypotheses or reverberating circuits. These hypothetical entities supposedly pre-developed as a result of repetition of given input patterns, connect inputs from the environment with outputs providing appropriate behavior patterns.

The defect in strict structuralist theories is that they do not specify the neuronal basis of the processes they discuss. Except for the theories which rely on reverberating circuits, and on Gestalt theories which depend on changing electrical fields of the brain, most of the other structuralistic theories have difficulties explaining how the "cognitive structures" (schemata, hypotheses, cognitive maps) they hypothesize are translated into behavior. It is said of Tolman's theory, for instance, that it left his rats "lost in thought" (Miller, 1978, p.411).

In conclusion, there is no doubt that there exist responses to stimuli elicited because there is a neuronal connection between the fibers serving the stimulus transmission and the fibers serving the response transmission. On the other hand, there is no doubt, also, that there exist adaptive behaviors which are unrelated to immediate
stimulus-response synaptic sequences. We see it every day, either in experimental animals or in man. The difficulty for the associationists is to account for behavior by which the living organism accomplishes a goal by means not learned from sets or series of stimulus-response sequences. The difficulty of the structuralists is to account for the correspondance and connections of the functions of the higher brain with simple behavior such as those designated by a simple stimulus-response sequence.

The Theory of Learning of Mandler

The theoretical work of Mandler (1954) will help us understand better what may be the real difficulties that the formation of a theory of learning may be presented with. Mandler admits that the initial response to an information input is a differentiating response which may be verbal, motor, or symbolic (verbal includes motor also; symbolic may not include motor response). Since the only way to the brain is through nerves (neurons) and the only means is a sequence of electrical impulses-neurotransmitters, it is obvious that without differentiating response, one input cannot be distinguished from any other. If two inputs were to evoke the same differentiating response, they would be perceived as identical by the brain. Then Mandler supposes that if the input is a complex pattern, each of its aspects evokes a separate differentiating response. But he does not make it clear how one can explain the
differentiating response in terms of physiology. In any event, the important thing, in order to proceed, is to admit that the stimulus is somehow differentiated. Besides, no animal - of all the animals reported in the thousands of experiments performed around these areas - can account for a "tabula rasa". They all come to an experimental situation with a repertoire of separate responses which through repetition of a new situation, become integrated into a response pattern suitable for the new situation. This differentiation of animals in their previous experiences already provides a background for a differentiating response. So, previous learning influences (usually facilitates) the response to a new situation. In the course of this integration, trial-and-error behavior occurs. The inappropriate responses are usually eliminated and after a behavior responsive to the new situation is built up, the discrete aspects of it meld into a single functional unit which is elicited as its component responses were in the past. At the same time, a central analogic structure develops which can function independently of the overt response and which is available for potential application to future new situations. Again, it was not clear to me which are the physiological functions that correspond to this function. However, such a process appears to be logically acceptable.

If a number of such analogic structures are available, and if they are relevant to a new input, they can be tested by a covert trial-and-error function, without actual performance of the
associated responses. The analogic structures function like the hypotheses or schemata which the structuralists hypothesize as functioning in the solution of problems solved mentally. The learning of new concepts, under which future inputs can be classified, may also be explained as involving such central analogic structures. This is very briefly Mandler's theory of learning.

The important thing about Mandler's theory is that he takes into account in his explanations the evolution of the learning abilities. It is obvious that individual brains have an evolution during life. Thus, for me, it would be a mistake if one tried to formulate a theory of learning beginning from a static structure and not take into account the previous history that brought into existence the structure that is examined. Structures are slow processes. Thus, for me the mistake which is being committed by both associationists and structuralists is that they try to project certain standard structures at all levels of the development of an evolving nervous system. But the situation that has been created within an individual after a certain time of development may not be the same as the situation from which the development started. Thus, it may not be indispensable for new synaptic connections to be created in order for new learning to be realized after the brain has reached a certain growth, i.e., a certain point during its evolution at which it can solve problems by reverberating circuits or schemata. Besides, it is in accordance with the process of progressive mechanization to
admit that exactly because of such a type of organization, systems achieve the differentiation by which they can handle complex processes. Instead, insistence upon the necessity for the formation of synaptic connections for learning in a late stage of the evolution of the brain means application of a static concept in all levels of development and this is simply not true. Of course, the same holds for an application which would ask for reverberating circuits, schemata, etc., to apply in a level of development at which they simply do not yet exist.
CHAPTER III

RELATION OF THE BRAIN WITH THE ENVIRONMENT:

THE PSYCHOLOGICAL BASIS OF LEARNING

As an educator I am concerned with learning, but not only at the level of the brain's physiology. A learner is a whole individual existing, acting and learning within his natural environment. If learning, as realized by the brain, can be influenced by drugs or other treatments directly improving brain functions, this is outside the field of operations of educators. Educators are concerned with environmental factors which facilitate learning indirectly. They strive to find how best a learner's environment and/or his actions can facilitate learning. It is self-evident, then, that analysis of learning at the level of the brain's physiology does not suffice. So, I am interested rather in the correlations of the two levels of an individual's activities and being: The level of the individual within his own environment, and the level of his brain physiology, which, of course, as levels of the systems hierarchy, are interrelated and influencing each other.

Determination of these correlations will be the subject of this chapter. An easy approach to these is to clear up the meaning of
several concepts related to both levels. For instance, "thinking" or "creativity" are terms which not only presuppose a mental activity (thus brain function), but also denote a correlation of the individual with his environment, either by action in a creative act or by the way the environment may be represented in thought.

Subsequently, I will have to examine how all these correlate with education. In this task there are some intrinsic difficulties: Correlation of environmental conditions which facilitate the brain's learning with education means, practically, correlation of these conditions with some kind of educational policy. And this, in its turn, means correlation of these conditions with goals of education.

Definitions of the goals of education and of educational development are of primary importance in determining the kind of educational propositions one makes. In the present study I will try to determine which environmental conditions may have a negative or positive correlation with the brain while learning. Then the goals that I think education should have will be easily identified: eliminate the environmental conditions that may impair learning (negative correlation) and promote the conditions that facilitate it (positive correlations).

The basis of learning is information processing by the brain, and anything existing in our environment constitutes potential information which may be processed and learned by the brain. It follows that there is nothing existing in the environment which can have negative correlation with learning in an absolute sense. As a
negative correlation, then, I will determine these environmental factors which may impair learning.

Learning of undesirable information by learners may sometimes be erroneously described as negative correlation of environmental factors with learning. I will try to avoid this potential trap.

Although all these discussions concern the same level of organization, I will divide the material into two chapters because of its length. In this chapter, I will analyze the correlation of learning and connected concepts at two levels of an individual's existence: The level of his brain function; and the higher level of the individual, perceived as a learning unit within his environment. In the next chapter I will discuss creative thinking in relation to adaptation and education.

Artificial Intelligence Machines: Basic Concepts

A comparison of the brain with existing computing machines will provide us with an insight into the functions of the brain that mediate the interrelation of the individual with his environment. These machines were initially built for the purpose to perform the four basic arithmetical operations through the use of numbers. Numbers are a kind of information input for these machines. Numbers, though, as we write them graphically or pronounce them phonetically, cannot be submitted to the operations for which the machines were built. They must be transformed into some kind of "representation" that the machines can use. This is true for any kind of information processed by any kind of physical information processor as, for
instance, language as processed by the brain. This is the reason
why the brain is performing an analysis of whatever information it
processes.

A unit of information may be represented:

1. By markers; the simplest and most usual markers
   are the double-valued markers.

2. By another physical quantity.

Communication engineers have used both of these solutions with
numbers. They represented them either by a physical quantity, for
instance, the angle by which a certain disc rotates, the amount of
an electrical voltage or current, etc.; or by marker arrangements
using as a marker the presence or absence of electrical impulses on
a set of preassigned lines in time-space.

Analog and Digital

The type of machines in which information is represented by a
physical quantity, are measuring machines; their prototype is the
slide rule and they appeared historically first (Sebeok, 1962). They
are called analog or "more-or-less" machines and they operate on the
basis of connections between measured quantities and their represent-
ations. Addition or subtraction, for instance, of 1 and 2, would be
realized by merging in parallel or antiparallel direction the
currents that represent 1 and 2. The disadvantage of these machines was low precision.

Development of such machines to serve more complex functions presented the engineers with some problems which were solved by interposition of punched cards, which are a kind of marker and do not belong to the analog type of information representation. The need to intervene in this system of representation of information by a kind of marker, shows that the analog type, if not coupled by the other kind of representation, cannot reach the degree of perfection needed to serve human affairs.

The second type of machines are counting machines; their prototype is the abacus. They are of the "yes-or-no" type and they are called digital machines. They operate on the basis of rules of strict and logical character. They can achieve any desired precision, given sufficient capacity and time. But the physical system which is processed by these machines (numbers, for instance) must be broken down, analyzed into markers which, of course, have no relation to the physical system that they represent; but they are in sufficient numbers so that appropriate arrangements of them represent all the numbers we want to represent (or any other physical system we would like to analyze).

Since a marker has always a mass-energy nature, it can be considered as a physical quantity. By the same token, a physical quantity as used in analog systems, can be considered as a sum of
markers (see, also, my discussion on information on pp.28-45). Thus, understanding of the possibility of conversion of the one type of information representation to the other should not present us with difficulties.

In this context, the genetic phenomena play an especially typical role. The genes themselves are clearly parts of a digital system of components.\textsuperscript{18} Their effects, however, consist of stimulating the formation of specific chemicals, namely of definite enzymes that are characteristics of the gene involved, and, therefore, belong in the analog area. (Von Neuman, 1958, p.69)

The Brain as a Mixed Analog-Digital System

The nervous system is a mixed analog-digital system. If for a moment we consider a neuron and its function, we will understand better the mixed nature of the brain, as an information processing system.

When an impulse is generated, it travels through the dendrites-the body of the cell-and the axon very fast until it is transmitted to the next cell through the synapses. This phase clearly belongs to the digital part of the mechanism. At the same time, though, the

\textsuperscript{18}The DNA on which the genes are located is composed of nucleotides which are the least markers that this system of information representation has available. Rearrangement of these markers in time-space represents by it combinations all the information that the genetic material carries with it. This is a digital system.
impulse is causing the secretion of neurotransmitters at the sides of the synapses which, again, represent the information that is processed by the brain, although as a physical quantity this time.

This phenomenon is one belonging to the analog class, but it may be the origin of a train of nerve pulses which are due to its being sensed by suitable inner receptors. When such nerve pulses are being generated, we are back in the digital line of progressions again. (Von Neuman, 1958, p. 69)

This being the basis upon which all brain functions are built, any single function of the brain concerning information processing should be understood as carried out by a mixed type of system. For instance, memory, for the function of which circuits, neurotransmitters, RNA and protein and/or "membrane protein" participate, is another mixed digital-analog system by itself. Its high complexity has not as yet been disentangled. Its analogy in the computers is, according to Neuman, the "flip-flaps", i.e., pairs of vacuum tubes that are mutually gating and controlling each other" (Neuman, 1958, p. 6). There is a lot of controversy around the real nature of memory (Eccles, 1977 and Pribram, 1978). But let us assume that the brain, through neurons mutually gating and controlling each other, may operate in a fashion similar to a computer, as engrams according to Eccles, or as a holography according to Pribram. In any case, its basis is a mixed digital-analog system.
Models^19

As a second step to the analysis of the relations of the brain with the environment, I will develop the notion of "ideal model" formation. The model of an artist is a real-life object. The artist perceives the information sent by the model: Shape, colors, glamor, etc. by performing with his brain analysis-synthesis. His painting is also a real-life object; it represents the artist's version of the real-life model, his synthesis. At the same time, it is a marker "representing" the artist's ideal model. And the ideal model is the synthesis performed in the artist's mind according to the generalization of abstractions that the real model's analysis revealed in the artist's brain. The painting is even more representative of the process/product of the synthesis than the analysis that took place in the artist's mind. In this case, the process/product is a "synthetic" model.

The model of a photographer is a real-life object and the picture is also a real-life object. What the photographer does is to look through his camera and to shoot when he is satisfied with the composition (objects, light, etc.) that he perceives. While in this case the result represents also the creation from an ideal - how the photographer had in mind what the picture should look like - the process/product is much more analysis than synthesis. In this case, this process/product is an "analytic" model.

^19My discussion on models is based on examples used by Silvern (1975, pp.20-23), but I use them differently.
In these two examples all the elements which produced the outputs of the individual are present: (1) inputs (the-real-life model), (2) throughputs (analysis-synthesis by the brain: the ideal model), and (3) outputs: one version of the ideal, that is:

1. An analytic or a more abstract, synthetic ideal model, plus

2. The conditions of the moment.

These conditions could be, for instance, materials available to the artist (quality of the film, lights, chemicals, colors, camera, etc.) or others.

Replica

Consider, now, the replica of an animal used to train veterinarians. This is not the real-life object but a replica of the real object. At the same time, it is a real-life object itself. Between the real-life object and the replica, an analytic-synthetic process of another mind has intervened. In this respect, the replica is an ideal model in a certain version. If we consider thoughts as real things, we might represent thought as the replica of reality in a certain version, built up by materials available to the brain (electricity, neural circuits, etc.).

To continue my example: Because the result of this first procedure usually represents the analytic part of the process, new
observers can receive information about the true object which approximates the information they would have received from the real object itself. But, for teaching purposes, one might emphasize or simplify in the replica a part or a function of the real object. For example, one might form a replica of an animal in which its nervous system is emphasized. In this case, the interference of a synthetic process during the creation of the replica is greater than before.

Two analytic/synthetic procedures take place in this example. The first takes place during the production of the replica in the mind of its creator. This procedure can be categorized as an analytic model with different degrees of convergence towards a synthetic model (increasing involvement of the synthetic process).

The second analytic/synthetic process is the one taking place in the people who see the replica. Here, again, a real-life object exists as an input; an ideal is formed in their minds. The outputs are not shown. They remain potential. The manufacturer of the replica and the other persons who see the replica may be represented as the same brain in two different stages. This brain now sees reality at different times (manufacturer-others), and forms accordingly ideal models, replicas, of it. Consequently one can see that the same reality can be perceived differently at different times by a developing brain. That is, different synthetic processes may take place according to the intentions of the moment or to the general condition of the brain at the moment, or to differences of the same reality in a different framework (like looking
at a replica and not at the reality itself) giving genesis to
different ideal models from one and the same reality.

The Ideal Model

The expression "model student" reveals in people's minds a model
according to which the student's behaviors are evaluated, measured
and compared. The inputs and outputs are absent in this expression.
The expression is the ideal itself. There are several things to be
noted in this case.

1. The expression is a valued statement. "Harry
   is a model student" means that Harry is a very
good student.

2. We do not compare the value attributed to the
   present model student to a standard, apparent,
   real-life person (object).

The comparison which led us to the expression "Harry is a model
student" is exercised versus a hypothetical ideal model, created in
our mind previously purely by synthesis. The hypothetical ideal
is a generalization of abstractions from multiple real-life objects,
in which the convergence towards a desired ideal (goal) is affected
by values other than the values concerning the model itself as a
whole. For instance, an ideal student for us should behave in a
certain way, wear certain clothes, read so many books, etc. The abstract, valued models that we have in mind for these aspects of the general model (behavior, clothes, reading, etc.) have been evaluated before the evaluation of the general model, against values corresponding to these specific aspects. Then, we form a synthesis in our mind of all these abstractions and we have "our model student". In other words, we do not know how good a student Harry is because he has been judged by too many different standards. For a mother of the inner city ghetto, Harry is a "model student" if he is absent from school only twice a week. For a suburban educated mother, Harry is a model student if he devotes his weekend free time to activities related to school.

Logical Abstractions: The Mathematical Model

A right-angled triangle is presented in Figure 15. This geometrical form corresponds to an ideal mathematical model: \( c^2 = a^2 + b^2 \) which expresses the relationship of its sides but is

![Figure 15. A right-angled triangle](image)
also a kind of a model for all right-angled triangles. If one follows the "relations" of the triangle's sides included in the equation, he can draw any number of triangles he wants, any size, with the same relations. Therefore, the equation is equivalent to a pattern according to which one can draw similar triangles. Now, this can also be written as $c = \sqrt{a^2 + b^2}$, which is another form of the same model, but is based on a series of logical procedures. To write this second model, I did not use any correspondence with reality as Pythagoras has used to write the first equation (Bronowski, 1973). I used only my logic. Mathematical models are exactly that: Ideals, i.e., generalizations of abstractions based on logical rules. Application of logical rules on a set of abstractions will come up with more abstracted abstractions (generalizations of models). The continuous application of logical rules, though, would not mean that some new correspondence with reality was added to the model. The content of the model will still be the triangle I have drawn. The new model, however, will be a different representation, a different ideal model for the same triangle.

Representation of Reality In the Brain

Through these examples and in combination with my discussion on brain functions, I can draw some logical assumptions about the character of the processes which take place in the mind. The points I want to stress are the following:
1. The brain formulates "models" which originates in reality. By performing analysis-synthesis while processing information, the brain comes up with a representation of reality which by no means is reality itself.

2. The representation of reality within the brain is a concrete existence in itself, realized in markers, that are formed during the processing of the information emanating from reality. This process results in the formation of patterns of impulses which, by modifications, acquire a specificity so that this specific pattern of impulses can be differentiated from others which are built up from the same materials. This is a process of model formation. The process of model formation is a learning process, and if we want to compare this stage with a stage in the theory of learning of Mandler, we may say that initial modification of impulse patterns corresponds to the "differentiating response", while the "learning" brain is formulating primary patterns of behavioral trial-and-error mechanisms which correspond but also modify the initial pattern of impulses. More synthetic models correspond to the "central analogic structure" of Mandler, and are formed later.
3. The closer the models remain to the reality that they represent, the more they deserve the characterization of the "analytic" model. When, during the synthetic process (which always takes place in the formulation of models) factors interfere that cause the ideal model to deviate from its faithful representation of reality, then, the models deserve the characterization of "synthetic" model.

4. There are degrees of convergence from an analytic to a synthetic model. The degrees of convergence of an analytic model towards a synthetic model may depend on the condition of the brain at the moment it formulates the model. By "condition" I mean intentions of the individual at this moment, functioning conditions of the brain, stage of its development, and, generally, any factor that could interfere with brain functions at the moment of the model formation. The outputs of the analytic/synthetic process of the brain (i.e., the models) are comparisons. Harry is one input, the ideal model is existing, and the new output is Harry seen through the glasses of the ideal. Harry's different see-throughs are Harry's different comparisons, or simulations.
5. A major role is played during resynthesis and simulation of models by values. The degree of convergence towards the synthetic side of the models will obviously depend on the normal function of the brain, on the kind of reality processed, on values, and on the ability for abstraction.

To find out how these representations of reality (the ideal models) can become real, synthetic or abstract, I will have to describe "thinking". Thought, in terms of brain materials, is the pattern of impulses that prevails for a period of time as the dominant pattern of excitation of the brain. "Thinking" at this level of brain function, is understood as a turn-over of thoughts. But in order to understand how this is realized, I will have to discuss the notion of consciousness and subconsciousness at this level.

Consciousness and Subconsciousness

We do not know exactly what is consciousness and subconsciousness. But we can make a pretty good guess as to its nature combining information from machines with "artificial intelligence" and from

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Of course, "thought" and/or "thinking" can only function when "memory is normally functioning. Because, as we will see later on more extensively, thinking presupposes a form of "information comparison" and/or "evaluation", and cannot exist unless there is something to compare with.
neurophysiology. The "rule of force" and the "plasticity" of the brain correspond, in computer terms, to a system of electrical "reinforcement" (rule of force), and "inhibition" (plasticity): SRI (Systems of Reinforcement and Inhibition).

The functioning of SRI permits us to explain such terms as consciousness, and subconsciousness. Thinking and thought. Consciousness is a program providing at any given moment the domination of activity of one model over the others. Any model, including an image of an outer world, feeling, action, perception, desire, or so on, may be in the sphere of consciousness. The model reinforced at a given moment, is a thought. (Amosov, 1968, pp.39-40)

And he continues:

As SRI cannot stay too long upon one model, the reinforcement regularly turns to some other model, then to a third one. All of this chain of models is connected by the short-term memory. The processing of information, i.e., the movement of the excitation from one model to another, takes place not only in the sphere of consciousness, along the chain of excited models, but also it takes place in the subconscious, between models that are partly (not completely) inhibited. (Amosov, 1968, p.40)

So, this is probably the subconscious in terms of the physiology of the brain. And Amosov continues:
The role of the subconscious is very large; the amount of information processed subconsciously is much more than the quantity of information processed in the consciousness, although the level of activity of the subconscious models is lower. The primary "recognition" of images and preparations of models for "capturing" consciousness in the next moment takes place in the subconscious, as does the starting of learned programs of actions and the influencing of feelings. (Amosov, 1968, pp.40-41)

Amosov and other investigators, using SRI in robot-computers were able to make them simulate human behavior. The robots were able to learn some behaviors. I find the assumptions of these investigators about the real nature of consciousness and subconsciousness persuasive, more so because they were successful in building these concepts mechanically. Therefore, I will consider as consciousness, in physiological terms, the electrical impulses prevailing at any given moment in the brain, and as subconsciousness all other brain activity which takes place at the same time, and which does not have enough strength to become prevailing.

Nevertheless, in doing so, I do not want to mislead the reader into believing that these are facts or proofs. They are just assumptions. I consider "thought" as the pattern of the electrical impulses that are prevailing in consciousness. Thus, any information which is processed by the brain is generating an electrical activity which may prevail and, thus, be appreciated by the individual. But at the same time, all other information is not lost. It is associated with the one being appreciated by the brain (being conscious),
and it can at any time appear in the center of consciousness.

Without external stimulus no marker printing can be realized (see, for instance, the blind kittens). Let us see, then, if the concepts of consciousness, subconsciousness, thinking, etc., explained on the physiological basis I presented, can explain the evolution of the brain on the basis of progressive mechanization of the physiological elements that we know we begin with in the brain; i.e., marker formation. I will not discuss in detail neurogenesis or the creation of synaptic learning and other aspects. Rather, I will consider the whole process from the point of view of marker formation based on the understanding that, as markers, in this instance, are considered the establishment of neural pathways through synaptic learning, changes in the protein and RNA content of the neurons, and changes of "membrane memory substances" (Pribram, 1978). I also need to assess what may be the contribution of all these factors in the realm of a new synthesis. The new element will pop up in all resyntheses of the brain. But the outputs may be characterized either as ordinary thought, as something foolish, or as a new creation. We see, then, immediately that understanding a resynthesis as creative depends on other people's minds as well as the mind of the creator. In the following sections, therefore, I will not only assess the contribution of spontaneity\(^2\) and previous experiences in a creative resynthesis;

\(^2\)As "spontaneous" I understand this part of a creative work which in an analysis cannot be attributed to an apparent influence
I will also describe how a resynthesis can be understood by others than the creator, since we do not possess other means to evaluate creation except our judgement. But in order to approach these problems, I will first discuss the concept of value.22

Knowledge as Valued Information and Brain Development

Imagine a flat desert: Sand, sand, sand, Then one puts a stick in the middle of it. Now the desert is not the same. One can say how close to the stick he is, or if the stick is producing a shadow, or how many hours he has walked away from the stick. Briefly, he now can measure things in relation to the stick, and the stick for him constitutes a value. The same thing holds true for any physical existence.

Let me now take another example: A sculptor went up to the Parthenon with his chisel to write on marble: "Glory to You, Great Zeus", and he found his message already written. This man has now

22When people refer to the value of something, they usually refer to its worth. In other instances, value may refer to the significance of a certain thing for someone. An extension of the meaning includes the notion of evaluation of something; in other words, it includes the notion of a certain judgement. My point of view is that all these meanings are simultaneous with the mere presence of an entity. I will try to support my point of view by the above examples.
many choices: He may not write his message at all or he may write it on another marble. Or he may correct the already written message. In any case, whatever he may do, his behavior will be an expression of judgement, of evaluation of the situation that he found already existing. This existence constitutes the value against which he measures his message. In the absence of any written message, there would be no evaluation of the message itself. Perhaps, he would choose appropriate stones, etc. But now he also has to evaluate the message.

By this example I want to show that the mere presence of anything, especially of similar markers, is a value. Then, the first thing one should think of in the sequence of information processed by the brain is that a "second" message now has the opportunity to be evaluated by the system, mainly as similar or different to the previous messages, but perhaps also by other means.

Is there any value against which the first inscription made in the brain measured itself? I think that there is. And this is the relation of the materials themselves: The nucleotides and the aminoacids and the electrical forces by the way they were related. These relations, by the way, mean that the individual is alive. Otherwise, other relations would have existed. So, a message processed by a living system evaluates itself in the first place with some type of organization which is due to the fact that the organism is alive. This is the first and ultimate value: Life and Survival.
Subsequently, the first inscriptions already constitute an existence for the second ones which can only be inscribed in relation to the first. In terms of marker printing and probabilities and given the fact that the incoming information is evaluated according to the pre-existing information, it is most probable that a second or a third identical message will pass through the same pathways. If I may continue my example with the sculptor, a second and a third man write the same message on the same marble and the grooves become more and more discernible. In the brain, neural paths become established, spines are growing, axons are projecting; all of them following a certain way that they would not have followed without information processing and without the kind of information which has been processed.

Briefly, evaluation of learning through information processing at the level of the brain means a continuous shaping and "reshaping" of markers, according to the previous markers. On this characteristic is based the organization of the brain with participation of consciousness, subconsciouness, etc. Similar messages will go to similar places and will contribute to the formation of centers. The centers will be interrelated and connections will be established between them, as they are processed at the same time. But different messages are also being processed and evaluated at the same time. Thus, interconnections will be established between all areas of the brain resulting of course in the formation of centers indispensable
just for these interconnections. At the same time, because they are interconnected and the one influences the other by its mere presence, and they all work at the same time as a system, they should also be coordinated. Thus, coordination centers develop while the brain is working all the time as a whole.

This is my assumption on how, through a process of progressive mechanization, this formidable tool, the brain, came into being as we know it today. Of course, this is hypothetical. However, if there is truth in it we should not forget that in spite of the high complexity of today's brain, the same basic mechanisms operate with respect to it's physiology; and we have to build on them in order to explain the several psychological or educational concepts in terms of physiology. Therefore, in order to explain an individual's growth in learning, I will use the same physiological concepts. So far, I have related some of the basic concepts which we use to describe several functions or features of our mind at the level of the individual as a person, to the level of the brain's physiology, and to the representation of reality in our mind.

I will now analyze generalization, discrimination, concept formation, abstract thinking, and the relation of emotions with cognition. Clarification of these areas constitutes an indispensable step for a full discussion of creative thinking which is my ultimate goal.
Concepts

"When a symbol stands for a class of objects or events with common properties, we say that it refers to a concept" (Hilgard, et al., 1975, p.273).

One of the symbols that man uses is "words". Concepts are expressed in words or are included in the meaning of only one word. However, concepts can be learned without the use of language.

"Rats can learn the concept of triangularity - by being rewarded for selecting triangles of various shapes and sizes and not rewarded for responding to other geometrical forms....Since the triangles vary in shape and size they are not responding to a specific object but to the concept of triangularity. (Hilgard et al., 1975, p.273)

During concept formation the individual utilizes the mental processes of generalization and discrimination. Both man and animals use the same processes. However, since language is a unique human characteristic, there are differences in the development of concepts in humans and animals which stem exactly from this unique characteristic. In conclusion, concepts are the ideal images reflecting the general essential properties and connections of the objects and phenomena of the surrounding world, and they represent one step forward from the development of general notions. They are ideally expressed in words or combinations of words.

While developing the concept of "apple tree" a child may initially generalize the term to include all trees. But with
subsequent observations and corrections (within the social framework) the child makes more subtle discriminations until the concept approximates the conventional conception of an apple tree. Something similar happens to the animal.

"In learning the concept of triangularity, a rat generalizes the response initially to other geometrical forms, but, since these responses go unrewarded, they are extinguished and it eventually narrows the discrimination to triangles. (Hilgard, et al., 1975, p.273)

But, because of the existence of language, although the physiological mechanisms underlying concept formation are basically similar in man and animal, humans becomes able to form more and more abstract concepts; because they are able to narrow down (by the use of the words as symbols) the number of properties which connect the concepts. These properties may at the same time be generalizations. This human ability renders man capable of abstract thinking—a unique human characteristic. In this sense, language is immediately related to abstract thinking.

Since education's aim is to enable the learner to grow in knowledge, and this implies that he will eventually become able to use abstract thinking, it is very important to scrutinize as much as possible the ways by which this ability develops. Educators should know the steps which man's cognitive development will undergo, in
can see, on the one hand, how concepts that already exist in the language have developed and also how an individual can internalize them.

Concept is a qualitatively new form of the reflection of reality deferring markedly from the forms of sense knowledge. It originates in sense knowledge, but it acquires this qualitative difference by using language as a symbol (signal system).

Analyzing this in terms of information as representation of reality and/or language processed by the brain, I note several things from the point of view of development of concepts during the building up of the cognitive apparatus of an individual.

1. The associations of a certain unit of information may constitute its meaning; this is, also, the content of a concept. A word is a written or an oral unit of information processed by the brain which initially serves the description of a certain concrete reality; The word viewed as a sense knowledge (acoustic or visual stimulus) is associated with other sense knowledge which is processed as information by the brain at the same time as the word. Also, previous sense knowledge modifies through evaluation the newly processed word. Thus, the individual acquires an initial general notion which is related to sense knowledge, be
ita word or other sensual experience. At the same time, the associations included in the general notion attribute to the word a certain meaning. On the other hand, many words existing in the language, for which the individual develops general notions, are already concepts. As such the word has initially the meaning that the sensual associations attribute to it. Thus, all of us attach, initially, different meanings to the same concepts, because different associations are formed in our brains due to different environments and experiences. Therefore, initially, we will ascribe to the concept-information different meaning: Briefly, the same word may become for anyone of us at a certain point of our development a different concept.

2. Our cognitive structures is built up in a framework of organized information-concepts. Beginning from the very simple concepts, by connecting new incoming information with the old existing information, and by correcting the initial meanings of concepts through comparisons with the social realities, and a trial-and-error behavior, our brain attributes gradually similar meanings to the same concepts and builds up our cognitive structure like a tree - the tree of
knowledge - through associating pieces of information. This shows two things:

a. The more associations one has the more easily he may understand different points of view, differences in concepts. On the other hand,

b. Since the incoming information is from the beginning associated with a very large variety of experiences, understanding of concepts may present a great diversity, despite the equalization that takes place later.

Exactly through this continuous interaction of concepts with social realities the concepts gradually become void of their sensual content and stop representing sense knowledge. As distinct from the latter, concepts now are devoid of visuality. It is impossible to visualize, for example, a chemical element, valency, patriotism, courage, democracy, etc. All these ideal images are now thoughts expressing the "understanding" of particular phenomenon. Moreover, sense images, sensation, perception, notion reflect the external properties and connections of the objects and phenomena of the surrounding world, whereas concepts reflect the inner essential properties inherent in them.
Through the process of thinking, concepts interact with each other and make up other forms of the reflection of reality by using judgements and inferences. Judgements are the simplest forms of thinking. They reflect through definite interconnection between concepts or notions, sensations, etc., the presence or absence of connections between objects and their properties. Inferences are a form of thinking which is built on judgements. They represent connections between judgements and engender a new judgement that contains a new thought. By combining relevant concepts into judgements and these into inferences, man is reproducing in his consciousness the necessary aspects and connections of reality and the essence of the object under study through a system of ideal images. Exactly this ability to penetrate the essence of a certain field of reality and to isolate its inherent aspects and connections is a major feature of "abstract thinking", distinguishing it from sense knowledge.

"To define a concept by classifying a specific object, phenomenon, or activity within a larger category amounts to one of the most elementary operations of abstract thought". (Luria, 1976, p.84)

But this type of classification is a generalization.

"A person who defines an apple tree as a tree and a goat as an animal disregards the attributes peculiar to an apple tree or a goat and isolates some essential quality of each that pertains to a generic category". (Luria, 1976, p.84)
This implies not only a generalization, but together with it also an abstraction. Thus, abstract thinking makes use of the properties of the brain for generalization and discrimination at the same time.

As we know from standard psychological experiments, the definition of a concept is a clear-cut verbal and logical operation in which one uses a series of logically subordinate ideas to arrive at a general conclusion automatically disregarding all extralogical considerations. (Luria, 1976, p.84)

To elucidate the process of generalization and abstraction which, together with logic (judgement, inference) underlie abstract thinking, it will be helpful to see how, through similar processes, language has evolved within the society.

**Socio-anthropological Aspects of Language**

Language includes many abstractions and generalizations. These should not be confused with the ability of the human brain to generalize and abstract, although they are derivatives of this ability. It is important to understand how linguistic abstractions and generalizations have evolved as concepts before trying to understand how concepts are learned. This will help in understanding how, through an interaction of language and the brain, abstract ideas have evolved.
The abstractions and generalizations which exist in our language are the product of the evolution of language, and they should be seen in this frame of reference in order to be better understood.

Now I claim that the ethnographer's perspective is the one relevant and real for the formation of fundamental linguistic conceptions, and for the study of the life of languages. (Malinowski, In Korzybski, 1933, p.19)

Several tribes which have lived in isolation from the rest of humanity are, from the point of view of their social development, in rather primitive stages (the brain capacity, however, being as good as any). These tribes have some linguistic characteristics which are surprising; they have a different word for "snow on the ground", "snow falling now", "snow of the blizzard", and "snow of the snowdrift". They have 40 different words (not combinations) for different conditions of snow, but they do not have the general idea of snow and they do not understand the generalization "snow" separately from its concrete - existing in the environment - situations. The same condition applies to "seal" in other tribes which cannot understand a generalization of the animal separately from its concrete situations; but they have different words for "seal on an iceberg", "seal in the water", "seal coming out of the water", and so forth. They also have about 75 different words to indicate different positions of the body during the process of walking, but they do not have the word "walk" (Glezos, 1977).

23The underlining is my own.
Let us assume that at a certain point of social development, a tribe similar to the ones I have already mentioned, was living in a place where there were seals, penguins, and bears; and the people had 75 different names for each of the animals according to the situation in which they came in contact with the animals. This kind of communication, at this point of social development, adequately served the conditions these people were living in. If we now suppose that after some thousands of years they have tamed a great number of animal species and that they are also hunting many other animal species in addition to seals, penguins and bears, we easily understand that the number of animals multiplied by the number of situations that they have to describe causes the language they have to be inefficient for communication at this level of social development.

So, they introduce new names: For example, the words "seal", "penguin" and "bear" which describe the animals as we, also, today understand them. If one wants to clarify these words in terms of abstraction and generalization, one sees that they certainly are abstractions as compared to "seal on an iceberg", etc., since now the animal is isolated from the other elements of the picture. At the same time, "seal" is a generalization, because by this word all the animals that have certain similarities in all the stages of their development, and during all the situations in which they may be found, are described by the term "seal": The seal mother, the
seal father, the seal child, as well as a seal swimming, etc. Nevertheless, this expression reveals images which are similar only in few of their characteristics. In order to find the similarities, one has to perform abstractions, eliminating from the images the details which are not similar. These thoughts explain why sometimes generalizations are thought of as abstractions; essentially generalizations are generalizations of abstractions.

This is how these processes are taking place at the level of language evolution. And, in this sense, language is a purely social product, because creation of new terms occurs only to fulfill needs for communication in the social level.

Mental Processes Leading to Abstract Thinking

Let us now see which of these two processes is related to brain function and how. Abstraction, which means to reduce by separation or by removal, can be considered as an inbuilt feature of the human brain. In fact, abstraction is a feature of all living substance.

All living material, usually called protoplasm, has, in some degree, the nervous functions of irritability, conductivity, integration. It is obvious that a stimulus $S$ does not affect the small piece of primitive protoplasm $A$ "all over and at once" (infinite velocity), but that it affects it first in a definite spot $B$, that the wave of excitation spreads, with finite velocity and usually in a diminishing gradient, to the more remote portions of $A$. In life.... abstracting in different orders, seems to be structurally and uniquely appropriate for describing the effects of external stimuli on living protoplasm. (Korzybski, 1933, pp.165-166)
In this sense, the brain being composed of cells, has an inbuilt capacity for abstraction. In physiological terms, generalization is also related to brain function. More specifically, generalization is related to responses to a conditioned stimulus.

"When a conditioned response to a stimulus has been acquired, other similar stimuli will evoke the same response. A dog that learns to salivate to the sound of a tuning fork producing a tone of middle C, will also salivate to high or lower tones without further conditioning. (Hilgard, et al. 1975, p.198)

Anokhin (1974) analyzing the evolution of conditioned responses enables us to understand why this quality of the human brain is inbuilt in the living matter. The process of the conditioned response is based on the evolution of the timing of the chemical reactions by which the living matter responds to periodically occurring external stimuli. During the evolution of living matter several phenomena were occurring occasionally and only once, while others were occurring occasionally but periodically. Also, the living matter by possessing the ability to move was meeting different objects and/or phenomena of the surrounding world in the same manner. Let us take a series of phenomena A, B, C, and D which occurred periodically and to which the living matter responded by a series of chemical reactions, a, b, c, and d. The property which was different in the sequence of A, B, C, D than to a, b, c, d was the
timing. While A--B--C--D were occurring at long intervals, a--b--c--d could occur within very short periods of time. This led to the following: While in the beginning the occurrence of A was necessary to elicit reaction a, B to elicit reaction b, etc., after a certain time in evolution, occurrence of A was automatically eliciting the whole chain of reactions a, b, c, d. For instance

"...A refers to the opening of the door into the room where the dog is, B to the entrance of a man with a dish, and C to the movement of the man toward the dog. D, however, is the intake of the food from the dish by the dog. If this sequence is repeated many times, then in the protoplasm of the nerve cells of the brain an intimate chemical connection is established not merely on the basis of the sequence alone, but also due to the reinforcing action of the vitally important stimulus, i.e., the reverse chemical influence of the reinforcement on the preceding processes from the preceding events (the stimuli). In our example these are A, B, C. It follows that with such a sequence of factors (a recurring sequence), the chemical process evoked by factor A (or by any earlier factor) is not retained in the structures alone, but spreads immediately all the way to the chemical complex d. As is evident, in this case, the chemical process d, which corresponds to the phenomenon D of the external world, will develop in the cells of the brain or in the protoplasm of a primordial organism sooner than the actual phenomenon D sets in. This is the chemical process of the protoplasm (or the excitation) which anticipates the course of the external events that occur considerably more slowly. Thus, the living protoplasm has become a unique "accelerator" of the course of external events. (Anokhin, 1974, p.14)"

This is the basis of generalization. A sequence of phenomena which are not similar (A, B, C, D) will evoke the same response (a,b,c,d).
Also, a whole host of phenomena which are similar to A, B, C, D may evoke the same chain of chemical reactions a, b, c, d because these phenomena, although not identical, will be classified on the basis of the same reactions. Thus we see that the living matter has built in the properties of abstraction and generalization. Words are, in fact, acting as conditioned stimuli. This has been proven by experiments of Volkova (1953). She used a modification of Pavlov's salivary conditioning method in an experiment with young children. The unconditioned stimulus was cranberry puree, delivered to the children's mouths. The response was salivation. The conditioned stimulus was the word "good" pronounced aloud by the experimenter.

"After the conditioning had been established, the experimenter tested for generalization by pronouncing some sentences that could be construed as possessing a "good" meaning and some that could not. She found that the children would salivate to sentences like "the pioneer helps his comrade" and "Leningrad is a wonderful city" but not to ones like "the pupil was rude to the teacher" and "my friend is seriously ill". (Hilgard, et al., 1975, p.199)

On this basis, i.e., on the ability for generalizations, abstracting and concepts acting as a conditioned stimulus, the cognitive development of the individual is built. However, other factors should be taken into account:
"The classical studies of Binet and other psychologists proved long ago that a person can detect differences in objects long before he can establish a basis of similarity among them. (Luria, 1976, p.80)

The explanations for this fact differ. Korzybski (1933) claims that one cannot discern the similarities when they are blurred by details. Therefore, one first has to perform an abstraction in order to be able to perform a generalization. Instead, Luria (1976) claims that the reason one first detects differences is that:

In order to discern how two contrasting objects differ, one need only describe their physical "attributes"; hence, the whole procedure hinges on immediate impressions or visual memory. On the other hand, it is far more difficult to establish a resemblance between objects (particularly when this is not apparent from immediate impressions). Insofar as it implies an ability to isolate and compare attributes, such a procedure inevitably includes certain verbal and logical components. (Luria, 1976, p.80)

The analysis of Luria appears to me much more complete. However, it is not faraway from what Korzybski says (Korzybski: "Can not discern the similarities"; Luria: "it is far more difficult to establish a resemblance"). My analysis is as follows: If both abstraction and generalization are properties of the living matter then they should occur simultaneously. However, both Korzybski and Luria (the latter based on more recent psychological observation)
admit that it is more difficult to establish a "resemblance" than to see a "difference". But the reason for which this happens appears to me not to be based on strict physiological grounds, since the living matter possesses both possibilities. It appears to me that this difference should be attributed to the way by which the cognitive development of the individual is realized. Briefly, to establish a resemblance one needs to see similarities. This is the basis of forming a generalization. And this the brain appears able to do spontaneously (the child after seeing an apple tree calls all trees apple trees). However, this is only the basis for the generalizations that we form in our language, because one also has to put the resembling objects into categories. To form categories one needs to see resemblances of only some of the properties of the objects that will belong (for this reason) into the same category. Usually the objects include on them many other details also, in addition to the properties that will allow them to be classified in the same category. And many times these isolated properties are blurred by the details existing in the observandum. Thus, one needs to perform an abstraction and isolate the properties which will allow him to classify, in the same category, objects loaded with many other details, also. The brain performs abstractions naturally. But which one of them will be chosen to be put in the same category does not depend on any natural property of the living matter. The choice will depend on how well the individual is trained in putting things into categories. And this training means that he has seen others doing
so by following certain rules. In one word, this process requires that the individual has observed and internalized some rules of logic. Thus, in performing a generalization, acceptable by the social environment, one uses abstractions and rules of logic. In this sense, the abstraction that one will use to form his generalizations has to conform to the rules of logic. Thus, although the hard thing to do is a successful generalization, the difficult step will be to choose the appropriate abstractions. This analysis explains both the difficulty that exists in establishing a resemblance (Luria) and the observation that mentally retarded children can be taught to generalize but have a difficult time to come up with abstraction (Leland, personal communication, 1979). In the realm of language only heavy social need for effective communication has brought about generalizations like the words "horse" or "animal", etc. In any case, generalizations existing in the language are generalizations of abstractions.

In the social level, however, a generalization does not enter the vocabulary unless most of the people can see the similarities which only one has seen; this, of course, means that the abstractions which form the generalizations correspond with reality, and so they obtain a common consensus. They have, as we say, "common sense".

In this sense, generalizations correspond to words that have been produced during the evolution of language in society. But during the cognitive development of an individual they are processed by the brain in the same way as any other word that may not constitute a generalization.
In order to understand abstract thinking let us see how the brain processes language. All individuals are born within a society which speaks a language. The human brain processes language as a ready-found product, as a system of semantics for communication. Initially, one attributes to a word the meaning that the associations of the moment will give to the pattern of impulses that the word reveals (sense knowledge, perceptions). With time, and by a trial-and-error mechanism, one will attribute to the word the meaning that one's environment attributes to it (formation of general notions). So, the word gradually loses for him the concrete meaning that it initially had. The word, however, will continue to correspond to a pattern of impulses at this level as well. By recombining such abstracted patterns of impulses of words one reaches a level at which it is very difficult to find what was the initial concrete content of the word. One reaches a high level of abstraction. Thinking in terms of words, at this level, represents the basis of abstract thinking.

We see that although the patterns of impulses by which one thinks are not completely void from their concrete content, their meaning depends largely on words and the way words correspond to reality. At this level, by the use of judgements and inferences which interfere in the process of thinking and which modify even more the meaning of the words, words become abstract concepts which constitute the raw material for abstract thinking.

The work of Piaget is especially significant concerning the cognitive development of humans and the acquisition by them of abstract thinking. Piaget (1936, 1947) considers intelligence as a special instance of adaptation.
"Life is a continuous creative interaction between the organism and the environment. This interaction functions outwardly as adaptive coping and inwardly as organization. Adaptation and organization are considered to be complementary aspects of a single cyclical mechanism. (Piaget, 1936, p.7)

Piaget's thinking is consistent with systems. He claims that it is the structures which change (e.g. epigenesis of the heart in embryology); the functions (e.g. assimilation and accommodation) remain invariant.

Assimilation corresponds to inner organization. It occurs whenever an organism utilizes something from the environment and incorporates it. For instance, assimilation operates whenever the organism sees something new in terms of something familiar, whenever it acts in a new situation as it has acted in other situations in the past, whenever it invests anything with familiarity (recognition), importance, or value. In this respect, assimilation includes the phenomena which Pavlov (1927), Luria (1972), and Anohkin (1974) called "conditioning" which Hull (1943) has termed "stimulus generalization" and "response generalization". However, Piaget takes the view that the organism always acts in terms of the centrally-organized Gestalt-like structures which are present within it ("analogue" of Hull's (1943), "central analogic structure" of Mandler (1954)).

These structures which in psychological experiments are observed as repeatable and generalized pieces of behavior are termed
"schemata" and are presumably mediated by neurophysiological processes.

**Accomodation** corresponds to outer adaptation and is a process complementary to assimilation. It operates as the variations in environmental circumstances demand coping which modifies existing schemata. Thus, the environmental circumstances act upon the organism not by merely evoking a fixed response, not by getting a passive submission to circumstances, but rather by modifying the action or schema affecting them.

During this dual adaptive process the already-existing reflexive schemata of the newborn human become progressively transformed (differentiations and coordinations) into the logical "organizations" or operations for information processing of adult intelligence. This is the epigenesis of the mind. In this sense,

"Life is a continuous creation of increasingly complex forms and a progressive adaptation of these forms to the environment". (Piaget, 1936, p.3)

Piaget (1947) accepts the view that the emotional domain can be distinguished from the intellect but he regards them as inseparable.

"...all interaction with the environment involves both a structuring and a valuation...we cannot
reason, even in pure mathematics, without experiencing certain feelings, and conversely, no affect can exist without a minimum of understanding or of discrimination. (p.6)

Thus, humans develop gradually the ability of abstract thinking utilizing assimilation and accommodation to adapt creatively, while at the same time emotions which are inseparable from the intellect provide a basis for motivation. During this progressive development of the cognitive abilities of the individual one can recognize several different stages (see Hilgard, et al., 1975, p.75). Although the development of the ability for abstract thinking is placed between 7 and 12 years of age, the understanding of abstract concepts (e.g. the concept of number) usually occurs around the age of six. (Hilgard, et al., 1975, p.75)

Luria (1974) in a series of unique experiments conducted during the years of turmoil after the revolution (1930) has shown that illiterate people of far more advanced age did not possess the ability of abstract thinking. He showed that the development of this ability depended on the degree of education and/or interaction of the individual with more educated social groups. Luria conducted his experiments within the guidelines of the "experimental-genetical" method of Vygotsky.

Vygotsky (1934) argued that the source of man's consciousness is outside the individual himself and consists of the internalization of signs as a means of communication. Words were seen by
Vygotsky as signs. Signs and symbols enable men to master the lower psychobiological functions and elevate them to the level of the cultural functions. Thus, the higher functions are the inferior functions plus their organization or orientation. An intellectual reaction represents a system of habits. Signs and symbols signal object and/or behaviors and habits which are interrelated. Thus, the sign is never a symbol for an object alone but it also includes some interaction of the individual with his environment. The same happens with words as a signal system. Words are the raw material for the formation of abstract concepts.

Concept formation is the result of a complex activity in which all the basic intellectual functions take part. The process cannot, however, be reduced to association, attention, imagery, inference, or determining tendencies. They are all indispensable but they are insufficient without the use of sign, or word, as a means by which we direct our mental operations, control their course, and channel them toward the solution of the problem confronting us. (Vygotsky, 1934, p.58)

In this sense Vygotsky (1934) argued that there exists such a thing as "inner speech" and that relevant aspects of mental life had been ignored because of lack of research toward this direction. According to his theory, the development of the cognitive abilities of the child is a unitary process and depends on his education. In this respect, uneducated people would not have developed the ability for abstract thinking no matter what their age. Abstract thinking,
then, which is considered as a unique human characteristic would be absent in these persons. Thus, this characteristic reflects mainly the social condition of an individual and it is acquired by the interaction of the individual with society. In order to investigate this hypothesis Vygotsky:

"...proposed a method of investigation establishing "the zone of proximal development", that is to determine how a child solves a problem independently, and how he solves it with an adult's help." (Levy Rahmani, 1973, p.44)

Vygotsky died very young. Luria (1961) offered an instructive application of this method to the study of mentally retarded children. He also used a modification of the same method to investigate the cognitive development of illiterate people. He applied the same questionnaire to groups of people who had grown up in isolated villages, to groups of persons who had a minimal amount of education within cooperatives, and to other groups of more educated people. By this method he investigated "perception", "generalization", "abstraction", "deduction", "inference", "reasoning", "problem-solving", "imagination", "self-analysis" and "self-awareness". The results are striking. His conclusions are as follows:

The facts show convincingly that the structure of cognitive activity does not remain static during different stages of historical development and that the most important forms of cognitive
processes - perception, generalization, deduction, reasoning, imagination, and analysis of one's own inner life vary as the conditions of social life change and the rudiments of knowledge are mastered. (Luria, 1974, p.161)

These experiments show that the stages of cognitive development described refer to some concrete social conditions. They do not depend on the maturation of the brain which through an interaction with the environment reaches the stage of abstract thinking, etc. Conversely, for the biological development of the brain, sensual information inputs and perhaps inputs of other elementary forms of information appear to be adequate. However, the development of mental abilities (cognitive development) is not a direct result of the biological maturation of the brain. It requires the additive effect of interaction with society. From all the societal factors which influence the mental development, education appears to be the most important factor.

In conclusion, man's cognitive development should be viewed within the following framework.

Based on the abilities of the living matter for abstraction, generalization, and on the "conditioned reflex", we have the evolution of the anticipatory abilities of the brain. On this basis, formation of signs and symbols becomes understandable. Language, a unique human characteristic, is a system of signs which, due exactly to the above-mentioned properties of the human brain, includes in
the words not only the reflection of the outer reality but also the anticipatory action of the living matter. Thus, linguistic symbols have inbuilt in them a reflection of the inner qualities of objects, behaviors, etc. During the process of thinking, interconnection of these qualities results in the formation of concepts through the action of abstraction and generalization. Abstract thinking represents the ability for categorizing into the same general categories more and more highly abstracted concepts. This ability, because of the type of development of man's cognitive structure, is immediately related to the individual's social environment and especially to his previous education. This, in a way, reflects the amount of pre-existing knowledge which, by a quantitative building up of experience results in a qualitative difference of thinking, which, however, is mediated by the same physiological mechanisms. In this sense, education is of paramount importance for the individual. Furthermore, abstract thinking would not be possible without the evolution of language through social means. The individual himself, in the process of learning a language, attributes the conventional meaning to the words only by acting to test their meaning through a trial-and-error behavior in the framework of a society.

We have now seen the mechanisms by which concepts acquire their meaning. The interplay of the human brain with its environment gives to the concepts their diversity and their plasticity. These characteristics constitute both the weakness and the strength
of concepts in the sense that careless use of them lead to confusion, but, on the other hand, they enable us to do abstract thinking. Perhaps, the ultimate wisdom for effective communication is to demand a clearing up of the concepts and agreements for action on surely "agreed grounds", since "each one of us forms a framework of concepts in idiosyncratic ways, even when we attend the same schools and experience similarities" (Novak, 1977, p.202). Although "this uniqueness of the individual gives the human race its enormous collective potential", on the other hand, it causes obscurity in concepts. As a result, some problems cannot be solved because "insofar as problems are solved - from the daily problems of individuals to the pressing problems of society - they are solved by humans using concepts" (Novak, 1977, p.202).

The description of concepts in terms of brain function and markers provides us with the opportunity to clarify the concept of concepts. But many concepts may be emotionally loaded. Indeed, some concepts are heavily loaded with different emotional messages. Analysis of this relationship is therefore necessary.

**Emotions**

Emotions are built up by the same materials of the brain: Electrical impulses, etc. Excitations of the brain, of emotional origin, should follow the same physiological rules that all other excitations generated in the brain follow in order to be appreciated
by the individual. And it seems that they really follow them since they may occupy at a certain point in time the center of consciousness. Theoretically then, I should not separate the discussion of the physiological basis of emotions from the previous discussion. There are, however, some differences which made me decide to separate it. First, it is believed that emotions are the reflection of regulations concerning the internal environment of the brain (Stanley-Jones, 1970). This makes them somehow different from the rest of the mental processes, although they continue to belong fundamentally to the category of information processes. This time the information concerns the inner brain environment.

Secondly, they appear to be more closely related than the rest of the information processes to the autonomic nervous system. For these reasons I prefer to discuss them separately.

The fact that emotions are closely related to the autonomic nervous system causes them to be more closely related to systems such as the endocrine system. They are responsible for the homeostasis of the inner environment of the body as is the endocrine system. Indeed, hormone secretion appears to depend on a number of feedback mechanisms. Some of them are closely related to the function of the autonomic nervous system. From this point of view, I speculate that the markers into which messages related to emotions are translated may be different in the sense that they may have some characteristic which will make them more easily accessible to the autonomic
nervous system and to hormones. Whether this depends on the location at which the "emotional circuits" of the brain are formed, or on some differences in the neurons themselves which realize these interconnections, or in the neurotransmitters that are secreted, is not known. But I do not want to exclude the possibility that some difference in the markers themselves may exist. That is, a difference may exist in the nature of the raw material on which the brain inscribes the "emotional" information it processes, or in the location of the neurons responsible for "emotion" in time-space. Of course, these thoughts are highly speculative. But since this possibility should not be excluded, let us classify the messages and their resulting markers into two categories: Emotional and non-emotional. This will be done only for purposes of analysis.

It is a fact that the brain works as a whole and that everything in the brain is interrelated. Any kind of sensation reveals a kind of emotion. What we mean by "emotion" colloquially should be interpreted in terms of brain function as regulation of the brain's internal status.

Emotions may be perceived as corresponding to the information that the brain has about its own inner environment. The neurons exchange messages among themselves to constantly inform each other about the internal environment of the brain, and regulate mechanisms - and/or feedbacks - by which the brain keeps its internal environment. It is not known exactly how this process works, or
how everything we perceive as emotions (love, hate, rage, lust, etc.) corresponds to these processes of the brain. Nevertheless, it is believed that:

...Human emotion is primarily homeostatic. Its purpose is to maintain an attitude of tranquility which is as necessary for the proper working of the higher faculties of the mind as in the constancy of the milieu interieur for the working of the body. (Stanley-Jones, 1970, p.23)

And Kugelmass, in his preface to Stanley-Jones' book states:

The nervous system is a coherent network of reflex arcs acting upon each other to modify the relationship between the incoming information and outgoing command....The author view homeostasis of the nervous system in kybernetic terms describing the crucial processes concerned in controlling the physical and chemical properties of the internal environment. Emotion, thus, maintains mental homeostasis rather than disturbs it. (Kugelmass. In Stanley-Jones, 1970, pp.V-VI).

This is not a common belief about the physiological role of emotions. There is no debate as to what are the emotions in psychological terms (hate, rage, etc.). But in terms of the physiological mechanisms of the brain that operate when the individual is under the influence of emotion, there is no consensus. There are psychologists who believe that emotion in terms of physiology represents some disturbance of the inner homeostasis of the brain
Hilgard, et al., 1975) and not the maintenance of homeostasis.

In any case, the most plausible hypothesis as to what concerns the relation of concepts and emotions is that markers representing emotions are also formed during times when the brain is inscribing information from the environment, which ends up on the formation of concepts. Novak expresses a similar position when saying that "some form of internal (emotional) information is stored in the brain" (Novak, 1977, p.27). Therefore, most of the time recalling an experience reveals through associations to emotional markers several emotions.

In the case that the sensual experiences are judged as pleasant or threatening by the individual, a series of reactions takes place which is related to the inner homeostasis of the brain. It is really of little importance for my purposes at this point to decide with what type of mechanisms - upsetting or maintaining the homeostasis - emotions are related. As an educator, I am concerned with the possible impact of the interrelations of the cognitive experiences and emotions on learning.

Learning will be realized when and if the sensual experiences that are processed by the brain will have the opportunity to occupy consciousness for a while, so that they have the opportunity to be inscribed in the brain. If emotional markers, in spite of their possible difference from other markers, must also be appreciated
by the brain in order to be understood, it follows that for a certain period of time they will occupy consciousness. For this reason, during that period, learning will not be possible. This may explain why emotionally disturbed individuals cannot learn. On the other hand, association of a sensual experience with emotional markers may help learning. Because, recalling the emotional markers that are associated with this experience, one may recall, also, the experience itself. Thus, emotional markers and good use of them may help learning. The association of the emotional with cognitive markers may also be the basis of the explanation of the so-called aesthetic experiences. If the cognitive marker that an artistic creation reveals generates an emotional marker through associations, then the aesthetic experience is explained. How true this is I do not know. The whole area is only speculative since very little work has been done on emotions from the physiological point of view, despite the enormous interest of psychology in them.

In conclusion, seen from the point of view of "markers", and "marker formation", emotions are tightly related to the cognitive functions as cognitive functions are related to aesthetic-emotional processes. Emotions may also facilitate learning, while emotional disturbance impairs it. The brain works as a system. And its inner environment (emotions) is at least equally, if not more, important to the brain than its outer environment (cognitive processes). Everything, then, should be viewed as a whole: Evolution and
development of the brain during an individual's life, and continuous interrelations of all its functions during any type of performance, including learning.

Theory of Learning-Re-evaluation

Before I start discussing creativity and creative thinking, I feel that a re-evaluation of the theory of learning which I presented in the previous chapter is needed.

An individual who begins to learn, has behind him all the previous evolution of the nervous system of the human race. From this point of view, inheritance provides us with tremendous possibilities: It provides us with a brain. But this does not mean that if there will not be interaction with the environment, the possibilities will develop by themselves because the same physiological mechanisms have to operate in order to develop the existing potential. Thus, I consider inheritance as a factor which greatly facilitates the evolution of learning in an individual, but which alone will not promote learning. Consequently, I attribute great importance to environmental factors. On this basis (see my discussion on concept formation and abstract thinking), I can see why we learn differently than animals, but I do not accept that we can learn if we do not pass through the same physiological mechanisms that all neuronal tissue has to pass in order to learn. Viewing then, from this platform a possible theory of learning, I
may describe it as follows.

All learning is built on the basis of information processing and marker formation. An individual must be born with some kind of already-created markers during his gestational period. All other kinds of behavior, however, which develop after birth, may be considered as "learned" behaviors. Even sleep habits\textsuperscript{24}, or seeing, hearing (see p.88), etc., are learned behaviors. Information concerning these functions starts being processed by the brain immediately after birth. The information is sent to our brain by our surrounding realities (entities, behaviors, etc.). This information is processed by the brain in parallel with a whole host of other similar and different information being analyzed and re-synthesized by the brain which is working as a mixed digital-analog system (Von Neuman, 1958). The information which is processed is eventually inscribed in the brain in neuronal circuits by biochemical reactions (Anokhin, 1974). These constitute the markers of the information that represents reality, which is inscribed in the brain. The markers that will be formed, have to be formed using something already existing (materials as shaped by previous

\textsuperscript{24}\textit{That sleep is a learned behavior is extensively and persuasively analyzed by M.B. Sterman and Toke Hoppenbrouwers in a paper entitled: "The Development of Sleep-Waking and Rest-Activity Patterns from Fetus to Adult in Man". In \textit{Brain Development and Behavior}. M.B. Sterman, (Ed), New York: Academic Press, 1971, p. 203.}
markers). That is, they are evaluated, measured against these previous existences. This evaluation may introduce modifications of the initial form that the markers may have had, if these types of experiences were not there. In this modification all representations related to the process of marker formation participate. Thus, the types of behavior that will actually be elicited as a result of the marker formation participate as well. In this sense, behavior modifies information processing and marker formation in the brain, actually participating in the learning process.  

From this point of view, learning constitutes inscription in the brain of valued information. Value is attributed to information by testing through action. This whole process that ends up in such inscriptions of information may constitute what Mandler (1954) calls a "differentiating response". In any case, this now constitutes a model which the brain is able to recognize as the pattern of a certain type of information, and which the brain is able to recall by as yet unknown mechanisms.

As a result of the continuous firing of all its neurons the brain is working in the environment of the continuous existence of a certain electrical potential. This is the basis by which the brain works as a whole (Luria, 1972). Any new incoming information or any model that will be recalled has to be higher than this basic

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25 The above-described processes correspond to the concept of assimilation of Piaget.
potential, the threshold of the brain, in order to be appreciated, in order to dominate for a certain period in the brain's electrical forces. This is called consciousness (Amosov, 1968). In other words, the brain becomes conscious of a reality because for a certain time it is dominated by the electrical impulse that represents, as a model, this reality. The pattern of impulses that dominate the brain for that moment is called thought (Amosov, 1968). It is obvious that two impulses cannot simultaneously dominate the brain's potential. This constitutes the rule of force (Pavlov, 1923). However, due to the simultaneous function of inhibitory synapses, the brain cannot remain for long under the influence of one dominating pattern of impulses, but it switches to another. This characteristic of the brain is referred to as plasticity (Luria, 1974). The interchange of pattern of impulses existing in consciousness, constitutes thinking, i.e. a switch from one thought (dominating pattern of impulses) to another. All other patterns of impulses or models existing or being created by the environment of the brain, and not dominating at a moment, constitute the subconscious (Amosov, 1968). It is then possible at the time at which the brain switches from the one thought to the other, to switch to a pattern of impulses which is closer to the one just switched off. Close patterns of impulses are probably closely interrelated and the possibilities for interrelated entities to achieve a state of excitation capable to dominate on the electrical activity of the
brain, are higher than the possibilities of non-related entities. In this sense, the subconscious plays, in a way, a very important role in preparing for the next thought which will be viewed in consciousness. There is, of course, the possibility that such continuation of thoughts may be disturbed by external factors. These factors, although not related to the thoughts being in consciousness at the moment, may generate such a potent excitation that automatically the brain comes to be dominated by the pattern of impulses that the external factors created through sensoria. And there is, of course, the possibility that external factors generate rather mild excitation which cannot dominate the brain's electrical activity immediately; but by the way they enter the subconscious and are associated with it, they contribute to the preparation of the next state of excitation of the brain. In other words, they may modify the course of thinking. On this basis we may understand how importantly associations of models, which have been established, influence thinking and also how new associations may be formed.

It is conceivable that new associations, new information, or new behavior will influence and modify by their mere presence the models that have already been inscribed. To the degree that these factors modify the previous models and to the degree that they will influence learning, understood as the inscription of models (or patterns of impulses) in the brain, they will also influence
perception of reality, the pattern of impulses representing reality. In terms of markers, this may be understood as modification of pre-existing markers by reshaping them or by adding new connections in them. Modification of a pre-existing marker is more likely to occur than a de novo inscription of a new marker, since we know this last to happen with repetition of an experience. This function of reshaping and creating new associations for existing models may correspond to Mandler's theory of the formation of a central analogic structure.

For us educators, this is important because it shows that learning is more easily realized when we can relate concepts that we want to teach with concepts that have already been learned previously. Finally, relation of learning with thinking, reality and the physiological functions of the brain, shows that learning may happen any moment of the day or night if a unit of information related to the environment is processed by the brain and is inscribed as an impulse pattern in it. It also demonstrates that learning is a life-long process.

Creativity

I will now try to analyze how creativity and creative thinking may be understood in terms of physiological functions of the brain.

26 This corresponds to Piaget's modification of schemata through accomodation.
This is indispensable in order to fully analyze correspondence of learning, brain functions, and representations of reality; resynthesis being realized through an ideal model, is never identical to reality and is considered always as some kind of creative work.

I separate creativity from creative thinking, defining creativity as the property of humans to see existing realities from new points of view and act accordingly, creating new items, behaviors, pieces of art, etc. I define "creative thinking" as the mechanisms of the human brain by which it obtains a new (creative) resynthesis of reality. Thus, creativity has creative thinking as one of its conditions, but it also depends on other factors. However, creative thinking is not necessarily followed by creativity. Following this line of thinking, all learning is considered by some as dependent upon creative thinking (learning presupposes thinking and thinking presupposes resynthesis).

Creativity is a concept overloaded with different, frequently confusing meanings. I will analyze and discuss creativity extensively. Because of the diversity of issues, the different parts of the discussion may at first appear unrelated. The reader is asked to have a little patience. I will relate all the parts of the discussion at the end of this section.

As a starting point, I will use a paper by Cohen (1962) on "Information Theory and Music". Music is perceived as a system of
signs; songs are perceived as different patterns of these signs and the composer's work as a synthesis of these signs, according to a new pattern. In this article, Cohen examines the results of computers synthesizing music, and he evaluates computers as potential music composers. In the course of this, he examines music composed according to analytical patterns, synthetic patterns, or analytic-synthetic patterns. A composer's work is traditionally viewed as a creation.

Creativity is traditionally seen as a purely synthetic capability. If this were correct, computers that were fed with musical signs and synthetic patterns should be able to compose music by choosing the correct pattern of synthesis for the appropriate signs. The questions that follow such an understanding are obvious. How can a computer choose correctly among this material to produce a synthesis aesthetically acceptable? Who is going to judge the acceptability of the new synthesis? Is "choice" a matter of probabilities only? What mental processes does a composer use: Only synthesis or others as well?

Jonathan Swift once said that good writing was a matter of getting the right words in the right order. Similarly, a composer's task can be described as selecting among available sounds and arranging these sounds into some sort of pattern. (Cohen, 1962, p.137)
In this sense, creative synthesis can be viewed mainly as a function of choice; and creativity may be viewed as synthetic capability, under the condition that the pattern of the synthesis is something new. If the pattern is new, a new synthesis comes out. A creation has been formed. Let me now follow this notion systematically, at least, in the realm of the arts:

The machine cannot have any artistic capabilities ...(although) it might be remembered that quite a lot of computer painting and computer poems exist ...(But) whatever you do with a computer it does not genuinely paint pictures, write poems, etc., the point being that there were some sort of genuine and spontaneous feelings and emotions which accompanied the spontaneous (or sometimes so) activities that go to make up the artist. The real question, therefore, is whether this is impossible to reproduce even in principle. The answer seems to be that it is not impossible. (George, 1974 p.9).

That means that if we could feed the computer with the right feelings and reactions to help it choose emotions while synthesizing, it may associate a new synthesis with the appropriate feelings and emotions and become a true composer. This being in principle possible, we have to analyze the associations of the patterns (new or old) with the feelings and emotions in order to find out if we can do this.

Information theory, by the use of several integrations (Shannon's measure of information, Markov's chain, etc.) can put
the musical alphabet in different sets of probabilities (pure synthetic approach). In fact, people started doing this in the beginning of the computer era; but the results were trivial, not creative. Many researchers, then, tried to use the process that the brain uses: The analytic-synthetic process.

The Analytic-Synthetic Process

Although present computers cannot induce generalized rules, but can only deduce, they are able to induce probabilities by counting relative frequencies and are able to use the results for probabilistic deduction. (Cohen, 1962, p.143)

These researchers then did the following: They analyzed many samples \(\{S_1, S_2, S_3, \ldots, S_n\}\) of different tunes, then formed a set of probabilistic generalizations \(\{G\}\) and, on the basis of these generalizations, they formed synthesis: Outputs \(S'_1, S'_2, \ldots\ldots\).

\[ (G) \]

\[ S_1, S_2, S_3, \ldots, S \]

\[ S'_1, \quad S'_2, \quad \ldots, \quad \]

Figure 16. General model of the Analytic-Synthetic process.

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\(^{27}\) F. P. Brooks, Jr., et al. (1975), H. Quastler, (1955) and J. E. Cohen, (1962) to mention but a few.
In some cases, they had satisfactory results.

Cowboy songs: The first analytic-synthetic application of information theory to music...analyzed Western Cowboy songs to obtain transition probabilities for every note preceding a particular note. From a final note C, they started a Markov chain with the proper probabilities going backwards after selecting a standard form and rhythm. Two "perfectly convincing" cowboy songs resulted from a few dozen random walks of the chain.... (Cohen, 1962, p.143)

This is not the only approach to music composition by computers that Cohen reviews in his paper. He also describes three types of application of Information Theory in music, i.e., analytic-synthetic, purely synthetic and purely analytic. I already have described the analytic-synthetic application.

According to the synthetic application, "composition may be regarded as selecting acceptable sequences from a random source" (Cohen, 1962, p.149). In fact, "the synthetic applications of information theory to music are really a special case of the general analytic-synthetic process....In all synthetic experiments human analysis of existing musical samples yielded the body of rules and restrictions" (Cohen, 1962, p.149). Thus, according to this application, the researchers were using patterns or fragments of patterns for musical composition from random sources, putting them together; they also used randomly other materials: Keys, notes, etc. from random sources. The results were disappointing. It was as though
one had taken parts of an airplane engine and connected them according to the pattern of a tractor engine.

The analytic studies (applications) are also a special case of the analytic-synthetic process. Their primary goal is to obtain a set of generalizations about a sample of music. But their more ambitious goals are expressed by Rameau:

Music is a science which ought to have certain rules; these rules ought to be derived from a self-evident principle; and this principle can scarcely be known to us without the help of mathematics. (Rameau, 1722, pp.565-566; Cohen, 1962, p.150)

Several researchers obtained the needed generalizations either by analyzing musical samples or by the use of mathematics. Using these studies, they did not succeed in making a computer compose good music. They had, however, more success than with the synthetic studies and they were able to use many more approaches to the problem than with synthetic studies alone. Characterization of the music, composed by computers, as good, bad, or acceptable, is done by us listeners and Cohen takes that into account. He concludes that "information theory alone cannot say what the nature of musical experience is. It can only be applied to a conception of musical experience which is arrived at by other means"(Cohen, 1962, p.162).
No matter what Cohen's conclusions are, the way these researchers looked at things, for example, "composition as selection", "styles as probabilities", etc., and the fact that the analytic approach was slightly superior to the synthetic, and the analytic-synthetic to both, put the problem for me in its correct dimension. Creativity should be viewed in all its interrelations: As a new synthesis, as acceptance of the new synthesis, and as factors related to the creation of the new synthesis and its acceptance. This gave me the initiative to follow a certain line of thought in approaching the question of creativity.

Let me first analyze what I may understand as creative work or creative ideas. In science, interdisciplinary views are usually creative views. Gibbs, for instance, was a statistician and a physicist. His probabilistic ideas (statistician) about the existence of many universes (physicist), are considered highly creative. In art, creative ideas are much more difficult to describe. They are more closely related to emotional than to rational acceptance from the part of the public and, thus, judgements about them are much more diversified. Generally, I would describe as artistically creative a synthesis that would evoke in me emotional-aesthetic pleasure.

Creation, as a new synthesis, depends on processing information through a new pattern. As Cohen shows, a random pattern has almost no probability of giving an acceptable output, although the output
is a new synthesis. What could be the reason for that?

One could typically analyze it from the point of view of "creator" and from the point of view of "public". I will take a different stand. I will analyze it from the point of view of "relations", i.e. creation as a result of the relation of all persons, creator or public, with their environment.

The creator is related to the environment he comes from, i.e. his creation is related to the markers he carries in his head. We have seen that without interaction with the environment the brain does not develop. We have also seen that heredity can be perceived only as the facilitator to the process of brain development. In this sense, heredity by itself, cannot account for spontaneity. Nothing can come out of a brain, despite our inheritance, if the brain has not previously interacted with the environment, and if pathways and associations have not been established through previous experience. As a consequence, one's creative "inductions" will depend on his previous experience. Or they may be created in the subconscious through concurrent experiences. This factor then, is what gives to the creator his criteria to choose the appropriate pattern for a new synthesis.

On the other hand, the recognition of a work as a creation on the part of the public depends on how the public can relate to this; because it may be that other people, aside from the creator himself, cannot understand the creation at all. They may consider it as
trivial or schizophrenic because they cannot relate to it through any kind of associations. This, again, will depend on the previous experiences of the receivers.

Therefore, the successful synthetic work which is a creative work, seen as a result of the usual brain functions, depends, in all cases, on the relations of the individual with his environment. But this is not the only aspect of a creative work. The other factor is the very fact that the creative synthesis is new. That is, during this synthesis new associations, new "insights" (Bargar, 1975) have been obtained in different mental patterns or models. This depends on the ability of an individual to deviate acceptably from trivial models. Both factors are working in both cases, the case of the creator and the case of the public, but with different weights. For the creator it is more important to "deviate" and form new associations, and for the public more important to "know" many things in order to understand the new associations. But in both cases creativity depends on: (1) the richness of the previous experiences, and (2) the freedom for deviations from the norm. Now, this depends on the confidence that an individual will have in himself. Let me analyze these factors.

The first means many and very careful analyses. The second means the degree of freedom existing in the creative mind to escape from what he now knows and to permit himself to think uninhibitedly.
The following discussion scrutinizes the factors that may inhibit a potential creator. A person acquires freedom in thinking only when and if he gains confidence that he can think correctly. And this he cannot acquire unless he really thinks correctly, which means meaningfully (by "meaningfully" I do not mean only logically, but also rationally and substantially). On the other hand, a person cannot really gain confidence in himself unless he is accepted by his environment. And this happens only when what he says or does makes sense. So, his freedom from others depends on his acceptance by them. Let us see how can one obtain this freedom.

A creative work is, from a certain point of view, a new "explanation", a new theory about a part of the world, or an event, etc. It demonstrates to others an aspect of reality which, probably, was hidden from their eyes, or not accepted by them, perhaps because of the conditioning of their brains. Thus, the things that a creator will say or do should make sense; and they will do so when they are meaningful. This is in accordance with the brain's function. The brain, a digital-analog system, processes information by analyzing its environment. This process is realized under strict rules of logic (digital). This logic, however, makes sense only when it corresponds to reality. The brain developed its logic because of and not despite its relations to reality. Thus, it has a logic which corresponds to reality, to nature, and which should be included in the creation in order to be recognized as such. Thus,
the nature of the brain itself shows us the way by which we can be creative. And, it seems to me, that this is the only way.

People prefer stereotypes because they feel safe when they are protected under the logic of others. But when one follows stereotypes he is not creative. The creator should be free to form new associations. But in order to do so, he should feel secure, i.e. accepted by others. The creative work, however, might not be recognized as such for several reasons. Thus, the creator, in order to feel secure should be confident that by checking his associations with his mind he finds them meaningful. He must not depend on others. Based on these thoughts, I find that: (1) there is no real creative work which is not meaningful-logical, at least for one person, the creator. If we do not understand it, we may lack some information which, when acquired, will show us the links of the new creation with some aspects of reality. There are, however, especially in the arts, some people who exploit the notion of "diversity", constructing meaningless work. This is not creation. (2) The mechanism of acquisition of "freedom to create" is circular and works through evaluations of new incoming information versus the old previously-processed information. Everything which is
new is related emotionally with the fear of the unknown.\textsuperscript{28} As a result, the new information is rejected by the individual when he is given the opportunity to continue to be safe without learning it. When the new is rejected, the brain is safe, but it has not learned. If, however, by some mechanisms (pressure from external necessity, "learning by stress", or alleviation of the fear through another person's support) the individual manages to acquire a certain amount of knowledge, the next time he will have less "unknown" to be afraid of, because of his increase in knowledge. He will also have the experience of how to acquire knowledge. This, then, is the circularity of the process: Overcome the fear of the unknown to acquire more knowledge, which, in turn, liberates from the fear of the unknown and helps acquire more knowledge. The individual becomes free to incorporate the new only when, after the acquisition of a certain amount of knowledge, he gains self-confidence which liberates him from his own fears that usually enthrall him to his environment.

\textsuperscript{28}Fear of the unknown originates in the basic need for survival as learning by adaptation (see also pp.235-238). Ignorance of what may be the impact of a new (unknown) situation on the well being of the organism is creating fear, hesitations, doubts, and, generally, a negative behavior toward the unknown; the organism adopts a protective attitude to confront a new situation. On the contrary, the need for inputs (living organisms are open systems) leads to interaction with the environment which is the basis of learning by adaptation. To accomplish this need, the organism takes an exploratory attitude. These two attitudes (protective-exploratory) are in many ways contrary to one another. The way to reconcile them within the organism is by a circular process during which the one or the other attitude prevails.
The brain is a mixed system working simultaneously as a digital-analog information processor. Its logic, the logic of its environment, is incorporated in its digital part; as a result, the brain does not accept any information which has "logical contradictions" in it or which logically contradicts previously-inscribed information, or which it has not the indispensable amount of previous information to render it meaningful. Thus, isolated information, contradictory (but not simply opposite) information, or meaningless work, will be rejected; they will not be accepted as creation. Since all information processed by the brain is being evaluated against previously-existing information, the values that the brain will accept as worthwhile are not standard or absolute. They clearly depend on what type of information is processed by the brain which further clearly depends on the type of the environment in which individuals grow up.

The fact that values are taught (they constitute knowledge) is easily exemplified. If one takes away an Eskimo's fur coat the Eskimo is upset. He knows that he will die from cold if he goes out without his fur coat. If one would give a fur coat to a jungle's permanent inhabitant he would remain indifferent. He puts no value on it. He does not know what the Eskimo knows about cold. Finally, these behaviors are not genetically determined, because if one raises an Eskimo child from birth in the jungle, this person will have the behavior of a jungle's inhabitant towards the coat, and
all other things, of course. Therefore, values depend on previous experiences of an individual. They are learned.

Considering this process in relation to the need for acceptance by the group, one may understand the meaning of "cultural conditioning". One's own social environment and values are naturally internalized and highly appreciated. It is very difficult to persuade someone to learn something new, let us say a new creation, a new view of the world, if this novelty contradicts previous beliefs which are built upon internalized values. The brain rejects the novelty almost naturally.

When novelties are so difficult for individuals, just to be understood, imagine what it takes for an individual to be himself the creator of the novelty. The only way by which one can really be a creator is to make new associations. And, in order to be able to make them without caring if he is rejected by the group, he must become confident about his thinking, about himself. For this purpose, he must first overcome the cultural conditioning which is realized naturally, because everyone is raised in some kind of society. This he can only achieve if he undergoes the circular process that gives him confidence through knowledge.

These are, for me, the conditions for creativity. As a result, I see creativity as a characteristic found rarely, only because rarely may people overcome the difficulties I mentioned. But I do not see anything mystical in creators. Also, I do not consider
creativity as depending on some "special ability for synthesis". If an individual had reached the degree of freedom needed to make a creator out of him, then his creative work would mainly depend on the richness of his experiences, offering to him more probabilities to achieve more free associations. On this basis, I explain why application of analytical approaches to "composer" computers gave better results than did application of synthetic approaches only.

Finally, discussing the concept of creativity let us briefly consider the so-called "split-brain theory" (Grady, 1978). This theory holds that the right hemisphere carries out holistic, intuitive operations, for example, "creative thinking", and that the left hemisphere carries out linear, sequential operations, for example, reading and mathematical computations. My understanding of the matter is as follows.

Constituting a mixed system, the brain works as a whole. From neuron to neurotransmitter, the analog type interchanges to digital, and from subsystems to systems, the two hemispheres work in relation to each other. There is the possibility that creativity corresponds to analog, and linear thinking to digital. But since every function of the brain goes back and forth from digital to analog, there is no way that one of the hemispheres processes information only the one or the other way, unless the right hemisphere did not consist of neurons which is not true.
What may be true is that there is a differentiation as to what kind of information is usually processed by the one or the other hemisphere. It appears that differentiation really exists and that the right hemisphere processes spatial, geometrical schemes, images and music. This, however, is only potential. For example, musicians who are trained to read notes, understand music by their left hemisphere. This has been proven (Johnson, 1977). Thus, for them it is not true that their left hemisphere does not understand music, because this hemisphere is logical and music "illogical". Besides, each hemisphere may have a differentiating function, but during re-synthesis both hemispheres operate as a whole. Therefore, creative work cannot be considered only as analog, located in the right hemisphere only. Since it is proven that digital works under strict rules of logic, no creative work, which is the final product of the whole individual, can be illogical. If it were illogical, it would have been rejected by the digital process. What may happen, however, is that what our brain understands as "logic", is not perceived as such. The following poem makes the point beautifully:

We are using our minds
To comprehend our brains;
As we do so, we acknowledge
That is is our brains that
Are comprehending our minds.
This is so because our minds
Are products of our brains,
And therefore less inclusive
Than our brains are. What we seek to understand already understands us better than we do. (R. Mooney, personal communication, 1979)

This is a natural outcome of the analysis of the back and forth digital and analog processes. The logic of the digital processes necessarily follows the rationale which exists in the analog process. Thus, the logic that exists in our brain is the one logic that nature and generally our environment has. This means that because of the way we have been culturally conditioned or because of lack of associations, we may be inhibited from understanding a creator's logic, although it may correspond to nature's logic.

The previous discussions explain only partially what is the basis of creativity. Because, if things were only as I described them up to this point, then, logically, computers could become creators, if we could achieve sufficient technological perfection. Although some researchers support this point of view, from what we know this cannot be true. Computers can create only according to patterns that we humans give to them. They cannot create new patterns. Humans possess something which operates as a source of new aspects of reality; something which shows to us hidden aspects of nature, revelation of which by us is in accordance with nature's logic; this constitutes creativity. Then, I may say that computers do not have creativity at all.
Then, where is this meaning of creativity hidden, the true meaning of creativity of the human brain? And to what physiological functions of it may creativity correspond? My personal view on the matter, based on systems and on Pribram's theory (1978), is as follows.

Creative thinking is different from creativity. I understand as creative thinking only some functions of the brain which help us reveal new aspects of reality. I understand as creativity the very inclusion of all aspects of reality in our brains.

I associate this characteristic of the human brain with the natural features of light. Light is composed of many wave lengths. Our brain can sense through the sensoria (and because of the nature of them) only a limited number of these wave lengths. We have learned, however, through the laser beam, that any one of these waves carries with it the picture of an entity through which it has passed in its entirety. This has been proven because we are able to reproduce the entities that have been photographed on a silver plate by lensless photography, in their three-dimensional entirety, by passing a laser beam through even a small piece of them. The projections are called holograms. 29 I believe along with Pribram that the brain, while processing information by analyzing it into

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29 The notion of the brain performing holography, interpreting the holographic universe, is extensively discussed in a whole issue of the journal "Re-vision", Vol.1 N° 3/4, Summer/Fall, 1978. See, also, Pribram's article in the same issue. pp.14-18.
parts and patterns, processes it as holograms also, which include the whole entities that we see, the whole of reality.

Being in possession of such aspects of reality is the source of creativity and it may become possible for the brain to appreciate in its consciousness, new aspects of reality through new associations during resynthesis of information which is being or has already been processed. In fact, this is always possible for the brain when it works uninhibitedly. Nevertheless, for the brain to become able to perform new or free associations, all the conditions of freeing itself from emotional-cognitive previous limiting experiences must be realized. Otherwise, it cannot perform free, creative associations.

For the purposes of the present study, namely the generation of propositions for educational processes based on learning, such an extensive analysis of creativity may not have been needed. However, I had to develop all my views on creativity in order to defend my subsequent analysis of creative thinking. Otherwise, someone rejecting my views on creativity could have rejected creative thinking and subsequently my propositions on educational processes which depend on it.

In any case, what may be useful for an educator to know out of all this discussion is that if one wants to make a potential creator out of a student, the way to do it is to build confidence in him about his mental abilities.
From this point of view, and in combination with what I said regarding concept formation and self-confidence (being built up only through acceptance of the individual by his environment) one can already visualize a correct way of teaching. The teacher knowing how these mechanisms work, understands the brain of any learner as a brain struggling to understand any "new" concept that is presented to him as an unknown and thus threatening knowledge. Briefly, the teacher learns what is the cognitive status of the student and by means of demonstrating to him similarities of the new knowledge with the previous associations, thus alleviating the learner's emotional disturbance that the knowledge itself causes, eases the assimilation of the new knowledge by the brain. At the same time, the teacher tries to remove all "other" obstacles that may stand between the student's brain and the new knowledge. The learner, growing in knowledge, becomes able to formulate logical arguments built upon the knowledge he acquires. By doing so, the individual gains social acceptance, because usually logical arguments are accepted as correct. Growing in acceptance, the learner becomes more self-confident and, thus, less afraid of confrontation with any new knowledge. Of course, after a certain point of a learner's growth, I believe that he may learn anything he may wish by himself.

A few points concerning creativity may be worth making: (1) My concept of the brain's functions points to an understanding
according to which creativity depends mainly on analytical and not very much on synthetic processes, given the condition that the creator has reached the degree of freedom needed to perform free associations. This has been observed widely and is explicitly expressed by many people who say that you have to know your subject in order to come up with new ideas. I believe that this means that when performing an analysis, if a brain has a lot of models relative to the analyzed information already inscribed in it, the subconscious can prepare more associations. Thus, a person might make some comparisons and come up with a new model, freedom for him to do so being considered, in this case, a precondition: (2) If one does not learn well his analysandum, he cannot make successful associations. This last is the reason, I believe, underlying the emphasis some authors like Sarason (1972), for example, put in the analysis of the schools themselves, if one wants to bring about a change (i.e., a new model). These authors emphasize freedom also, and they perceive this as a person's ability to get rid of norms.

In conclusion, creation as a new synthesis is not a random choice. It requires a deep interest in a subject, which leads to multiple and deep analyses of it, and to long practice with different aspects of the subject. All these lead to even deeper knowledge of the subject and its relationships with the environment. It requires, also, a high degree of personal freedom. So, if one is full of these rich associations, if he also possesses a high degree
of freedom and self-confidence, then, he may succeed in seeing new associations of the subjects; that is, he may bring into the center of his consciousness "the associations" with other models which cannot come otherwise into the center of his consciousness. Every type of creation is related to emotional experiences. But when the creator is really free, he may probably reach deeply rooted associations; then, his creations can reveal powerful archaic emotions. Any type of creation and/or creative understanding, and not only the one related with artistic work, can reveal such emotions. Creative thinking is a condition for creativity. Creativity does not depend only on brain functions, but on the condition of the individual itself.

What is needed is an understanding of creative thinking which has to be distinguished from creativity in order to avoid misunderstanding. I will elaborate on the notion of creative thinking in the next chapter in order to show that the process of creative thinking does not take place only in the cases of special people, who possess special characteristics of thinking creatively, but it takes place all the time we are learning by an interrelation of learning with adaptation to new situations.
In this chapter I address myself to education and educational development. A familiar way to approach the subject is to initially examine by way of "analytical philosophy" or "linguistic analysis" the meaning of the terms in which the subject is expressed. This approach consists of an analysis of available definitions. If a definition is not available, one tries to give a definition, clarifying precisely the meaning of the terms used.

The situation with definitions of "education" is well described by the following quotation:

Soltis continues with a realization which is important for anyone preoccupied with educational matters:

Under this barrage of definitions, however, a very crucial assumption is frequently hidden. That is,
we assume that there is a definition of education or the definition of education. (Soltis, 1968, p.2)

Then he addresses the obvious question: "Is there such a thing as the definition of education?" A possible positive answer to this question would be of crucial importance for me since I intent to, finally, make some propositions for effective education, and I would very much like to formulate propositions which could elicit consensus.

Scheffler (1960) discusses three types of definitions, the stipulative, the descriptive and the programatic. Stipulative is a definition given by an author who, knowing the diversity of definitions existing, wants to keep things straight by adopting one definition he proposes for a certain text and/or purpose.

The descriptive is the type of definition which enters into details or particulars. Dictionaries, for example, use descriptive definitions. However, when there are several definitions, it is understood that they are not offered as alternatives from which to choose (many definitions). The dictionary usually provides with different contexts in which a definition of a word may be used.

In this sense we should not have real disagreements over descriptive definitions. Use of different meanings of the same word to describe different situations does not mean that the definitions of the word clash with each other, because they are the result of the different situations that they describe. For example, a
stipulative may become a descriptive definition by frequent occurrence of the same situations, i.e. by frequent use of the word with its stipulative definition. "After all, the objective description of anything is but an attempt to be true to what is in the public domain." (Soltis, 1968, p.4-5)

Thus, the basis for disagreements over concepts defined differently—which frequently occur—is that usually definitions are not strictly descriptive. They include a small or bigger part of what Scheffler calls a programatic definition. Such a definition "tells us overtly or implicitly that this is the way things should be." (Soltis, 1968, p.5)

If I examine under this light the question as to whether there is such a thing as the definition of education, I see that, if there were such a thing, it could not belong to the "stipulative" type because this type serves occasional situations, by definition. Programatic definitions are obviously out of consideration also since it would be most surprising to expect "everybody" to agree on a certain program for education. Chances are that among descriptive definitions of education we might be able to find one which will meet general agreement (for example, "education is learning"); but,

It may very well leave us cold,...for when we ask for the definition of education it hardly seems that what we have in mind is such a broad, indiscriminate, and non-evaluative use of the term. (Soltis, 1968, p.6)
It should, then, not be surprising that educational definitions are "most probably a quest for a statement of the right or the best program for education, and, as such, is a prescription for certain valued means or ends to be sought in educating." (Soltis, 1968, p.7). After all, education is a human enterprise and as such it has purposes - emerging from a set of values and preferences - and requires that some strategy and some tactics be followed to achieve the purposes.

Soltis continues by stating that for him asking for the true programatic definition of education is like asking "which is the true religion of man" or "which is the true flavor of ice cream, chocolate or vanilla?", indicating by this that because the whole area is so heavily based on values and preferences, and because values - not to mention preferences - have diversity, the whole area is so diversified and controversial that he spends his whole book in "an attempt to get at the meaning of education".

I have no intention to spend the rest of my dissertation in search of the meaning of education. Therefore, no matter how cold it leaves me, I will begin with something that nobody disputes: That education has learning as one of its primary goals.

Furthermore, there is no dispute that the meaning of "the educating process" is an intervention to another person's life taking place for the purpose of facilitating a person's learning (Sanders, personal communication, 1979). Therefore, I will try to suggest
propositions about what could facilitate learning. I do not consider this a simple task, nor one which leaves me indifferent. On the contrary, I am passionately moved by this task because I perceive knowledge (which is the result of learning) as the key to freedom, security and happiness. Indeed, in a situation in which one does not know how to interpret his environment, he feels threatened by the unknown, and insecure. This surely is not a happy way to live one's life. Instead, when one can understand what he meets, he gets rid of these fears and he is less preoccupied with interpreting his environment. This gives him more time for himself, and this means freedom. But this is not the only reason why people should be educated. Intervention in someone's life for the purpose of facilitating his learning is justified by the fact that learning is the means to adaptation. Offering knowledge to the members of today's society through education should not only be viewed as offering them something with which they cannot do without, but is should be viewed as offering them something indispensable for their adaptation to society. How deep an impact education has on people's lives can be better estimated by the next example which demonstrates what catastrophic results the lack of education may have for the life itself of an individual.

There is a recent publication (Weinblatt, 1978) in which a statistical comparison was made between people with heart disease who are well-educated and people with heart disease who are poorly
educated. The study shows that the poor uneducated people with heart disease die 3.3 times more often than the educated people with heart disease. The authors are very careful to exclude from the possible causes of this increased rate of death in poorly educated people factors like age, race, color, sex, occupation, diet habits, etc.; generally, they excluded all factors that are known to contribute to a higher risk for heart attacks in patients with heart disease. The higher rate of death of the uneducated people correlated in their statistics only with the low level of education and with a higher and abnormal cardiac rate.

Physiologically, a high and/or abnormal cardiac rate may initiate a heart attack in persons with compromised hearts. The following is an explanation which tries to correlate the low level of education with the initiation of a high cardiac rate.

In a situation in which one does not know how to interpret his environment he usually feels insecure or threatened. If he is forced to "do" something, emotions will make his heart beat faster and faster. Then, if he already has heart trouble he has an infarct and he dies. I believe this is why uneducated people die from heart attacks much more frequently than educated people. They find themselves much more often in situations which they cannot understand and they feel threatened by such a situation. The effect of poverty, despair and social deprivation on learning and education has been well documented (Alexander, 1973). These conditions, being
to a great extent responsible for the poor education of these persons, render them not only socially inferior but also constitute a threat for their lives. Thus, this example indirectly emphasizes the importance of education.

Consequently, I feel that facilitation of learning (Sanders, 1977) is quite sufficient a goal for education if knowledge can help us adapt to today's society and can make us feel secure and free. I will elaborate on this.

One question that has been raised is how much of the knowledge needed by an individual for adaptation to his ever-changing environment can we pass to him by training. Modernization has created an explosion in knowledge and vice versa.

Explosion in knowledge may be one of the factors creating situations difficult for one's adaptation in modern society. Therefore, before I start any investigation of the ways by which learning can be facilitated, I should see if the human brain is capable of learning all that it should learn in order to adapt to today's sophisticated society.

The answer is that the human brain has almost unlimited capabilities. Szent Györgyi (1970) says that man's brain was not developed by nature to search for truth but to search for food; however, he says it proved to be a tool more formidable than anything else for survival; that it has many traits in common with the computer; and that education is nothing but the programming of the
brain. In fact, the brain has a formidable ability to learn and it is presently believed that we use only about 10% of the potential of our brain (Faure, et al., 1972). Therefore, there is no question of the brain's capability to learn. If one remains uneducated it will be for other reasons.

Conditions for Learning

Let us see, then, how we can facilitate learning. In this framework I will eventually have to examine the thesis that "learning" (which results in abstract thinking (pp.192-197)) depends on "creative" thinking (for my understanding of "creative thinking" see pp.259-266). If this is true, we will then have to find out how we can facilitate creative thinking.

I have already reached the conclusion that learning is a lifelong process. But, I have also mentioned that the brain, during an individual's life, undergoes evolution and differentiation by progressive mechanization. Then, it may be possible that learning is

30 In this chapter and thereafter by "learning" I will mean the full cognitive development of an individual: Beginning from simple reflexes (in which probably even "thought" may not be present and which represent the lowest form of learning), humans build up cognition to the point of acquiring the ability for abstract thinking. As an educator I am concerned with normal individuals all of which have the potential to reach this point of cognitive development. If this will happen early or late in their lives and if it will decisively influence their lives, it will depend on how well their learning will be facilitated. Since this development constitutes a continuous process from the simplest form of "learning" (reflex) to the most complex one (abstract thinking), I will thereafter designate as "learning" all the stages of cognitive development.
realized differently during different periods of an individual's life, although it continues throughout life.

Indeed, it appears that during the period of neurogenesis learning through information processing may affect different functions and/or activities of the brain than later in life.

Deprivation of information processing results in defective growth of the brain during this period, but not later on. Kittens become blind because of deprivation of light, while adult cats do not. Supposedly, in man, information processing during his first four years of life (neurogenesis) has the same results in the anatomical level as in kittens, since, if he is deprived of information during those years, he performs poorly in school later on in life (Faure, et al., 1972)

Man, during his neurogenesis, is creating in his brain the ways and the hooks for future information to pass through and hang onto. It appears that if these connections are not created, most of the information with which man will be bombarded in the future will not be retained by the brain, thus, it will not contribute to man's learning.

In addition, during early stages of life, children do not appear able to perform abstract thinking, while this feature characterizes the adult. A valid hypothesis, then, should be that since the results of learning are different in the child and the adult there may also be differences in the ways by which learning is realized in
the brain. This may mean that facilitation of learning should follow different pathways during these two different periods of brain growth.

To check this hypothesis, I should examine the methods (the ways) that individuals use by themselves while learning during these two different periods of life. The hypothesis which is most widely supported in this field is that learning originates in adaptation (Ashby, 1960; Piaget, 1947; Hebb, 1949; Hunt, 1961; Luria, 1976; Anokin, 1974, etc.). Learning through adaptation characterizes an individual's entire life but with different emphases at different ages. Therefore, I should just examine the relation of learning with adaptation.

Learning is a property of living matter. The result of the learning process, knowledge, constitutes the basis of adaptive behavior of all living organisms (man and animals). Living organisms are living within an environment, together with other living and non-living existences. Their primary purpose is to survive and for this purpose they have to learn in which ways they can coexist with all other existences. In this sense, learning is more than just the processing by the brain of information sent to the organism from all other existences and the inscription in it's memory. The living organism has to find out which of his actions will not result in his elimination.
That learning is understood in this way is supported by the cases of the "mnemonists" (Luria, 1968). These individuals have a so-called "photographic memory" which has the ability to inscribe all kinds of information which is presented to them. They can recall every place they have been and every situation that has happened to them for perhaps all the years of their lives. From the point of view of "learning", however, their situation is pathological.

Along with this trait there is also a non-selectivity about his memory, such that what remains behind is a kind of junk heap of impressions. (J. Bruner, In Rubinstein, 1974, p.553)

We see, then, that in this instance, what we consider as "learning" is not the mere inscription in our memory of the information that is being processed by our brain, but the inscription of information after a process of selection has taken place. The information which has been processed but which has not been selected as worthwhile is forgotten. I am not interested in the mechanisms which mediate forgetting or in the mechanisms between short-term and long-term memory. I am interested in finding out which are the mechanisms that the individual organism uses in order to realize his selection. And these mechanisms are the mechanisms of trial-and-error behavior. This always means action. Sometimes in adults the step of action is
not obvious. But it is potential and pre-experienced. The process stops, as in the example of replica, in the formation of an ideal model, and the action that the model implies is not explicit.

Therefore, learning, as I perceive it, always includes selection of a behavior through new or previous action. In other words, learning results in a change in the behavior of an organism based on experience. This happens if the environment changes. If the environment does not change there is usually no need for the organism to learn what reciprocal change to make in order to adapt. Thus, the notion of "new" is always included when we speak about adaptation.

Is change, however, the only initiator of action? It is obvious that if the organism existed alone in time-space he would not receive any kind of information from the environment about other existences, and he would not have any reason to get into any kind of activity. Thus, the coexistence of the living organisms with other creatures brings them into action. The result of this is what we call adaptation to our environment.

Ashby refers to it as a change in behavior for the "better" (Ashby, 1960). "Better" is understood as whatever promotes survival. It is necessary to understand this in respect to adaptation, because it appears that the nervous system can learn a wide range of possible behaviors and not only those which will promote survival. A combination, though, of what can be learned and what promotes
survival, constitutes adaptation to a certain environment. Learning, in this sense, is a combination of adaptive behavior and intentionality of the organism, the latter originating in coexistence.

The notions of homeostasis and stability of the variables of a system are central in this understanding. Ashby has proven that because living organisms, as systems, can exist only under external and internal "conditions", they must have balance in the relationships of the inner variables of the system they form, and of the parameters of the system they belong to, this being realized by "learning".

Actually, this conclusion presupposes that we conceive living organisms as open systems which, in order to continue existing, have to have inputs of mass-energy and information. Hence, they are forced, simply in order to survive, to interact with their outer environment in order to obtain the inputs that they need. But in acting to do so, they may create conditions which may be adverse with the mere purpose for which they act, i.e. their survival. Thus, they interact with it by a trial-and-error mechanism, modifying their behavior according to the results of their trial.

Thus, organization of their inner variables into a system, and coexistence of them as open systems with other existences in their suprasystem, is the basis of their intentional, active participation in their environment. This is the essence of adaptation which leads to learning.
Adaptation should not be confused with simple adjustment. Adaptation includes the notion of action in itself or of the active and non-passive participation in the environment. This notion has its roots in the intentionality which is present in any form of life as a result of its organization in open systems. The fact that we do not see it easily in lower forms of life does not mean that they only adjust to their environment, and that they do not adapt to it. It only means that they do not possess the means to act in such a way that would change their environment. As a result, the selectivity which they make use of in their adaptation-learning is limited to choosing among existing alternatives for action. This does not cause big, apparent changes in the environment and from this point of view, their adaptation is more passive and less apparent than ours. The fact, however, that they make a choice before any action, and then learn by that action is apparent from the fact that they demonstrate preferences in food, behavior, shelter, etc., which have been established after they tried these foods or behaviors. This is, also, manifested in the experiments concerning animals.

Let me take, as Ashby did, the example of a little cat which stepped into a fire, got burned and learned not to touch the fire. Next time, the cat went less close to the fire, did not get burned, but got very hot, and learned not go that close either. Finally, by a trial-and-error mechanism it found the place where it was warm and pleasant; not too close to be burned, not too far to be
cold, and it learned to sit there, ever after. The cat proceeding in its initial steps of learning, used a trial-and-error behavior in order to learn.

Active participation in the environment by adaptation, concerns individuals. Species evolution through selection of the fittest, works through individual adaptation, but it appears more passive because at the level of species the active participation of the individuals who give birth to the strain that will continue the species is less apparent.

This small degree of participation which is apparent in animals is largely increased in man; man, by his ability to act intentionally upon his environment with better means than animals, while adapting to it, can actually change it. This behavior is an extension of his initial ability to adapt by action.

In conclusion, such an understanding of adaptation and learning in man implies that learning cannot be realized unless the individual acts during his initial effort to adapt, and, also, that this behavior changes after he learns.

Humans always follow this method. But, in addition, we can perform hypothetical trial-and-error efforts, mental efforts; we can speculate, suggest hypothetical adaptive behaviors, in a word, anticipate before we choose among probable approaches, before we get into action. Indeed, "anticipation" is a central point for the understanding of brain function. Maron (1962, p.5179) writes:
...the brain is not merely a mechanism for maintenance of homeostasis, but...it is a mechanism for anticipating the future...This means that the essence of brain function is prediction... (Anokhin, 1974, p.244)

This, however, comes after a first amount of "knowledge" is accumulated in the brain. Nevertheless, it appears that we can use two approaches while adapting: A trial-and-error behavior and a mental approach. Can a baby use both these tactics? The obvious answer is that he cannot do this unless he has enough experience for situations similar to which he has to adapt.

This is true but it only reflects quantitative differences in the amount of the previous knowledge an individual has, and not real qualitative differences in the way an individual can learn a new situation and adapt to it. Because the adult, also, has to finally make a concrete trial if he is to learn the new situation. No matter how similar a situation may be to an already confronted situation, it might have some differences which may escape observation. If a concrete trial is not made we cannot be sure about the new situation. Therefore, the real difference between learning during early life and later life is a difference of degree; a difference in the number of the trial-and-error behaviors one has to go through before he learns. The fact that during neurogenesis the learning process that takes place in the brain has different results than later does not make the ways individuals use to learn and adapt
later qualitatively different. Simply because of lack of sufficient knowledge, the step of simulation of models cannot take place during early life, although potentially it is possible.

According to the above analysis of adaptation-learning, the position of Piaget about stages of cognitive development of children in relation to abstract thinking, can be explained not as an inability for abstract thinking related to the physiological functions of the brain but as an inability determined by socio-educational factors (Luria, 1976). The degree of this inability depends on the amount and quality of previous knowledge which gives rise to a certain number of ideal models. However, as far as the brain is equipped with ideal models, it performs simulations, i.e. the brain has the ability for abstract thinking but it has not yet, at a young age, plenty of materials with which to work. As soon as it has enough materials to work with, it performs comparisons (simulations). These simulations become gradually more and more abstract requiring, after a certain stage, rules of logic in order to perform the comparisons and, thus, to arrive at qualitative differences in the way of thinking. This gradual building up of the cognitive development also shows that the rules of logic we use have developed gradually during the generations of humans performing comparisons within the framework of their societies. Thus, it shows, on the one hand, the social and educational character of the development of abstract thinking during which the use of logic is indispensable;
and, on the other hand, it shows that logic is not detached from
the environment but it constitutes the rules one has to follow in
order to compare ideal models which originate in the environment.
Having this character, abstract thinking may be absent in individuals
that did not have the opportunity to internalize through education
the previous experience of the humanity that gave shape to definite
rules of logic. These individuals may be adults (Luria, 1976) or
children. In children the situation is explained by the lack of
the appropriate ideal models (with which to make comparisons)
because of lack of enough experience; while in adults it is the
lack of the appropriate experiences. For this reason, simulations
of a concrete situation that is presented to the child with an
ideal model which is in the mind of the investigator, may not take
place not because the child's brain cannot form the hypothesis
(ideal model) that is expected from him, but because he lacks this
ideal model. Many of the ideal models that are lacking from
children's minds are fully elaborated ideal models of words. In
other words, children may understand language and the words that
are pronounced by others only in association with some concrete
situations. The meaning that a word may have in other situations,
except those which the child has previously encountered, probably
escapes the child's mind. A recent article by Margaret Donaldson
(1979) who has worked at Piaget's Research Institute in Geneva and
with Jerome Bruner, supports the above ideas.
It is now clear that we have tended to underestimate both children's competence as thinkers and to overestimate their understanding of language. The underestimations are in large measure a result of the theories of the most influential of all students of child development, Jean Piaget (Donaldson, 1979, p.60)

Typical for language misunderstandings in children is the following example:

Laurie Lee gives an account of his own first day at school: "What's the matter, love? Didn't he like it at school, then?" - "They never gave me the present." - "Present? What present?" - "They said they'd give me a present". - "Well, now, I'm sure they didn't". - "They did. They said: "You're Laurie Lee, aren't you? Well, you just sit there for the present". - "I sat there all day but I never got it." (Donaldson, 1979, p.67)

An investigator who is asking questions of children may not appreciate that the inability of the children to answer his question correctly may be due to such misunderstandings of language and he may characterize the cognitive development of the children as lower than it actually is. The misunderstandings, however, do not characterize the brain development of a child but his cognitive development; and they will vanish as soon as the child has the opportunity to encounter the word in different contexts or situations. Thus, in this sense, cognitive development is simply a matter of
experience and it does not depend on some specific ability that the adult brain has and the child's brain lacks.

Difficulties of some individuals in dissociating themselves from concrete situations may be due not only to linguistic incompetence but also to the lack of other experiences (in addition to linguistic), and primarily of one's experience to dissociate himself from concrete situations and think abstractly. But the brain is able to think in ways similar to the ones necessary for abstract thinking; it associates the question or the new concrete situations with which it is confronted with ideal models other than the ones expected. Namely, it associates the new situations or the questions that he is addressed with, either with the limited number of the ideal models with which he is equipped or with observations of the moment which run concurrently with the question. In support of this point of view come some experiments of Donaldson (1979). These experiments point to the direction that in children,

...the shift in interpretation (in a test of conservation of number) had to do not with the physical context of the experiment, like fullness of garages or length of rows, but with what the children thought was the intention underlying the experimenter's behavior. (Donaldson, 1979, p.64)

McGarigle devised an experiment to test this hypothesis. The experiment made use of a number conservation task, similar to the Piagetian conservation tests. In Piaget's technique the
experimenter shows the child two rows of objects, equal in number and laid out opposite one another, in one-to-one correspondence. The child is asked whether there is the same number in the two rows. If he cannot perceive this the test is discontinued. If he recognizes this, the experimenter moves the objects in one row closer together. Then, the child is asked the same question, preferably using the same words as previously (i.e. whether the number of objects is the same in the two rows). Children who continue to say that the two rows are equal are said to conserve and are called conservers. The others are non-conservers. Piaget's explanation for observations like this is that non-conservers cannot sufficiently "decenter", that is, they are not flexible about shifting their point of view. They center their attention in one feature of reality, failing to take into account either transformations between states or other features of the object. As a result, they say that now the rows are not equal because now the one row is longer than the other, and they fail to notice that the other is more dense. Thus, the stage of their cognitive development is judged by their ability to decenter their attention from one feature of reality to another and to take into account more features of reality itself. This implies that at a certain stage of cognitive (mental) development the child does not have the ability to think generally, in other words, more abstractly (see p.192), as he has in another stage. The experiments of McGarigle proceeded in the usual way up
to the point where the child knew that in the two rows the number
of objects was equal. At this point a doll bear emerged and dis-
arranged the one row. Then, 50 out of 80 children (62.5%) answered
correctly the question about equality of number of objects in the
two rows, and proved to be conservers while only 13 out of 80
children (16.25%) were proved conservers in the traditional version
of the number-conservation task. Failure of the non-conservers to
answer correctly the question in the traditional test was interpreted
by the experimenters as due to reasons attributable not to the rows
of the objects that the children were observing (since in both
versions, the traditional and the "bear doll" version, the trans-
formations observed by the children were the same), but to the
presence of the doll bear in the one version and of the experimenter
himself in the other version. So, they say that "...non-conserving
children fail to answer the experimenter's question in the same way
on the second occasion because, for them, it is not the same ques-
tion. It seems different because it is not sufficiently detached,
or disembedded from the context of what the child believes the ex-
perimenter wants" (Donaldson, 1979, p.64).

These researchers believe that the children have difficulties
in disembedding and not in decentering. But, they do not proceed
further to say that there are not differences in the "maturational"
stages of the brain. Replacement of the term "decentering" by the
term "disembedding" is not the only reason why I find these
experiments very important. These experiments could be interpreted as indicating that the child has the ability to think by the same basic physiological mechanisms that an adult has, but, because of lack of experience (accumulated knowledge), he forms other associations in his brain than the associations an adult would form. It is possible, then, that the child proves to be a non-conserver for the reason that these scientists claim. But what might have happened in the child's brain may be that the child anticipated some intention in the experimenter and formulated his answer to fulfill this need. Thus, the child's brain worked in ways similar to the ways we use for abstract thinking; only his comparisons of the concrete situations with ideal models is not the one expected by us who are trained to use our logic and answer the concrete question; but it is a comparison with other things which for the child are more important (intentions of the experimenter). Since the doll bear interference made some 46.25% of the children who were previously believed as non-conservers to fall in the category of conservers, this argument appears logical. But what about the other 37.5% of the children who prove to be non-conservers by both tests, the traditional and the doll version of it? We previously believed that there are differences in the development of functions like attention and decentering. What is going to change if we now start saying that there are differences in the development of a function called disembedding? And, by which means is the development of these
functions realized?

It appears to me that the development of the brain is one thing - neurobiologically - and the cognitive development of an individual is another. There is no doubt that there is an interplay between information processing to the brain and normal neuronal development. But the brain functions as a whole at all stages of its development, and performs associations in order to attribute meaning to the realities that it is observing. The difference in abstract thinking which is observable between young and adult ages is merely a difference in the quantity of information previously processed by the brain (which only gradually becomes a qualitative difference) and not a difference in the way learning is realized.

This conclusion permits me to analyze methods for learning uniformly for all ages. But I will also see if quantitative differences in knowledge imply differences in the tactics that an educator should follow in order to facilitate learning.

For this reason I will discuss how an adult, after acquiring a certain amount of knowledge through initial trial-and-error mechanisms, may mentally speculate which behavior would better fit a new situation into which he has to adapt. Briefly, one has to understand how perceptive learning is realized.

I will begin my understanding of perceptive learning by asking the question not "how" but "what" a man may learn if he does not really embark into action in response to an environmental entity,
condition, etc. The answer to this is that the only thing he may remember is his hypotheses, his thoughts about the situation. How successful his hypotheses are in explaining the situation and in indicating the appropriate behavior can only be proven by testing the suggested behavior through action. The interesting thing, then, is that we accept in this case as learning the inscription of these hypotheses in his memory before we are sure that they are correct. Obviously, in this case, we take a different stand from the stand that we took previously, in the case of the mnemonist. In his case, we did not admit that a process which ended up in the inscription in his memory of an information processed by his brain constituted learning, while in the case of perceptive learning we admit it as learning. Before I come to a conclusion that will allow me to describe how abstract theoretical knowledge can be viewed, I will have to analyze the above cases in terms of brain function.

The brain, while processing information coming from a new environmental element, will form a model of a new situation. However, understanding of the new situation will only take place if the brain can associate the new model with previously existing models. When this happens, the individual can attribute a meaning to the new situation. If this can be made on the basis of the existence of adequate and appropriate ideal models, we may say that understanding of the new situation takes place using only a mental process. Inscription of this meaningful information in the brain
is perceived as learning. If the individual cannot associate the new model with other ideal models, he cannot understand it because he cannot attribute any meaning to it. The only thing that may happen in this case is what happens in the mnemonicist's mind: retain a meaningless image of the new situation. This is not perceived as learning (or we may say that it constitutes only the first steps of the learning process which is also observed in animals, mentally retarded people, or mnemonicists). This last situation for a "normal" person may correspond to what is called "rote learning". The other case corresponds to "meaningful learning". What makes learning meaningful is its associations. An educator is interested in "meaningful learning" because he deals with "normal" individuals and he intends to lead them to this kind of learning. Let me, then, try to see to what kind of models these associations correspond.

If we see the brain in its evolution during an individual's life, we have to admit that sometime, someplace, all learning begins as "rote learning" because no information at all has been processed by the brain until this point in time. But, due to the structure of the brain, an incredible amount of information is always processed simultaneously. At the same time, the individual manifests some activity. The patterns of all this information can, now, associate with each other constituting the first meaning of his impressions. Building up through these mechanisms, movements become coordinated and the environment acquires meaning. Finally,
forming central analogic structures, the individual has included in them patterns of behavior and patterns of action. The upwards organization of the brain does not stop there. Associations of patterns of words with these analogic structures occurs now, enabling the individual to start associating these structures as wholes (the complex of images, actions, and words). So, the initial meaning of the structures, modified and remodified, may make the patterns of action which are included less and less concrete or more and more blurred. Initially, then, models of actions corresponding to the concepts represented by these analogic structures are never absent.

Because of the constantly changing milieu we never reach a point where no action is needed for learning to be realized. What happens is that the orientation process is no longer necessary. Eventually we can reach a stage at which minimal action is needed for learning to be realized. This stage, in terms of the brain's development, should be understood as the stage at which, due to the organization of the brain through progressive mechanization, the brain becomes able to operate through schemata, reverberating circuits, etc. This is manifested by the fact that before an individual reaches a certain age and acquires a certain amount of knowledge, he is not able to do this type of learning or abstract thinking. What we educators should not forget is how the development of concepts is realized in an individual. By forcing "rote learning" we act towards the learners as if they were mnemonists or
babies; but the simple recalling of items, situations, etc. is not learning.

Indeed, the case of perceptive learning may be simulated with the abstract mathematical model of the right-angled triangle that I presented in the previous chapter. Learning of the model $c^2 = a^2 + b^2$ or of the model $c = \sqrt{a^2 + b^2}$ is what can be simulated with learning of an abstract concept; but still $c = \sqrt{a^2 + b^2}$ by itself does not mean anything. What makes it meaningful is that someone, sometime, has demonstrated by a concrete way that this equation describes the relationships of any right-angled triangle.

Perceptive learning, then, is clearly associated with previous experiences which includes patterns of behavior. In this sense it is not dissociated from action. The same is true for animals which demonstrate perceptive learning since no living organism which is brought under experimentation is deprived of previous experiences.

Thus, one thing to keep in mind is that if we want the learners to achieve meaningful learning, we should supply them with sufficient and appropriate models related to concrete realities and concrete trials to supply them with sufficient experience and help them undergo perceptive learning. Also, we should not forget that almost always, despite the possibility that an individual can learn through perceptive learning concrete realities and behaviors are a superior way to embed knowledge in the minds of learners.
Creative Thinking

Let me now examine what corresponds with a successful simulation of models in the brain. In the following paragraphs I describe within my frame of reference what Piaget (1947) describes as "assimilation", and Leland as "apperception" (personal communication, 1978). These processes require a personal "digestion" of external material, but at no point are they derived or created from innate or internal bases.

We have seen that learning will be realized when information processed by the brain will produce an ideal model which will be inscribed in the memory after selectivity through action, i.e. association of the new experience with models of previous successful behaviors; in other words, learning will be realized after simulation with previous models, which also include patterns of action. During these mental processes the brain is understood as performing analysis-synthesis-modeling-simulation.

Due to its physiology the brain cannot have but one thought at a time in its consciousness. Thus, while simulating models at the moment at which the individual becomes conscious of them, we may say that he is thinking. At the same time, through associations or concomittant (at the time) happenings which the brain processes,

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31 I remind the reader that the adjective "creative" is optional since, as I already explained (and I will do in more detail in this section), all "thinking is by its nature creative, representing, in fact, a simulation of ideal models which, by no means, can be "identical" to the real models.
the subconscious prepares the next activity of the brain that will reach the state of excitation required to dominate consciousness. Thus, simulation of models takes place through these mechanisms which, colloquially, are called thinking.

A synthesis which is performed according to a new "pattern" of relationships of parts is a new creation. If the resynthesis that the brain does corresponds to the exact pattern of the model resulting from the information processed, this will not be a creation, because the brain, supposedly, did not modify the pattern of the model.

What may happen in a process of comparison (that simulation essentially is), outside the brain, is to put two entities side by side and compare them. This, however, is not possible in the brain because only one impulse pattern at a time can dominate the brain. That means that only one model-representation of reality occupies consciousness at a time. Simulation in the brain has its real meaning, which is reconstruction, according to a similar pattern. If the brain attributes meaning only through associations, and if it can be dominated only by one model at a time, it means that when the brain becomes conscious of the reconstruction of a model, it is aware, together with the new model, of the associations that also attribute meaning to it.

Following this line of thinking, I can understand the model that the brain now understands as "meaningful" (i.e. with its
associations) as a model which has on it the modifications that have been effectuated on it through its associations. Otherwise, the brain would not be able to attribute meaning to it. The model, however, that has on it these modifications is not the same model that it was initially. It is a new model. As such, any resynthesis that the brain performs (except perhaps the pathological "mnemonistic" ones) is a creation. Indeed, if the process of creation, of remodeling, did not interfere, we would not be able to "understand" (i.e. attribute meaning to) the patterns of reality. This is the basis for the statement that adaptation includes creative transformations of reality.

These thoughts based on the rules by which the brain functions explain why I perceive learning as the result of creative thinking. Since "thinking" in normal human beings passes through the same processes previously described, any kind of thinking would be in this sense "creative". Then, one may question my use of the term "creative" in connection to thinking. In fact, the simple term "thinking" would suffice. Nevertheless, the creative process which is inbuilt in this mental activity could be easily overlooked. For this reason I added the term "creative", and I indicate that it does not mean anything more or less than what I just described.

That a creative process takes place in the process of understanding reality is demonstrated by the validity of the common belief that we see reality only through our ideas. This has been
said in many ways by many authors. I will just mention Popper (1962) because the fact that I agree with him in this statement, while I disagree in the explanation he provides, makes the persuasiveness of the agreed point even greater. Popper says that we know only our theories and then he says that theories are creative efforts to understand reality; that we can only learn after we make a creative suggestion.

I think that my explanation not only shows that a creative process underlies our understanding of reality, but it also shows the extent of this process since it shows that creative thinking (understanding) precedes all learning, or, at least, what is understood as learning.

There are some points that need to be clarified. What I presented as creative thinking is not the perception that everyone has about it. Usually, "creative thinking" is perceived as the type of thinking that artists, great scientists, philosophers, and generally, great creators, like Einstein and Wiener, manifest. I think that the great innovative impact that the thoughts of these people had is not due to the fact that they used a different kind of thinking, but it is due to the content of their thoughts which, in its turn, is due to the degree of freedom they were able to have while thinking.

A necessary step in the mental processes needed for learning is the creative step. As we proceed in life, building up our
cognitive structure, we form a number of perceptions about reality, a number of ideas which are related to our environment, experiences, culture, science, etc. In the process of understanding the realities around us, all these preformed ideas participate as I have described in the previous paragraph: as associations that attribute their meaning to the surrounding realities. Thus, the thing most likely to happen is to attribute to reality the meaning that the perception of the world dictates to us. The great creators, then, according to this view, had the freedom to dissociate themselves from previously-formed ideas and to see reality through new associations. But the process of thinking that they used is the same as anybody else's.

If "creative" thinking were some special feature that these exceptional individuals possessed, then the most logical thing to admit would be that they had it because of some special structure of their brain through inheritance. If this had been the case they would have manifested this quality throughout life and not after a certain point in their development. And, if we reject the argument of inheritance, we are confronted with two other arguments: First, why doesn't everyone become a great creator? Second, how did these people manage to escape the preformed ideas since they, as everyone else, grew up in the same world, culture, etc., and, according to the way the brain works, they should have passed through the same experiences as others which should have made them see the world as did the others.
These arguments are answered when and if one understands the nature of the process of acquiring our cognitive structures. As we know, emotions and feelings are interrelated with cognition. An individual who is building up his cognitive structure is going through a circular process. He needs a previous experience to understand a new reality, because that is what attributes meaning to reality. In the process of understanding the next reality, he is equipped with more knowledge permitting him to better understand this new reality. But while this process equips him with more knowledge, it also ties him more and more to one point of view since everything is interrelated and the point of view of the environment infiltrates all the knowledge that he accumulates.

This process seen from the point of view of "values" means that all the knowledge that one accumulates is valued against the points of view of one's environment, in other words, against the values, beliefs, customs, preferences, goals, etc. of one's culture. One cannot overcome this barrier unless he somehow perceives that all these values are relative: All the points of view in science, literature, knowledge, etc. are relative. If and when one perceives this, he becomes free to make new associations, to see reality through new ideas.

The interesting thing in this process is that it is not sufficient to tell someone that all is relative. This does not liberate him. And the reason for this is simple. In order to be really
free one has to gain enough confidence in himself to be free from the emotions which accompany the conquest of freedom. Acceptance by our peers, our family, our social environment is so important to us that loss is one of the biggest threats that can confront us. This threat is one of the major factors which makes us conform with our environment. Rejection by our environment can be so frustrating and emotionally disturbing as to cancel out growth in knowledge. Growth in knowledge, accepted by our environment, is a factor which not only makes us acceptable by our environment, but which gives us also self-confidence. Therefore, only when, through growth in knowledge, we reach the point at which our self-confidence is enough to overcome the fear of loss of acceptance, we have acquired our freedom.

From this point on we can use the creative steps of our understanding of reality for true "creative" views, i.e. new views of reality. If we do not pass through this circular process, we are not really liberated from our fears; the simple insight that knowledge is relative does not help us in liberating ourselves from the chains of conformity.

I hope that this analysis answers both the arguments that initiated this discussion. Individuals fortunate enough to have been helped in self liberation through knowledge may choose to have different point of view from others. And this makes everyone a potential creator. I perceive, then, as the most important task of
an educator, the creation of a climate for the learners (within their limits) that will make them self-confident and eager to learn. Only then will the learners have the option to reach real freedom through acquisition of knowledge.

In this respect, the way learning is realized by the brain shows us the way we should follow to make it happen.
CHAPTER V

PROPOSITIONS FOR EFFECTIVE EDUCATION

Education Through Relativity and Systems

We see the world through our theories (Popper, 1962), a system of facts and beliefs hopefully emerging from the facts. In modern society, much more than in older societies, the prevailing theories through which we understand the world are influenced by science and its discoveries. As Toulmin (1972) and Kuhn (1962) say, theories that emerge in a branch of science, if they are powerful, may set a "paradigm" for the other sciences also: a paradigm for their epoch.

Today's paradigm is Relativity. Slowly but surely, the point of view of Relativity is spreading to all branches of science, attributing to the world a "new image". In my effort to generate propositions for effective education based on brain functioning, I also encountered these points of view, especially in works concerning brain function and I was influenced by them. I will discuss them briefly because they provide a different point of view and make the world and its pursuits (education included) more comprehensive in its complexity.

To say that one understands the principles of Relativity is not as simple as to say that everything is relative to everything else.

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The first difficulty in understanding Relativity lies in ridding ourselves of our previous concepts which are embedded in us as we grew up in a world understood through a different paradigm.

We have forgotten what features in the world of experience caused us to frame (pre-scientific) concepts and we have great difficulty in representing the world of experience to ourselves without the spectacles of the old, established conceptual interpretation. There is the further difficulty that our language is compelled to work with words which are inseparably connected with those primitive concepts. These are the obstacles which confront us when we try to describe the essential nature of the pre-scientific concept of space. (Einstein. In Bronowski, 1973, pp.255-256)

In order to grasp, then, the essence of Relativity one has to work with these concepts, to understand "how" and from what basic acceptances these concepts have emerged.

My understanding of Relativity began with Bronowski's understanding of Einstein's thoughts when he was thinking about the world: "What would the world look like if I rode on a beam of light? (Bronowski, 1973, p.247). That for me meant: What would the world look like if the observer and the physical means by which he makes his observations (seeing and light) were the same thing?

Einstein became one with nature: he included in his thoughts the observer; and he was still able to think as an observer (as seeing), and in terms of light. The example that initiated me to an understanding of Relativity is as follows: Suppose that we are in
a wagon. And, suppose this wagon moves away from a clock on the
very beam of light with which I see the clock. The speed with which
the wagon moves is the speed of light. Now, let us say that when
I started traveling it was noon. After I travel 365,000 kilometers
away from that clock, a second (I") must have passed. But this
would be true only for an observer who would be standing outside my
wagon and supposedly could see me at two instances: When I started
traveling and after the passing of a second. It is not true for me
that I am traveling with the beam because I see through light. And
I will see the clock through the beam of light that I am traveling
with. So, I would see (if I could) the time on the clock to be still
"noon" since light passes through the clock at noon and light does
not go back and it constitutes for me the carrier of information that
I receive. The unidirectional movement of light at this speed is time
itself. Thus, for light there is no time and I have identified my-
self with light. Thus, time for me is frozen. It has stopped.

So, I and my universe in the wagon will have eternal noon. But
for another observer it may be a second past noon. And for a third
observer a different time. The movement of light is stable and it
represents an absolute time only because there is no faster movement

32Of course, this is hypothetical. Since I am traveling on a
beam of light I have the highest speed possible in the world. In
order to see me, a second observer has to relate his eyes to a
second beam which, after it passed from him, reached me and so made
it possible for him to see me. But, this is impossible because his
beam cannot run faster than mine since both are light and both are
running with the highest possible speed.
than this. All other movements are relative to this. Time as we understand it, is relative to this movement. Thus, time is not universal. Bodies moving with different speeds will have different time. For example, the center of the earth that moves slower than its rim is aging faster than the rim.

Einstein formulated the hypothesis that, if his theory were correct, then the center of a turning sphere or plate would age faster than the rim. This proposition has been proven experimentally for the earth. Also, from 1905 when Einstein presented those thoughts until 1955 when he died, humanity became able to measure time to a thousand millionth of a second. What he predicted was measured by H. J. Hay in Harwell by the use of a radioactive clock posed on a rim and another such clock posed at the center of a turn plate. The center of the plate had a slower time; it was aging faster than it's rim with every turn.

I understood the whole impact of those observations in the following way. Light is signals (as are the other radiations in the universe, radio waves, x-rays, etc.). We the observers have a means by which we understand light (our eyes and our brain), and we relate to the world by light (and not by these other radiations). I receive information and I know what I know because the light brings me this information. Otherwise I would not have known anything. Now, from where do these radiations originate?
(They).....are spread out from an event like ripples through the universe, and there is no way in which news of the event can move outwards faster than they do. The light or the radio wave or the x-ray is the ultimate carrier of news or messages and forms a basic network of information which links the material universe together. Even if the message that we want to send is simply the time, we cannot get it from one place to another faster than the light or the radio wave that carries it. (Bronowski, 1973, p.248)

By measuring the thermal microwave radiation emanating from this initial event, Penzias has proven the correctness of this theory (Nobel Prize, 1978). Thus, what relates me to the other world is this information; everything else is relative to these radiations. Light is only one of these, but it is the only one by which humans can relate to this aspect of the world because they developed sensory for receiving it.

Now, let me return to the wagon that travels by the speed of light in order to clarify a few more points. Although my experiences in the wagon remain the same, as do the experiences of the observer outside the wagon, my values for the experiences will be different. For example, I can receive a message in no time at all because there is no possible faster message carrier than light, and I am traveling with light. Therefore, the statement that time does not exist in this speed is not absolutely correct. A more correct statement is that time has a zero value.

Consequently, although the physical laws are the same inside and outside the wagon, they give different values in and outside it.
As I demonstrated with time, space is also different with different speed. Ten kilometers for someone moving by the speed of light is no time at all, but for me this is a two hour walk, and for a car a two minute run. Thus, space measured in terms of time has a different value for each one of the moving entities. It is relative to their speed.

A question then arose in my mind: What is the primary existence that makes entities relative to each other? The only value that remained the same was the movement of light. But the movement itself is a relation of time and space. Since this is the "primary existence" then the primary existence is relations. For my conditioned brain this was the first break in my previous inability to understand Relativity. As our brain is conditioned to understand everything as different or separate entities, I could not understand the proposition that nothing exists by itself. I could not understand the real meaning of coexistence. Then, I realized that "relations" as a separate entity are primary existences. Relation means connections of at least two things. These two things could not really exist by themselves as entities alone. Since relation was the primary reality, they had to coexist, otherwise the relation would not be primary. Thus, nothing exists by itself since before its existence its relation exists. Thus, the only way to exist is coexistence.
This means that the existence of the one is only possible under the conditions the other existence creates. And, in this sense, the one existence is relative to the other existences and everything is relative to light which represents the stable value for the fastest movement. Then, everything should move all the time. Movement, then, is understood not only as the change in space with time but all is understood as change, even that which we do not appreciate as movement with our conditioned brains. Then, I conceive my existence as a part of this continuous change, this continuous movement. Thus, the whole world is not really structures but a continuous process, a continuous movement and the relations of all moving existences attribute to them their temporary appearance. What gives them this appearance are the laws governing this movement. The laws express the types of relations existing between entities and they are the same for all entities but they have different values, according to the relations established. The only value which is absolute is the value of the movement of light.

Naturally, then, not only time and space but the mass also must be different in different movements because all existences have to follow the same laws for all movements; for instance, for me in the wagon and for the man outside, consistently - yet, they have to follow the same value for the speed of light.

Now, if I really travel by the speed of light I should have a certain mass and a certain length (I should occupy a certain space). What would these values be for my mass in the speed of light? The
answer is that in the speed of light I cannot be but light particles, photons. Thus, my existence is relative to my speed in this continuous movement of the world. In other words, my existence includes this movement. Otherwise I cannot exist. In this way I understand the relation of mass with energy. The matter from which I am composed is not only what I can understand as mass; it is also movement which in the speed that the changes I undergo have cannot be appreciated as energy because of the slow movement the energy-mass includes. However, if I change the relations of the speed of my mass, it will no longer continue to have the same form. It will take its other form, the form of energy. This has been very dramatically proven by the explosion of the atomic bomb. Within this bomb scientists gave to some particles of mass so much speed that they converted them into energy. Matter then, of which all the realities I know are composed, is a combination of mass and energy at certain speeds. The world is composed of entities that change as an expression of its movement. The raw material from which all realities are composed includes this movement.

This is the core of the principle of Relativity. The existences are real, they are there. Everything exists. But the values, the measurements of the existences, in a word, the world as I know it, is relative to the speed these existences have as compared to the speed of light. And what I "know" is their present relations: the one with the other and everything with light, and through it
with me. Light is, in a sense, the expression of the movement that exists in us.

This understanding changed my philosophy in a fundamental way. To learn to look at the world as relations, as processes and not as structures, is a disclosure that brings together with it innumerable other consequences. All of a sudden one understands that the reality we see around us at one time is a moment of this continuous movement. Structures are only an instance of the processes that continuously go on. A certain structure expresses the only possible relations existing for the concrete masses-energies we observe in a concrete time-space, while some concrete processes are going on. At another moment one might see a different reality, not because truth does not exist as some philosophers claim but because the relations of the existences among them, during this phase of the movement, demand changes in the structures since the processes remain stable.

We, the observers, are moving together with all the rest of the world and we change together with it. Therefore, we can only exist under conditions, dictated by the fact that we coexist. These conditions are outside our will; they are there existing, will it or not. And they are determining the world of our will. Einstein expressed this idea by quoting Schopenhauer:

"A man can surely do what he wills to do, but he cannot determine what he wills" - (his saying) impressed itself upon me in youth..." (Einstein. In Leach, 1931, pp.3-4)
In this sense, the world we are born in is deterministic for our existence. As a result what we "understand" or "know" is not absolutely dependent on us, but is a matter of choice between us and what exists around us. Furthermore, everything we and our environment are, is in a continuous state of change. This is not madness. This is reality.

We may not appreciate the continuous change in ourselves, because we are moving too slowly to understand it all the time. But, we can easily admit that we are changing when we see ourselves in the perspective of a longer time. Because we know it is us now and thirty years ago, and the change is apparent.

So, I believe that the meaning of entities, words, ideas, etc. can change for an individual with time because the relation of the brain with reality, each time, is a relation of a new brain with a new reality to the extent that both have been changed by previous information processing and continuous change. According to Relativity, the type of relations of different things is different in order to keep the same laws, the same processes. The brain, the realities around it, and the thoughts all exist in a concrete manner; ideas originate from reality; all are real, all are true, but they are continuously changing.

Consequently, truth is relative to change. In the continuing movement that we exist, "You cannot walk in the same river twice." (ΔΙΣ ΕΣ ΤΟΝ ΑΥΤΟΝ ΠΟΤΑΜΟΝ ΟΥΚ ΑΝ ΕΜΒΑΙΕΙ), as my
celebrated ancestor Heracletus said. Thus, brain and reality are both continuously changing. Thought is their relation. Ideas, being exactly the content of a thought but starting as thoughts, i.e. relations of the brain with reality, may be different at each time for the reasons I already mentioned: because everything is really different, continuously changing and rearranging its relations, the one to the other, and, ultimately, to the speed of light. To the extent that my previous ideas interfere with new model formation, as I described in the previous chapter, they attribute to the reality new meaning.

Education and Educational Development, for me, can be conceived as inseparable entities, since education, as everything else, changes together with all other entities of the changing societies. But as it changes:

1. It continues to be related to other entities, but,

2. It continues to be related to them by the same processes.

This does not bring about an abrupt change but an evolution, a development. In this respect the real task of a developer in education is to determine the entities that constitute education, the relations of these entities, and the processes that it undergoes. Only then may one find ways to facilitate the processes. It is obvious that he cannot change them. From this point of view, GST is one of the best approaches to education since it incorporates the notion of evolution by admitting that processes and not structures
are the determining factors of a system. Today, as a result of the work of Einstein, it is easy to comprehend what was puzzling our understanding of the world for many centuries: That everything is really processes. But, because of the appearance of reality in our eyes, we can better understand it as structures and processes. This combination is better seen in a system.

In terms of systems, the subsystems of a system which are its structure are, also, very slow processes. Now, with this in mind, let us recall that a system can be viewed hierarchically as a variable and as a subsystem of its suprasystem being, at the same time, itself a system with its subsystems. That is, education can be viewed as a variable and a subsystem of its suprasystem - which is society - and, at the same time, itself a system with its subsystems.

Einstein also speaks about the inner necessities of reality. In terms of systems and Relativity, what mainly characterizes the coalition of subsystems into a system are two things. One is the "emergent" process or property of the system which did not exist in the subsystem. And the other is the "inner necessity" of the system which is the result of the nature of the subsystems, and the fact that they constitute a system within a hierarchy of systems.

The relations that can be established among the subsystems of a system are of limited number because the subsystems, because of their nature (their own inner necessity), present the system with only a limited number of possible interrelations among them. The
system now, existing within a hierarchy itself, constitutes a sub-system of the higher level, i.e. of its suprasystem. The one set of relationships, among others possible, that has been established in the system exactly because it coexists with other systems on a higher level, is its inner necessity. Thus, although another type of interrelation could have existed if other circumstances existed, the fact that it has not determines now, in this case, in this time-space, which is the interrelation that must exist. This for each one of the subsystems now constitutes the only possible condition by which the subsystems can exist. Thus, for them, this is now the law.

On the other hand, the possible types of interrelations that could have been realized in another case depend absolutely on the set of probabilities that each subsystem presents to its suprasystem. One can change types of interrelations only on existing probabilities. He cannot choose the non-existing. Thus, if I supposedly wanted to correlate several entities into a system called education, I would have only a limited number of choices to correlate the entities. This number of choices would be presented to me as a result of the inner necessities of the entities under consideration. Suppose that I have related the subsystems of a system according to one of the possible ways. This set of possibilities which has been chosen constitutes for my system its inner necessity.

Let me now examine, for a while, the emergent itself. The emergent, being a process, is, at the same time, a property of the
system and a variable of the higher level expressed in a structure, also. The structure which expresses the emergent is the system itself, since the emergent can only exist: (1) After the subsystems relate into a system, and (2) as the variable of its suprasystem which, when viewed as a structure, constitutes the whole system itself. Thus, the set of possible relations, chosen now for this system, will constitute its inner necessity (if it wants now to continue to exist as a system) and, at the same time, they will give birth to the system's emergent.

Being chosen by its suprasystem to carry out for it one of its variables, the system cannot now change its function, it cannot switch to its other possibilities but only in accordance with its suprasystem. So it continues to carry out its emergent for its suprasystem as the function that the suprasystem needs in order to keep its own identity as a system. Thus, there is an infinite series of systems which constitute subsystems for another system and suprasystems for their own subsystems, or an infinite series of processes which constitute subprocesses for their supraprocesses, and supraprocesses for their subprocesses, the one being deterministic for the other.

As suprasystems, we constitute the law for our subsystems. As subsystems, we can only live by the law of our suprasystem. And as systems, we are subject to our inner necessities; in other words, we are subject to the limitations of our subsystems, or we can say that we can only do as much as to exhaust the possibilities of our
subsystems in accordance with (or with the license of) our suprasystem.

How true these thoughts are is demonstrated by the fact that they have led the way to the biggest innovation of our time: Relativity. I believe that the following lines by Einstein are the philosophical essence of his work and, thus, they initiated the thoughts that led him to the theory of Relativity:

I do not believe we can have any freedom at all in the philosophical sense, for we act not only under external compulsion but also by inner necessity. (Einstein. In Leach, 1931, p.3)

Let us look at education from this perspective. Education, as a subsystem of society, carries out a function for it. This function will be its emergent. If one asks individual educators what they think is the function of education in society, one will receive a number of answers. And, if one had let them arrange programs which would carry out the functions of education for society, one would have a number of "goals" of education. In this sense the "goals" of education would constitute what education is expected to accomplish as system, i.e., its emergent. However, not all of the goals people choose for education would be possible; because these goals, being emergents of the system education, correlate with the inner necessity of this system also.
Thus, if one would ask (as society, i.e. as a suprasystem) an educational system to accomplish goals that (hypothetically) do not correlate with its inner necessity, he would have two choices: Either to give up these goals since the subsystems cannot carry out expected emergent, or to disrupt the system in its subsystems (systems that cannot adapt to their suprasystems may be disrupted or destroyed) and establish a new system with new correlations. This last alternative is not impossible in human-made systems.

However, since systems are perceptual entities, the question becomes: Up to what unit-entity can one disrupt systems and establish new ones? The obvious answer is: Up to a unit that can no longer be disrupted. In physical systems we have been able to disrupt the several entities-systems into molecules, then into atoms, and then into the particles of the atom. What, then, is the last unit into which education can be disrupted? Education is organized into schools, universities, special educational centers, etc. These have been organized to serve certain purposes. If, for instance, we think that these units do not serve the functions that they should, we may decide to break them down into smaller groups. If we do not like them either, we may break them down into very small groups and, finally, to individual teachers and students. We cannot go beyond that. The smallest units, then, into which we can break down education, is individual men. These should also be the units that we will use to organize other larger units of education.
Suppose, however, that a society wants to build up an educational system which (hypothetically) cannot be served by the properties inbuilt in these units, i.e. the man. That is, men as we know them cannot coalesce to form the hypothetical educational system that would have the emergent that the society asks for. Can this hypothetical society break down the man in soul and body, for example, and use only one of these elements to build up educational systems? The obvious answer is no. Then, in this case, only the other alternative exists of the two alternatives that I mentioned earlier. Since the unit man is indisruptable, even if he cannot carry out the goals that the hypothetical society thinks he should, this society has to abolish or change its goals. Then, in order for any society not to reach such a contradiction, the following question should be put forward in the first place: With what should the goals of the educational system always be in agreement in order to be carried out by these indisruptable units? Since, (1) the goals of education are emergents of the (educational) systems, and (2) since emergents of any system are in correlation with the inner necessity of the system, and (3) since the primary unit of systems of education is man, then the goals of education should be in agreement with the inner necessities of the indisruptable unit of education, i.e. man.

This may appear self-evident to some individuals who have the greatest respect for man and the human qualities; but it is not so evident to other individuals who raise their children to serve other purposes. There are individuals who raise their children to be
thieves or terrorists. So, I thought that this should be emphasized. Furthermore, adoption of this concept would be very helpful for any kind of educational propositions because then one would know to which basic relations to refer to in order to find if a proposition for education is consistent or inconsistent with the inner necessity of the learners. If inconsistent, the propositions would be condemned to failure. If consistent, they would have equal possibilities with other consistent propositions.

Thus, for general understanding of any educational system, what must first be determined are the basic units or structures of it and then, the basic relation under which these units operate, i.e. their inner necessity. We already have seen that these basic units are man himself. But, after this step, the units-relations (man) may be connected in bigger units (with new relations), the relations of the bigger units now constituting the laws of the systems, and the whole constituting an educational system. In human systems, the "general laws" that we might say exist, i.e. the external necessities of the system are confusing and, in a way, secondary - although very important - because these laws can be changed by us humans. One must not misunderstand this as saying that for a certain situation in time-space, with the same inner necessities, one can expect two different laws after a system has been established. This is not the case. One must understand the previous proposition as saying that with the same inner necessities in a different time-space one can create a different system, a different reality because of choice of
different relations in the first place. Hopefully, in establishing these laws, we will take into account the inner necessities of the indisruptable units and we will not threaten them with disruption. I believe that the inner necessities of the basic units, being more deterministic than the laws, should always be taken into account.

The basic unit of education is the learner. It is the least unit into which all educational systems can be dissolved. It appears that he can continue learning under variable conditions. Using the term "learner" (and not simply "man"), I want to emphasize that I view man in his activity of learning. This emphasizes the fact that, in this instance, man should not be thought of as an isolated existence, but in relation with his environment. Learning means interaction with the environment.

Searching for the inner necessity of the learner, i.e. the basic relation that should exist in order for someone to learn, I will search for the limiting factors of learning in man's relationship with his environment. Limiting factors are understood as those factors which, if violated, will not allow a man, interacting with his environment, to learn. This is how I understand the "inner necessity of learning".

Any man born in this world is learning. Just because he exists he can think and can interact with his environment. He therefore can learn. The inner necessity of learning, then, originates from this situation: The relation of man with his surrounding realities
through thinking.

I have identified thinking as the brain function by which the brain is related to the real world. Impairment of learning, then, may be due simply to impairment of thinking because of malnutrition, disease, etc. I have also shown in the previous chapter that any thinking which results in learning is creative thinking just because of the function of the brain. Conditions, then, that impair the creative aspect of thinking will also impair learning.

Secondly, thoughts are parts of the process of thinking in which reality is represented; and learning is realized by the inscription in the brain of valued information. This information comes from reality and is evaluated against the brain's raw materials themselves and against previously inscribed information. There is a practical impossibility of separating thought from its content which is reality-environment. It is, then, possible that some realities generate thoughts which, evaluated as threatening the individual, impair further learning. This should be taken into account in our search for limiting factors of learning.

We may avoid these realities either by getting away from them or by changing them through action in our effort to adapt to reality. Thus, in our evaluations of some realities as limiting factors of learning, we should take into account our possibility of changing reality through action.
Through action, the individual evaluates behaviors towards the realities existing in the environment. And the patterns of behavior that fit with the situation of the environment enter our thoughts as an inseparable part of our way of learning. Shortly, this is described as learning by adaptation.

So, the full scale of limiting conditions will be: **Existence requires adaptation** which is realized by learning through action. And the condition for learning is thinking (creatively). These are the conditions by which an individual can learn; therefore, these conditions constitute the inner necessity of learning.

There is an apparent circularity in these notions. To survive one has to adapt and he cannot adapt unless he learns; then, he cannot learn unless he acts and thinks creatively, which makes him learn and helps him adapt and, thus, survive.

As I have shown in the previous chapter, the more knowledge one acquires, the more free from previous notions and emotions he becomes, and the more creatively he can think. This circular process in combination with the other circular process that I just described, helps man to improve his environment according to his needs. That is, it helps man to adapt and survive (Huxley, 1979). Thus, one could include this second process in the concept of inner necessity.

For the sake of brevity, I will describe the inner necessity of learning as "creative thinking-adaptation".
In a different context, Ross Mooney expresses about the same idea as follows:

"...The model of the creative being is likely to be man's most constructive conception. I feel it offers our best hope for developing ways of growing strong individuals, self-realized in depth...and fit with the increasing human pressures of the times. (Mooney, 1955, p.275)

Evaluating the previous descriptive definition of the inner necessity of a learner we see that if one does not "think", he really cannot learn, since his brain does not work. Secondly, we have seen that learning does not mean inscription of simple information in the brain, but of valued information. Thus, the fact that thoughts constitute "representations" of reality does not cover the matter of evaluation of this information. Evaluation of it is made by the brain through creative resynthesis which constitutes part of the normal function of the brain (see pp.258-262), and, through adaptation, which constitutes the basis of learning through action (see pp.240-246).

The short definition of the inner necessity of learning by the terms "creative thinking-adaptation" appears to be adequate. The use of the term "thinking" and of the terms "creative" and "adaptation" with the indication that there is an interrelation of creative thinking and adaptation probably covers the conditions that should exist for an individual to learn."
There is, however, one thing left out of this short definition: The indispensability of a normally-functioning brain for a normal process of learning. Thinking, however, in its more colloquial meaning presupposes a good function of the brain and this could not be realized without a previous normal development of the brain, the simultaneous participation of a well-functioning memory, etc. Thus, I do not feel that I should include any other term in the description of the inner necessity of learning, although some confusion may be created in cases of mentally retarded persons, mnemonists or in cases of amnesia. Such persons, however, are relatively rare and their cases are pathological and they do not constitute the subject of "education", in general, but of "special education".

In closing this chapter I should mention the reasons for using Relativity to better understand education. Relativity, it seems to me, is the theory which is as much scientific as it is philosophical. In fact, the philosophical parts of it have been proven experimentally also and, thus, the theory became science. The basis of the philosophical aspects of Relativity is a deep understanding of the fact of coexistence. This understanding justifies the early acceptance by Einstein of the notion that "a man can surely do what he wills to do, but he cannot determine what he wills"; or his early acceptance of the latter gave birth to his subsequent ideas. Coexistence, then, is the essence of reality. Without the necessities that originate from the very fact of coexistence, I would not be
able to scientifically support either the external compulsion or the notion of inner necessity. With Relativity, however, these notions do not constitute simple philosophical arguments that can be rejected by an opposite philosophical school. In the speed of light, the only possible existence is the photon and Relativity made us understand the necessities that emerge from the coexistence and the relations of all things with each other. The existence at this speed as a photon is necessary. There is no other way of existing with these relations, i.e. at this speed.

Also, Relativity and the explanation through Relativity of the physical phenomena presupposed the existence of a central event of the universe (Big Bang) which gave rise to a constant motion of the universe. Without acceptance of this constant motion, Relativity does not make sense. This, however, was only a postulate until thermal remnants of the Big Bang were measured by Penzias and Wilson (1965). Thus, this part of the theory became scientifically proven. The fact that we exist in constant motion explains why (not how) everything is in a constant evolution and establishes the fact that all existences are processes and not structures.

Within this frame of reference I developed the following arguments: (1) Perception of education as a concrete, open, goal-oriented subsystem of society. As soon as one admits that everything that exists exists in time-space, and not abstractly as a philosophical concept existing nowhere or everywhere, he has to admit
that education and learning, if they exist, should exist as concrete entities. Then they should exist in man because they are realized by man; if educational institutions exist, then they are not simply abstract concepts but they are material entities existing in time-space, which, as material entities, are subject to the laws of the universe (Relativity); then one has to admit that educational processes are an interplay between men who exist in the universe as concrete entities. It is not my intention to argue a denial of the material world. But, whoever accepts the existence of a material world (along or in combination with an immaterial world), is forced to admit that these entities co-exist with all other entities of the world and, thus, that education coexists with all the other entities of the world. This thesis of the present dissertation is a thesis which, if I did not adopt Relativity, I would have to support by other means which, by not being scientifically proven, would only constitute logical arguments. They would not have the demonstrative value that Relativity attributes to them.

The above thesis permits me indisputably to establish education as one of the variables of society interrelated with all the other elements of society. This I could not have done by systems alone. Systems constitute a philosophical movements and, although they may be extremely helpful, their demonstrative value would not be as strong as it is now that they are seen within the framework of concepts such as time-space and mass-energy, which they have borrowed
from Relativity. A simple statement that "we exist in a continuous movement" and that "mass and energy are interchangeable" would not have much value if the unity of time-space (which is the basis for acceptance of movement) and of mass-energy had not been proven by experiments. Only in the face of these proofs can systems gain the power that they have.

Therefore, we can now speak about education as being one among other entities of society (and we can support the thesis that education should be viewed within the framework of the society in which it exists) by accepting only one postulate: That the world has a material element also. From this point on, coexistence is a fact. Thus, self-existing and self-fulfilling education can exist only within the philosophical thesis that the world is immaterial.

For this dissertation it was crucial to show that: (2) The continuous change of reality could only be supported by Relativity. For the present work it was crucial to show that (because of its very nature), the brain, as a concrete material entity belonging to this universe, changes continuously. This was necessary. Otherwise, my thesis of shaping and reshaping of the markers in the brain would be debatable. (3) Coexistence, which is the basis of adaptation, is best understood through Relativity. I consider adaptation as one of the cornerstones of the ideas about learning that I support. In fact, continuous adaptation of the living organisms to the ever-changing reality is necessary exactly because the reality is always
changing. Only the theory of Relativity explains this continuous change, this continuous movement. (4) Education, in order to serve the needs of the evolving world, has to understand the needs of man as an evolving entity and serve these needs during all the stages of his evolution. On the other hand, evolution is a fact for societies, also, since they exist in an ever-changing world (see also pp. 275-277). Thus, the concrete educational systems existing in the society are going to evolve naturally. The basis of all evolution is best explained by Relativity (movement).

In this sense, education should not seek to find if it should adapt or not to the needs of the evolving society because the evolution and change of it are facts. Education should probably seek to find how best to adapt or even how best to guide adaptation, since adaptation is realized by learning and education facilitates learning.

It appears, then, that seeing education through Relativity was necessary for my point of view. It provided scientific grounds for a number of concepts which, otherwise, would have been disputable.

In terms of systems, the "external compulsion" of Einstein is understood as the relations of a certain system with other systems in order to form its suprasystem. The inner necessity is understood as the relations of a system's subsystems. In nature all entities are harmoniously interrelated to each other until a point in time at which, due to the continuous movement of the universe, a change
in the suprasystem is realized, requiring changes in the interrelations of its subsystems. Some of them adapt to the change, others are destroyed. Obviously, the ones that are destroyed are those which could not realize a change in the relations of their subsystems which would help them to adapt.

Human systems are considered as systems composed of men and non-living elements of all kinds: material entities, independent initially from men but transformed by men (buildings, towns, fields, books, paintings, etc.); and "immaterial" entities which are purely and always the products of man but which are realized into a number of material elements and behaviors (culture, customs, religion, art, etc.) (Milstein, 1973). In this case, man is a subsystem of human systems. Evolution of human systems is inevitable as of all other systems, although sometimes we have the impression that we, men are the only ones responsible for this evolution. This is not true. If we suppose that none of the progress known to us had been realized since the paleolithic time, still societies could not be the same as the paleolithic societies simply because of the increase in human population, for example. Increased numbers of men have made the earth more densely inhabited, have helped communcation, etc. Of course, the progress in health sciences has helped in the increase of population. So, ingenuity of man may be considered a factor in the population increase. But, we should not forget that population was increasing over the long run before and during the Middle Ages,
for example, at which time medicine was still in its dawn and epi­
demics had not been controlled. On the other hand, the ingenuity of
man has accelerated the rate of progress and change of the human
systems. The question, then, that is critical for human systems is
the following: In the face of the inevitability of change, how
should we use our ingenuity?

There are some who have said that because they fear that this
progress is destroying man himself (as one of the subsystems that
cannot adapt), we should put a stop to progress in order to save men.
In view of the inevitability of change, I find this proposition a
simple outcry of fear and not rational. Education plays an enormous
role in this process. I think that the time has come for education
to place the human being and his needs as its first priority, and to
look at finding ways in which this progress can be realized in
accordance with these needs and without disrupting the human being.
To do so, education should take into account as its first priority
the inner necessity of the learner.

Let us then see, briefly, how society has treated man up to
now as a learner and let us first consider the needs of a learner
during his development. Learning is a life-long process (Faure,
1972), because the brain, by functioning during all instances and
in all ages of a man's life, is, at the same time, realizing learn­
ing. Thus, learning can only stop when the function of the brain
stops. Therefore, learning is inbuilt in life itself (see p. 208 ).
During his development, man passes initially from the stage of his neurogenesis, which is crucial for his subsequent development as a learner. Appropriate environments should be created for him. Then, man continues growing by having the need to build up an initial amount of knowledge and internalize language, processes that will help him to form enough ideal models, enabling him to think abstractly and spare him from a number of trial-and-error behaviors. During this time, there is a concrete need for learning by doing. This should be given to him. Later on, man can more easily absorb theoretical types of knowledge needed to enable him to adapt to the innovations of science. This should be given to him in types of programs of continuous education by the use of much theoretical teaching and a parallel moderate amount of learning by doing. So, I perceive the learning life of a human being as a continuous process, but into which the learning needs of man can be satisfied by offering to him three slightly different types of education according to the stage of his cognitive development. It goes without saying that I do not perceive educational institutions as the only means for education. In my perception of the world as a system of interrelated subsystems and of learning as a property of the living matter, it is self-evident that the individual picks up knowledge from all sources around him. We can now see how society handled these needs of the learner in the past.
Society never did take care of the individual itself as an individual but as a part of its collective needs. This is exemplified by:

1. The newer findings of how the brain can learn.

These findings show clearly that the ages chosen by society for the beginning of the schooling period were not matched with the development of the learning abilities of the brain. Of course, society has the excuse that these facts were not known in earlier years.

2. The way that society behaves towards the education of the preschooling age.

Society always needed women as a labor force. But their work in earlier societies was limited mainly within the house and the fields where women had the opportunity to take care of their children also. Society now needs women as a labor force outside the house; and, for lack of time, women are no longer able (in the developed and developing countries and in their majority) to take care of their children during the preschool age. As a result, we are witnessing the growth and the multiplication of several types of day-care centers to cover this need.

In this spontaneous development I see lack of continuous investigations conducted to show the appropriateness of the day-care centers. For instance, we do not know if the child of preschool age (i.e. the stage of man's mental development during neurogenesis and
the initial few years after) should be taken care of in day-care centers away from the parents (especially the mother) of if he should stay close to his parents. Also, we do not know if the preschool age, which comprises two different periods of brain development (period of neurogenesis and post-neurogenesis) can be divided into different educational periods. Thirdly, studies that show the brain's development during neurogenesis and the need for appropriate educational material during this period were not done in connection with day-care centers and on a large scale. My conclusion is that, again, this move towards day-care centers is not done on the basis of the development of a human's learning abilities. It is done on the basis of other societal needs.

3. The indifference of society towards the development of the learning abilities and the learning needs of its members is exemplified in thousands of cases. But, it is more deeply touching and more massive and obvious in the attitude of society towards the needs of the females.

The present society is created by men to serve men. According to this logic, it was only natural to care for the females to the extent that they served man's needs and purposes. In the domain of quantity and quality of education for females, the practice differed according, again, to men's preferences for "female education". This was a common practice up until one or two generations before ours in the developed countries, and it continues in the undeveloped ones.
This example shows very well that society never took care of all of the individuals themselves, but of its collective needs or, more specifically, of the needs of the group that dominated society.

In any case, society did not, and does not, base its separation of education in preschooling and post-schooling periods on any scientific basis or even an intuitive understanding of the development of the learning abilities of the human brain. The division of at least the pre- and schooling periods of education has a basis which is sound in the sense that the children, by the age school programs begin, are able to take care of themselves; but this is unsound in the sense that there is not really any effort made by society to match this age with the periods of the development of the learning abilities of the human brain.

The indifference of society for the learning needs of the individual is not only demonstrated during preschool age. The adult learner is also mistreated in this area.

Propositions

In face of this general situation and in accordance with the insights about: (1) Coexistence, originating in Relativity, (2) the interconnection of system's levels among them, and especially (3) the functioning of the human brain, I consider the following propositions to bear some importance for educational realities:
1. Wide publicity should be given to the studies that concern the period of neurogenesis.

The example of the blind kittens is dramatic. Although the extrapolation of findings in animals to humans should be done very carefully from a physiological point of view as already noted, there is no great difference between mammalian species in the pattern of brain development. With the danger of serious permanent damage being probable, such as the one affected in the kittens, experimental deprivation in humans cannot be justified.

Similar experiments with humans cannot be done and we will have to extrapolate from animal experiments. However, there are situations into which a relative degree of deprivation of experience in humans has taken place, due mainly to adverse social conditions (Leland, 1974). A condition similar to that of the blind kittens is reported by von Senden (1932) in congenitally blind humans who were given sight after a surgical operation. These individuals showed great difficulties in perceiving even simple figures. Also, studies of children (Dennis, 1960) enclosed in an orphanage in Teheran who were given little activity, attention, and experience, showed shocking retardation in sitting up and walking. At the age of two more than half of the children could not sit up by themselves; at the age of four, 85 percent still could not walk. Many studies (Dennis and Dennis, 1940; Dennis and Najarian, 1957) confirm the hypothesis that deprivation of experiences makes a difference in
the rate at which infant organisms develop. The more severe the deprivation of experiences, the greater the damaging effects on an individual's development.

The public should learn that the first prerequisites for a human brain to become able to develop its genetically-inherited abilities is input of mass, energy, and information.

Normal growth of the nervous system is the background for an adequate mental, linguistic, and intellectual development, and the subsequent competence and performance of the individual. This is analyzed in a formation of adequate and appropriate neuronal pathways in the brain.

The inherited quality of the brain cannot be changed. But, the environmental factors must be thoroughly analyzed. Adequacy and appropriateness of nutritional and, in general, material conditions should be emphasized (Faure, et al., 1972). It should be also demonstrated that factors which are either ignored or neglected and sometimes even mocked are at least equally important for the future mental growth of an individual as nutritional factors. I have shown that by the time human brains are processing language together with the rest of the environment, they connect each item, detail, and action in the environment with some language element, and that the same basic mechanisms operate when they are forming the basis for their future understanding, concept formation, behavioral patterns, etc.
Thus, children during this age should be provided not only with appropriate nutritional and material conditions, in general, but, also with environmental richness in materials and actions.

The preschool child requires a varied, huge, and heavily cross-modal mass of sensory experiences. Quantity and variety of experiences is what counts for this age. These experiences should be acquired in real situations where a human being sees, hears, touches, tastes, and smells real objects (Hart, 1975).

Richness in inputs should not be understood as a selective and taught input. It means a great variety of ordinary, random, and largely real input. This proposition has special implications for preschool day-care centers. There, the focus, according to more or less valid speculations based on research, should be on rich, random and real input instead of organized, school-oriented teaching. To try to control and teach children at that age appears to have little value and may even turn out to be damaging. We really have little knowledge of how the development of the mental abilities of humans proceeds during this age. But all the existing evidence points to the notion that the above concepts are correct (Luria, 1976). Thus, some environments or behaviors, like schooling, during this age, may really prove to be damaging, given differences between preschool and schooling age in neuronal maturity, rate of learning, emotional problems, and a whole host of other variables.
Society is probably not ready to take care of the children aged 0-4 in an organized manner, creating appropriate conditions (institutions or educational centers) for the development of children of this age. Besides, I do not know if this would be appropriate for all the human needs of the children and of the parents, also. So, I propose that, in parallel with longitudinal studies that should be initiated to answer this question, an educational campaign should start to educate the parents and the public in general about the nutritional and informational needs of the human brain during the period of neurogenesis.

In what concerns the quality of the environmental richness, there may be no consensus. I personally consider as appropriate environmental factors:

1. Richness and variety in materials, behaviors, items, etc.; in a word, a diversified environment.

2. Order in actions and consistency in behavior, and

3. Love.

Concerning the first factor, I relate it to the brain functions and the cognitive development of an individual as follows. During the period of neurogenesis the individual is at a very young age and, because of that, the amount of knowledge he possesses is small. On the other hand, every situation with which an individual is confronted provides him the opportunity to associate this situation with his previous experience. Since this is the mechanism underlying
the cognitive development of the individual together with the physiological development of the brain, it becomes apparent that richness and variety in environmental stimuli is necessary for an individual to enable him to develop a plethora of associations and to later enable him to attribute meaning to a variety of situations. In terms of physiological growth of the brain, this may help the learner develop neuronal pathways that otherwise would not have been developed. Since meaning is given to reality by associations, an individual exposed to a limited amount of experiences will be limited in the potential meanings that he will be able to attribute later on to different circumstances. On the other hand, the mere presence of previous knowledge (ideal models) is a means by which an individual evaluates the new incoming information. And, in this respect, the second factor that I mentioned initially is of importance. In respect to evaluation, it is necessary to provide an individual a rather stable evaluating criterion. Otherwise, he may be confused. In this respect it is of paramount importance to provide the individual with the opportunity to imitate actions and behaviors which have order and consistency.

As previously discussed, the process of selection during learning is realized mainly by patterning actions and behaviors.

In conclusion, both richness and variety in materials and order and consistency in behavior are important for the cognitive and also the physiological development of the individual. Richness
and variety in materials equip the individual with a plethora of meanings for reality; and order in actions and consistency in behavior are the factors by which this plethora of meanings is organized in comprehensive entities. Since interplay of the environment with the developing brain is proven scientifically, and since this proof indicates that neuronal pathways may not be established because of lack of information processed by the brain, we may postulate that the environmental influence may help in establishing pathways which otherwise would not have been established.

Before the newer findings about neuronal development during neurogenesis (synaptic learning) were known, Piaget had described very similar ways of cognitive development from observations of children of preschool age. The most revealing hypothesis derived from Piaget's observations was that the rate of a child's development depends on the variations in environmental circumstances (Piaget, 1936). It states that the more new things an infant has seen or heard, the more he wishes to see or hear; and the more variation in real situations he has coped with, the greater becomes his capacity for coping. This hypothesis provides a good explanation for the effects of early experience on later capacity. It is, also, an explanation quite similar with that formulated by Hebb (1949). Various studies, for example, the study of Riesen (1947), which derived from Hebb's theorizing, are both relevant and supportive of Piaget's formulation.
Love is proposed as a behavioral pattern to be copied. That is, the adults should behave with acceptance and understanding towards all persons and situations around the youngsters, including the youngsters themselves, always showing tolerance towards different behaviors. However, adults should not accept all types of behavior. Some limits should exist. In other words, the offering of love should not be irrational. Rejection of some types of behavior should take place with kindness but firmly. The young learner always has the opportunity later in his life to change his criteria about what behaviors should be accepted and what should be rejected. Thus, the type of behaviors that will be chosen as accepted should not constitute a major point. The important thing is to demonstrate a balance between love and consistency as a behavior to be patterned.

This meaning of love reflects a true and deep concern for the human being. Support and handling of the learner with love is necessary for his cognitive development since the brain cannot learn under threat (see emotions). Nevertheless, such protection should not be given irrationally. Because, according to what has previously been described, it would destroy the criterion that the learners should have on how to handle situations. Thus, there should be a balance between the amount of support (protection) offered to the learner and the reasons for which this support is offered. Such a handling of the learner with love and support allows him to undergo a normal cognitive and affective development. At the same time, the
intervention of judgement (when and where love should be offered) - rationality - gives him the criterion for self-guidance.

I will now develop another aspect of love, although it does not refer only to the preschool age. Handling the learner with love means that the educator should handle with acceptance the initiatives of the learner to choose his own subject of study. This is very important because motivation is a strong factor for learning.

According to what I said about brain function, the brain can turn its attention only to one item at a time. Disagreement between the learner and educator as to what needs to be studied will present the learner with two choices: either to follow his subject of interest or to comply to the teacher's advice. Of course, this last situation is the rule at the young age. This, however, may deprive the learner from his motivation and will ultimately impair his learning. This situation may be avoided when the learner is handled with care and love.

Love and empathy seem to appeal to every human being. The reason seems to be that love as a behavior facilitates adaptation and promotion of life itself. With this in mind and knowing that adaptation is mediated by learning, and that the brain cannot learn under adverse circumstances, love facilitates learning.

Moreover, love is an expression of life itself. In this sense, love is life-giving and receiving. It is a reverence for life itself. Stating it in another way, we may say that as living beings
what we have in common is life. Every attitude, therefore, which promotes life makes us feel complete and satisfied and our experience as having meaning. So, love perceived as reverence for life is a fundamental element on which we should base not only our personal life, but also our attitude towards our fellow man. Meaningful teaching expresses this fundamental attitude towards our fellow man: the student. Only then can it promote the life of both and allow them to grow and develop.

We tend to attribute to some individuals around irrationality and malignancy. With the exception of pathological cases with some sort of brain damage, I do not believe that there are stupid persons. There are persons raised in stupidity. Inheritance will, of course, make some difference. But there will be no intellectually incompetent person among normal individuals, if raised appropriately during neurogenesis. In respect to malignancy, I do not believe that there are good or bad persons. There are persons raised in indifference and hate who turned to be bad. An individual raised in a warm and loving environment acts differently than an individual raised in a disorganized indifference of hate.

Prediction of adult behavior from early data was difficult and Bronson (1967) concluded that information used to predict adult behavior should be obtained at certain periods during the developmental years....Evidence available from both animal and infant studies indicates that infants who have satisfying interpersonal relationships develop a
perceptual set of expectancy for future satisfaction, but those who have had frustration and deprivation of opportunity for fulfilling needs tend to see many of the new stimuli in environmental interaction as holding possible dissatisfaction. (Alexander, 1973, pp.185-186)

And he continues:

The family remains the most significant social structure in the socialization process, and its influence comes at a time in the child's life when basic response patterns are being established. (Alexander, 1973, p.201)

In this sense, transferring of patterns of behavior of love to the child is critical for his subsequent life and development. Especially giving and receiving as an expression of love is a pattern of behavior which, if internalized early in life, helps individuals to escape from alienation in their adult years.

Signs of deprivation of love are observed in animals, also. If one judges differently raised animals, he finds a remarkable difference in their behavior, depending on the way they are raised. Animals receiving punishment inconsistently become anxious and hostile (Corson, 1969, 1975).

In conclusion, one should admit that individuals as well as animals, who are perceived as behaving in a malignant way, were, perhaps, raised to do so.
Finally, linguistic competence, which I mentioned previously, is facilitated by the same factors I described up to now.

All these experiences being inscribed together with the words in the brain, in fact, included in the meaning of the words, will contribute to the individual's vocabulary richness and his intelligence (by richness in variability in meanings and words). Patterning of behaviors such as love, order and consistency, will be the seeds for a reasonable (order), positive (consistency), and affective (love) behavior.

2. Within the same matrix of efforts that point to the same goal, i.e. better management of the ages 0-4, I propose the organization of concrete groups of experts. These groups will include individuals who, first of all, possess a deep knowledge of neurophysiology and psychology, and who may have more concrete specialization in this age of the human being. I see the function of these groups as twofold. One is to organize programs of continuing education for day-care center operators, and second, to generate from observations and research, in general, the data needed for a better understanding and treatment of this age.

Today, there are relatively few requirements needed for someone to open and operate a day-care center and much fewer requirements to work as an employee in such a center. I believe that the primary requirement for any one who operates a day-care center should be a relatively extensive amount of knowledge about the needs of the
learner at these ages. Programs of continuing education exist for several professions. I consider a program in this area more necessary than for any other area. Children are our future and hope. They should at least be given what they need.

3. Propositions for education which will take into account only one part of the population are not very likely to be successful, in view of the interrelation of all parts of society, and of the modeling power and impact that the behavior of the older exerts over the education of the younger. This latter is a reflection of the way that learning is realized. In this sense, it does not suffice to put the basis for future normal mental development of children during the preschool age. A parallel effort should be undertaken for all the other ages of the learner. Because there is a continuous interaction among persons, the older ages always influence the learning of the schooling ages, not to mention the almost exclusive impact of the mature ages in raising children during neurogenesis.

This proposition is related to both factors, namely to the ways by which learning is realized by the brain, and the fact that education is only a subsystem of society. In summary, society, as a whole, is bearing perhaps the biggest responsibility of what the young generation will learn, and not the educational system alone.

4. The ages of admission to the schools should be reevaluated. When possible, they should be adjusted to the needs of the
developing brain of the learners. These needs are different during neurogenesis than in later ages. I have already elaborated in Proposition 1. about what these needs are during the years 0-4. In later years, the cognitive development of the learners is determined from the amount of accumulated knowledge rather than from any other specific brain ability (see p.248). It is generally believed that before the seventh year of age the individual is not able to perform abstract thinking (Piaget, 1947). Since this ability is related to a certain amount of knowledge that the learner will acquire, provisions should be made to give him the necessary amount and quality of knowledge that will help him reach the point of abstract thinking. This is very critical. Luria (1976) has shown that even adults that do not have the necessary amount of knowledge cannot form associations corresponding to abstract thinking (categories corresponding to general properties). Thus, education should concentrate its efforts in the designing of curricula which, by a well-calculated amount of knowledge that should be provided to the learner, and a careful timing of when this knowledge should be given, will enable the learner to think abstractly as early as possible.

Another critical period is adolescence. The main difference for the individual in this age is his encounter with sexual activities. This situation creates emotional instability which may influence learning.
A learner may need emotional support during this age in order to find an emotional balance which will facilitate his learning. Specification of the ages for entering school and/or specification of the content of the curriculum for the several ages cannot be based on an understanding of the needs of the developing brain alone. One should also take into account the social conditions in which the individual develops. What I am trying to say is that society, in determining educational policies, should take into account, together with the other existing variables, the educational needs of the cognitive development of the individual and the timing of his cognitive development.

5. The educational programs should necessarily include "action". The reason is that, as I have shown in the third and fourth chapters, during learning a selection process takes place (selection of information to be inscribed in the memory), which is realized by adapting a behavior to respond to an incoming information. During early ages of an individual's development (and, in some instances, during the adult years, also) knowledge is better or perhaps solely embedded in the brain through "doing" what is verbally taught.

Knowledge should be offered through a multiplicity of means and methods. The human brain learns better if the same information is provided to more than one of his senses, a fact which is best accomplished through action.
Since it is not possible to divorce the process of learning from its own source within the learner himself, and since every man has to "know" in order to be effective in some form of action, while at the same time learning is realized during action, it follows that knowledge would grow out of the unity of theory and action.

The objective of this type of education would be better accomplished if incorporated in life. Incorporation in life, in this sense, means to put the principle of the unity between theory and action into practice, using instances and events presented to the learner during his everyday life, because this greatly promotes motivation in the learner. So, in the midst of actual problems, creativity (mental and practical) would be experienced often. Motivation and curiosity of the students would be really enhanced in solving problems of life. The learners, encouraged to create new types of action and behavior, would gradually assume the role and the responsibility for their own learning, perceiving it as a life-long process; because they not only realize their learning within the course of life events, but they also have the opportunity to realize that knowledge means power to understand situations and solve practical problems. Hence, one of the principle objectives of this type of education would be to make the connection between theory and action, school and life, perceiving knowledge as "an organ of personal illumination and liberation" (Dewey, 1929, p.15).
The evaluating power of action is a means to evaluate information and it is incorporated in learning at all ages. Nevertheless, the step of action can be omitted after a sufficient amount of knowledge by doing has been accumulated. For this reason, while in the first schooling years, most of the educational processes should concern a combination of theory and practice, during adolescence and later years this type of educational approach can be gradually replaced by other educational approaches and methods such as discussion, lecturing, etc. (theoretical approaches). Nevertheless, a combination of providing the theoretical information through means that refer to more than one of the senses (for example, combining lecturing with audio-visual materials) greatly facilitates learning. This is in accordance with brain findings about the attribution of meaning to realities through multiple associations. Another of the best ways to create multiple associations while at the same time providing a criterion to the learner himself for judging the success of this learning, is action. Thus, a moderate amount of learning by doing should be incorporated in teaching a new subject in adults as well.

6. Starting from the fact that the brain builds up concepts gradually, by associating information patterns originating in concrete situations, it becomes obvious that (1) every individual has, at a certain point in time, his own meaning for different concepts and (2) the individual cannot build up his concepts and
develop his own cognitive tree effectively if care is not taken to associate new concepts with previous ones. Despite the fact that individuals have different starting points in their cognitive development, there occurs a gradual equalization of the concepts which again depends on the realities surrounding the individual. That is, the markers that are initially inscribed in the brain as patterns of information representing the concrete surroundings are acquiring new associations by frequent encounters of the individual with new realities; through them the individual reaches a point at which he usually attributes to the concepts meanings which are different from the initial ones and which, most of the time, are the same or very similar in meaning with those that others have attributed to the same reality.

In this sense, the educational system should not develop rigid programs for each school year and/or for all areas. Starting from the learner's needs and taking into account the diversity of concepts that individuals may have created in their minds at the time they are attending schools, different areas should have different programs. In the process of applying such policies, we will find the real needs of the learners of different backgrounds, for differential initial treatment and for subsequent equalization of meanings. Because I believe that, if we want to communicate to each other, a progressive equalization of the individual differences in the conceptual apparatus of the learners should be the aim.
7. The amount of knowledge which should be offered and hopefully absorbed by possibly all learners should be adequate for them in order to meet the needs of their lives at any certain point in time.

Based on this basic principle-proposition and in relation with the needs that an individual may have during his development, I think that the following propositions are pertinent.

8. We discussed in previous chapters the detrimental results that lack of knowledge, leading to inability for adaptation, may have. What happens to individuals who cannot adapt is that they become emotionally disturbed. This impairs them from further learning. It appears, then, that because of the way that the brain functions if there is no monitoring of the amount of knowledge needed for the learner to adapt to his social realities, he may enter a vicious circle in which his cognitive development is practically stagnated. An education concerned with the inner necessity of the learner should avoid that. In this sense, education should monitor the amount of knowledge needed for the normal adaptation of an individual in his social realities.

9. Based on the same basic needs of the individual (adapt to the realities of the existing society, at least in their own nation and, hopefully, in the world), I propose that a sufficient amount of general knowledge, a sense of historic continuity and of the common human heritage should be offered to all learners before they begin
acquiring specialized knowledge. Early fragmentation of different types of knowledge to be offered - theoretical, technical, professional, etc., - must be considered as an updated, very inefficient educational approach, since its final result is the creation of fragmented minds, able to work efficiently in one professional spot but unable to deal successfully with general problems, even with their own adaptation to today's highly complex social realities. We have seen the example of the inability for adaptation through the dramatic example of the patients with heart disease. An education which is interested in satisfying the educational needs of the learner should be unified, including aspects of practical and theoretical knowledge at the same time, and covering a rather broad area in general education.

10. During adolescence there should be given to the learners a means of alleviating the emotional charge which is generated to them as they approach the sexually active period of their life, in order to secure a normal cognitive development during this period, also. In this sense, not only the sexual act should be explained to them but, also, the efforts of the youngsters to learn sex should be handled with care and understanding. Over or under-estimation of this human need may result in ruined lives. Such false estimations usually originate in emotional factors. Alleviation of the emotional disturbances of this age should be given to the adolescents by showing them the real significance and weight of these activities
during the course of a person's life. It should be demonstrated that isolating sex from other aspects of life, which happens rather easily in adolescents, is a mistake. Other alternatives for emotional discharge and creation of meaningful relationships with individuals of the opposite sex should be given to the adolescents. For instance, exposing them to a number of activities which may satisfy primarily their emotional needs (music, theater, arts, sports, etc.). All this would aim at helping the continuation of the cognitive development of the adolescents. Since emotionally disturbed individuals cannot learn, to facilitate learning during this period one should find ways to handle the emotions of the learner.

11. Due to the simultaneous existence of two things: the obvious need of a certain amount of knowledge for the adaptation of an individual, and the continuous change of the amount of knowledge (explosion of knowledge) within the rapidly changing societies, I propose the formation of appropriate committees whose job would be to determine which is the least amount of general knowledge required for all men to enable them to adapt to their environment. The function of these committees should be rather permanent, readjusting the amount of general knowledge needed for adaptation to the ever-changing realities.

12. Within this framework of reference and in view of the possible inability of educational institutions to transfer to all
men the amount of knowledge required in order to follow the development of today's ever changing society, I propose the design of a pioneer program by starting teaching at a late point in school - for example, after the ninth grade - one of the three subjects: (1) General System Theory, (2) logic in connection with calculus or (3) Dialectic methodology. The purpose of this pilot program would be to evaluate the results of the introduction of such a way of thinking and such a point of view of the world in the minds of the students. Of course, this should be done at a point in the learner's growth at which he will probably be able to understand it. If this will help the learners acquire confidence in their logic, and will make them feel self-confident, it would probably be a way to overcome the pressure of the explosion of knowledge that we all feel, and a way to freedom so precious for creative thinking.

13. The purpose of early education should be to enable the learners to progress to the subsequent stages of cognitive development. This is extremely important and, although it is related to the maturation of the individual as a whole, it seems that it depends mainly on the amount of knowledge that an individual will acquire (Luria, 1976). However, since this knowledge can be acquired and accumulated through a circular way, by interchanging increase of knowledge with increase in self-confidence as illustrated in the discussion on creativity, the behavior of the teacher towards the student becomes equally as important as the amount of knowledge a
14. I have discussed the importance of emotions in the learning process and the way they impair creative thinking. On this basis I propose elimination of the evaluation of students by the teacher because I perceive it as a threat that any student feels hanging over his head continuously. Man, starting from an early age, needs to feel "free of threat", secure, and loved by his immediate environment in order to be able to develop his full human potential. A mild level of emotional arousal tends to facilitate learning because it provokes alertness and interest in the task. Nevertheless, "emotions, when sufficiently intense, can seriously impair the processes that control organized behavior (Hilgard, et al., 1975, p.357). Individuals differ in the degree to which they react in emotional response to threatening situations.

Observations of people during crises suggest that 15 percent show organized, effective behavior. The majority, some 70 percent, show various degrees of disorganization but are still able to function with some effectiveness. The remaining 15 percent are so disorganized that they are unable to function at all;......(Hilgard, et al., 1975, p.357)

We see that the majority of the people cannot function normally under threatening situations. They are far less able to learn. I believe that evaluation by the teacher or by examinations taken by the student creates a sufficiently intense threatening situation and
interferes with learning. However, there should be a way to evaluate students' performances. I believe that in finding ways of evaluation, the educator should always take into account the inner necessity of the learner and handle the students with care.

15. Evaluation, overt or hidden, is always present in human activities. It cannot be avoided. The question, then, becomes what could be a helpful type of evaluation in schools. In this sense, I think that evaluation of the students could be made by the whole class in a diversity of subjects (fields), so that everybody has an opportunity to be favorably judged while, at the same time, criticized in other fields. This type of evaluation may be proven to be of the type of the moderate challenge, which is not harmful to the individual. Such or similar types of evaluation should be tried before we find out what will be the best approach to this problem. Meanwhile, the present type of evaluation, in all its complexity, is considered to be harmful to the individual.

16. Moderately challenging experiences are needed for effective learning because they promote man's ability to take risks and enable him later to cope effectively with difficulties. These experiences will, eventually, strengthen his sense of inner confidence. This is, in other words, the meaning of learning by adaptation to new realities and has its basis in the brain functions. Overprotection, ready solutions, easy going, may kill, together with the motivation for learning, the learning abilities themselves.
Applied to the school realities, the realization of such an approach requires great skill from the part of the teacher. He should be sensitive enough (to discern the risk as perceived by the student) and truly supportive (to help the student overcome inner fears and hesitations without "overprotecting" him). These abilities of a teacher are, of course, based primarily on a deep and sincere love of his fellow man, in this case for the student; but they can be further developed through an understanding of the brain functioning.

17. Teachers and perhaps school administrators, also, should be provided with basic knowledge in neurophysiology and educational psychology. Briefly, I think that they should know what they are dealing with, namely the human being in general and especially the brain, where learning is realized. Since we do not know how many of these basic elements will be necessary for teachers to enable them to understand how a learning brain works, I cannot propose specific programs with specific contents. But, I think that teachers should know: (1) How the human brain works while learning, and (2) that every learner should be approached as a whole person, an adaptive open system which is in a continuous interaction and transaction with his environment. They should be aware of the brain functions in order to understand how information is processed. They should also be aware of the factors which may impair the learning processes of the brain. They should know the processes that have to be
followed by a learner to reach the point of personal freedom needed for creative thinking. There is no doubt in my mind that the best approach to a learner is love. But I believe that deep knowledge of a professional’s field improves his performance. And, I believe that the field of a teacher is the developing brain, the developing man.

18. Programs of continuing education should be established for teachers in order to enable them to become acquainted with all recent findings in brain functioning and learning.

19. Some of the instructional methods frequently used in schools and higher educational institutions could be re-evaluated under the light of the knowledge of brain functioning.

It appears that simple lecturing is the weaker approach to facilitate learning because it uses only one medium by which information is processed by the brain, and it does not create many associations in the listener’s brain. Furthermore, it may lead to confusion of concepts although it is supposedly addressed to an audience that has already high ability in abstract thinking. A better approach than simple lecturing seems to be lecturing in combination with the use of visual media, the reason being that it provides information to more than one of the senses and enables the human brain to form more associations and, thus, to reach a better understanding of the concepts presented. An even better approach is an audio-visual presentation followed by simultaneous discussion.
This provides the teacher the opportunity to discover what possible differences may exist in the understanding of concepts between him and his audience and clarify the meaning of concepts.

A special type of discussion is the "socratic" method of dialogue in which the learner is driven to discover the meaning of a concept or the solution of a problem by himself, being appropriately led by the questions of the teacher. This last approach is in complete accordance with brain functioning because it provides the learner with the opportunity to form the necessary associations which he needs in order to understand the meaning of a certain concept or the steps leading to the solution of a problem. A still better instructional approach is to combine theory and practice. In this case the learner gets into action while learning an entity, which involves almost all of his senses in the learning process together with the motor centers of the brain. His attention is intensified since he is forced to make decisions and give solutions to the situation while learning it. At the same time, he is provided with a criterion (the results of his action) that allows him to evaluate his own learning. Thus, in this case, he is making full use of all his natural resources that participate in learning. A subcase of this approach is the "discovery learning" which is valid for the same reasons.

"Individualized instruction", on the other hand, in all its variety, is basically addressed to the needs of an individual
learner. From this point of view, the teacher has the opportunity to discover the stage of the cognitive development of a learner, and build on it through appropriate materials and discussions. As far as individualized instruction is combined with some form of action, it is the best instructional approach to satisfy the needs of a learning brain.

20. When analyzing the previous propositions, we see that the teacher, in order to effectively facilitate learning, has to investigate the concrete situations surrounding the learners. From this point of view, the teacher is a learner himself. Furthermore, during teaching, there is a continuous exchange of ideas and concepts between the teacher and the students. There may, then, be instances where the student, during his effort to internalize a concept, makes points which may be new to the teacher. In this sense, the teacher, by being ready to learn from his student, shows through his example that the position of a learner is not an inferior one. This, in its turn, alleviates all remnants of authoritarian teaching patterns, and renders the learner more open and ready to learn. Thus, the teacher should primarily be aware that he will be fulfill his task when he perceives himself as learner as much as a teacher.

Reevaluating these propositions (which seen from another point of view also constitute the conclusions of this theoretical study), I have the following comments:
(1) They do not constitute "goals" for education, in the sense that they do not constitute specific programs, but, rather, guidelines according to which an education, which has as its center man himself, and not abstract ideas or corporate ideals, should develop. However, propositions for education cannot be completely void from programmatic content. The present propositions are very general and allow for a wide range of more concrete programs and propositions for their realization. The one goal hidden underneath all of them is: Progress and evolution of society through an education which does not disrupt its individuals, but respects their inner necessity. I maintain that, despite my opposition to "goals" in general, I could not escape such a goal since both evolution and inner necessity are conditions for life.

(2) A theoretical study like the present one is not expected to bring about experimental proof for its conclusions. These conclusions constitute practically hypotheses, the validity of which should be tested experimentally. On the other hand, the hypotheses originate in well-documented facts or logical assumptions and theories of others. However, the validity of any hypothesis can be tested mentally before it is brought under experimentation, by evaluating its rationality. My rationale is based on the assumption that man himself is the raw material for education. Thus, the development of persons is a presupposition for any other goal of education (Sanders, 1977). Ross Mooney expressed the same idea in
Based on this assumption, I undertook a study of the brain's ability for learning because development of persons depends mainly on their ability to learn, and this depends on their brain functions. As far as brain functions are experimentally proven to be related to learning, propositions for education based on brain functions acquire not only theoretical but, also, scientific value. Unfortunately, at the level of the brain's physiology (as opposed to psychology), most of the findings on brain function that have real demonstrative value are related to animal experiments. One cannot open human skulls and experiment on the human brain. Thus, most of our knowledge on brain function is by extrapolation of the results of animal experiments. Nevertheless, whenever possible, I used data from observations on human patients with brain lesions. This is one of the main reasons why I used language, which is a uniquely human characteristic, to approach the problem of information processing by the brain. In spite of all this, the level of the work
of an educator is not the level of the brain's physiology, but it is the level of an individual's behavior and existence within his environment. In order to raise the level of the physiological facts to this second level, one has to formulate assumptions. Experimental testing of these assumptions is abundant in psychology, and although I used results of such studies extensively, especially in my effort to provide evidence of brain functioning originating in humans, my conclusions are only indirectly based on brain functions. In any case, the reader may disagree with my assumptions which are developed in the third and fourth chapters of this dissertation. His hypothetical disagreement, then, will consist in the interpretation of the brain functions that I presented in the second chapter. And, logically, it will be based on his theories about the world. Unfortunately, objectivity goes as far as the objectivity of our theories goes. We can see the world only through our theories. For this reason, before proceeding in the development of the above propositions, I presented briefly the origin and the nature of my theories: Relativity and systems through Relativity.

This is my rationale. Propositions deriving from such a theoretical treatment could only be of general nature. Any effort for application of any of them presupposes the elaboration of more concrete and specific propositions, which will take into account the concrete time-space and conditions of the learners for whom they will be elaborated.
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