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System : an approach to educational problems and issues.

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SYSTEM: AN APPROACH TO EDUCATIONAL PROBLEMS AND ISSUES

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ABSTRACT

This paper attempts to develop a general theory of concrete systems and to apply it to educational problems and issues at both the organizational level (schools) and the organismic level (students in schools). Part I presents the need for a general theory which is applicable at different levels. The importance of maintaining an appropriate level of generality is stressed; appropriateness being determined by the ability of the theory to distinguish clearly the systems it pertains to from the systems it does not pertain to, as well as the comprehensive application of the theory to all systems it perports to pertain to. Part I also distinguishes between concrete systems - those which exist and change in space/time - and abstracted systems - ideas, theories, and models which, while contained in concrete systems, are not themselves concrete. The paper contends that while theories may apply to both concrete and abstracted systems, only concrete systems can be analysed through observation and measurement.

Part II develops the general theory. First, closed and open systems are distinguished. Open systems are then classified into three types:

1) non-adjusting systems which have unchanging lines of behavior;

2) adjusting systems which can change their behavior in pre-determined ways; and

3) learning systems which can change both their behavior and their organization through self-regulation.

The relationship between these types of systems, their capacity for change, and their relationships with changing environments is explored. The particular characteristics of learning systems are analysed in terms of their inputs, subsystem processes, and outputs.

Part III applies the theory to schools and students. As concrete learning systems, both the school and the student are seen to share certain general characteristics; they are open, they control their own transformations, and they are probabilistic. They are well-adapted to their concrete environments. They tend towards increasing complexity; including more differentiation of subsystems, more decentralization of decision-making, more interdependence of subsystems, and more elaborate adjustment processes. Their capacity to learn depends upon the quantity and variety of information stored in the system, the structure of their communications network, the pattern of subsystem allocation, the function of feedback loops, the memory facility, and the program determining the systems structure and behavior.

These general characteristics are developed with reference to common problems and issues faced by educators, including the development of appropriate learning environments, the relationship between learning and behavior, and the capacity of both school and student to learn under different environmental conditions.

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PART I

INTRODUCTION

CHAPTER I

THE IDEA OF GENERAL THEORY

1.1 This paper attempts to develop a way of thinking about puzzling and complex educational issues which may be new and unfamiliar to a great many educators. Part of its novelty may be terminological; its conceptual constructs are drawn from relatively recent developments in system theory and information theory. However, its intrinsic novelty - and the test of its ultimate value - extends beyond mere vocabulary. It rest instead on two fundamental premises, the first shared by steadily increasing numbers of specialists and theorists in diverse disciplines, while the second is less widely accepted.

1.2 The first premise is that there is an appropriate level of generality which permits a non-reductionist analysis of complex phenomena. It develops general principles of organization and of transaction with environment which all phenomena share. It assumes the Aristotelian dictum that the whole is greater than the sum of its parts, and adds to this that the behavior of the whole is a function both of its parts and of the relationships among its parts. When rigorously applied, this premise leads to the discovery of formal isomorphisms among systems of different types and levels. Non-rigorously, it facilitates the development and analysis of suggestive and fruitful analogies which can lead to new insights about familiar systems.

1.3 The second, and more controversial, premise is that all behavior is well-adapted to the particular environment of the system whose behavior is being observed. Behavior, from this viewpoint, is a reciprocal and transactional relationship between the system and its environment. An analysis based upon this premise must be both non-judgmental and non-normative. While the notion of being "non-judgmental" is familiar and comfortable to most scientists, the notion of a "non-normative" analysis is strange to a great many. This Introduction will develop and elaborate these premises as a context for the theory which follows in Part II and the application of the theory to educational concerns in Part III.

1.4 The idea of general theory has been the impossible dream of poets and philosophers, scientists and mystics, throughout the centuries. The idea that all knowledge and behavior could be explained by one all-embracing set of simple ideas or formulae has informed the thinking of both fools and scholars, and has led theologians to God, physicists to energy, psychologists to _thanatos_ and _eros_, aestheticians to beauty, and hedonists to pleasure. Among scientists pursuing what Kuhn has called "normal science," the search for theory which would relate the concerns of their disciplines to those of other disciplines has been skeptically received, unless the theory could be shown to adher rigorously to their own accepted paradigms. The notion of a "discipline," with its own fundamental principles, rigorous vocabulary, and distinctive methodology has been inmical to less rigorous efforts to find commonalities or "hidden likenesses"[1] among the disciplines. The creation of new disciplines is slow and cumbersome, and generally requires practitioners who are both skilled and credentialled in the disciplines being combined. The psycholinguist is trained in both psychology and linguistics, the biochemist in

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[1] Bronowski, J., _Science and Human Values_ (New York: Harper, 1965).

1.4

both biology and chemistry. As communities of psycholinguists and biochemists continue to grow, eventually university departments are created, and these new disciplines develop their own paradigms and methods. Their practitioners, however, tend to guard the boundaries of their new disciplines just as vigorously as their forerunners had guarded theirs.

1.5 No matter how skeptically regarded, then, the search for theories of greater generality has been a driving force in the history of ideas, and we need not be apologetic to be a part of an intellectual tradition which seeks to discover and analyze commonalities among disparate phenomena. We must be aware, however, of the pitfalls and dangers which beset the path of general theorists. The first, and perhaps the most important, is <u>the tendency of general theorists to overlook significant differences in the phenomena they are exploring</u>. To say that different phenomena are alike in some ways is not to say that they are alike in other ways as well. It is inevitable that the more phenomena are subsumed under a general theory, the fewer aspects of those phenomena will be dealt with by that theory. A theory of fat, green frumkins will apply to all fat, green frumkins, while a theory of frumkins will apply to fat, thin, red, and green frumkins. It is tempting for the theorist dealing with frumkins to assume that all frumkins are alike, but the truth is that they are alike only in their frumkinness; they are different in size and color, and these may be significant differences, indeed. Toynbee has been severely criticized within the historians' guild for ignoring the differences among the societies whose commonalities he explicated. Freud has been criticized by psychiatrists for assuming that early childhood experiences are similar for most people. General systems theorists have been charged with transforming provocative analogies into general principles. It is true that general theory cannot account for idiosyncratic behavior, and it is equally true that some general theorists, in their enthusiasm, seem to forget this. General theory can be a powerful analytic tool, but it is frequently a weak predictive tool.

1.6 Another danger of general theory is its tendency towards triviality. The more general the theory - the more distinct types and levels it encompasses - the less likely it is to illuminate important properties or characteristics of the particulars it is applied to. That a theory is trivial does not mean that it is untrue, only that it is obvious. Of course, one man's triviality may be another man's profound insight. We tend to overlook the obvious, and sometimes it is helpful to restate the obvious in a new and different context. For example, the statement, "all concrete things change over time," may appear to be a trivial observation, although the corollary, that different kinds of concrete things change in similar ways, may be novel and significant to many readers. Likewise, the distinction between concrete things which change over time, and abstract things (like models and theories) which need not change over time may well illuminate a difficulty in applying abstract models and theories to concrete systems. However, the general theorist must still guard against the possibility that in applying new terminology to old situations he is merely obfuscating the obvious. The emperor may, in fact, have new clothes and still be the same old emperor.

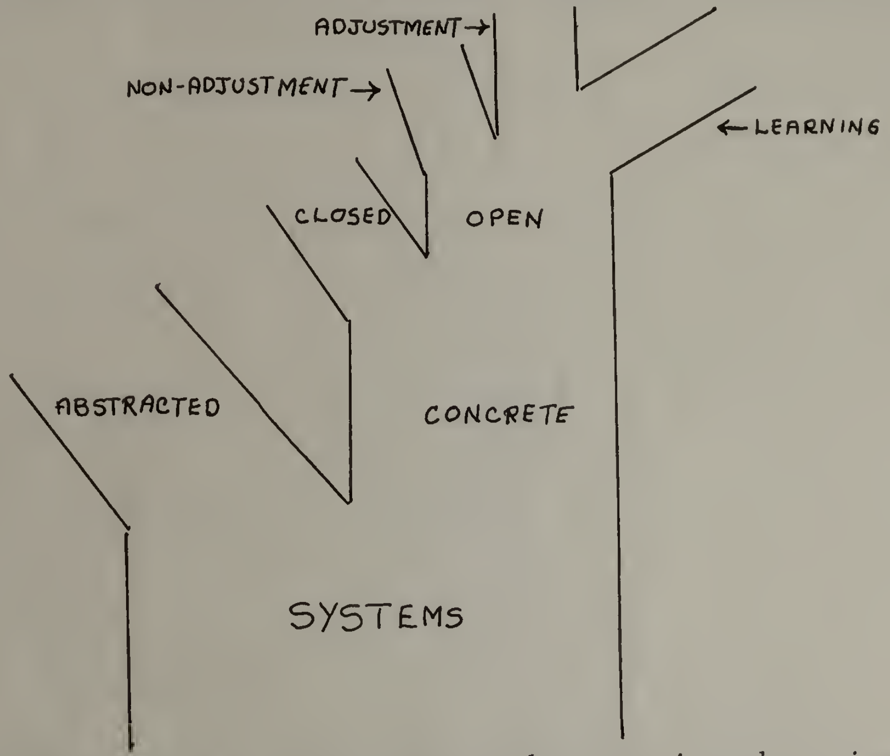
1.7 Finally, there is the problem of maintaining a given level of generality. If we think of a continuum of theories, we might have at one extreme "content-bound" theories, highly specialized and pertinent only to a given class of phenomena. At the other extreme, we would find "content-free" theories, generally mathematical, which are internally consistent and axiomatic, but without reference to anything, whether concrete or abstract, other than themselves. Within these extremes there is a lot of room to wiggle, and general theorists frequently wiggle a lot. To avoid the conceptual problems which wiggling can lead to, general theorists most constantly ask themselves two questions: first, does the theory clearly distinguish the things it pertains to from the things it doesn't pertain to; and, second, does the theory always pertain to all things it purports to pertain to? In general theory there are no exceptions which prove the rule. Any exception questions either the validity of the theory or the level of generality at which the theory operates. Any statement which begins "In general. . ." is a wiggly statement and ought not be a part of a general theory at a given level.

1.8 This paper develops a general theory of concrete learning systmes. It attempts to avoid the first pitfall by stressing that the system one is studying is a set of variables drawn from the object one is interested in (2.4 and 2.11), not the object itself. To look at a human being as a biological system does not mean that a human being is only a biological system.

1.9 It attempts to avoid the second pitfall by applying the theory to the world of schools and students so that the significance of the theoretical propositions can be judged against their utility. Ultimately, perhaps, triviality, like beauty, is in the eye of the beholder. Whether this paper successfully avoids it must be decided by the reader.

1.10 Finally, this paper attempts to maintain a consistant level of generality by clearly delineating at every step the classes of systems to which the theory refers. These classes are successively restricted in the following manner: Chapter One deals with all systems, whether abstracted or concrete. Chapters Two and Three and subsequent chapters restrict consideration to the subclass of systems called concrete systems. Chapter Four further partitions concrete systems into open and closed systems, and then classifies open concrete systems as non-adjusting, adjusting, or learning systems. The remainder of the paper is concerned only with learning systems. All statements made are true of all learning systems, and unless otherwise indicated, true only of learning systems.

The following tree may help the reader visualize this classification scheme.



Some words about this classification scheme are in order, since it has profound significance for the mode of analysis used in this paper.

Concrete Systems

1.11 First, the distinction between concrete and abstracted systems is paramount. The tests of a concrete system are two-fold:

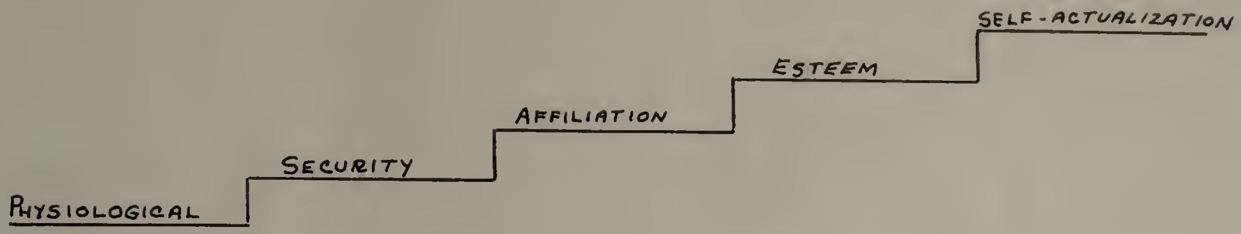
1) The system and its components consist of matter-energy and occupy physical space;

2) The system and its components change over time.

Any system not having these two characteristics is excluded from this inquiry, not because it is unimportant or unreal, but because it is fundamentally different and requires a fundamentally different mode of analysis. It is also a contention of this paper that much social science theory confuses abstracted and concrete systems, that indeed the prevailing mode of social science analysis is based upon the application of abstracted systems to concrete systems.

1.12 What sorts of things are abstracted systems? They are theories, ideas, and models that don't have reference to concrete systems. They are found in books and heads and frequently have great internal plausibility. While all theories, including this one, are abstracted systems, they may have reference to either concrete systems or to other abstracted systems, which can be then called "abstractions." While a "general theory of concrete learning systems" is itself an abstracted system (its elements being abstracted from the class of concrete learning systems), all of the systems to which it pertains meet the criteria listed above for concrete systems. All of its statements can be applied to actual physical entities.

1.13 Some examples may help to clarify this point. Maslow's "hierarchy of needs" is a good example of an abstracted system which applies to an abstraction, not a concrete system. Maslow postulated a hierarchy of basic human needs, ranging from physiological needs at the bottom to "self-actualization" at the top.[2]



Presumably, each level of need requires some degree of satisfaction before the next level emerges into dominance. This theory has intrinsic plausibility and undoubtedly represents a valuable contribution to human psychology. It is, however, not a concrete system for two reasons. First, the elements of the system, "needs," are not concrete according to the first criterion above, and the system itself does not meet the second criterion; namely it does not change over time. Second, the system refers to an abstract entity called "man" and not necessarily to any or all concrete persons. A particular individual may or may not exemplify the theory. A psychologist working therapeutically with a great many particular individuals may find that the theory is generally true. Abstracted theory may indeed be generally true, or statistically true, without being true of particular instances. I must stress that this is not a deficiency of abstracted systems, it is a characteristic of them. We shall mention below, however, that one of the fallacies which infects social science is the presumption that a particular instance which does not exemplify

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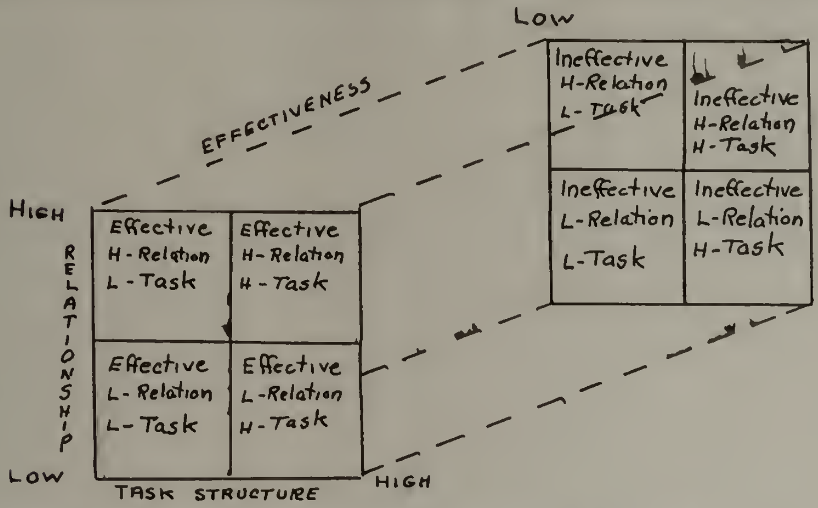
[2]Adapted from Hersey, Paul and Blanchard, Kenneth H., Management of Organizational Behavior (Englewood Cliffs: Prentice-Hall, 1969), p. 18.

the abstracted theory is in some way deficient, maladjusted, or deviant.

1.14 Organizational theory is rich in examples of abstracted theories which are essentially models of abstracted systems. Hersey and Blanchard develop a three-dimensional model of "leader behavior" with a relationship dimension, a task dimension, and an effectiveness dimension.[3]



Presumably, those occupying "leadership roles" in organizations will have a style which falls somewhere within this cube. Hersey and Blanchard also maintain that successful leadership calls for an adaptable style, one that can change as circumstances dictate. Again, this is a theory of attractive plausibility. It is undoubtedly a useful tool for analysing leadership styles in concrete organizations, particularly those in which "leadership" is localized in the "leadership role." Unlike Maslow's theory, Hersey and Blanchard's model does not suggest an invarient model of behavior, but rather stipulates definitional boundaries within which leadership behavior may take place. Nonetheless, the components of the system, "leadership" "relationship behavior" "task behavior", and "effectiveness" are not concrete. Two intelligent trained analysts could disagree about the nature of these abstracted components. It is interesting

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[3] Ibid., pp. 73-80.

to note that if the components of an abstracted system are themselves abstractions, then the variables of that system are concrete: the actual leaders and followers with their particular personalities and styles.

1.15 This can be generalized to say that whereas the components of concrete systems are themselves concrete, the components of abstracted systems are relationships among concrete entities. Miller comments:

> To some it may appear that the distinction between concrete and abstracted systems is something like the difference between saying "A has the property _r_" and saying "_r_ is a property of A". This translation is logically trivial. In empirical work, however, there can be an important difference between discovering that A has the property r and finding an A which has the property r.[4]

Miller is a strong advocate of focusing on concrete rather than abstracted systems. He suggests five reasons:

> 1. In the first place, it is easier. . .We are used to seeing the world as a collection of objects in space-time. . .
>
> 2. Variations in the units of systems appear to contribute as much or more to the tool variance in the systems than variations in their relationships. . .
>
> 3. Theory which deals with concrete systems avoids the sort of confusion that arises when theory in social science or other areas appears to assume that actions, roles, or relationships carry on a life of their own, independent of other aspects of the people or other concrete systems whose processes they are. . .
>
> 4. . . .Behavioral scientists, if they deal with abstracted systems, easily forget the intra-system relationships in concrete systems which influence processes within and between those systems. . .

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[4]Miller, James G., "Living Systems: Basic Concepts" in Gray, Duhl, and Rizzo, eds., _General Systems Theory and Psychiatry_ (Boston: Little, Brown, 1969), p. 78.

1.15

> 5. If the social sciences were to formulate their problems, whenever possible, in the way which has proved most convenient for the natural sciences over centuries, unification of all the sciences would be accelerated.[5]

1.16 Miller, I believe, has overstated his position. Natural science could not exist without abstracted systems any more than social science can. Natural scientists are increasingly coming to realize that in many instances variations in relationships are more important to system behavior than variation in units. Nonetheless, this paper attempts to follow Miller's advice for three reasons:

1) Most of the work in system theory of interest to students of human behavior has been abstracted theory;

2) Most of the theory included in educational training of school people has concerned abstracted theory;

3) An emphasis upon concrete systems provides a novel way of looking at familiar phenomena.

Learning Systems

1.17 The distinction between learning systems and other types of concrete open systems is also fundamental, and while the technical differences will be described in Chapter Four, it is appropriate to describe them generally in this Introduction. The term "learning" is used in this paper to mean both more and less than it means in colloquial usage. It means more in the sense that it does not necessarily connote either consciousness or purpose. It means less in the sense that it does not necessarily

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[5] Ibid., pp. 80-82.

1.17

include all new behaviors that a system may manifest. Put most simply, a learning system is one which has the capacity to exercise some control over its own behavior, in contrast to those systems whose behavior is controlled from the environment. The behavior of a learning system cannot be controlled by controlling the inputs into the system. Non-learning systems are essentially linear: the output can be predicted given the input; the input can be inferred given the output. Learning systems, on the other hand, are non-linear; their output can range from highly improbable (and therefore highly predictable) to a high degree of probable (random and therefore unpredictable) behavior. Given the same input, a learning system can produce different outputs; given different inputs, a learning system can produce similar outputs.

1.18 The behavior of a learning system depends upon both its inputs and its organization. It is undoubtedly true that learning systems will vary greatly in their capacity to learn, but it is equally true that a learning system will learn - not necessarily what another system might want it to learn - but because it can learn, it must learn. Theory based upon linear system analysis is clearly not applicable to this special class of systems.

1.19 The case for a special treatment of learning systems has been persuasively presented by Miller, Galenter, and Pribram[6], although admittedly not in a systems context. Looking at human behavior, they argue that both molecular and molar behavioral acts emenate from "plans" for action. These plans are formed from the individual's prior experiences, his internal representation of reality, as well as inputs from the

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[6]Miller, Galenter, Pribram, Plans and the Structure of Behavior (New York: Holt, Rinehart, and Winston, 1960).

environment. Taken together, these form the image of the way things are. Successful plans are "filed" in the image, to be drawn upon again. Unsuccessful plans are discarded or revised, tested, and further revised in a continuous process of modification and adaptation. A plan, thus, is any process, or combination of processes, in the system which controls the sequence of behaviors which constitute the system's output. A plan is to behavior as a strategy is to tactics. Just as there can be strategies which can generate other strategies, so too there can be plans which generate other plans. The capacity of a system to learn will depend to some extent on how well it can learn "how to learn," that is to say, whether it can generate "metaplans" for generating plans, or whether it is a prisoner of its program. Nonetheless, any system that has some degree of control over its behavior is a learning system, and requires a different mode of analysis than does a system whose behavior is uniquely determined by its input.

CHAPTER II

TOWARDS A NON-NORMATIVE SOCIAL SCIENCE

2.1 All concrete systems behave in concrete ways. A concrete system cannot "not behave." An analysis of a concrete system must start with the way it does behave, not with the way it might behave or the way it ought to behave. If a class of concrete systems, such as automobiles, fourth grade students, petunias, or hospitals, customarily behave in certain ways, students of these systems are likely to see a particular systme in terms of the customary behavior of the class to which it belongs. If the behavior of the particular system diverges from the customary or expected behavior of the class, it is often viewed as "abnormal," "maladjusted," or "deviant." These are common and useful concepts in social science as it is generally practiced. They can create serious analytical problems, however, if the class of systems to which the behavior of a particular system is compared is not a class of concrete systems but rather is an abstracted system. The abstracted system has a "normal" way of behaving which may be unlike the way in which any concrete system in that class behaves. Any statistical treatment, of course, will be an abstracted system which may be a reliable indicator of the way a class of systems behaves but is not necessarily a reliable indicator of the way any particular concrete member of that class will behave.

2.2 A particular concrete learning system behaves the way it does not only because of the class of systems to which it may belong, but also because of its own organization and the character of the particular environment it inhabits. Norms, therefore, can be blinders which inhibit the analyst or observer from really seeing the behavior of the particular system under study. It is the contention of this paper that every concrete learning system is well-adapted to its environment. Another way of saying this is that all behavior is adaptive. From the point of view of the analyst or observer, the behavior may be good or bad, normal or abnormal, desireable or undesireable, but these judgments are external to the behavior itself. Laing and his colleagues have adopted this point of view in their study of schizophrenia[7], maintaining in essence that mental "illness" is an adaptation to an untenable social or familial situation. In an insane world, Laing suggests, it is the sane person who is mad. This was the catch in Heller's Catch-22. Only sane airmen could be allowed to fly air missions. Only insane airmen would want to fly bomber missions. Therefore, any pilot trying to get out of flying was clearly sane and able to fly. In less whimsical terms, this is the dilemma of all who try to act justly in an unjust world or rationally in an irrational society. If we remove the blinders which our labels and judgments impose on our study of behavior, and limit ourselves to a purely descriptive language of analysis, we can come to a better realization of the transactional nature of behavior. We are arguing for what some sociologist's have called a "field view" of behavior. Buckly states that "behavior is a function of the tendency-system and situational field, not of the tendency-system alone. In a word, it cannot be supposed that ready-made behavior is carried around in the head."[8]

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[7]Laing and Esterson, Sanity, Madness and the Family (London: Tavistock, 1964).

[8]Buckley, Walter, Sociology and Modern Systems Theory (Englewood Cliffs: Prentice-Hall, 1967), p. 117.

We may add to this the qualification that it is the internal representation of the situation field, as well as the field itself, that is an element in the behavior. That the "subject" may have a different internal representation of a given field than the analyst means that they inhabit different environments, regardless of their physical proximity. It is the analyst's tendency to objectify his own internal representation of the field - to assume that his internal representation _is_ the field - that allows him to apply normative constructs in analyzing behavior. This paper attempts to avoid this fallacy by assuming that all behavior is well adapted to the system's environment.

2.3 There is another kind of construct that a theory of concrete systems must do without; the construct is exemplified by the concept of "need." A "need" is the absence or lack of a particular thing, quality, or process. The thing, quality, or process that is needed is not present and is, therefore, not a component of the concrete environment. Since concrete systems exist only in concrete environments, their behaviors cannot be described or explained in terms of "needs." As Ashby points out,

> the absence of an entity can always be converted to a reading on a scale simply by considering the entity to be present but in zero degree. Thus, "still air" can be treated as a wind blowing at 0 m.p.h., "darkness" can be treated as an illumination of 0 foot-candles; and the giving of a drug can be represented by indicating that its concentration in the tissues has risen from its usual value of 0 per cent.[9]

When the thing needed is not concrete, however, and is not susceptible to either observation or measurement, its lack cannot be used either to

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[9] Ashby, W. Ross, _Design for a Brain_, 2d ed. (London: Chapman and Hall, 1960), p. 15.

describe or to explain the behavior of a concrete system. An infant may "need" love, a schoolchild may "need" a positive self-image, but to explain behavior on the basis of these needs is to build castles in the sand. Schools frequently talk about "meeting the needs" of children, or even "meeting the needs of the individual child," but most often these needs are abstractions based upon the observer's preconceptions. The easily distracted child "needs" to learn to concentrate because the observer feels that concentration is good and distractibility is bad. The introverted or shy child "needs" to socialize for the same reason.

2.4 I must stress that I am not saying that needs do not exist, only that they cannot be used either to understand or explain the behavior of concrete systems. Statements of needs and feelings of need both exist; the first are concrete data and can be dealt with within the theory of concrete systems, while the second can be considered implied statements of a sentient system. I can explain my own behavior in terms of my own feelings of need, but I cannot similarly explain another's behavior. I may choose to accept another's explanations of his feelings of need as a sufficient rationale for his behavior, or I may consider it inadequate or specious. One of the advantages of a general theory of systems which is applied to human systems is that it is easier to avoid talking about the needs of systems in general than it is with human systems in particular.

2.5 Finally, a theory of concrete systems must do without sociological concepts such as "institution" and "role." The presence of these terms in an analysis indicates that the analysis is dealing with abstractions rather than concrete systems. An "institution" is a abstracted social system, the components of which are roles. The organizational chart of a company or school is the model of that organization as an institution. It defines roles and role-relationships. The actual role-incumbants are variables that may change without altering the structure of the institution or the relationships among the roles. In a concrete system, however, it is not roles that relate to one another but concrete components. In a human system, human beings are the components, and role-perceptions are among the myriad variables which may affect the actual behavior of the human beings. This distinction is well-defined in a colloquy between Jurgen Reusch, a psychologist, Talcott Parsons, a sociologist, and Anatol Rapoport, a mathematical systems theorist.

> Ruesch: Previously I defined culture as the cumulative body of knowledge of the past, contained in memories and assumptions of people who express this knowledge in definite ways. The social system is the actual habitual network of communication between people. If you use the analogy of the telephone line, it corresponds to actual calls made. The society is the network - the whole telephone network. Do you agree with these definitions?
>
> Parsons: No, not quite. In the limiting conception a society is composed of human individuals, organisms; but a social system is not, and for a very important reason, namely, that the unit of a partial social system is a role and not the individual.
>
> Rapoport: The monarch is not an individual, but is a site into which different individuals step. Is that your unit of the social system?
>
> Parsons: Yes. A social system is a behavioral system. It is an organized set of behaviors of persons interacting with each other: a pattern of roles. The roles are the units of a social system. We say, "John Jones is Mary Jones' husband." He is the same person who is the mail carrier, but when we are talking about the mail carrier we are abstracting from his marriage relationship. So the mail carrier is not a person, just a role. On the other hand, the society is an aggregate of social sub-

> systems, and as a limiting case it is that social system which comprises all the roles of all the individuals who participate.[10]

2.6 This paper will employ a mode of analysis in which John and Mary Jones are the components of the system, not their roles. We shall do this for the simple reason that in the concrete world it is individuals, not roles, who interact. In rejecting Parson's approach, we do not deny its usefulness in analysing concrete situations. Many real situations are susceptible to abstracted analyses. Two individuals can, indeed, have conflicting role definitions; there can be ambiguity and confusion about role expectations in human organizations. Nonetheless, it remains true that it is the individuals who are conflicting or confused, not their roles.

2.7 Therefore, instead of "institutions," we shall be talking about "systems," and instead of "roles" we shall be talking about "critical subsystem processes," those processes necessary for the system to function. We shall see that these processes can be allocated among the components of systems in different ways, and that the system's organization is really its pattern of allocation of its critical subsystem processes among its components.

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[10] quoted by Miller in Op. cit., p. 77.

CHAPTER III

TOWARDS A SCIENCE OF COMPLEXITY

3.1 Most of the systems of interest to an analyst are exceedingly complex. Their components are so numerous and are interrelated in so many ways that any analysis which attempts to understand them in terms of their components or the interaction among their components is doomed to frustration. This is particularly true of learning systems, whose essential nonlinearity makes any causal analysis impossible. The selection of relevant variables from the literally infinite number of variables which comprise the system is frequently an impossible task, particularly with concrete systems which change over time.

3.2 One of the significant contributions of general systems theory to the study of complex phenomena is the proposition that the behavior of a complex system can be analyzed according to certain principles of organization which all systems share, regardless of the nature or the number of their components. Pre-eminent among these principles is the notion of "hierarchy." The organization of both the natural and man-made environments appears to be according to hierarchical principles. Any system one is observing is comprised of other systems and is itself a component of a larger system. Given the system one is looking steadily at, its components can be called sub-systems. The system or systems of which it is a part can be called suprasystems. An individual human being is a system. Physiologically he consists of a great many subsystems. Socially, he is a subsystem in a great many suprasystems. At an appropriate level of generality, principles of organization which can be observed and measured at one level of system will also be true of systems at both lower and higher levels. This is a profoundly useful insight but also one which is highly susceptible to misuse. For example, human beings and other organisms have sense organs which bring information into the system. However, at the sub-organismic level and at the supra-organismic level systems do not have sense organs. They do have, nonetheless, subsystem processes which bring information into the system, although the components of these subsystems may have no physical or analagous similarity to organismic sense organs. Miller's term "input transducer" is at an appropriate level of generality to refer to a systemic prerequisite at all levels. Miller states that

> the importance of interindividual, intertype, or interlevel formal identities among systems, and what makes them of absorbing interest, is that very different structures, if they can be shown to carry out similar processes, may well turn out to perform in ways which are so alike that they can be very precisely described by the same formal model.[11]

Such a formal model would be a part of a rigorous general theory. This paper cannot claim to be a formal model in the sense that scientists and mathematicians use that term. It can claim, though, that it is a step in that direction - that both the approach and the terminology are consistent with the rigor that mathematical scientists strive towards. It remains for specialists in particular disciplines or systems theorists competent in different disciplines to advance the search for formal identities which will allow our understanding of complex phenomena to grow in sophistication.

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[11] Miller, op. cit., p. 96.

The Use of a General Theory

3.3 School people can be excused if they view with suspicion the contention that they need more theory, and yet this paper suggests that a general theory of concrete systems can challenge much of the conventional wisdom which abstracted theory has supported about schools and the process of learning. Some of the insights about education that can be gained from this approach are listed below.

3.4 The American public day school, with its myriad purposes, is a poorly-defined system. This is not a deficiency, it is a characteristic. Neither its inputs, its boundaries, nor its outputs can be well-defined. To make the school a well-defined system, we would have to design a society in which no learning took place outside of school, or design a school whose pupils and teachers could never leave, watch television, or read newspapers. There is no point in trying to analyze schools according to models of well-defined systems, or in comparing schools with business or other human orgainzations which are well-defined.

3.5 Both the school and the student, as learning systems, will, over time, adapt to their environments and take on the characteristics of their environment. It must be remembered, however, that whereas the community is the environment for the school, the school is only a portion of the environment for the student. Nonetheless, it is a significant part of the student's environment. Schools that want students to learn how to learn must be organized in such a way as to develop this competence.

3.6 The movement towards performance objectives, one of the dominant trends in American schools, can be seriously questioned from a general systems viewpoint. It can be argued that the more precisely

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desired outputs are specified, the more the student will perform as an adjusting system, and the less likely his performance will result from learning. Put another way, the more specific the conditions under which specified behavior is to take place, the more likely that the behavior will occur only when those specified conditions are present.

3.7 Learning performance appears to be based upon something we may call learning competence. A strict input-output analysis of the learning process and approaches to teaching which emphasize the relationship between given inputs and desired outputs seem to short-circuit the development of learning competence. The familiar phenomenon of children who have "mastered" their performance objectives but do not know what they have learned is a manifestation of this problem. The issue is not one of objectives, which have great value, but rather one of the relationship between behavior and learning.

3.8 It is the ultimate purpose of this paper to give educators a new way of thinking about the situations they are in. Synecticians talk about "making the strange familiar" and "making the familiar strange." This paper is an exercise in making the familiar strange. It provides a different set of cognitive tools for those who wish to think seriously about educational problems and issues. Hopefully, it may lead researchers to develop new designs for exploring the educational enterprise, designs based upon theories of schools and students as open learning systems interacting reciprocally with their environments. This approach may also suggest a meeting ground for behavioral and cognitive psychologists, although the prospects for this are neither immediate nor promising.

3.9 Finally, this approach may set a direction fro a more rigorous generalism and allow scholars and scientists in diverse fields to have a

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common, technical vocabulary which, while preserving the integrity of particular disciplines, allows the commonalities to be explored in accord with accepted scientific principles and methods, to the end that the ancient dream of poets and philosophers may become more than a pious hope.

PART II

A GENERAL THEORY OF CONCRETE SYSTEMS

CHAPTER IV

THINGS

4.1 We shall begin by talking about "things." A "thing" can be anything - an object, an idea, an organization. It can be an extremely complex aggregate of many inter-related parts, or it can appear to be a simple, undifferentiated, unitary type of phenomenon. It can be a leaf, the branch on which that leaf hangs, the tree to which the branch belongs, the forest in which the tree is located, or the geographic area which includes the forest. The only requirement we make of a thing is that we can differentiate it from other things and look staeadily at it. It is the object of our attention, whereas other things are not. Soon we shall be substituting the term "system" for the term "thing." This is not because there is any difference between things and systems; there is only a difference in the language we use in talking about things as systems. It is a more rigorous language and more helpful in examining some of the interesting properties of things, particularly the most interesting and complicated sorts of things that we have found it difficult to talk and think about. No matter how complicated our language, however, it will still be things we are talking about.

4.2 One characteristic which is true of all things is that they are real - they exist. Some things exist in time and space and are composed of matter, expend energy, and process information. Trees and automobiles are things of this sort; so are people and groups of people. One property of such things is that they change, and because they are palpable things, their change can be measured and spoken about. Two people observing the same thing are likely to notice the same changes and are likely to agree about what they see.[1] Such things which have a palpable existence will be called <u>concrete</u>.

4.3 Other real things exist in other ways. Two oranges and three oranges together are five oranges. These are concrete things. But "2 + 3 = 5," while just as real, is not concrete. Although it is a property of concrete things that they can be added together, the property itself is not concrete. It is no less real than concrete things, but it exists independent of them. Such things, which are properties or attributes of concrete things, will be called <u>abstract</u> things. Abstract things may be true of great numbers of concrete things; the additive property, for example, is true of all concrete things. Weight is a property of all concrete things. Growth is a property of many concrete things. Interaction with the environment is a property of most concrete things. Change is a property of all concrete things. None of these things, however, is concrete. Every concrete thing is a particularized exemplification of abstract things. Without abstractions we would be unable to think about or talk about concrete things.

4.4 Many things are neither concrete nor abstract. They are still real and we have to deal with them. False statements (or true statements, for that matter), hypotheses, and statistics are examples of things that are neither concrete nor abstract. All symbol systems exist without being

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[1]Later on (7.35) we shall want to admit that this statement is not true. A landscape artist and an astronomer looking at a sunset probably do not see the same thing. However, since we want to introduce complications very gradually, we shall say that this statement is truer of concrete things than of abstract or conceptual things to be treated below. See Hanson, <u>Patterns of Discovery</u>, Ch. 1, for the arguments against this statement.

concrete or abstract. Abraham Lincoln was, at one time, a concrete thing, but when the palpable Abraham Lincoln was assassinated, "Abraham Lincoln" remained. The idea of "Abraham Lincoln," the words of Abraham Lincoln, statements about Abraham Lincoln still exist. "Abraham Lincoln" is now a conceptual thing. All ideas are conceptual things. All statements are conceptual things. All symbols are conceptual things.[2] Concepts are real; they may be true or false, important or trivial. They may refer to concrete things or abstract things or other conceptual things, but they are real. All things are real. Myths, fantasies, and delusions are real. Monsters, ghosts, and purple cows are real. Concrete things, abstract things, and conceptual things are all real.[3]

4.5 Every thing is composed of things. The thing we are looking steadily at is composed of things called parts. The parts, of course, are also things, and every thing is a part of some other thing. There is no concrete thing so minute and undifferentiated that it is not composed of other things. Likewise there is no concrete thing so grand and all encompassing that it is not part of something else.[4] The world is made up of parts which are things and things which are parts. What we look steadily at, however, is a thing, and the things of which it is composed are its parts. Things which affect the thing we are looking

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[2]The acutal markers which bear the concepts are, of course, concrete when they are committed to writing. These distinctions can lead us into muddy waters, but they are important.

[3]This scheme of classification is taken from J.G. Miller. See Behavior Science 10: 193-237, 1965, and Behavioral Science 16: 277-310, 1971.

[4]We can postulate such things, but they are conceptual and not concrete.

4.5

steadily at, or which are affected by it, compose the thing's environment. Things which do not affect the thing we are looking steadily at, or which are unaffected by it are of no interest to us. They are not part of the thing's environment.

4.6 We have made some fundamental distinctions. The distinction between concrete, abstract, and conceptual things is intrinsic. It is a way of classifying reality. We have seen that abstract things are the properties of concrete things, and that concrete things are the data for abstract things. Conceptual things are the tools for thinking and talking about both concrete and abstract things. All of them are real. The distinction between part, thing, and environment is a conceptual thing. It is, of course, real. It is also wholly arbitrary and depends upon the observer or student. No thing is intrinsically part, thing, or environment.

4.7 We may now do away with the ungainly term, "thing." This paper is about systems, concrete systems, abstracted systems, and conceptual systems. It is concerned with the relationships between systems, their parts, and their environments. If it is helpful, the reader may continue to substitute the term "thing" for the term "system." There is no difference.

CHAPTER V

SYSTEMS

5.1 Everything we say in this chapter will be true of all concrete systems; that is to say, all statements, definitions, and propositions will be true of everything that exists in time/space. In subsequent chapters we shall be making useful distinctions between various types of concrete systems, but for now we make no distinctions.

5.2 We shall start by developing a vocabulary with which to talk about concrete systems. The vocabulary will necessarily be very general, since we are talking about systems in general rather than any kind of system in particular. Generality should not be confused with vagueness, however. The test of our terms is that they are useful in making distinctions; while not all systems are alike, they are all alike _in some ways_. The terms we use will be helpful in determining these ways and will thus allow us to make comparisons between very dissimilar things.

5.3 A concrete system is whole thing composed of inter-related parts. We do not need the term "whole" because the term "system" means the same thing. We do have to come to terms with the notion of "part," however. Systems are composed of _components_, which have _attributes_, or _properties_. The number of attributes which a component may have may be very small or very large. They may be changing or unchanging.[1] They may appear relevant to the concerns of the observer or irrelevent to his concerns. While the component is always matter/energy, the attributes of the component may

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[1]Some theorists would disagree with this and claim that all attributes of concrete systems change, some slowly and some quickly. Whether the chnage is observed depends on the relative time scales of the system and the observer. See Reusch, in Grinker, ed., _Toward a Unified Theory of Human Behavior_, 2d ed. (New York: Basic Books, 1967), p. 317.

be quantities, qualities, or conditions.

5.4 The important point is that the parts of concrete systems are both components and their attributes. This may be a simple point, but it is a source of fundamental confusion among those who think about systems, particularly in the field of education. It is the reason why models of abstracted systems so rarely apply well to concrete systems. The components of abstracted systems can be postulated (and are usually the attributes of concrete systems), while the components and attributes of concrete systems must be selected from those that in fact exist in time/space.

5.5 Some examples will help. The components of a human group are people, but the parts of that human system include not only the people but also their personalities, perceptions, ideas, habits, expectations, mannerisms, feelings, prior experiences. . .and so on. We could also include their heights, weights, complexions, bank accounts, clothing, hobbies, political and religious affiliations. . .and so on. There is no end to the list of attributes that people can have. Not all of them, of course, will be of interest to the observer. Most likely, not all of them will influence the behavior of the human group to which these people belong. Some of them will, however, and those that do are parts of the system.

5.6 As I write, I can look out the window of my study and see a childrens' swing set. The components of this swing set are swings, ladders, poles, a slide, and support braces. Each of these components, however, has a set of attributes which are part of that concrete system. The strength of the material, the length of the ropes, the angle of the slide, the stress on the braces are just a few of the attributes that are parts of the system which is that swing set.

5.7 A wristwatch is a collection of many specialized components, but the ratio of the gears and the tautness of the spring are also parts of the system.

5.8 Further reflection makes it clear that in fact a "component" is nothing more than a collection of attributes. Any tangible thing has, for example, size, weight, shape, and composition. A large, red, wodden triangle can only be described in terms of its attributes. Things, in general, can always be described in terms of their attributes. We may choose to describe them in terms of their purposes and relationships, also, but again, closer examination will show that these, too, are functions of their attributes.

5.9 It would be perfectly possible, therefore, to talk about concrete systems without reference to their components but it would be impossible to talk about concrete systems without reference to their components' attributes. A component is a particular disposition of a set of attributes at a specific point in time.

5.10 The reader may be tempted to ask whether this approach means that the entity or "wholeness" of components is unimportant. From a systems point of view, the answer is "yes." If we recall from 4.1 that a system is a thing we are looking at steadily, it is, in fact, helpful to look at its components as particular dispositions of attributes. It prevents us from inadvertantly shifting the focus of our attention and viewing the component as a system. Whether components exist as entities is a question of philosophical and legal interest, but of little concern to our inquiry. The changes which a neonate goes through as he passes through infancy, childhood, adolescence, maturity, old age, and death can all be described in specific terms as dispositions of attributes.

Whether the infant, child, and adult are the same person is ultimately an unanswerable question. If the large, red, wooden triange changes and one of its attributes, we will recognize the change and call it a different object. That we tend to consider some attributes more essential to a thing than others is a habit of our thought rather than a quality of the thing.

5.11 The preceding discussion indicates both why we are justified in considering a system to be an ensemble of attributes and why it is preferable to do so. Components are complexes of attributes at a particular point in time. The complex of attributes at a subsequent point in time might be very different. Moreover, at any given point in time some of a component's attributes may be of interest to the observer of a system, while others may be of no interest. To take into account both the difference in time and the focus of the observer without having to explain in every instance what we mean, we will use the term <u>variable</u> to describe those attributes which, according to the interests and needs of an observer, are parts of the system. A system can thus be described in terms of its variables, which are those attributes selected from an often limitless list of attributes which may be ascribed to the system's components. While the identification of a system's variables is dependent in some measure upon the interests and needs of the observer, it is not by any means an arbitrary process; it is based upon relationships that are observed to exist in the system. A system may be described in terms of a limited and specific number of variables, regardless of the complexity and large number of the attributes of its components.

5.12 The condition of a variable at a given point in time will be called its <u>state</u>. We shall assume that variables may have more than one state and thus are capable of change. The particular disposition of a system's variables at a particular point in time will be the state of the system. The state of the system will thus change as a function of the states of its variables; however, we must avoid assuming that a system's performance will vary with its states. Many systems achieve stability through the change in their internal states; the human being is such a system.

5.13 A truly rigorous treatment of variables would limit them to attributes whose changes could be measured and quantified.[2] We shall fall short of that rigor, but shall attempt to treat non-quantifiable changes as though they were quantifiable. This procedure has real pitfalls, as many social scientists have found, but as long as we limit ourselves to dealing with concrete systems whose changes can be observed, we will be able to avoid these pitfalls.

5.14 For the purposes of illustration, we shall hypothesize a concrete system of three variables, each of which can have states. We shall call the variables "A," "B," and "C" and we shall designate their states as "+" and "-."

	1	2	3	4	5	6	7	8
A	+	+	+	+	-	-	-	-
B	+	+	-	-	+	+	-	-
C	+	-	+	-	+	-	+	-

The above diagram lists the eight possible states that the system might be in. The reader might want to imagine a traffic light with three bulbs,

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[2] See Ashby, <u>Design for a Brain</u>, (London: Chapman and Hall, 1960), pp. 14-15, 33.

A=red, B=yellow, and C=green, to help him visualize this system, but if he does so, he must remember that we are not talking about a traffic light but about any system of three variables which can have two states. This system could just as well be a human being with

A = mood ("+" happy/"-" unhappy)

B = alertness ("+" awake/"-" asleep)

C = occupation ("+" busy/"-" idle)

The possible states of our system, then, can be determined by listing all possible combinations of the states of the variables. If there is an equal probability that each variable will be in either of its states, then any of the eight states of the system is equally likely to occur at any point in time.

5.15 It is important to note that this mode of analysis can be used with any system that has a finite number of variables which can take a finite number of states over a finite period of time. The addition of variables or of states of variables does not change the mode of analysis, although it will greatly increase the number of states of a system. The addition of one variable with two states to the system in 5.14 would increase the number of possible states in the system from eight to sixteen:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	+	+	+	+	-	-	-	-	+	+	+	+	-	-	-	-
B	+	+	-	-	+	+	-	-	+	+	-	-	+	+	-	-
C	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
D	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-

The addition of a third state to our three-variable would result in a system of twenty-seven possible states:

5.15

	1	2	3	4	5	6	7	8	9	10	11	12	13
A	+	+	+	+	+	+	+	+	+	-	-	-	-
B	+	+	+	-	-	-	o	o	o	+	+	+	+
C	+	-	o	+	-	o	+	-	o	+	-	o	+

	14	15	16	17	18	19	20	21	22	23	24	25	26
A	-	-	-	-	-	o	o	o	o	o	o	o	o
B	+	-	o	o	o	+	+	+	-	-	-	o	o
C	-	o	+	-	o	+	-	o	+	-	o	+	-

5.16 Of course, most systems in which observers would be interested have many more than three variables and their variables have many more than three states. The fact that it is possible to ennumerate and specify the possible states of a system does not mean that it is often practical or useful to do so. One of the problems with much research, especially in the field of education, is the lack of a methodology to deal with complex systems consisting of a great many variables capable of having a great many states. Researchers are thus obliged to reduce the number of variables to a manageable number and are therefore no longer dealing with concrete systems but with abstracted systems. There is a definite need, therefore, for a method of dealing with complex systems which does not require a specification of all of their possible states.

5.17 We can get closer to such a method by realizing that concrete systems do not often behave in such a way that all of their states are equally probable. Instead, systems are organized in such a manner that certain states are more probable than other states. The more organized a system is, the more improbable its behavior becomes. A perfectly organized system would have absolutely predictable behavior. Most systems

5.17

of interest to us fall between the two extremes of being unorganized (in which any state is equally probable) and being perfectly organized (in which every state is absolutely predictable).

5.18 The movement of a system from state to state over time is its line of behavior.[3] The line of behavior thus is change from state to state. A system with a single line of behavior is a tightly organized system. If the observer knows the state that the system is in at a given point in time he can predict with certainty the state of the system at some following point in time. The line of behavior may or may not include all the possible states the system may take. A traditional traffic light, for example, which alternates among red, yellow, and green states, utilizes only three of its eight possible states. These would be states 4, 6, and 7 in the system of 5.14.

5.19 Some systems have more than one line of behavior and under certain conditions will change from one line of behavior to another. If the traffic light has a "Walk" signal, for example, it has the capability of interrupting one line of behavior (its regular cycle) to follow another line of behavior, one with only a single state. (In Massachusetts, this would correspond to state 2 in 5.14, since the red and yellow together serves as the "walk" signal.) Following Ashby, we shall designate the change from one line of behavior to another a transformation.[4]

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[3] Ibid.

[4] Ashby, Introduction to Cybernetics, (London: Chapman and Hall, 1961), pp. 10-16, 42-46.

5.20 We are now in a position to make a fundamental distinction: the distinction between change from state to state and change from transformation to transformation. The latter is clearly of a different order than the former. All behavior consists of change from state to state. However, a change in behavior is moving from transformation to transformation. If a system has only one line of behavior, no matter how varied and intricate, it will be unable to change its behavior; that is to say, it will be unable to change the way in which it changes.

5.21 The importance of this distinction cannot be overemphasized. Some systems may have a great number of richly varied states to pass through and yet have only a single line of behavior. Other systems may have a limited number of states and yet a great many lines of behavior. The first system may be capable of richer and more varied behavior than the second, yet in one crucial respect it is more limited; it cannot change its behavior. It can neither adjust to different conditions nor adapt to changing conditions. The point is not that it can behave more richly; the point is that it must behave more richly. While its behavior consists of more change, it cannot change its behavior.

5.22 Students of change, and those who consider themselves "change agents" frequently get trapped by this distinction, and it is easy to see why. It is frequently impossible to determine from the system's behavior whether it is following a single line of behavior or changing its behavior. If, for example, a system cycles regularly among its transformations, so that one line of behavior is followed regularly by another line of behavior, it will appear to be following a single line of behavior. If, on the other hand, the system moved randomly from one line of behavior to another, an observer would be hard put to determine whether or not that system had one or more lines of behavior.

5.23 It is, therefore, very difficult to distinguish between those changes which are behavior and changes in behavior from the system's behavior alone. More knowledge is needed; not knowledge of the system's states, but knowledge of the system's organization. This is particularly helpful to realize when we are dealing with complex systems. The system's behavior is a function of how it is organized rather than how its variables can behave. Any organization which limits the lines of behavior (usually infinite) introduces powerful constraints into the system, for it means that the state a variable may assume is a function of either a prior state of that variable or the state of another variable, or both.

5.24 We can intuitively recognize that without constraints, that is to say, without organization, it would be impossible to gain any useful information either from or about the system. If a system did, in fact, follow all the lines of behavior which it was possible for it to follow, the practical consequences for the observer would be the same as if the system had only one line of behavior. Being absolutely predictable and absolutely unpredictable have the same information value.[5]

5.25 In looking at concrete systems, therefore, we shall be more interested in the nature of the constraints than in the nature of the variables. Systems of widely differing types can have similar sorts of constraints, and we can learn much about all systems by studying the various ways in which systems are organized. This will be the approach of this paper.

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[5] See sections 8.6-8.20 below for elaboration.

CHAPTER VI

ENVIRONMENT

6.1 The system we are looking steadily at exists in a field of many other systems, only some of which affect it or are affected by it. Just as system components may have an infinite number of attributes which are not variables in the system, so, too, the system's field may contain an infinte number of variables which are not part of its environment. Only those variables which do affect a system or which are affected by it are parts of that system's environment.

6.2 Environmental variables will be called parameters to distinguish them from system variables. Most of the systems of interest to us exist in a rich environment; that is to say, they interact with a great many parameters. It will frequently be the case that the environments will manifest some degree of organization; parameters will be subject to similar sorts of constraints as system variables. We may make the same sort of observation about environments that we made about systems in sections 5.23-5.24. An unorganized environment, one without constraints, would be chaotic; parameter values would be completely unpredictable. The only system which could exist in such an environment would be a system without constraints. While we can hypothesize such environments and such systems, no such concrete system or environment can really exist. On the other hand, a tightly-joined, completely organized environment, one in which parameter values were completely predictable, would be appropriate for systems with only singe lines of behaviors - that is, completely organized systems.

6.3 Most environments, and certainly those in which human beings exist, are loosely-joined.[1] They fall between being unjoined and tightly-joined, just as most systems fall between being unorganized and completely organized. This observation is highly significant, for it allows us to draw parallels between the degree of organization in a system and the degree of "joined-ness" in the environment. It will be particularly useful in the case of complex systems all of whose variables and constraints are not known to us. If the environment is known to us and the system is surviving, we can make highly probable inferences about the organization of the system from our knowledge of the organization of the environment. Even more significant, if we wish to "change" the behavior of a complex system (or induce the system to change its behavior, which is not at all the same thing), we can manipulate the environment by increasing or decreasing the degree of organization which inhers in it. Generally speaking, the greater the degree of organization in the environment, the easier it is to control, and therefore change, the system. Conversely, the more loosely-joined the environment, the more necessary it is for the system to develop self-control, that is, to be able to change itself.

6.4 The reverse is, of course, also true. We can infer the degree of organization in the environment from the behavior of the system. Both lines of inquiry are useful. While the relationship of a system to its environment will be the topic of the next chapter, for now it will suffice to note that there is a relationship between the degree of organization in the system and the degree of organization in the system's environment.

6.5 Parameters, like variables, ordinarily can have a range of values which fall within specified limits. If the system variables can assume the

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[1]Ashby, Design for a Brain, pp. 193-196.

same range of states as the system's parameters, then that system has the capacity to be well-adapted to its environment. If the system's variables have a more limited range of states, then the system is mal-adapted and its survival is in jeopardy, or, at the very least, it will be dysfunctional.

6.6 Some simple examples will illustrate this important point. If, in a particular locality, winter temperatures are likely to fall to -50 degrees and a car owner puts enough anti-freeze in his radiator to protect it to -30 degrees, then the car is not well-adapted to its environment. If a piece of music has a range of seven octaves and a particular instrument has a range of only four octaves, then the instrument will not be able to play that piece. A language which has a great many terms to describe the nuances of affection and love cannot be well-translated into a language which has only a few such terms.

6.7 If, on the other hand, the variables have a wider range than the parameters, the parameters will constrain the behavior of the system. That is to say, the system will not be able to utilize the full range of its available behavior. If the environment is regularly more tightly organized than the system, the system, if it is able to change, will become more tightly organized; its range of behaviors will become more restricted. Unneeded organs atrophy, unused knowledge disappears, unpracticed skills leave the repetoire. What remains, after a period of time, is a system which is well-adapted to a more restrictive environment.

6.8 These remarks suggest what will have to be the central theme of the following chapters: the processes whereby systems relate to their environments. What we have said thus far has been true of all concrete systems. What we say hereafter will be true of only certain kinds of systems: those that have the capacity to change. We will accept as axiomatic an environment which falls between being unorganized and being tightly organized, between being unpredictable and totally predictable, because most concrete systems exist in such an environment. Given such an environment, the fundamental question we shall be asking is how systems maintain themselves within it.

CHAPTER VII

OPEN SYSTEMS

7.1 It is time to make some distinctions among concrete systems. What we shall do in this chapter is classify concrete systems in accordance with their capacity to adapt to a changing environment.

Closed Systems

7.2 We must first consider a class of systems which are impervious to their environments. It is easy enough to conceive of such systems; classical physics is based upon the study of such systems. We call them closed systems; they conduct no transactions with their environment. They can receive neither matter nor energy nor information from their environment; they transmit neither matter, nor energy, nor information to their environment. The Second Law of Thermodynamics states that closed systems over time tend toward disorganization and attain their most probable (random) distribution of matter and energy. This tendency is called entropy. We can see in nature many examples of entropy; indeed, nature, when left alone, will always assume its most probable, least organized state. An untended garden is a clear example of this. As both Norbert Wiener[1] and Buckminster Fuller[2] have reminded us, the universe, to the best of our knowledge, is a closed system which now contains all the matter and energy it will ever contain. Spaceship Earth is a closed system.

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[1] The Human Use of Human Beings, (Garden City: Doubleday Anchor, 1954).

[2] Operating Manual for Spaceship Earth, (New York: Simon and Schuster, 1969).

7.3 Except for this cosmic level, however, it is doubtful that any concrete system can be completely closed. Certainly the untended lawn is part of the eco-system and receives nutrients from its environment. Aside from trivial examples of hermetically sealed caskets and the like (trivial from the point of view of our analysis but not necessarily scientifically trivial), the closed system can be regarded as the logical limit towards which systems might tend, rather than a state which concrete systems can manifest.

Open Systems

7.4 The systems with which we are concerned, then, are open systems which are involved in transactions with their environments. There are degrees of openness; some systems will conduct more transactions than others. The degree of openness is clearly significant to system survival; the richer and more changeable the environment, the more openness becomes a necessary (though not sufficient) condition of system survival.

7.5 The transactions between a system and its environment consist of exchanges of matter, energy, and information. When entering the system, these are called inputs; when leaving the system, they are called outputs. While we may talk about transactions with the environment in terms of larger purposes systems are intended to serve, our point of view in this chapter will be that open systems depend upon inputs and outputs in order to maintain themselves so that they may serve what may be considered to be larger purposes. System survival is the first concern.

7.6 The significance of this viewpoint is by no means widely recognized. To anticipate our argument somewhat, we may mention that many social scientists have developed models of social systems which are essentially based upon the theory of closed systems.[3] The system is seen as energizing itself, finding its own level of optimal performance which is described as a state of equilibrium. Inputs from the environment are seen as intrusions or disturbances, upsetting the equilibrium. System processes are thus devoted to restoring the system either to its previous state of equilibrium by extruding the disturbances, or to a new state of equilibrium by assimilating the inputs into the system. The "norm" in such conceptual systems is thus seen to be a tension-less, disturbance-free condition. System processes are devoted to counteracting deviations from this norm.

7.7 Open systems, on the other hand, thrive on deviation. The characteristics of open systems with which we are most concerned - growth, change, learning, and complexity - are based as much on deviation-amplifying processes[4] as upon deviation-counterbalancing processes. Without deviations, such systems would not survive.

7.8 We may state axiomatically, therefore, that open systems maintain themselves through transactions with their environments. We shall now proceed to classify open systems in accordance with their ability to maintain themselves in changing environments.

Non-adjusting systems. 7.9 We begin with those systems which cannot survive significant environmental change. Such systems have only one line of behavior, and that line of behavior can occur only at specified para-

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[3] see Buckley, Sociology and Modern Systems Theory, (Englewood Cliffs: Prentice-Hall, 1967) for a critique of closed system models.

[4] Maruyama, "The Second Cybernetics: Deviation-Amplifying Mutual Causal Processes," in Buckley (ed.), Modern Systems Research for the Behavioral Scientist, (Chicago: Aldine, 1968).

meter values. It makes no difference whether we speak of one parameter, as in the case of an electrical appliance which either has an energy source or doesn't, or of several parameters, as in the case of a hothouse flower which can survive only in an environment in which temperatures, light, moisture, and soil condition are carefully controlled. In either case, any significant change in parameter values will make it impossible for the system to maintain itself. The essential point is that the system has no way of changing or correcting its performance, since it can perform in only one way.

7.10 One characteristic of such systems is that they are easily controlled. If one can control the parameter values, one can control the system absolutely. If, however, one cannot control the parameter values, or if the parameter values fluctuate a great deal, the system's chances for survival are slim. Hospitals are equipped to provide carefully controlled environments for patients who can survive only in those environments. Incubators, for example, effectively limit the range of parameter values to those within which the premature infant can survive.

7.11 Systems that can only behave in one way are well-adapted to environments that behave in only one way. We will refer to such systems as <u>non-adjusting maintenance systems</u>. The world is full of them and they are of little interest to us.

<u>Adjusting systems</u>. 7.12 Of much greater interest is the class of concrete open systems which we may call <u>adjusting systems</u>. These systems have the capacity to adjust their outputs to predetermined environmental parameters. The thermostatically controlled heating system is the classical example of an adjusting system. Such a system must have a pre-set

standard of performance "built in" to the system against which it can measure its actual performance. The process by which it compares its actual performance against its desired performance is called feedback.

7.13 "Feedback" has gained currency in the language as referring to any information a system may receive about its performance, but we shall be using the term in a more restrictive sense to refer to any information a system receives from its performance which serves to regulate its subsequent performance. The essential notion is regulation through a testing of output values against parameter values. If desired parameter values can be pre-determined, the system can be designed to adjust to them. Thus, the thermostatically-controlled heating system will maintain room temperature at a predetermined level. It cannot, however, vary that level. It cannot, for example, decide that the night-time temperature should be 65 degrees and the day-time temperature should be 72 degrees. These decisions come from outside the system. The actual room temperature at any given time is the system's output. Note that this is true whether or not the furnace is running at that time. The system has two states, "on" and "off," and it is performing just as well when it is off as when it is on. (From the home-owner's viewpoint, the more it is "off" the better.) If the house "holds" the heat produced by the furnace so that the output variable and the environmental parameter approximate the same value, the system will be performing optimally. System variables thus include the amount of space to be heated, the quality of insulation, the height of the ceilings, and so forth, as well as the states of the components connected by circuitry.

7.14 The "purpose" of the thermostatically-controlled heating system, then, is to maintain constancy of output when measured against a pre-set and pre-determined environmental parameter. We can generalize from this example and make the same statement about adjusting systems in general. Through the mechanism of feedback, the adjusting system can regulate its actual output by measuring it against its desired output as determined by the environment. The system will change from state to state depending on the deviation of the actual output from the desired output. If there were no deviation, of course, or if deviation within limits was tolerated by the environment, there would be nothing for the system to adjust to. While adjusting systems are designed to counter-balance deviation, they also require deviation as a <u>sine qua non</u> of their existence. This point is conceptually vital to the argument. Adjusting systems avoid large and significant deviations from desired outputs by allowing small and insignificant deviations from the output. It is the deviations which activate the system and initiate its line of behavior. To speak metaphorically, adjusting systems thrive on small deviations; they cannot survive without them.

7.15 For all practical purposes, the difference between adjusting systems and non-adjusting systems is slight and more a matter of convenience than anything else. After all, in place of the thermostat, one could have a mere switch that would turn the furnace on and off; the same purpose would be accomplished with only slightly more inconvenience to the residents of the house. Conceptually, however, the difference is great and powerful, for the adjusting system is <u>self-regulating</u>. Admittedly, it is a very simple and limited sort of self-regulation, one that is appropriate to very simple and limited sorts of environments, but the

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principal of self-regulation is the basis of organization and life itself. The simplicity of the adjusting system in actuality, as well as its lack of adaptability, should not blind us to the significance of this difference.

7.16 At the same time, the attractiveness and conceptual simplicity of the adjusting system should not lead us into equating adjustment and self-regulations. Adjustment is a special type of self-regulation appropriate to special types of environments. Many sophisticated social and behavioral scientists have developed models of society using the adjusting system as their point of departure. Societal "norms," "roles," and "institutions" are seen as the parameters; actual behaviors of individuals and groups are the system outputs, and the system performs by reducing the deviation between the actual human behaviors and normative societal expectations. Such theories are attractive but inadequate to deal with the phenomena of human systems. To show why this is the case, we must deal more specifically with the limitations of adjusting systems.

7.17 In the first place, adjusting systems have pre-set and pre-determined lines of behavior corresponding to the pre-set and pre-determined parameter values the system is to match. The number of lines of behavior is inconsequential, as is the number of pre-determined parameters. Adjusting systems may be extremely complex, but they are never unpredictable (unless they malfunction). Adjusting systems are, therefore, _deterministic_. Ashby defines determinancy as that situation in which "each part, if in a particular state internally and affected by particular conditions externally, will behave in one way only."[5]

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[5] _Design for a Brain_, p. 9.

7.18 Hare gives a beautiful example of an exceedingly complex adjusting system[6] - an automatic elevator system which must test and adjust its performance to a complex set of conditions. However, if at any given time those conditions are known, the system's behavior can be infallibly predicted.

7.19 In the second place, and following from the first, adjusting systems are appropriate only in environments whose parameters can be controlled and specified. Each state of the system depends upon the testing of its performance against these parameters. The behavior of the system is controlled by the environment. This, of course, is a severe limitation upon the system's ability to regulate itself.

7.20 The popular television series, Mission: Impossible, is based upon the premise that the crooks and tyrants to be thwarted and destroyed are adjusting systems who will react in predictable ways to specified environmental conditions as contrived by the team of heroes. The entertainment value of the show is due in large measure to the juxtaposition of a totally predictable response to a totally improbable contrived environment. The same comment can be made about Rube Goldberg's marvelously complicated adjusting systems which accomplish very simple tasks.

7.21 Finally, the system has no choice. It cannot decide whether or not to counterbalance deviations from its desired performance. It cannot decide to take a lunch break and come back to its job later. It must act upon its feedback. If it does not, it is malfunctioning.

7.22 The simplist way of summarizing the limitations of the adjusting system is to say that it must be programmed by its environment. Given

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[6] Systems Analysis: A Diagnostic Approach, (New York: Harcourt, Brace, and World, 1967), pp. 61-63.

the program, its behavior is uniquely and specifically determined. The horror of HAL, the computer in "2001: A Space Odyssey," was that it somehow had "learned" to behave without a program.

7.23 Before any given concrete system is construed to be an adjusting system, therefore, the observer must decide whether the system is subject to these limitations:

1. The system's lines of behavior can be specified;
2. Environmental parameters can be specified;
3. The system's behavior is programmed by the environment.

Learning Systems

7.24 The next class of systems we consider can exist in environments which cannot be either entirely predictable nor entirely controlled. We shall designate such systems as <u>learning systems</u>. Learning systems have the capacity to adapt their behavior to new and continually changing environmental circumstances. While adjusting systems can vary their outputs, learning systems can change their internal organization as well. While adjusting systems require small deviations in order to prevent large deviations from desired parameter values, learning systems may amplify deviation. While adjusting systems maintain a pre-determined level of organization, learning systems tend towards elaborated structures and higher levels of organization. While adjusting systems are deterministic, learning systems are probabilistic.

7.25 In sum, while adjusting systems cannot be responsive to environmental change, learning systems can, and because they can, they must. If they do not, they will not survive. The difference between adjusting and learning systems is one of kind, not of degree. Adjusting systems and learning systems occupy very different environments, regardless of their physical proximity. Since the environments in which human beings exist are neither completely predictable nor completely controllable, the human being is the best example of a learning system. Phylogenetically, the evolution of the species is evedence of learning. Ontogenetically, the life cycle of the organism provides the same evidence.

7.26 In using the human being as our prototypical learning system, we must recognize that we have changed our point of view somewhat from that of the system designer to that of the system analyst. We shall not enter the controversy over whether learning systems can be designed, a controversy which has tended to divide cyberneticians and organismic theorists. We shall instead ask: given a learning system, how does it adapt to a changing environment?

7.27 The simple answer, of course, is that it adapts by changing - both its output and its internal organization - to counter-balance those environmental changes which would jeopardize the survival of the system. While the states of environmental parameters at any given time may be neither predictable nor controllable, the range within which parameter values may fall is roughly predictable. If the range is larger than the system can tolerate, the system will create what is, in effect, an internal environment which will keep those system variables essential to the survival of the system within the range necessary for their survival. In other words, the system has the capacity to maintain a steady state in the presence of an environment which changes unpredictably, but within predictable limits.

7.28 The notion of "steady state" has come to have two meanings in the literature of systems theory. On the one hand, following the classical work of Walter B. Cannon[7], it has come to be identified with homeostasis, the complex and intricate processes by which an organism adapts to variability in the environment. The physiological stability an organism achieves is not due to the stability of physiological structures or materials. Indeed, the most vital of these structures and materials are so unstable that the most minute fluctuation or change in their environment could well be fatal to the organism. Taken individually, the vital physiological systems are non-adjusting, yet taken together they form a marvelous learning system.

> When we consider the extreme instability of our bodily structure, its readiness for disturbance by the slightest application of external forces and the rapid onset of its decomposition as soon as favoring circumstances are withdrawn, its persistance through many decades seems almost miraculous. The wonder increases when we realize that the system is open, engaging in free exchange with the outer world, and that the structure itself is not permanent but is being continuously broken down by the wear and tear of action, and is continuously built up again by processes of repair.[8]

7.29 This notion of "steady state," then, emphasizes the processes by which a system composed of inherently unstable components creates its own internal stability through a high degree of specialized functions, division

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[7] The Wisdom of the Body, (New York: Norton, 1963).

[8] Ibid., p. 20.

of labor, and checks and balances. The steady state of the whole system is achieved through the incessant activity and changing relationships of its parts. Change is of the essence of steady state; a system that cannot change its internal organization cannot survive in an unpredictably changing environment.

7.30 On the other hand, there is a common view of "steady state" which makes "growth" of the essence. This school of thought views the learning system over time, and notes that the steady states achieved by the systems themselves change - that homeostasis can be dynamic. Adapting (learning) systems not only maintain their organization through change, but also change their organization through elaboration of structure and differentiation of function. Cannon's notion of homeostasis does not adequately allow for structure-elaborating processes. The biologist, Emerson[9], is one of the most persuasive advocates of extending the notion of homeostasis to structure-elaborating processes.[10] Cannon, himself, encouraged and indulged in such extentions of his concept.

> Bodily homeostasis . . . results in liberating those functions of the nervous system that adapt the organism to new situations, from the necessity of paying routine attention to the management of the details of bare existence. . . The main service of social homeostasis would be to support bodily homeostasis. It would therefore help

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[9]in Grinker, ed., Toward a Unified Theory of Human Behavior, (New York: Basic Books, 1967), pp. 147-163.

[10]Talcott Parsons acknowledges his debt to Emerson ("On Building Social System Theory," Daedalus, Fall, 1970, p.831) in reinforcing his movement from equilibrial to homeostatic models of social processes.

> to release the highest activities of the nervous system for adventure and achievement. With essential needs assured, the priceless unessentials could be freely sought.[11]

7.31 Cannon, in my view, has been richly misunderstood by those who would extend his physiological notion of homeostasis to non-physiological domains. While there is no doubt that learning systems require the ability to maintain steady states among their critical subsystems, we may question whether the structure-elaborating processes can best be viewed as "dynamic" homeostasis. Intuitively we observe that many learning systems appear to move out of steady states towards greater disequilibrium, tension, and deviation. What we shall later (13.6B) call "proactive" learning describes the learning system's propensity for creativity, discover, and inquiry, for dealing with hypotheses, conjectures, and fantasies. Attempts to subsume these propensities under the rubric of "dyanmic homeostasis" robs the term of much of its rigor. Learning systems which manifest these propensities achieve new steady states only incidentally, and not necessarily as a response to environmental variety.

7.32 In dealing with learning systems, therefore, we shall incline towards the first, more restrictive, usage of "homeostasis," and shall view the steady state as one which achieves stability in a changing environment through internal change. At the same time, we acknowledge that change in learning systems can extend beyond homeostasis, that learning systems require the generation as well as the resolution of tension, instability, and deviation. In other words, change in learning systems cannot be ascribed solely to change in their environments. The

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[11] Cannon, op. cit., p. 323.

capacity to dream, to wish, and to hope are among the "priceless unessentials" which, from our point of view, are non-homeostatic in nature.

7.33 Unlike the adjusting system, in which desired environmental parameters were "built in" to the system, the adapting system must receive a steady flow of information from the environment, and this information must be in a form which is understood by the system. The learning system must include some sort of decoder, and the decoder must be capable of handling as much information as the system will need to represent the environment for its purposes. The adaptability of the system will frequently depend upon the ability of the decoder to handle the variety which exists in the environment. We have all had the experience of attending foreign-language films in which we know that the English sub-titles were only pale approximations of the spoken dialogue. We knew that we were missing a great deal, but not what it was. Similarly, the usefulness of any code depends upon its ability to handle all the variety that exists in the environment. The Morse Code can handle all possible messages because it has the same variety as the alphabet it is encoding.

7.34 We must remind ourselves that the environment, according to 6.1, consists only of those parameters which do affect the system. A blind person and a deaf person walking down the same street would inhabit very different environments, regardless of the fact that they may occupy nearly identical physical space. Visual data would not affect the first, and auditory data would not affect the second. There is an important conceptual difference, however, in thinking of each as an impaired system unable to encode important environmental data and thinking of them as different systems inhabiting different environments. The second approach, of course, is the one we are using in this paper. If the blind person and the deaf person were to join forces the result would be a single system able to encode both visual and auditory information.

7.35 It is worth adding here that two persons with fully functioning sensory apparatus walking down the same street may also be inhabiting different environments. If one is hurrying to make an appointment for which he is late and the other is ambling down the street taking in all the sights and sounds, each will be encoding very different information from the environment. The implication of these examples is that for concrete learning systems there are no normative environments, only an infinite number of different environments which may co-exist for different systems in the same space/time field.[12]

7.36 Once the information has entered the system as input and has been encoded into a form that can be processed by the system, the system must be capable of at least as much variety as the environment it is adapting to. "When the internal organization of an adaptive system acquires features that permit it to discriminate, act upon, and respond to aspects of the environmental variety and its constraints, we say that the system has <u>mapped</u> part of the environmental variety and constraints into its organization."[13] It is this process of mapping which activates the homeostatic mechanisms so that at all times they are responding to the actual environmental conditions which exist.

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[12] see footnote 1 to section 4.2.

[13] Buckley, Walter, <u>Sociology and Modern Systems Theory</u>, (Englewood Cliffs: Prentice-Hall, 1967), p. 63. Emphasis added.

7.37 We must note that if it were possible to map in advance all possible environmental variety into the system we would have a very complex adjusting system which would behave in precisely the same way as a learning system. To construct an adjusting system which behaves as though it were learning is well within the capability of science and engineering. To assume, however, that in so doing we have explained learning is a serious error[14], for the learning system is not one which has a greater number of built-in possible behaviors, but instead has a built-in plan for generating appropriate behaviors for a great number of environmental situations.

7.38 The learning system can thus adapt its behavior in a way that the adjusting system cannot. Colloguial language has alwyas made this distinction. The "adaptable" person - or organization - is one who can change his behavior appropriately to the situation at hand without knowing in advance what the situation may be, thus enhancing his ability to survive in a wide variety of situations. The question that system designers and system analysts must ask is whether the environment is more suitable for an adjusting system or an adapting system. The ability to survive in a wide variety of situations can be disfunctional if there are not a wide variety of situations to adapt to. As Ashby has pointed out[15], no particular form of system organization is intrinsically good or bad, but is relative to the environment in which it exists. An adapting system is not

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[14] It is an error that limits the usefulness of Ashby's two extraordinary books, Design for a Brain and Introduction to Cybernetics. To simulate learning is not the same thing as accounting for it in learning systems.

[15] in Buckley, Modern Systems Research for the Behavioral Scientist, (Chicago: Aldine, 1968), pp. 111-113.

"better" than adjusting system in any absolute sense; it is wasteful and inefficient in a restircted environment. Again, our common vocabulary reflects this destinction; we talk of "adapting" to new situations, but of "adjusting" to, say, army life. We might comment that we ordinarily talk of children "adjusting" to school, which says something, probably true, about the school as an environment.

7.39 We may now return to our arguement in 7.36 and ask what enables an adapting system to both behave appropriately and maintain a steady state. An essential part of the answer is that the adapting system has a memory which can store properly encoded environmental input as well as previously successful plans for behavior. It must be stressed that the use of the term "memory" implies no vitalistic explanation of adaptive behavior; we are talking about organization which can both be designed, observed, and modeled. The memory function stores the inputs and the plans in highly discrete segments so that the system can not only retrieve the input but can combine the input data in a limitless number of ways so that the "interior environment," or the system's image of the external environment, is extraordinarily flexible. We need think only of the linguistic capacity of human beings who live constantly with the need to respond verbally to unpredictable utterances from the environment. A finite number of sounds and a finite set of combinatorial rules can generate an infinite number of understandable utterances, none of which was in the system's memory.

7.40 Thus, in addition to storing the environmental input, the adapting system can store plans for combining the input data and for acting upon the various combinations of data that it can generate. It can, in effect, organize itself to meet new environmental conditions.

7.41 The ability of a system to adapt to environmental change by learning is limited by the plans built-in to the system's memory. The adapting system does not have the capacity to change its plans. It can neither change its template nor adapt to crises or emergencies wherein environmental parameters may assume values beyond their customary limits. Adapting systems are essentially re-active, not pro-active. They can follow rich and complex plans for changing both their lines of behavior and their organization, but they cannot change these plans. Just as adjusting systems are slaves to their input, so are learning systems slaves to their plans. It is a higher order of slavery, to be sure, but slavery nonetheless. A system which is to survive in an environment characterized by irregular or changing limits of variation must have the capacity to change its plans as well as its behavior. Such a system must be able to learn how to learn. We shall be considering such systems shortly.

7.42 Before we leave learning systems, however, we must stress two characteristics which distinguish them from adjusting systems, both of which can be inferred from the preceding treatment. First, the enhanced survival value of learning systems is due to their ability to achieve steady states independent of initial conditions or prior steady states. Their stability is always with reference to actual environmental conditions rather than reference to a set of assigned variable values. For this reason, it is impossible to predict with certainty what the values of any future steady state might be from the values of a given steady state. Depending on the number and complexity of its plans, a learning system can arrive at a steady state through a wide variety of ways of re-ordering its internal organization. A steady state may require a greater degree of organization

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(if the environment becomes more highly organized) so that the system must elaborate its structure and continually amplify the deviation from its prior conditions. Ecology provides splendid examples of the difference between an adjusting system and a learning system in this regard. Every schoolchild knows that there is a relationship between the size of a species population in a given area and the availability of food. Adjustment mechanisms regulate the size of the population to that which the supply of food can accomodate. Ordinarily this is accomplished by diminishing the size of the population through death, disease, and declining birth-rate. Human beings, however, also have the option of increasing the supply of food to accomodate an increasing population. As Maruyama illustrates[16], the growth of cities can be explained as an example of deviation-amplifying adaptation.

7.43 This suggests the second important point. Learning systems can act upon their environments to maintain them within the limits that the systems can adapt to. There is a nonlinear relationship between system inputs and outputs; each influences the other. The inputs received by the system are more likely to be encodable because they have been influenced by the system's outputs. Just as earlier we spoke of the adapting system's capacity to map environmental features into its internal organization, so, too, the system can project aspects of its own organization into the environment.[17] Not all learning systems have this

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[16] Op. cit., in Buckley, p. 305.

[17] Laszlo, Ervin, System, Structure, and Experience, (New York: Gordon and Breach, 1969), pp. 5-6.

capacity, but most living systems do. This kind of circular causality, of course, enhances the chances of system survival by exercising some control over the environment to which it must adapt.

CHAPTER VIII

INPUTS

8.1 "Input" is a generic term denoting the environmental features which enter the system to be processed, transformed, and utilized both to maintain the system and to produce outputs which re-enter the environment. All open systems have inputs as a condition of their existence, although systems will vary widely in their ability to accept differing amounts and differing kinds of inputs. All systems have boundaries and threshholds which serve to limit inputs to those which can be processed by the system. The boundary and threshhold act as filters to protect the system from inputs which would disturb system functioning or threaten system existence. If a system exists in a space/time field which contains many potentially dangerous inputs, the boundary and threshhold functions become of paramount importance (7.10). The greater the system's capacity to process environmental variety (7.33) when that variety is, in fact, present, the more stable the system will be and the less its survival will depend upon the vigilant maintenance of boundaries and threshholds. This hypothesis receives striking corroboration from history; the more energy a political entity devotes to its boundary functions - to preventing "harmful" inputs from entering the system - the more "harmful" those inputs become if they do, in fact, enter.

8.2 By definition, our taxonomy in Chapter Four indicates the capacity of the system to process both varied kinds and varied amounts of input. The non-adjusting system accepts only specified kinds and specified amounts of input. If either amount or kind of input varies, the system will malfunction. In an electrical system, fuses and circuitbreakers act as threshholds to prevent overloaded circuits.[1] However, there are minimal as well as maximal threshholds. Too little input is as damaging to the non-adjusting system as too much or too varied input. If the energy input to a non-adjusting system falls below the threshhold, the system will also malfunction.

8.3 Adjusting systems require a greater range in the amount of input, although not necessarily in the kind of input. Generally speaking, the output of an adjusting system will vary inversely with the input; thus variation of input from a specified norm is a precondition of an adjusting system's existence. The threshholds must therefore be wide enough to permit minor deviations to enter the system but narrow enough to prevent major deviations to injure the system's processes, which cannot be changed.

8.4 Learning systems require great variety in both the amounts and kinds of inputs, to the extent that if the environment does not naturally contain sufficient variety, the system, through its outputs, will enrich the environment to provide sufficiently varied inputs. The boundaries of learning systems are less easily ascertained than the boundaries of less adaptable systems. They are dynamic, as the system is; their threshholds may be indetectable to an observer whose threshholds are narrower than theirs. The threshholds of learning systems are idiosynchratic; they may expand or contract over time. Two interacting learning systems may have very different threshholds, even if we remember that we are talking about the admissability of input, not its interpretation. There is the story of the child who, when asked by his teacher to describe "infinity,"

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[1]This should not be confused with adjustment processes which use negative feedback. The circuit-breaker terminates system performance; it does not correct it.

replied, "Infinity is like a Quaker Oats box." The boy was chastised to be serious. Test of creativity, or "divergent thinking" are usually based upon the assumption that the investigator is more divergent than the subject and can, therefore, ascertain the degree of the subject's creativity.

8.5 Inputs may be classified in several ways. Miller distinguishes between matter-energy and information inputs.[2] We shall not develop the notions of "matter" and "energy," for while the reaer may not be knowledgeable in the disciplines dealing with them, he will know the appropriate domains in which they fall. "Inforamtion," hoever, is used in the special sense developed by communication theory and requires special explanation.

8.6 Information is a measure of the degree of uncertainty in a given situation, and is related both to the number of choices the sender of a message has to select his messages from and to the knowledge that the receiver has of the number of choices from which a particular message was selected. The information value of any message will vary directly with:

a. the greater number of possible messages from which the particular message was selected;

b. the degree of organization in the environment sending the message.

The information value of a message will vary inversely with:

a. the constraints upon the transmitter

b. the degree of probability in the environment.

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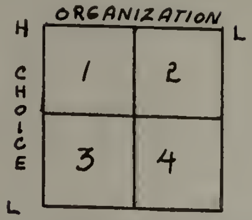
[2] Miller, James G., "The Nature of Living Systems" in Behavioral Science, vol. 16, 1971, pp. 279-281.

8.7 We can see this more clearly by forming the following table.



The horizontal continuum represents the degree of organization on the environment, ranging from high on the left to low on the right. The vertical continuum represents the degree of choice of the sender, ranging from high at the top to low at the bottom. Box One represents a highly-organized environment, one with a high degree of predictability and constraint and a low degree of probability. The sender has a high degree of choice in selecting the messages he will send. Because the environment is highly organized and highly predictable, it will require fewer messages to describe that environment, and each message will convey more information about it.

In Box Two, the environment is poorly organized with a low degree of predictability. It will take more messages to describe that environment, and each message will contain less information about the environment. The sender, however, has a high degree of choice, and so, despite the environments low degree of organization, given enough time, he can still describe it, although it will require many more messages to do so.

Box Three posts a highly-organized environment, but a sender who is highly constrained, with little or no choice; let us say that he is constrained to send only one message. Whether or not that message contained much information for the receiver would depend upon the receiver's knowledge of both the environment's organization and the sender's constraints. Because the environment is highly-organized, it is possible for a constrained message to convey information about it; however, there is no possibility for the accuracy of the message to be ascertained. Put another way, there would be no room for error since the sender could not correct his message.

Finally, in Box Four, the environment has little organization and the sender has little choice. Since it would take a great many messages to describe that environment, and since the sender is constrained to a few messages, it will be impossible for the sender to describe the environment, and the information value of the message will tend towards zero.

8.8 To illustrate, let us imagine an automobile engine and the dashboard guages. A smoothly-running engine is a highly-organized system; the performance of each component is dependent upon the performance of other components. The gauges provide a variety of information about the performance of this system: temperature, oil level, speed, gas level, and so forth. Assuming that the gauges are working smoothly, they will at any given time provide accurate information about the system as a whole. Note that the driver need not know much about how the engine works to know that it is working smoothly. This is an instance of a Box One situation.

8.9 Now let us assume that the engine begins to malfunction through some diminution in its degree of organization. Let us say that the temperature guage begins to indicate overheating. The gauge indicates that something is wrong, but not what is wrong. More information is needed, and the driver will either examine the engine or take the car to a mechanic to find out whether the difficulty is a leak in the radiator, evaporation of fluid, a loose fan-belt, or whatever. The mechanic will have a systematic way of examining the problem, based upon the ease of investigation and the probability of error. Some malfunctions are more likely than others in an organized system. As the system becomes increasingly disorganized it takes an increasingly greater number of messages to describe it. This is an example of a Box Two situation.

8.10 So far we can generalize to say that the more organized the system (or the environment) the less information is necessary to describe it, to predict its behavior, and, as we shall soon see, to control it. Likewise, the more organized the system, the greater the information value of any given message. Conversely, the less organized the system, the more information is necessary to describe, predict, or control it, and the less the information value of any given message.

8.11 Now let us assume a well-functioning, highly-organized engine, but a very limited gauge, perhaps a light that goes on when the system is overheated. In this instance, the gauge can give only two messages - either the system is overheated or it is not overheated. When the temperature passes the threshhold, a light goes on. The gauge cannot indicate that the system is becoming overheated, only that it has become overheated. Or, let us assume a more extreme case: the gauge is broken, the light bulb is burned out, or a fuse is blown. If the driver does not know that the gauge is not working, he may assume that the lack of a light indicates that the system is not overheated. Most of the time he will be right, but some of the time he will be wrong. Since the gauge can only sense one message, there is no way of validating its accuracy. In this case, the driver is getting no information about the cooling system, but he doesn't know that he is getting no information. When he discovers that the gauge is malfunctioning, he must either get it fixed or make extra effort to maintain the system in a high degree of organization. Whenever he stops for gas, let us say, he will check the fluid level and the fan belt to get the information that the gauge, because of its limited choice, cannot give him. This illustrates a Box Three situation, and demonstrates that a limitation on the freedom choice of the message sender reduces the information value of the message.

8.12 Finally, we come to Box Four, the loosely organized system and the highly constricted transmitter. If the engine doesn't work and the gauges don't work, the driver can get no information about the system. When his car is towed in to the mechanic, the mechanic will start probing the system according to the same two principles we mentioned in 8.9: the ease of investigation and probability of malfunction. If the car has been really neglected, the chance that any one repair will restore it to proper functioning is minimal. The mechanic will have to put the car through a great many tests, each of which will provide minimal information about the whole system, but taken together will provide a great deal of information. If the mechanic is trained to send a wide variety of messages to the car, ultimately he will be able to restore it. If, however, like many do-it-yourself mechanics, he can only kick it, the chances of restoration are slim.

8.13 Our illustration has chosen a deterministic system, the car engine, to explain the concept of information. It should be clear to the reader that the more probabilistic the system and the more that the system's organization is continually changing, the more difficult it becomes for a constrained transmitter to send messages about the system. The messages describing the state of a changing system at any given point in time may not, in fact, describe the system at the point in time that the receiver receives the message.

8.14 It will frequently happen that the receiving system will not know the range of the transmitter's freedom of choice of messages. I can recall with both delight and dismay the first time my baby daughter pointed to me and said "da-da." My bubble soon burst when she pointed at other members of the family and said "da-da." It may take repeated transmissions under a variety of circumstances before the range of choice can be roughly ascertained. The driver may not discover that the needle in the gas tank gauge is stuck until he runs out of gas.

8.15 There is one more observation we must make about information inputs. The more probable the message, the less information it contains. Probability, in this sense, is the inverse of organization; the law of entropy, developed within the theory of closed systems, states that without inputs a system will ultimately assume its most probable, that is to say its least organized, state. While open systems are by definition negentropic, some systems are more open than others and are more capable of maintaining a high degree of organization. Language systems provide good evidence of this. Given the phrase, "once upon a ________," most school children could predict the missing word with almost perfect accuracy, for the high degree of organization of our language makes it improbable that the missing word would be other than "time." If it were to turn out to be "mattress" we would receive more information that if it were "time," since "mattress" is less probable than time. If the missing word turned out to be "the," this would be so very unpredictable that we would suspect an error in transmission. Certain words follow

8.15

other words with great regularity in our language. If this were not the case, if any word were equally probable after any other word, we would be unable to communicate at all. Just so, if our environment were not organized similarly, if any event or situation with equal probability, we would be unable to survive in it.

8.16 This is one area where our common vocabulary plays tricks on us; if we say that a given outcome or result is "highly probable," it is only because the environment (or the system) is highly improbable. It is only because of the constraints in the environment which limit the probable behavior of its components that any given event or situation becomes more probable.

8.17 Miller has constructed the following table[3] to show the relationships between various terms used to talk about information and organization. Each term is the antonym of the other in the same row; the terms in each column are roughly synonymous in that they are different ways of describing the same phenomenon.

Information	Uncertainty
Negentropy	Entropy
Signal	Noise
Accuracy	Error
Form	Chaos
Regularity	Randomness
Pattern or form	Lack of pattern or formlessness
Order	Disorder
Organization	Disorganization
Regular Complexity	Irregular Complexity

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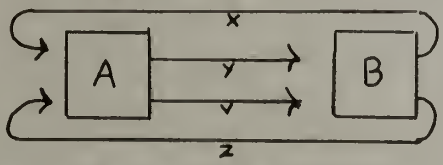
[3]"Living Systems: Basic Concepts" in Gray, Duhl, and Rizzo, General System Theory and Psychiatry, (Boston: Little, Brown, 1969), p. 67.

Heterogeneity	Homogeneity
Improbability	Probability
Predictability	Unpredictability

8.18 The value of information to the system will thus depend upon the character of the environment presenting the input. It will also depend upon the capacity of the system to process the information which enters it. We shall be talking about system processes in the next chapter, but for now we shall suggest that the ability of the environment to control the system is directly related to its ability both to provide information to it and to gain information from it. The ability of the system to control the environment is likewise directly related to its information processing capacity. If the system is capable of acting upon more information than the environment or a particular system in the environment, is able to send, the environment will be unable to control the system. The reciprocal is also true. This is but another way of stating the message of Chapter Four; that there must be (and therefore is) congruence between the system and its environments.

8.19 Control is closely related to predictability. The abount of information necessary to predict the behavior of a system is also the amount of information necessary to control that system. If, in the following diagram, systems A and B stand in interaction and A must control B, i.e., A's output will be B's input, and A requires output "x" from B, A must know not only all the ways "y" can be transformed to "x" but also



all the ways in which "y" might be transformed to some other output, say

8.19 "z," instead of "x." If, given "y," B can produce either "x" or "z," A's control over B is lacking. To increase its control, A must reduce the variety in B, and to do this it must have greater variety than B. It must be able to produce input into B which, in addition to "y" will constrain B's ability to produce "z." If, by failing to produce "x," B in some way jeopardizes A, then B's control over A is greater than A's control over B. Let us say that B desires or needs input "v." By producing "z" instead of "x," B can induce A to provide "b" in addition to, or in place of, "y." If A produces "v" and "y," B will produce "x." However, "x" input into A leads to "y" output which, in turn, produces "z" as frequently as it produces "x." Viewed as B's environment, A must be able to provide both "v" and "y" to be able to insure that B will produce "x." Viewed as A's environment, B must be able to provide both "x" and "z" to insure that A will produce "v." In such a mutually causitive system, we can say that control is shared; each system has enough information a variety to control the other.

8.20 Control and prediction are not identical, however. I may predict with absolute accuracy that the sun will rise tomorrow, that a train on a track will run in a given direction, or that a child will sneeze if I throw pepper at his nose. Control implies the ability to produce different results from the same initial conditions or similar results from different initial conditions. Knowledge of a deterministic relationship between initial conditions and subsequent states may give the appearance of control to those who are unaware of the deterministic nature of the system. Thus there can be predictability without control. There cannot be control without predictability, however.

8.21 The distinction between matter, energy, and information has helped us focus on some distinctive properties of the latter, but we should not forget that the distinction is highly artificial. Any given input into the system is likely to be composed of both matter/energy and information. This is similar to the distinction in Chapter Two between components and variables. Just as we said that it was appropriate to look at a system component as a particular disposition of variables at a given point in time, so, too, we can look at an input datum as a particular disposition of matter/energy and information at a particular point in time.

8.22 Berrien has provided another helpful way of classifying inputs according to function. He distinguishes between maintenance inputs and signal inputs.[4] Again, this tends to be an artificial distinction, since many, if not most, inputs will have both maintenance and signal functions, but it is helpful, when dealing with open systems, to distinguish between those inputs which are essential if the system is to function properly and those inputs, the processing of which *is* the system's function.

8.23 *Maintenance inputs* are essentially those which are necessary to counteract the inevitable entropy which would occur if they were not available. All open systems require an energy input to maintain themselves; all living systems, at least through the level of the organism, require matter inputs so that metabolic processes may occur. We add the qualification because it is difficult to conceptualize the nature of maintenance matter-input at the supra-organism level, e.g. group or organization, except as new members are added to replace members who leave the group for one reason or another. Open systems above the non-

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[4]Berrien, F. Kenneth, *General and Social Systems*, (Brunswick: Rutgers, 1968), p. 25.

8.23

adjusting level require some information inputs to permit the adaptive processes to occur. Non-adjusting systems do not require information input, since they cannot process it; nonetheless every matter or energy transmission from the environment will contain some information value.

8.24 For the learning system, maintenance inputs are those which activate the homeostatic mechanisms which enable the system to maintain a steady state. In the human being, for example, a steady maintenance input is required for life, although signal inputs may fluctuate a great deal. We might say that the human being when asleep, is receiving only, or primarily maintenance inputs.

8.25 The case is put nicely by Lashley:[5]

> ". . . the input is never into a quiescent or static system, but always into a system which is already actively excited and organized. In the intact organism, behavior is the result of interaction of this background of excitation with input from any designated stimulus."

It is the maintenance inputs which provide and maintain the excitation. Before any system can process signal inputs, therefore, maintenance inputs must be present.

8.26 Signal inputs are those that the functioning open system receives which, through its processes, are transformed into outputs. The non-adjusting system will accept only specific signal inputs that it has been

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[5]in Berrien, op. cit., p. 25.

designed to accept, and these will be task-specific inputs. The adjusting system will accept a wider range of signal inputs, although the modes of their values will be restricted to those the system can process. Thus, a thermostatically-controlled heating system will accept as signal inputs both the desired temperature as determined by the environment and the actual temperature as determined by its output. It will not accept humidity or dust-content signal inputs. The learning system will accept all those inputs, both ranges and modes, that it can encode.

8.27 Human beings receive signal inputs primarily through their sensory organs, which also act as filters. The presence of a particular "signal" in the environment does not necessarily mean that it is accepted by the system as input. Learning systems are highly selective in accepting signal inputs, much more so than is the case with maintenance inputs.

8.28 The distinction between maintenance and signal inputs is partiuclarly helpful in looking at groups and organizations as systems. It helps us to distinguish, for example, between working conditions (maintenance inputs) and the work itself (processed from signal inputs). Some useful and researchable hypotheses can be formed about the relationship between maintenance and signal inputs and the portion of a system's energy devoted to the processing of each. We might expect, for example, that the more the system must process maintenance inputs, the less adaptable it may be. As a corollary, we can suggest that the more components involved in maintenance input processing, the less likely that those components or that the system will be learning systems, although the greater the likelihood that the maintenance functions will be performed.

8.29 If, for example, an organization must expend a great deal of energy and time determining the rules, regulations, and protocol under which it will operate, the less energy and time it will have to operate under those rules, regulations, and protocol. The more members who are engaged in these activities, the less time and energy these members will have to process signal inputs.

8.30 This discussion of inputs has been extended because everything said in this chapter is true of processes and outputs as well. Whether any phenomenon is considered input, process, or output depends largely upon the system one is looking steadily at. Since any concrete thing may be viewed as system, as environment, and as "system and environment," what will be input from one perspective will be process or output from another perspective. This is why it is so important not to change perspective in mid-analysis.

CHAPTER IX

PROCESSES

9.1 We shall limit our attention in this chapter to the most interesting and pertinent classes of systems, the learning systems and the morphogenic systems, since these are the systems which change their internal processes, and because all living systems apparently fall into these classes. If we think conceptually of a system as a "black box" with identifiable inputs and identifiable outputs, everything within that black box will be subsumed under the heading, "process."

9.2 This treatment attempts to minimize the distinction between "process" and "structure," a distinction which has engendered lively debate among philosophers and social scientists, without ignoring the validity of the distinction for certain analytical purposes. We agree with Miller that "the structure of a system is the arrangement of its subsystems and components in three-dimensional space at a given moment of time. This always changes over time."[1] Since one of the characteristics of open systems is the relative instability of their structures (7.28 and 8.25), and since the instability of system structures appears to have no direct relationship to the stability of the system as a whole in relationship to its environment, we are stressing the dynamic rather than the static approach by focussing on the processes rather than structures. This is also consistent with our distinction in 5.9 between components and variables. The structural approach tends to regard system parts as components - entities having a spatial configuration at a point in time,

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[1] in Behavioral Science, vol. 16, 1971, p. 284.

whereas the process approach will view the system parts as subsystems which may or may not be identical with components.

9.3 We acknowledge, however, that systems do have a "deep structure" which remains relatively unchanging when compared to the processes observed over time. As the song says, "Fish gotta swim and birds gotta fly. . .," and the phylogenetic template of living systems is, for all practical purposes, unchanging. This is to say both that there are effective limits to structural change and that there are certain essential processes which all systems must have, regardless of how these processes are carried out. This chapter will identify these critical processes and describe various modes of system organization for carrying on these processes.

9.4 Several preliminary observations are necessary. First, this inquiry into system processes would be unnecessary if system processes were deterministic and if there were an invarient relationship between input and output. If the environment could control the system's outputs solely by controling the inputs, it could treat the system as a black box. The more probabilistic the system - that is to say, the more variety the system contains - the more knowledge of system processes is necessary if the environment is to exercise control over system outputs. It follows axiomatically that if the system is to exercise self-control, the more knowledge of its own processes it must have. "Knowledge" is not necessarily to be construed as "consciousness," but rather in the more general sense of being able to process internally generated information.

9.5 Second, it may appear that the system one is looking steadily at is not performing all the critical processes necessary for system survival. Miller distinguishes between totipotential systems which are capable of carrying out all critical processes, and partipotential systems which are dependent upon other systems for the carrying out of certain critical processes.[2] Any partipotential system is necessarily a subsystem of a totipotential system. Totipotential systems may also be subsystems of totipotential systems. Totipotential systems may also participate as subsystems of partipotential systems, and this gives rise to some interesting complexities at the supra-organismic levels. Presumably, all organisms are totipotential, unless parasitic or symbiotic, although the groups they belong to may be partipotential. As members of groups they must delegate some of their critical processes to the group and become partially-functioning totipotential systems, while at the same time the group they belong to is a fully-functioning partipotential system.

9.6 Thus, a public day school may be a fully-functioning partipotential system, depending upon its environment for the performance of certain critical processes, while its students and teachers, while in school, are partially-functioning totipotential systems. Sociologists might say that an individual can play many different roles, although at any given time he is not performing all the roles in his repetoire. We would say that a fully-functioning partipotential system is only a portion of the environment for the partially-functioning totipotential components. Both students and teachers receive inputs from sources other than schools. If the observer is attempting to understand the behavior of a totipotential subsystem in terms of the inputs from a partipotential supra-system, his analysis is likely to be faulty. Thus, a school may provide a fully-

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[2] "Living Systems: Basic Concepts" in Gray, Duhl, Rizzo, General Systems Theory and Psychiatry, (Boston: Little, Brown, 1969), pp. 74-75.

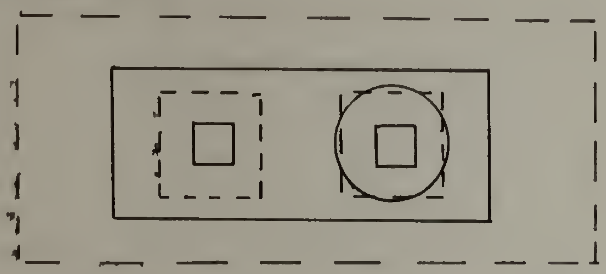
functioning learning environment, but it will only be a part of a child's learning environment. The rhetoric of educators frequently acknowledges this, but their practices just as often deny it.

9.7 It is frequently difficult to determine the boundaries of partipotential systems and thus distinguish between inputs, processes, and outputs. For example, are the students in the school to be seen as inputs or system components? What are the outputs of a school? These are difficult questions to answer with any degree of rigor because it is difficult to look steadily at a school as a system without shifting focus inadvertently to another level of analysis. We frequently resort to metaphors from the world of business and industry where boundaries, inputs and outputs are more readily identifiable. This has led us to organize our schools as though they were businesses and has led the public to hold the school accountable as though schools' "products" were as clearly identifiable as businesses'. However, an industy dealing in products is in fact a totipotential system, whether or not fully functioning. All the processes transforming the inputs into outputs can both conceptually and concretely be located within tempero-spatial boundaries.

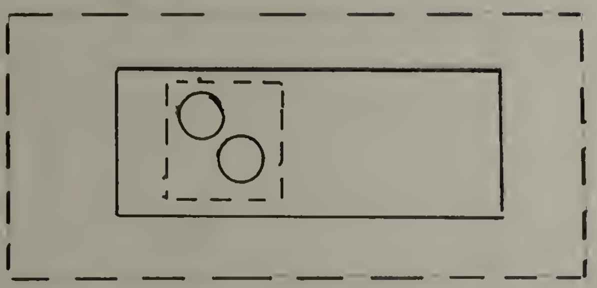
9.8 The third and final preliminary consideration has to do with the relationship between system components and critical subsystem processes. Miller states that "systems differ markedly . . . in their <u>patterns of allocation</u> of various subsystem processes to different structures. Such a process may be (1) localized in a single component; (2) combined with others in a single component; (3) dispersed laterally to other components in the system; (4) dispersed upward to the suprasystem or above; (5) dispersed downward to subsystems or below; or (6) dispersed to other systems external to the hierarchy it is in."[3] This consideration is of great significance to those who are interested in changing systems.

9.9 It will be helpful to illustrate these patterns of allocation schematically. In the following diagrams, the heavy rectangle will represent the system we are looking steadily at; the external dashed rectange will represent the suprasystem (environment); the internal dotted squares will represent components; the small heavy squares will represent subcomponents. The circle or oval will represent the critical subsystem process.

9.10 Local subsystem - If the critical subsystem process is carried out by a single component which carries out no other subsystem processes, this is a local subsystem.

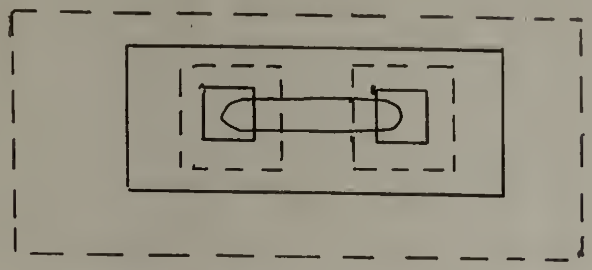


9.11 Combined subsystem - If a component is involved with more than one critical subsystem process, each of the subsystem processes is a combined subsystem.

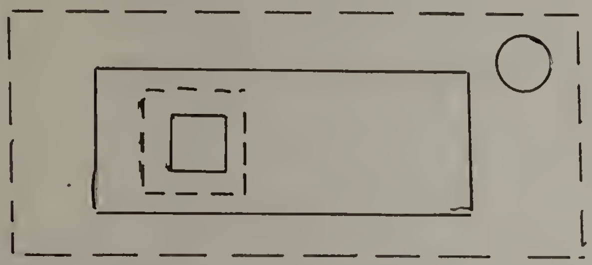


[3] Ibid., pp. 102-103.

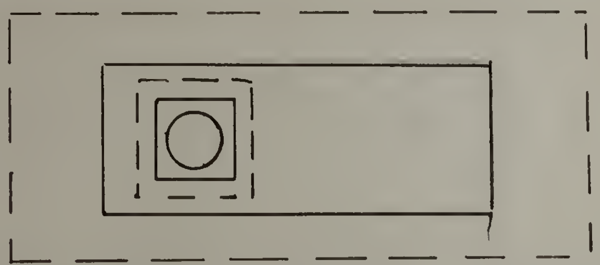
9.12 Laterally dispersed subsystem - If a critical subsystem process involves more than one component of a system, that subsystem is laterally dispersed.



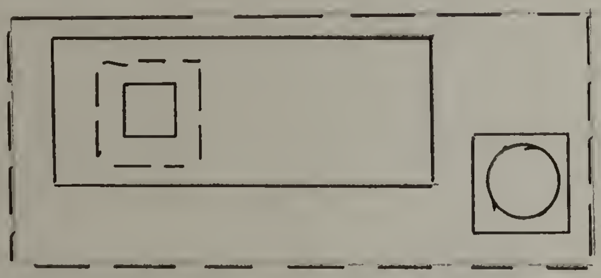
9.13 Upwardly dispersed subsystem - If the critical subsystem process is performed for the system by a component or components in the suprasystem (environment), that subsystem is upwardly dispersed. Such a system is by definition partipotential.



9.14 Downwardly dispersed subsystem - If the critical subsystem process is localized in or laterally dispersed among subcomponents, it si a downwardly dispersed subsystem.



9.15 Outwardly dispersed subsystem - If the system depends upon another system which would not naturally be considered part of its suprasystem for the performance of a critical subsystem process, that process is outwardly dispersed. The two systems together do, of course, form a single system with respect to that process, but the distinction is conceptually useful to accomodate the difference between, for example, a father carrying his infant upstairs, which would be an upwardly dispersed subsystem, and a blind man with a seeing-eye dog, which would be an outwardly dispersed subsystem. Miller suggests that outwardly dispersed subsystems are either parasitic or symbiotic,[4] whereas upwardly or downwardly dispersed subsystems are not. The distinction, however, is not as clear as Miller seems to imply. He says that "such assistance [outwardly dispersed subsystems] is required for all partipotential systems and all totipotential systems which are not functioning fully."[5] It seems, however, that a fully-functioning partipotential system would require upward dispersal, while only the partially-functioning totipotential system would require outward dispersal. Of course, the distinction between a fully-functioning partipotential system and a partially functioning totipotential system is not an easy one to make.



[4]Ibid., p. 104.

[5]Ibid., p. 105.

9.16 Miller identifies nineteen critical subsystems, two of which process both matter/energy and information, eight of which process matter-energy, and nine of which process information.[6] The following chart lists these subsystems and shows a rouch relationship between the matter-energy processing subsystems and the information- processing subsystems.

Matter-Energy Processing Subsystems	Subsystems which Process both Matter-Energy and Information	Information Processing Subsystems
	Reproducer	
	Boundary	
Ingestor		Input Transducer
		Internal Transducer
Distributor		Channel and Net
Converter		Decoder
Producer		Associator
Matter-Energy storage		Memory
		Decider
		Encoder
Extruder		Output Transducer
Motor		
Supporter		

In discussing these subsystems, we shall first quote Miller's definition[7]

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[6]The catagorization scheme and chart come from Miller's most recent writing on these issues (Behavioral Science, vol 16, 1971). Earlier papers (1964, 1965) classified these processes somewhat differently. Miller's definitive book, Living Systems, is promised for 1972 publication by Wiley but not available as of this writing.

[7]quoted definitions in section 9.17 - 9.37 are taken from "The Nature of Living Systems" in Behavioral Science, vol. 16, 1971, pp. 289-290.

9.16

and then provide examples of these processes, using the school as the system we are looking steadily at.

9.17 Reproducer - "the subsystem which is capable of giving rise to other systems similar to the one it is in." Few schools engage in this process, which is usually upwardly dispersed to the suprasystem of the school system, school board, and community. In some senses, however, the notion of the "school within a school," most frequently observed at the secondary level, wherein a large school is divided into smaller semi-autonomous schools, might be seen as an example of a reproducer subsystem.

9.18 Boundary - "the subsystem at the perimeter of a system that holds together the components which make up the system, protects them from environmental stresses, and excludes or permits entry to various sorts of matter-energy and information." Most literally, the school building is the boundary of the school, with the doors and windows permitting the entry of inputs. Occasionally, the front office will be a part of the boundary subsystem and admit or exclude certain inputs. Viewed thus , the perimeter of the school system is a localized subsystem. More realistically, however, the boundary processes should be seen as both laterally and upwardly dispersed among the members of the school community as well, particularly in terms of information processing. Information which is literally within the physical boundary of the school may well be effectively excluded from the system if it is considered to be harmful or inappropriate to the system. Consideration of "controversial" topics such as sex education can be seen as a discussion of the boundary subsystem process. Cf course, the more dispersed the boundary subsystem, the more difficult it is to control the entry of inputs into the system. As of this writing, the Supreme Court is about to consider the case of the Amish in Wisconsin who do not wish their children to attend secondary school. Disregarding the legal implications of the case, this can be seen as an effort by the Amish to control the boundary subsystem of their community.[8] Similarly, the stationing of uniformed policemen in school corridors is an effort to control the boundary subsystem of the school.

9.19 Ingestor - "the subsystem which brings matter-energy across the system boundary from the environment." Literally, school buses, delivery trucks, and the postal service perform this process which is thus both upwardly and outwardly dispersed. We would also include personnel who unpack boxes, open mail, and perform similar functions which prepare matter-energy for internal distribution within the system.

9.20 Distributor - "the subsystem which carries inputs from outside the system or outputs from its subsystems around the system to each component." This subsystem is laterally dispersed among many components, and is also combined with other subsystems. The secretary who distributes mail to the teachers' boxes, the teacher who hands out paper and pencils to students or who collects milk money are both participating in the distributing subsystem process.

9.21 Converter - "the subsystem which change certain inputs to the system into forms useful for the special processes of that particular system." Cafeteria workers who cook the food for a hot lunch program are clear participants in this subsystem process. So is the teacher who makes copies of a prepared ditto-master, and the teacher who makes a transparency from a chart in a book. There are clearly numerous examples, mostly trivial, of this process.

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[8]see Saturday Review, January 15, 1972, p. 52.

9.22 Producer - "the subsystem which forms stable associations that endure for significant periods among matter-energy inputs to the system or outputs from its converter, the materials synthesized being for growth, damage-repair, or replacement of components of the system, or for providing energy for moving or constituting the system's outputs of products or information markers to its suprasystem." Since schools are generally seen as information-processing systems, it is difficult to think of non-trivial examples of this crucial subsystem process. Of course, physical plant maintenance would be a part of the producer subsystem, but also the organization of students and teachers into groups such as classes, teams, and special interest clubs would be an example of this subsystem. The organization of a learning center or a materials resource center would also be an example. This subsystem is ordinarily dispersed upwardly, downwardly, and laterally, which is another reason that it is difficult to conceptualize.

9.23 Matter-energy storage - "the subsystem which retains in the system, for different periods of time, deposits of various sorts of matter-energy." Storage and supply closets provide this subsystem, as to teachers' and childrens' desks, cubbies, and pockets.

9.24 Extruder - "the subsystem which transmits matter-energy out of the system in the form of products and wastes." Children take home pictures and worksheets they have completed in school. Custodians empty the wastebaskets at the end of the school day. Of course, if one views students as inputs, one could also view them as matter-energy outputs.

9.25 Motor - "the subsystem which moves the system or parts of it in relation to part or all of its environment or moves components of its environment in relation to each other." Miller intends the notion of movement to be taken quite literally. On the level of the organism this is easy to conceive, but at the level of the organization it is more difficult. School field trips would be examples of motor functions, as would choral groups singing at nursing homes, but aside from these atypical examples it is significant that this subsystem is mostly lacking in schools. Schools-without-walls attempt to provide this subsystem, but most schools do not literally move in relation to their environment.

9.26 Supporter - "the subsystem which maintains the proper spatial arrangements among components of the system, so that they can interact without weighting each other down or crowding each other." Walls, doors, furniture arrangement are all part of this critical subsystem. The term "proper" may be unfortunate, since it introduces a matter of judgment into what is otherwise a relatively value-free description of system processes. Schools vary widely in terms of their organization to maximize flexibility of spatial organization and to combine the supporter subsystem with other subsystems. Thus, a portable blackboard may serve this subsystem as well as several information-processing subsystems such as internal transducer (9.28), decoder (9.30), and memory (9.32). The more flexible a school, the more laterally dispersed this subsystem will be. It is only recently that school people have recognized this as a critical subsystem. The work of Hall[9] and Sommer[10] suggests that possibly this

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[9]Hall, Edward T., The Hidden Dimension, (Garden City: Doubleday, 1966).

[10]Sommer, Robert, Personal Space: The Behavioral Basis of Design, (Englewood Cliffs: Prentice-Hall, 1969).

subsystem should be seen, along with the reproducer and boundary, as processing both matter-energy and information.

9.27 Input transducer - "the sensory subsystem which brings markers bearing information into the system, changing them to other matter-energy forms suitable for transmission within it." This is a widely dispersed subsystem which is combined with many other subsystems in the school's living and non-living components. All persons in the school bring information into the school with them and change the information into matter-energy forms - speaking and writing most frequently - that can be transmitted within the school. It must be recalled from 8.6 that we are using "information" in a technical sense having no necessary reference to the content of the message. Anything that can be seen, heard, smelled, touched or tasted will have some information value. This subsystem is responsible for bringing information from the environment into the school across the boundary (9.18). Other subsystems are responsible for generating and transmitting information within the school.

9.28 Internal transducer - "the sensory subsystem which receives, from all subsystems or components within the system, markers bearing information about significant alterations in those subsystems or components, changing them to other matter-energy forms of a sort which can be transmitted within it." It is a distinctive feature of the school as a system that the internal transducer subsystem is combined with the input transducer subsystem within the same components. Children bring information with them to school and presumably gain information within the school which is transmitted to their teachers and classmates as a "significant alteration." While the school as a system can exercise significant control over its internal transducer subsystem, it can exercise little control over its input transducing subsystem. Some schools, recognizing the difficulty that these combined subsystems entails, attempt to control their input transducer by running a boarding school, by increasing filter vigilence and admitting only students who meet certain kinds of criteria of wealth, background, intelligence, and so forth. However, such boundary vigilence is successful only to a degree; information introduced into the system and information generated within the system are inextricably intertwined. They are not always congruent or complementary; information brought into the school may inhibit the internal transducing subsystem. It is, of course, also true that the system may generate incongruent or conflicting information. Interpersonal relationship theory stresses that verbal and non-verbal messages sent simultaneously are frequently perceived as contradictory. The school as a system is uniquely intended for information processing; it is curious that so much of the information internally transduced in the system is neither intended nor attended to.

9.29 Channel and net - "the subsystem composed of a single route in physical space, or multiple interconnected routes, by which markers bearing information are transmitted to all parts of the system." Like the other information processing subsystems we have considered thus far, the channel and net is laterally dispersed and combined with other subsystems in the components which make up a school. Ignoring trivial examples such as public address systems, the essential channels of communication in a school are comprised of unmediated human interactions, non-discrete, multiple, and simultaneous. Organizational theorists frequently distinguish between "formal" and "informal" channels of communication, but from a system theory point of view the distinction is of little significance. The sorts of questions which systems theorists ask about channels - their capacity, reliability, and entropy - require no such distinction. Instead, we can substitute the notion of a network of nodes of interaction which comprise the communication channels of an organization. An observer spending enough time in a school could observe and chart such a network by noting who talks to whom, under what circumstances, and with what frequency. "Formal" channels, as when the principal holds a staff meeting, or a teacher conducts a class lesson, would certainly be included in such a network, although they would probably be less significant than many school people imagine. The most acute observer, however, would be unable to include in his network the essential channels of non-verbal communication which exist between individuals and groups in a school, communication generated both consciously and unconsciously by body and eye movement, intonation and inflexion, dress and use of time and space. Because human beings are capable of transmitting and receiving simultaneous messages, we may want to think of a school as having a number of superimposed networks, through all of which information is being transmitted incessantly.[11] The channels which comprise these networks will have varying capacities and characteristics. For instance, the eye can "take in" and follow several things happening at once by shifting focus very rapidly from one phenomenon to another. The ear, however, does not have the same sort of capacity for simultaneous reception. We cannot listen to two conversations simultaneously; we must tune in and tune out. Simultaneous sounds of the same volume and frequency will be heard as a babble. Individuals

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[11] Cherry, Colin, On Human Communication, second ed., (Cambridge: MIT, 1966), pp. 29-30.

will differ, too, in their capacity to process the rate of information being sent over these simultaneous channels, particularly if the messages are incongruent or contradictory. It is not possible in a complex system including human beings to calculate with any rigor the capacity of communication channels. It is possible, however, to state axiomatically that the channels will have finite capacities; that the capacity of any given channels will be effectively reduced if other superimposed channels are simultaneously carrying incongruent messages; and that if either the rate of transmission or the number of simultaneous or proximal incongruent messages transmitted exceeds the capacity or the number of channels available, the system will be unable to process the information either entering it or generated within it. Overloaded channels will not transmit effectively. Too much information can have similar consequences as too little information. Communication theorists have introduced the notion of redundancy to describe characteristics of messages which serve to increase the likelihood of reliable transmission in the face of limited channel capacity. Briefly and simply, if a message is repeated, or if it contains elements which have relatively little information value, it is more likely to be reliably transmitted than if the message is unrepeated or if every element of the message is crucial to its reliable transmission. The more redundancy a message contains, the more likely a receiver is to receive it accurately, even if he misses some of the message or if there is some interference (called "noise" by the theorists) in the channel. Lecturers have long known that if a point in a lecture is important it had best be repeated. They also know (or should know) that the more important points a given lecture contains, the less likely any given point is to be remembered. Redundancy is directly related to organization and predictability, and is inversely related to the information value of a given message. In other words, the less information a given transmission contains, the more likely that it will be transmitted reliably. The more organized the environment sending the transmission, the more redundancy that transmission will contain and the more reliable it will be. The syntactic and semantic redundancy of our language is such that much could be eliminated without a significant loss in meaning. Cherry illustrates this[12] by pointing out that "the ventious crapests pounted raditally" can be parsed and translated into French ("Les crapets ventieux pontaient raditallement") even though we have no idea of the meaning of the individual words. Likewise[13], the string of nouns "Woman, street, crowd, traffic, noise, haste, thief, bag, loss, scream, police" tell a story to which the reader can add the missing elements. Given the multiplicity of channels in complex human systems like schools, and the finite capacity and different characteristics of these channels, a significant degree of redundancy is necessary for reliable transmission, even at the expense of the amount of information transmitted.

9.30 Decoder - "the subsystem which alters the code of information input to it through the input transducer or the internal transducer into a 'private' code that can be used internally by the system." Again, this subsystem process is widely dispersed and combined. At its most elementary level, the decoder assigns common meanings to words and other signals,

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[12] Ibid., p. 120.

[13] Ibid., p. 121.

both verbal and non-verbal. More specifically, the decoder in schools translates the common meanings of words into the technical vocabulary and symbols of education. Frequently, this special 'private' code appears to outsiders (and some insiders) as obfuscating jargon, and frequently it is, but it does have the advantage of allowing a great deal of information to be processed with economy and uniformity. The designation of students as "slow learners," "bright," "emotionally disturbed," and so forth, serves as a private code, as do grades, test scores, inventories, and other such data. Most curriculum materials produced for schools are decoded into a language deemed appropriate for a particular group of children according to age and ability; to this extent, this subsystem is outwardly dispersed. A basal reader enters the system in its decoded form, whereas a teacher teaching economic theory to third graders using her old college text would have to do a great deal of decoding. In schools, as in many organizations whose existence depends upon the reliability of human communication, the decoding process is both essential and ineffective. What is frequently called "a failure of communication" is often in reality due to the multiplicity of incongruent messages being sent simultaneously over different channels, requiring different decoding processes. Just as there are multiple overlapping networks of channels, so there are multiple codes, both verbal and non-verbal, requiring different decoding processes. People who spend enough time in a given school, both adults and children, find that their first priority must be to deciding which of the conflicting or incongruous messages reflects the true intention of the sender. If the message is paradoxical, this task can be insoluble. Consider, for example, the following concotanation of conflicting messages:

A. The open classroom is the approach to education which best encourages active learning in children.

B. A school should be able to accomodate a variety of teaching styles and educational philosophies.

C. It is important for teachers to feel comfortable with innovations they introduce into their classrooms.

D. Teachers should be able to specify learning objectives in behavioral terms.

It is not uncommon to find messages such as these coming from administrators of progressive school systems. How should they be decoded? Is it more important to have a variety of teaching styles or to have an open classroom? Is it more important for teachers to feel comfortable or to use behavioral objectives? Is it more important to use behavioral objectives or to have an open classroom? What does the administrator want? What does he really want? Children ask the same questions of conflicting messages from their teachers. The real communication problem in complex organizations such as schools is that there is no rigorous and reliable decoding process for dealing with information about relationships, and it is just in this area that messages are most likely to be incongruent and conflicting.

9.31 Associator - "the subsystem which carries out the first stage of the learning process, forming enduring associations among items of information in the system." We must remind ourselves at this point that the system we are looking steadily at is the school, not the individual learner, and while we can see that this subsystem is also dispersed and combined, it is no easy task to distinguish between the associator subsystem of the school and the associators of the individuals who are the components of the system. We must start with the assumption, by no means certain in all instances, that the school is a learning system (7.24-7.43), that it is capable of a dynamic homeostasis that allows it to adapt to a wide variety of unpredictable input without jeopardizing its survival, that it is continually mapping environmental variety into its internal processes. Many educational reformers, usually outside the schools, in fact, from the opposite assumption, that the school is an adjusting system with a highly developed boundary subsystem which filters out the environmental variety that the school cannot adjust to. However, if the boundary is as widely dispersed as we claim (9.18), it is difficult to see how this view can be supported. Instead, we shall advance the hypothesis in Part III that the school is ordinarily a well-adapted learning system that inhabits a different environment than educational reformers inhabit. We assume that the school does have an associator subsystem, but one that is not as widely dispersed or combined as the other information processing subsystems we have thus far considered. Instead, it is usually quite centralized, and deals with what we might call second-order information - information about information - which is the domain of administrators, curriculum specialists, and psychologists. The school as a system does not learn reading, geometry, and current events; instead, it learns <u>about</u> reading, geometry, and current events. Some schools also fall into a radical confusion between these two orders of information and assume, for example, that because structural linguistics does describe how our language works, it is, therefore, the way to teach language. Teaching language and teaching about language are two very different things. Second-order information is, of course, information, and is processed by all of the subsystems we have discussed thus far. It can

9.31

enter the system from the environment or it can be internally generated by system components or ensembles of components. It travels through the same channels and over the same networks as first-order information. It is striking, therefore, that the associator subsystem is less widely dispersed than the other subsystems which process information. Put another way, we can say that the school as a system uses only a small portion of the information it processes, that it expends much energy processing information from which it does not learn. This is not necessarily inappropriate nor inefficient, since it does leave the associator subsystems of its components, i.e. students and teachers, with energy to process second-order information for their own purposes. Put concretely, the more time teachers and students spend on curriculum committees, the less time they will have to attend to their own intellectual growth. This is not unlike the observation in 8.28-8.29 that the more the system must attend to maintenance inputs, the less it can process signal inputs. Depending on the size and complexity of the system, it may be both efficient and productive to have the associative processes less widely dispersed than they might be. The danger, of course, is that the fewer the components engaged in this process, the less enduring the associations are likely to be and the more localized the learning is likely to be.

9.32 <u>Memory</u> - "the subsystem which carries out the second stage of the learning process, storing various sorts of information in the system for different periods of time." At any given time, the school's memory will be widely dispersed in all directions, among people and file cabinets and bookshelves, but over time it is really the file cabinets and bookshelves which serve as the enduring repositories of the school's memory.

9.32

Student records, curriculum guides, test scores, tried-and-true learning activities are the components of the school's collective memory. As students and teachers leave the school they take with them irretrievable information, both first-order and second-order, and what is left is only the information committed to writing, which tends to remain forever fossilized in the system's archives. The ability of the memory to store both second-order and first-order information corresponds to the computer's ability to store both programs and data and allows associations to be made between the two, as well as allowing a wide range of combinatorial possibilities (7.39-7.41). Thus the memory subsystem and the associator subsystem are closely related, and while Miller describes memory as the second stage in the learning process and association as the first stage, their relationship is reciprocal rather than linear. That the memory subsystem is generally more widely dispersed than the associator subsystem means that much of the information stored in the system is not used in its learning, although it may be used by components for their learning.

9.33 Before proceeding with Miller's definitions of critical subsystem processes, we must interject here a process which does not appear in Miller's list, but which, given his approach, seems to be critical. We may call it the <u>disassociator</u>, and define it as the subsystem which breaks up associations among items of information which are either maladaptive or inhibiting to new associations. In everyday language, we may say that the system, to learn, must be able to forget, and to forget not only its mistakes but also its successes. Successfully learned behavior is the greatest inhibitor of new learning, and learning systems tend to bind successful learning into their memories. Learning systems totally lacking in disassociators may over time evolve into adjusting systems at the point that their learned behavior precludes the learning of new behavior. The disassociator, to be effective, should be combined with the associator in the same components. This does not often occur, since few of us willingly diverge far from behavior we find successful to test new behavior which has an element of risk in it. What many schools need is not more efficient memories but more efficient forgetting. We shall return to this topic in Part III.

9.34 Decider - "the executive subsystem which receives information inputs from all other subsystems and transmits to them information on outputs that control the entire system." Miller states that of the critical subsystems, "only the decider is essential, in the sense that a system cannot be dependent on another system for its deciding. A living system does not exist if the decider is dispersed upwardly, downwardly, or outwardly." From the point of view of the system analyst, this means that he should be sure to conduct his analysis at the level that includes the decider. If, for a particular school, all decisions were made by the superintendent of schools, he would have to be considered a part of the school, not a part of its environment. We must note that Miller is referring to living systems. A non-adjusting system - one that had no decisions to make - could not be a living system. On the other hand, it is possible to conceive of adjusting systems, which are effectively controlled by their environments, as having a built-in decider, since the output of the system is measured against a specific criterion of performance. Even though living systems at the human level must be learning systems, they can and frequently do act as though they were adjusting systems with the decider upwardly dispersed. A concrete example of this would be the football team whose plays are decided by the coach on the sidelenes and transmitted to the quarterback by regular substitutions. So the case is not as unambiguous as Miller's statement appears to imply. Whether the decider is dispersed upwardly or outwardly seems to depend upon system definition. The organizational charts of schools would seem to suggest that the decider subsystem is essentially localized in the principal, and in some instances this is effectively true, although in all cases the principal is dependent upon the information he receives. Whether or not the decider is laterally dispersed does seem to depend upon the principal's style and preference, so that we may say the basic decision, whether and when to disperse, the decider subsystem, is localized. The principal who chooses not to exercise all the control vested in his role could, in most situations, revert to a more controlling style if he so chose. The decider is, of course, laterally dispersed among other members of the school community, and if we were to take the organizational chart as a model of system organization, we might be tempted to say that it is dispersed downwardly, in contradiction to Miller's statements. However, whenever decisions regarding the school as a whole, as distinguished from classrooms or other components, are dispersed, the dispersion is always lateral, regardless of what positions the deciders may occupy on the organizational chart.

9.35 We must, at this point, enter an important theoretical caveat, one which brings into question the isomorphic relationship of human systems with other levels of systems. In a profound sense, decision making in a human group or organization is always shared. Decisions made must be accepted by those whom the decisions affect. The outputs from the decider must be received as controlling inputs by other components of the human system, i.e. by other human beings. However, since these other human beings are learning systems, not adjusting system, they will not necessarily accept inputs from their environment as controlling. They must, in fact, decide to accept the control of the decider, or the decider will not control them. If the human being, or group, is a true morphogenic system, it may well be impervious to the attempts of the decider to control it. Revolutions, rebellions, and mutinies, on both a grand and minute scale, attest to the fact that deciders frequently cannot control the entire system. This element of choice exists in all learning and morphogenic systems, and the fact that in most functioning human systems, decisions are accepted, must not blind us to the realization that this acceptance is itself a decision.

9.36 <u>Encoder</u> - "the subsystem which alters the code of information inputs to it from other information processing subsystems, from a 'private' code used internally by the system into a 'public' code which can be interpreted by other systems in its environment." We saw in 9.30 the difficulties inherant in the decoding process, and we might expect the encoding process to be the mirror image of them. However, the problems attendant upon encoding are of a very different nature, since encoding deals only with signal inputs, while decoding must deal with obth maintenance and signal inputs. Information encoded by the school as a system is often of a statistical nature - performance of students in aggregate measured against national norms - and often of a platitudinous nature - annual reports to the Board of Education. Members of the school community take home with them each afternoon information which is shared by parents, spouses, and acquaintences. The grapevine and the rumor mill both are vital parts of the encoding process. Indeed, because it is so difficult to identify its encoding processes. The problem is exascerbated by the fact that the language of education is so similar to the language of the environment, with so little rigor and so many euphemisms, that little encoding appears necessary to allow outsiders to interpret its information. The only exception to this seems to be when the school is proposing or attempting a significant departure from its traditional program or organization and must gain community support for its plans. At this point, significant attention is paid to the encoding process and the school becomes very sensitive to public opinion. These occasions are relatively rare, however, and atypical of the enterprise. More typically, the school's private code is so similar to the environment's public code that little encoding is required. The essential issue that school people deal with is not "how can the public know what goes on in school," but rather "what should the public know?" This is a boundary problem, not an encoding problem.

9.37 Output transducer - "the subsystem which puts out markers bearing information from the system, changing markers within the system into other matter-energy forms which can be transmitted over channels in the system's environment." Report cards, news releases, special announcements, and Johnny's verbal dinner-table report on what he did in school today are all parts of the output transducing subsystem. Johnny himself, his behavior, attitudes, and opinions, is also an output transduced by the system. Presumably, his performance outside of school over time conveys information about the school as a system. Perhaps the same could be said of the teachers in a school - they, too, should grow and change as a result of being components of the school as a system, and their enthusiasm, fatigue, interests and opinions should convey information about the system to the environment. We must bear in mind, though, that if we view components as outputs, we are shifting our focus and redefining the system to the point where the school is now seen as environment and the particular individual is the system of interest to us. Since the school is only part of the individual's environment, we must avoid the temptation to ascribe any changes in the individual soley to the school.

CHAPTER X

OUTPUTS

10.1 Outputs are those transmissions of matter, energy, and information which cross the boundary from the system to its environment. Berrien distinguishes between "useful" and "useless" outputs[1], suggesting that the environment places some value on system outputs. While this is undoubtedly true, no output is inherently useful or useless; from the point of view of the observer or analyst it is more appropriate to classify outputs as "used" or "unused," since these are more rigorously verifiable, and do not compel the analyst to accept the environment's evaluation. Berrien's distinction becomes significant when one is interested in purposeful or goal-directed behavior. In terms of attainment of a specific goal, whether the system's or the environment's, it can be helpful to distinguish between useful and useless outputs. In a trivial sense, all behavior can be seen as goal-directed, the goal being inferred from the behavior. In a non-trivial sense, goal-directed behavior is characteristic of adjusting systems using negative feedback to meet behavior specifications. Learning systems may have a multiplicity of simultaneous goals, either congruent or incongruent. They are capable of instantaneously substituting one goal for another, altering priorities, developing new goals and abandoning old goals. While cyberneticians have made great headway in "de-mystifying" goal-directed behavior and in developing complex adjusting systems which can simulate learning, the application of their work to concrete learning systems has not yet arrived at a point which would permit an observer of

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[1] Berrien, F. Kenneth, Op. cit., p. 24-25.

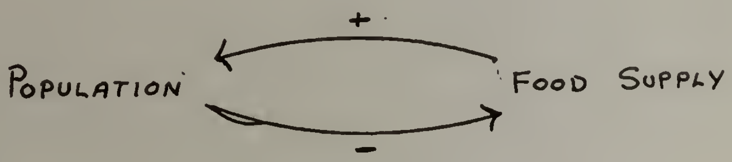
10.1 a concrete learning system to distinguish between useful and useless outputs.

10.2 This point is worth stressing because the distinction between useful and useless behavior is ubiquitous in education as well as other arenas of human activity in which evaluation plays a significant part. Output is observable behavior, and what behavior is observable depends in large measure upon the observer, his characteristics, sensitivity, training, experience, and bias. The observer is very much a part of the system's environment, and which of the system's outputs the observer will accept as his inputs will vary with the characteristics of the observer as a learning system. Outputs which an observer does not notice are unused, although not necessarily useless. From the point of view of this analysis, there are no useless outputs, only unused outputs. A teacher may be insensitive to - or unaware of - a students' non-verbal behavior; the observer of the student-teacher dyad may find it very useful, indeed. The notion of "purpose," therefore, can frequently serve as a filter for the observing system; we prefer the view that sees all behavior as useful from the environment's viewpoint, although not necessarily used by the environment.

10.3 Of particular interest to us are those outputs which either directly or indirectly affect the system's subsequent behavior. If output directly affects the subsequent behavior of the system, we refer to it as feedback. If feedback serves to amplify deviation from the prior state of the system, it is positive feedback. If it serves to reduce deviation from the prior state of the system, it is negative feedback. Change, growth, and evolution are evidence of positive feedback. Stability, homeostasis, and steady state are evidence of negative feedback. Open systems that grow and change by developing new steady states have an intricate interconnected network of feedback loops, both positive and negative, so that change occurs within acceptable limits and does not jeopardize the survival of the system. Theorists have stressed the importance of negative feedback in maintaining system stability, but they have tended to ignore the significance of positive feedback in promoting change. They have tended to see negative feedback as "good" and positive feedback as "bad." This has been largely due to the influence of cybernetics on system thinking, since cybernetics has been largely concerned with complex adjusting systems actuated by negative feedback.

10.4 Marayama, in his article "Toward a Second Cybernetics" focuses upon positive feedback, and gives, as a compelling example, the growth of cities over time.[2] The following illustrations use his method. An "+" over an arrow indicates positive feedback, and a "-" over an arrow indicates negative feedback.

10.5 The population of non-agrarian societies, like most animal species, was regulated by the available food supply:

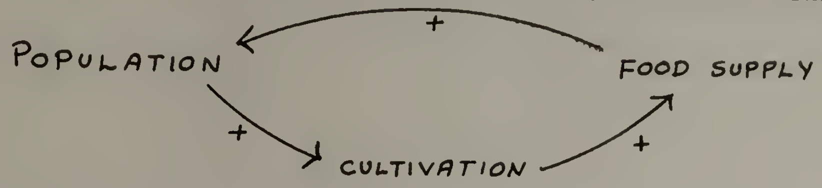


As population increased, the food supply decreased, an indication of negative feedback. As the food supply decreased, the population likewise decreased, an indication of positive feedback. As the population decreased, the food supply increased (negative feedback), and as the food supply in-

[2]The analysis which follows was stimulated by Marayama's example, but does not come from his article.

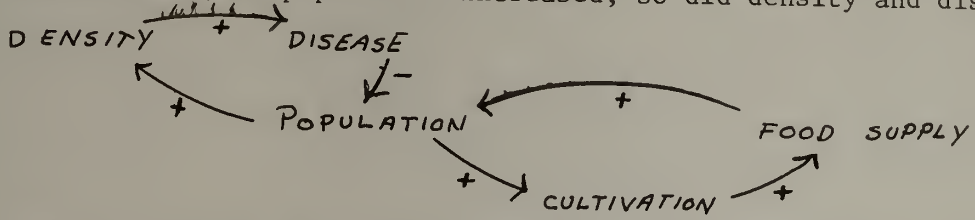
creased, so did the population. Thus, negative feedback held the relationship between population and food supply in a delicate equilibrium, using minor deviations to prevent major deviations.

10.6 The advent of cultivation upset this equilibrial mechanism:



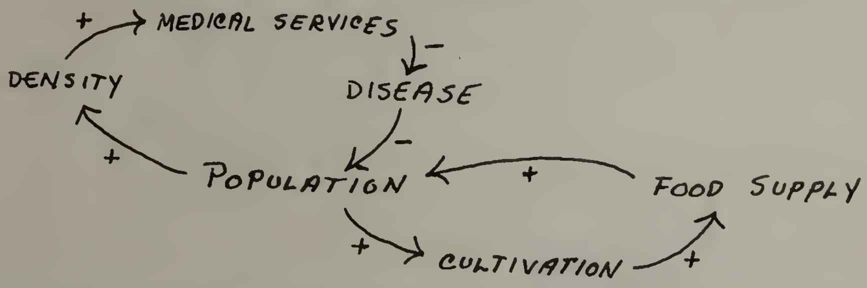
When conditions were favorable, increased population led to more cultivation, which increased the food supply, which further increased the population.

10.7 However, as population increased, so did density and disease:



As disease increased, population decreased, density decreased, and disease ultimately decreased, thus leading to an increase in population once again. Here we see two independent feedback loops affecting population growth, one negative and one positive.

10.8 With increased population density comes increased division of labor and specialization, including, presumably, medical services.



We have here an example of how the deviation-counterbalancing relationship between disease and population is itself counterbalanced by the deviation-counterbalancing relationship between medical services and disease. Two joined negative feedback loops have the effect of positive feedback; in this case, in spite of disease, the population will continue to grow. What we have today in over-populated poor countries is the negation of such negative feedback loops as may exist in the system.

10.9 This observation is easily generalizable to many areas of concern to educators. It has been supposed - and recently re-advocated by the President - that the massive application of federal funds to deteriorating schools would improve the quality of education in those schools.

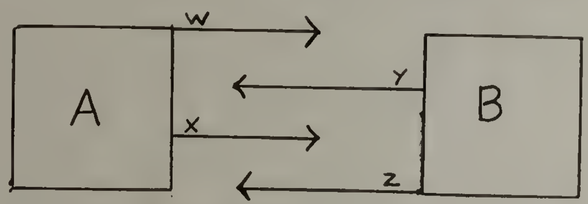
FEDERAL FUNDS —+→ QUALITY OF EDUCATION

This simplistic, linear input-output relationship has not proven effective. Poor schools continue to deteriorate in spite of highly funded Title I projects. Much of this can be explained by mis-application of funds and inadequate project design, but it is equally true that a host of intervening feedback loops can effectively negate the influence of federal funds on poor schools.

10.10 Positive feedback, thus, promotes change, while negative feedback promotes stability around assigned values. Whether the change - or lack of change - is desirable or undesirable depends largely upon the perspective of the observer. If he desires to inhibit change, he must design effective negative feedback loops. If he desires to inhibit change, he must design effective positive feedback loops.

10.11 In making this point, it is essential to distinguish between feedback and other input. Feedback is the direct input of the system's output; it is the output that is fed back into the system. There is a significant difference between information <u>from</u> performance and information about performance. When a teacher corrects and returns a student's paper, this is information about her performance. In neither case is this feedback, although we colloquially refer to it as such. It is, instead, information input from the environment which the student or teacher may choose to use or ignore. When a student, though, sees that a spelling word doesn't look right, or when he finds that a math problem he has worked doesn't check, or when a teacher senses her class getting restless or finds that her class did poorly on a particular test, this is information from performance and is genuine feedback. It is, of course, quite possible for the student or teacher not to act upon this information; human beings are learning systems, not adjusting systems, but assuming that they wish to improve their performance, they are more likely to use it and less likely to question its reliability.

10.12 Many of a learning system's outputs affect its subsequent behavior indirectly rather than directly. A system, may, through its outputs, affect its environment so that the environment will present it with inputs it desires and to which it can more easily adapt. The reader may more easily conceptualize this by thinking of two systems standing in interaction, each of which is the environment for the other.



A's output "w" leads to A's input "y." (We could as easily have said that B's input "w" leads to B's output "y.") A's output "x" leads to A's input "z." If A prefers "y" to "z" it will transmit "w" and not "x" to B. If it should happen that B prefers "w" to "x," it will transmit "y" and not "z" to A. Thus each is inducing the other to behave in such a way that it can behave the way it prefers. This is functionally the same as a positive feedback loop; A's "w" behavior is reinforced and leads to still further "w" behavior. A and B as reciprocal system and environment are well-adapted to each other.

10.13 Life rarely works out so beautifully, however. B may prefer "x" to "w," while A prefers "y" to "x." The only way B can induce A to give it "x" is to give A "z." In this instance, each must accomodate to the other; A must give B a certain amount of "x" so that B will give A a certain amount of "y." This is functionally the same as a negative feedback loop; A's "w" behavior is discouraged, so that at any given time "w" behavior will subsequently lead to less "w" behavior. In this case, A and B, as reciprocal system and environment, each adapts to the other through a subtle process of manipulation and negotiation. Each, through its outputs, is attempting to create the environment it wants.

10.14 This is the nature of most interpersonal encounters. If we translate our model into interpersonal terms, so that A and B become two people, perhaps husband and wife, perhaps student and teacher, and if we let "w" and "z" represent dominant behavior, and "x" and "y" represent submissive behavior, our model would represent a not uncommon interpersonal situation. Both A and B wish to dominate the relationship and wish to receive submissive behavior from the other. But the more A transmits dominant behavior, the more B transmits dominant behavior. Each, to receive the submissive input he desires has to transmit some submissive output to the other. However, each's submissive behavior reinforces the other's dominant behavior, which in turn requires each to transmit submissive behavior. This kind of spiral never ends. Schools, too, modify their environment by continually replenishing it with "schooled" adults, those who through the process of schooling share the values of the school so that the social environment which the school inhabits has been, to a significant extent, shaped by it.

10.15 There are, of course, many less subtle ways in which systems influence their environments through their outputs. Men build houses and heating systems to modify the natural weather. They wear clothes to protect their bodies. Spiders spin webs to trap food. The essential point to be made here, however, is the reciprocal and mutually causative nature of adaptation; the system is both shaping and being shaped by its environment. From this perspective, the significant difference between adjusting and learning systems is that adjusting systems use their outputs to return to an initial or specified state, while learning systems use their outputs to create new steady states.

10.16 Samuel Butler, in The Way of All Flesh, said it more simply, more eloquently, and more powerfully than any theoretical language can.

> All our lives long, every day and every hour, we are engaged in the process of accommodating our changed and unchanged selves to changed and unchanged surroundings; living, in fact, is nothing else than this process of accommodation; when we fail in it a little we are stupid, when we fail flagrently we are mad, when we suspend it temporarily we sleep, when we give up the attempt altogether we die. In quiet, uneventful lives the changes internal and external are so small that there is little or no strain in the process of fusion and accomodation; in other lives there is great strain, but there is also great fusing and accommodating power. A life will be successful or not, according as the power of accomodation is equal to or unequal to the strain of fusing and adjust-

ing internal and external changes.[3]

What Butler call "accomodation" we call "adaptation," and perhaps Butler does not adequately stress the active role the system plays in shaping its environment through its outputs, but he has captured the essence of the reciprocal relationship between system and environment that this paper has been about.

[3] quoted by Menninger, Karl in The Vital Balance, (New York: Viking Compass, 1963), p. 125.

PART III

SCHOOLS AND STUDENTS

CHAPTER XI

SYSTEM DEFINITION

11.1 In Part III we shall be testing the usefulness of the theory we have developed by applying it to some common areas of concern to educators. The test of its usefulness will be whether or not it provides helpful and new ways of thinking about educational problems and issues, not whether it contributes to their solution. Because a general theory is just that, "general," it must be translated into specifics before it can be applied to a particular situation. However, because it is a general theory of concrete systems, its hypotheses and propositions can be tested and applied to particular situations, whatever their complexity or configuration.

11.2 We select the school and the student as the two systems we are looking steadily at because they can well test the validity of a theory which proposes to be applicable to all levels of systems. If we can make statements which hold true for both the organism and the organization, then presumably such statements may be equally relevant to sub-organismic and supra-organizational levels as well. If such is the case, scientists will have a rigorous tool to supplement their use of analogy in dealing with complex phenomena.

11.3 There is another reason why the school and the student well fit our purpose in testing the theory. From the analytical point of view, they offer very different, but complementary, problems. The individual student is a well-defined concrete system with a clear physical boundary which permits rigorous distinctions between system and environment, and specific delineation of outputs as observable behavior. The internal organization of the student, however, is not observable, particularly in the information-processing domain, and can only be inferred from observable behavior. This has led the behaviorist schools of psychology to concentrate solely on the relationship of inputs and outputs, and to assume an essentially linear and causal relationship between them, eschewing any "mentalistic" explanation of behavior. Essentially, this school treats the individual as an adjusting system whose outputs (observable behavior) can be controlled from the environment by the careful regulation of inputs. This paper takes the position, instead, that while the internal organization of the human organism may not be observable, it does exist, and is isomorphic with the observable organization of learning systems at the supra-organismic level. This proposition is not currently provable, although the tremendous strides taken by cyberneticians in the simulation of both behavior and learning lends powerful support to the hypothesis.[1]

11.4 The school is such a supra-organismic system whose internal organization is observable. At the same time, it is not a well-defined system; it does not have a clear physical boundary (9.18), and it is not easy to distinguish between the school and its environment. The delineation of system outputs, as distinguished from the collective outputs of its components, is difficult indeed. We can talk with some assurance about how a school is organized, but we cannot talk with assurance about how a school behaves. Faced with this dilemma, many theorists have assumed an

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[1]see Apter, Michael J., The Computer Simulation of Behavior, (New York: Harper and Row, 1970).

anology between the school and a business whose outputs can be more easily identified. Educational organization theory has been essentially based upon research and theories drawn from the world of business and industry. Yet, it is a characteristic of the school as a system that its outputs are not clearly defined; any theory which assumes that they are is clearly not a theory dealing with concrete schools.

11.5 Thus, the two systems we are dealing with have complementary analytical problems: one has clearly defined outputs but unobservable processes; the other has poorly defined outputs but observable processes. A general theory, then, ought to help us think about student processes and school outputs in a way that conventional discipline-bound theory cannot.

11.6 In this chapter, we shall deal with a series of propositions drawn from Part II which will help us define the system we are looking steadily at. System definition is crucial; as we stated in 5.11, the variables of a system are selected from a usually infinite collection of attributes. The selection of variables thus defines the system under study. "The term <u>system</u> does not refer to 'that thing over there,' which may be described by an infinite number of systems, but to a particular list or collection of variables and relationships selected by the analyst for a particular purpose."[2] We will not presuppose the analyst's purposes in this chapter; instead, we shall examine some of those issues which the analyst must consider regardless of his purpose. In the next chapter, we shall consider a series of propositions concerning the relationship of the system and its environment. In Chapter 13, we shall examine some propositions relating to system organization.

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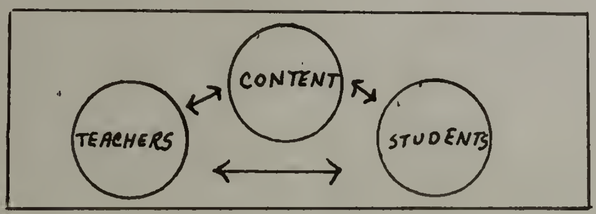
[2]Hare, <u>op</u>. <u>cit</u>., p. 136.

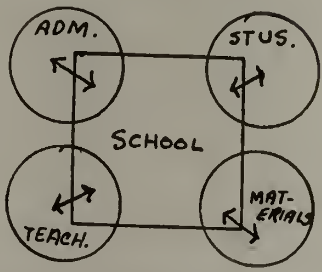
Our method in each of thse chapters will be similar. First, we shall state and explicate the proposition on a general level. We shall then, in paragraph "A" relate the proposition to the school and in paragraph "B" relate the proposition to the student. The reader interested in the application of a general theory to systems at different levels may choose to read the chapters as written. The reader primarily interested in the school as a system may choose to read all "A" paragraphs consecutively, while the reader primarily interested in the student as a system may read all "B" paragraphs consecutively. In either of the latter two cases the exposition will be as sequential and self-contained as in the first case.

11.8 <u>All concrete systems are open</u>. Not all systems are equally open, but all conduct transactions with their environments, and no system definition or description can neglect these transactions; that is to say, no system can be defined without reference to the nature, range, and amount of its inputs. Regardless of the analyst's purpose, the unit of analysis must be the system-in-environment, not the system alone. The next chapter will elaborate upon this proposition, but for purposes of system definition it is fundamental.

11.8A The school is commonly analyzed as though it were a closed system which could be understood solely in terms of its internal organization and relationships, and the internal dispositions of matter, energy, and information.



Viewed this way, the school is seen as a totipotential system existing within the physical boundary of its building walls. More realistically, however, the school should be viewed as a partipotential system whose components are also input transducers.



Teaching and learning go on outside the school walls as well as inside; the nature of the environment: rich or poor in stimuli, organized or disorganized, placid or turbulent, will be a prime factor in determining the character of the school. The relationship, of course, is not a simple or causal one. Because it is a kind of learning system, the school will tend to reflect its environment; if the environment is rich in stimuli, the school will be rich in responses; if the environment is highly organized (and predictable), so will the school be; if the environment is placid and regular, the school's behavior will be placid and regular. It is generally the radical critics of schools who consider them to be closed systems, unresponsive to their environments, while at the same time criticizing society in general on many of the same grounds that they criticize the schools. It may well be that many schools do not meet the "needs" of children or of the larger society, but "needs" are not among the parameters which comprise the school's environment. They are conceptual, not concrete. Statements of needs, of course, are concrete, as are statements of demands, expectations, and requirements. Such statements may well be part of the school's environment and be accepted by the school as inputs. If these statements are unambiguous, uncontradictory, and congruent, they may well be processed by the school and affect its outputs. If, however, as is frequently the case, they are ambiguous, contradictory, and incongruent, they tend to cancel each other out, or are filtered out by the school's boundary processes. It is important, too, to realize that the school's output will play a significant role in determining the nature of these inputs. Because nearly everyone in the school's environment has been to school, the statements of needs, demands, expectations, and requirements will be shaped in large measure by the culture of the school. If, for example, the environment places a high priority on the development of "basic skills" of reading, writing, and computation, this is at least partially to be explained by the fact that the school has always placed high priority on the development of these skills. Conversely, if the school appears to place high value on docile, submissive, and conforming behavior, it is because the environment, enculturated by the schools, places high value on such behavior. Indeed, the general presumption must be that the school, like any other open system that survives over time, is well-adapted to its environment. The nature of this adaptation will be explored in subsequent sections of this and the next chapter.

11.8B School people frequently resort to a curious dualism in thinking about student behavior. On the one hand, formal "learning behavior" is seen in an environmental context; in other words, learning is somehow the result of teaching, or at least the result of the student's interaction with persons and materials in his environment. Non-learning behavior, however, as in "behavior problem" is rarely viewed in the same way. Any particular molecular behavior is related first to prior behavior and only secondarily and occasionally to the environmental situation in which the behavior occured. Put in another way, when things adjudged "good" happen to a child, it is because he is an open system and the school can take the credit; when things adjudged "bad" happen, it is because he is a closed system, and the school abjures responsibility. There are responsive children (who conform to our expectations), and unresponsive children (who do not conform to our expectations); there are bright children (who are open to environmental inputs) and "slow learners" (who are relatively closed to environmental inputs). It is, of course, true that for any given parameter value, whether a national norm on a reading test, or the teachers expectation of classroom deportment, there will be a wide range of deviations in any student population, but it is equally true that any given parameter value is but one of a myriad inputs which at any time will be part of a student's environment. We are not arguing, of course, that all students have the same learning competence or that all students can process the same degree of environmental variety, but we <u>are</u> arguing that <u>all</u> students are open systems, that all behavior must be seen in its interpersonal and environmental context, and that the individual student is well-adapted to <u>his</u> environment. This last proposition may appear extreme and overstated, since we ordinarily talk so easily about "maladjustment," since we all know children who are not happy in school and do not do well in school, and since our jails and mental hospitals are full of people who apparently could not adapt to the larger social environment. Yet the proposition follows inexorably from the analysis of Part II; any molecular behavior of an open system is an adaptation to its environment. The proposition forces us to study the student-in-environment if we wish to understand his behavior. If we wish to do more than understand - if we wish to control or change, or to use the currently popular term, "modify" his behavior, we must be able to exercise the appropriate amount of control over his environment. We must remember, however, that we will always share this control with the student himself. We all recall the cartoon of the two mice in the cage commenting on how well they had trained the experimenter: every time they stepped on a lever he was conditioned to give them food. Such is the essence of open systems. This topic will be developed more extensively in the next chapter.

11.9 A learning system controls its own transformations; an adjusting system is controlled by its environment; therefore a learning system can change its behavior, while an adjusting system can only be changed by its environment. One of the paramount questions involved in defining a system is identifying the locus or locii of control. If the locus of control is in the environment, that is to say, if the system changes its line of behavior only in response to new parameter values, we can define the system as an adjusting system, particularly if the system's output does not affect the parameter values. If, at the other extreme, the locus of control is entirely within the boundary of the system, that is to say, if the system changes its line of behavior without regard to parameter values, we can define the system as morphogenic. If, as is most often the case with living systems, there are locii of control both within and outside the system, that is to say, if the system must accept certain inputs but can refuse others, and if the system can process these inputs in more than one way, and if the manner of processing these inputs is selected by the system, and if, finally, the system's outputs affect in some way subsequent inputs, we can define the system as a learning system. The essential factor, thus, is whether there is a linear relationship between inputs and outputs. If there is, then the system can be entirely controlled by the environment; if there is not, the system cannot be entirely controlled by the environment.

11.9A The school is a learning system. There are many among its critics who wish it were not, that it could be more readily controlled by the environment. There are other critics who claim, in effect, that the school is an adjusting system, controlled by school boards, politicians, and professional educators. These critics would like, at the least, to share control, and, at most, to wrest control from these forces. There is no doubt that the environment imposes many constraints upon schools; legislators through statutes, school boards through budgets, central adminstrators through requirements; however, we must be careful to distinguish between constraints and controls. If such constraints functioned as controls, if schools could be designed to specifications as adjusting systems are, so that given inputs would lead to predictable outputs, most of the critics of education, from whatever point of view, would be satisfied. However, as we have seen (9.36), it is difficult to identify, much less predict, the school's outputs. Unlike business, where profits, products, and gross sales can be identified, measured, and altered, or hospitals, which deal with a circumscribed and measurable segment of the human condition, public schools deal with a totality of complex, totipotential learning systems, and they attempt to deal with them in their totality, even though in the concrete world, people spend only a small portion of their time in school. One of the most widespread trends in schools today is the attempt to assert, as environment, greater control over the inputs and outputs of their students through the use and development of behavioral objectives. We shall be analysing this trend from a systems point of view in Chapter 13. Here we need only point out the paradoxical implications of attempting to facilitate learning by treating the learner as an adjusting system. The concomitant movement on the level of the school is generally referred to as "accountability," and while the term means different things to different people, in system terms it also means the establishment of a greater linear relationship between inputs and outputs. The implications here, too, are for greater environmental control over the school as a system, to the point where parameter values are specified and output values can be measured against them, and deviations corrected. As things stand now in most schools, it is possible to assign parameter values (national norms, for instance), and to measure some actual output against them (test results), but not to correct the deviation. Most schools lack the mechanisms to utilize this information as negative feedback to correct their performance. In spite of this lack, most schools still exert more control over their own behavior, for better or for worse, than do their environments. The great battles over aid to education during the past decade have generally been over local versus federal control of the schools. The truth of the matter in most instances is that no level of control has much influenced the school, whether national, state, or local.

11.9B The student is a learning system. This may, at first, appear to be an unexceptional statement, since the term "student" implies "learning," as commonly used. However, this is a catagorical statement which in terms of our analysis in Part II has implications beyond the common use of these terms. The salient characteristic of a learning systme is not that it can learn, but that it must learn (7.25). To use Pask's evocative phrase, "man (is) a system that needs to learn."[3] "Not to learn" is simply not an option open to man. We must hasten to add that this need to learn is not necessarily volitional. We are not saying that all men want to learn or seek to learn; we are saying, instead, that all men do learn, and while the rate of learning and the amount of learning may fluctuate over a lifetime, learning never ceases entirely as long as the brain is functioning. The statement does not imply that the learning will be necessarily appear relevant from the envrionment's point of view. It does not mean that a student will necessarily learn what someone else, like a teacher, wants or expects him to learn. In fact, it implies quite the opposite, since a learning system cannot be controlled by the environment. The more control the environment attemtps to exercise over the learning system, the less likely that learning will take place, or, to state the proposition more clearly, the less likely that the output behavior will result from learning. This is not a value judgment; not all behavior of learning systems can emenate from learning; if this were the case there would be no point in learning since the environment would be totally unpredictable and no learning would be useful in any subsequent situations. Those aspects of the environment which are predictable do not require learning or re-learning; the school legitimately deals with these aspects as well as the unpredictable aspects. A student must have a repetoire of learned behavior to apply in familiar or repetitious situations, much

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[3]Pask, Gordon, "Man As a System That Needs to Learn" in Stewart, ed., Automation Theory and Learning Systems, (Washington, DC: Thompson, 1967).

as an adjusting system has built-in lines of behavior to deal with its predictable input. Learning is valuable only in situations which are unfamiliar or novel. The implication of the statement that man needs to learn, however, is that he requires novelty and variety in his environment. If the school as environment does not provide sufficient variey for a student to learn, he will behave in such a way as to create variety in his environment. Such is the etiology of divergent behavior, whether or not considered creative or deviant by the environment. From all of this, it follows that environmental variety is a requisite for learning. Rich classroom environments are better for learning than sterile environments; heterogeneous populations (along whatever dimensions) are more conducive to learning than homogeneous populations. It is important, in terms of this analysis, not to confuse "variety" and "organization," two very different concepts. There can be organized variety and disorganized variety. A relatively impoverished environment can be either organized or disorganized. We will deal with these issues in the next chapter, but it is important to remind ourselves here that in arguing for the importance of environmental variety to learning we are not arguing for any particular degree of orgnaization, although we can anticipate our argument enough to say that variety must occur within a matrix of higher level organization. Just as in a transformational grammer a finite number of symbols and a finite number of combinatorial rules can generate an infinite number of words and sentences, so, too, there must exist in the environment some underlying regularity if the learning system is to survive in it. This argument may appear to be evading the central issue that schools are concerned with - not whether a student learns, but whether he learns what the school is intentionally teaching. The argument is frequently advanced that, for some students at least, a rich and varied environment distracts them from learning certain skills and concepts that they "need" to learn. Our analysis denies the validity of this argument; all students do, in fact, learn what they need to learn, although they do not necessarily learn what we want them to learn. The "abstracted student" may "need" to have a "positive self-image" and a "respect for others." The concrete student, negotiating his own environment, may not have these particular needs; he may need to be dependent, he may be fearful of competence, he may have a desk-top calculator at home, he may, as a condition of his survival, need to taunt, bully, and ridicule others. He learns what he needs to learn. The only way the environment can change his learning pattern is to exercise more control over him, but by exercising more control, by reducing the variety in the system, it is actually reducing the likelihood that the student's behavior is the result of learning. By focusing on specified outputs, the environment restricts the ability of the student to cope with environmental variety when he encounters it.

11.10 <u>The more probabilistic the system, and the more changing its organization, the more difficult it becomes for a constrained transmitter to send information about the system</u>. All open, learning systems are probabilistic. This means that at any given time, the state of the system cannot be predicted from its state at a prior point in time, and its subsequent state cannot be predicted from its state at the given point in time. The system, in simpler words, will have a repetoire of behaviors to select from, and if it cannot find a suitable behavior in its repetoire it can, through its associator and memory processes, create new behaviors.

Again, the creation of grammatical sentences is the clearest and best example of this. The number of unique sentences that a human being can generate is literally infinite, and except for special circumstances such as an actor playing a role, unpredictable. Just as remarkable as the ability to generate original and unpredictable sentences, however, is the ability of human beings to receive and immediately understand and act upon sentences that they have never heard before and could not anticipate. Most human beings share an underlying linguistic competence which governs their linguistic performance, both as senders and receivers of information.[4] So ingrained is the competence that most people, when instructed to talk "gobbledygook," emit a series of gutteral and labial sounds totally unrelated to the structure of their native language, accompanied by emphatic body gestures that they would ordinarily not employ. If asked to create a list of nonsense words, they could probably do so, but if asked to create nonsense sentences, their basic linguistic competence would make this an arduous and slow task. Men are "naturally" grammatical. While this competence permits the generation of unlimited understandable messages, therefore, it also inhibits the generation of messages which may lie outside the canon and conventions of the language. Put more generally, and within the context of our theory, the capacity of a system both to decode and encode information is constrained by the very competence which allows it to generate and understand an infinite number of meaningful messages. Furthermore, the capacity of a channel to transmit information is finite, and if its capacity to transmit information is less than the

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[4] see Chomsky, <u>Aspects of the Theory of Syntax</u>, ch. 2, (Cambridge: MIT, 1965).

capacity of the information source to generate it, this capacity will be a constraint on its ability to transmit information. Still further, most communication channels are "noisy;" elements of uncertainty and distortion not emenating from the information source enter the channel at points between the transmitter and receiver, and this noise further constrains the ability of the channel to transmit information reliably. Finally, and particularly in the domain of interpersonal communication, there are frequently multiple channels simultaneously transmitting incongruent and even contradictory messages. For any one such channel, the information in the other channels will function as noise. All of these constraints serve to limit the reliability of transmitting information, and the greater the variety (information, uncertainty) in the information source, the more serious are the constraints on the transmission process.

11.10A The school is a probabilistic system, and it generages a greater variety of information than it can transmit to its environment. The problem we are dealing with here is not, as school people often like to think, one of selection of data. Rather, the data that is selected for transmission will itself be subject to the systematic distortions of constrained transmission. One reason for this is that in selecting information for transmission, schools are subject to the problem of infinite regress. The most important information that the school transmits is about its components (Miss Smith's class, the football team, Johnny), each of which is also a probabilistic system. Pask makes this profound point in a somewhat different context when he asserts that "the least distinguishable or describable component of [an active control system] is also an active control system."[5] (Pask's term "active control system"

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[5]Pask, op. cit., p. 138.

is isomorphic with our term "probabilistic.") This means that the information from these components which the school wishes to transmit will have been subject to the systematic constraints we have described before the school considers it as information to be transmitted to the environment, at which point it is subject to the same constraints at the system level. Another reason, endemic to all complex systems, is the problem of distortion through generality. Any general statement conveys less information than the less general statements from which it is drawn (an instance of the whole being less than the sum of its parts). Every meaningful message exists at some level of generality, and thus contains this kind of systematic distortion. If a school reports that its sixth grade students achieved a mean grade level score of 6.8 on a battery of achievement tests, this conveys more distorted information than the report that the students received mean grade level scores of 7.2 and 6.4 on the vocabulary and math tests respectively. Each of these scores transmits more distorted information than the next lower level of analysis. When we come to the scores of individual students, they convey more distorted information than an item analysis, and so on. Schools searching for adequate reporting systems must become aware that distortion is "built-in" to the process, and while up to a point it can be minimized by reducing the variety of information, or by increasing channel capacity, or by reducing the noise in the channel, or by reducing the number of simultaneous channels, it can never be entirely eliminated without changing the system to a deterministic one. Most schools, faced with this problem, tend to deal with it by reducing the variety of information. They transmit information at a high level of generality; thus requiring fewer symbols, reducing the likelihood that the channel capacity will be exceeded or that noise will distort the transmission. They achieve this greater reliability of transmission, of course, at the expense of distortion through generality. If we consider the report card, the traditional five-point system (A, B, C, D, F) conveys very little information but is likely to convey it accurately. At the other extreme, an extended anecdotal, narrative statement of as many aspects of a student's work and growth as the teacher can discuss is going to convey much more information about that student, but will be much more subject to the first kind of distortion due to constraints on the process of transmission. There is more opportunity for misunderstanding, ambiguity, and incongruity. In trying to devise reporting systems which strike a balance between generality and specificity, between cognitive, affective, and psychomotor concerns, and between generalized learning skills and particular basic skills, schools should realize that their job, like the job of the cartographer, is not to eliminate distortion, but to select the distortion which is least likely to jeopardize the communication process and to develop means of counteracting the distortion which is inevitable to the greatest degree possible.

11.10B The student is a probabilistic system. This means that the relationship between his input transducers (largely his sensory apparatus), his channels, his associator and memory, and his output transducer is subject to systematic distortion for all the reasons described in 11.10. But most clearly and colloquially, we can say that there will always be systematic distortion between the "real world" and the student's experience of that real world, as well as between the student's experience and his behavior. As schools and curriculum developers place increasingly greater emphasis upon behavioral objectives, this point assumes increasingly greater significance. The "language" of experience and the "language" of behavior are incommensurate. The first is semantically rich but syntactically poor; the second is semantically poor but complex in syntax. In other words, our behavior is by necessity more highly structured than our experience. When behaviorists attempt to translate "learning" into a list of active verbs, no matter how extensive the list it will never accurately reflect the image that the learner has of the information he has processed. We shall deal with this issue more extensively in Chapter 13.

11.11 <u>The organization of learning systems tends towards increasing complexity</u>. The notion of "organized complexity" is important for system definition. System theorists have attempted to define the concept of complexity with some rigor, in terms of the amount of information necessary to describe or control the system. As we have seen (5.17 et passim), this amount of information is not related to the number of components or the size of the system, but rather to the degree of organization and to the relationships among the variables. The more complex the organization of a system, the more improbable its behavior (in a statistical sense) and the more information about its organization is necessary. At the same time, the more organized its complexity, the more likely that the amount of information necessary to control the system can be attained at the appropriate level with the appropriate effort. Thus, "organization" and "complexity" are independent concepts. Systems can increase in complexity without increasing in organization - can change in the direction of "chaotic complexity" - and the only reliable information about the system becomes statistical and relatively useless for controlling the system at any given point in time. If systems continue to evolve in the direction of chaotic complexity, at a certain point they loose their systemic properties and become mere aggregates of systems. Systems can also increase in organization without increasing in complexity, and the amount of information required to control the system correspondingly decreases. If systems continue to evolve in the direction of "organized simplicity," at a certain point they can no longer be considered learning systems, but instead become deterministic. Systems can increase in size and in number of components without increasing either their organization or the complexity, although this rarely happens with concrete systems if the increase in size or number is considerable or sudden. The statement that the organization of learning systems tends towards increasing complexity thus says something significant about the properties of learning systems as well as about the mode of analysis the observer employs in thinking about the system he is looking steadily at. If, as he observes the system over time, he finds that he needs increasing less information to control the system, he can infer that the system is not learning (taking into account, of course, the problems of the constrained transmitter discussed in 11.10). If, on the other hand, he finds that the only reliable information he can obtain about the system is statistical, he may infer that he is operating at an inappropriate level of analysis and that the "thing" he is looking steadily at is not, in fact, a "thing" but an aggregate of things.

11.11A If one defines the school as an open, learning, probabilistic system, one can expect it to increase in organized complexity. We will maintain that for most schools this is the case, although there are exceptions and the exceptions are significant. Both of the current "trends" in public schools, "behavioral objectives" and "open classrooms," while dissimilar in many respects, are movements towards greater organized complexity, and while the observer of any particular school must be careful to distinguish between rhetoric and actual practice, the evidence appears to support the contention that these two alternative approaches to individualizing the learning process both require the analyst to have more information of a different order.

> If a system is able to formulate its own goals and plans, to switch goals and plans at will, and to adjust internally its own allocation of resources and priorities of action, knowledge of current structure is less useful for prediction and control than knowledge of the guiding goals and values which integrate and guide the total system. Moreover, for very large systems, a detailed definition may not be feasible, even if it were useful. In short, the analyst's resources must be redeveloped and his thinking shifted to a different level if he is to make headway in an environment of true complexity.[6]

Information about goals and values is difficult to obtain, since statements about goals and values may or may not be reliable indicators of operational goals and values. Furthermore, in human organizations such as schools there may be a multiplicity of conflicting and incongruous goals and values, as well as conflicting priorities among common goals and values. Decision-making processes in actuality may differ significantly from those inferred from an organizational structure. When these considerations are taken together with the constraints on information transmission mentioned earlier,

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[6] Hare, <u>op. cit.</u>, p. 200.

we can understand that gaining reliable information about complex systems is an awesome task. It is a possible task, however, since if our analysis is at the appropriate level, and if the school, in fact, tends towards increasing organized complexity, fewer statements will each contain more information than a great many more statements would if the school were moving to chaotic complexity. The amount of information needed must not be confused with the number of data needed. As Herbert Simon amusingly put it, "Mother Hubbard did not have to check off the list of possible contents to say that her cupboard was bare."[7] The job of the school analyst is to discover that level of analysis at which the fewest possible statements will convey the most information. The increasing complexity of schools means that the number of statements will have to be greater over time and the level of analysis will have to become more general. However, the increasing organization of this complexity means that a limited number of these statements will do an adequate, if not optimal, job of describing the system for the analyst's purposes, whether they be prediction, control, or mere understanding. Chapter 9 provided the essential elements of this level of analysis by identifying the subsystems of which complex systems are composed. If for our purposes we omit from consideration matter-energy processing subsystems and focus only on information-processing subsystems, we can see that systems characterized by organized complexity can be described in terms of eleven subsystem processes, a perfectly feasible analytical task.

11.11B The growth of the organism and the evolution of the species are both clearly examples of increasing organized complexity; from both the

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[7]Simon, Herbert, The Sciences of the Artificial, (Cambridge: MIT, 1969), p. 110.

biological and psychological points of view, this point is beyond debate. That the student as a learning system shares in both the ontogenetic and phylogenetic propensities of the species is at this point a trivial observation. What is not trivial for our purposes is the realization that for the student, moreso than for the school, this propensity is innate and develops with a remarkable regularity. With the exception of special cases, all children appear to pass through developmental stages in roughly the same sequence and at approximately the same chronological ages. The work of Piaget, Bruner, and their colleagues strongly suggest that this development has relatively little to do with ability or schooling. From infancy through adulthood, cognitive competence develops through increasing differentiation and discrimination, classification, generalization, and abstraction, and the reciprocal processes of assimilation and accomodation. This is not to say that there will not be significant differences between children and between cultures. It is fair to say that the more the world into which the child is born manifests organized complexity, the more his own cognitive competence will develop in this direction. But while there can be significant differences in degree and rate of development, there is evidently little difference in the characteristic of the developmental process itself. There is, furthermore, some neurological evidence[8] to suggest that if the environment is singularly deficient in variety (complexity) or is markedly unorganized in its causal texture, the individual will compensate for these characteristics by creating an internal representation of reality which is richer and more organized that the envir-

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[8] Pribram, Karl H., Languages of the Brain, (Englewood Cliffs: Prentice-Hall, 1971).

onment. Daydreams, fantasies, obsessions, and compulsions may be explained as compensatory strategies. The student thus can be seen as a morphogenic system which, up to a point at least, will develop increasing organized complexity regardless of the characteristics of his environment. Colloquially, we might say that the student cannot tolerate boredom or confusion. What the school cannot provide in terms of variety and sense, the student will provide for himself. Truency and deviant behavior are evidence of this from children who cannot create rich and sensible interior lives for themselves.

11.12 In this chapter we have defined both school and student as open, learning, probabilistic systems which develop in the direction of increased organized complexity. We have attempted to indicate some issues involved in looking at schools and students as such systems. We will discuss these issues at greater length in Chapter 13.

CHAPTER XII

SYSTEM AND ENVIRONMENT

12.1 For concrete learning systems there are no normative environments. We recall from 6.1 that a system's environment consists of those parameters which affect it (as inputs) and which are affected by its outputs. The mere existence of a set of attributes or phenomena outside the boundary of a concrete system does not mean that these attributes or phenomena are necessarily parts of that system's environment. Before the environment can be identified, the system must be identified; that is, we must be clear about the system we are looking steadily at. We cannot make any general statements about the environment of a concrete system, although we can make general statements about the concrete environments that concrete systems inhabit. We shall use the term "field" to describe the general characteristics of concrete environments. A concrete system's environment will be seen as that protion of a field which at any given time affects the system or is affected by it. The characteristics of the field will play a large, but by no means sufficient, part in determining the nature of the system's environment.

12.1.1 There are three essential dimensions which determine the character of the field. The first is the dimension of variety; we can say that fields are either rich or poor in the number of distinguishable elements they contain. The richer the field, the greater the possibility of variety in the environment. But we must emphasize that it is only the possibility of variety that is greater; the actual variety in the envrionment may be a great deal less that the possible variety. If it is less, 12.1.1 the difference between the possible variety and the actual variety will be the measure of redundancy in the environment. Of course, the amount of variety in the environment cannot be greater than the variety in the field.

12.1.2 The second dimension is the dimension of organization. Emery and Trist have called this "the causal texture of organizational environments."[1] We have remarked (6.3) that most environments are loosely-joined; they fall between being tightly organized, in which every element affects every other element, and being unorganized, in which each element is unaffected by any other element. This is so because this is true of the field in general; a change in any given variable will ordinarily affect some but not all other variables. That it is true of the field in general, however, does not mean that it is equally true of all segments of the field; there will be some segments in which elements are tightly joined and other segments in which elements are loosely joined. The degree of joinedness in the field, therefore, will not play as large a role in determining the concrete system's environment as the degree of variety, since the environment cannot contain more variety than the field.

12.1.3 If we put these two dimensions together, we can have rich, organized fields and rich, unorganized fields; we can have poor, organized fields and poor, unorganized fields. When we add the third dimension, the dimension of change, we have a typology of eight kinds of fields. Emery and Trist use the picturesque terms "placid" and "turbulent" to describe the dimension of change,[2] but we must be careful to note that this dimen-

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[1] in Emery, F.E., ed., Systems Thinking, (Baltimore: Penguin, 1969), pp. 241-257.

[2] Ibid.

sion exists on the next higher level of analysis, since we are interested in change in the degree of variety and the degree of organization, and not the change implicit in variety and organization (5.18-5.20). While an unorganized field will be more turbulent than an organized field, we will use the term to refer to a field which changes its organization and variety at an observable rate and to a significant degree. A field which is becoming more or less organized, or is increasing or decreasing its variety will be said to be changing, whereas a field which maintains a relatively fixed level of organization and variety will be said to be stable, even though within that stability there can be a great deal of change.

12.1.4 The distinction between "field" and "environment" is frequently ignored by analysts and observers. They tend to assume that a description of the field from their point of view is also a description of the environment that the concrete system inhabits, and because one can make general statements about types of fields one can also make general statements about concrete environments. For learning systems that exercise control over their boundary and input transducer subsystems, it is not possible to assume that a description of their field from the observer's viewpoint will necessarily be a description of their environment. In a very real sense, the analyst's description of the field is a description of <u>his</u> environment, and, as we have said (7.34), concrete systems inhabiting the same field may have very different environments.

12.1.A.1 It may generally be said that schools inhabit environments which are less rich in variety, more organized, and less dynamic than the field, although this will not necessarily be true of a specific school. The reason for this generalization is rooted both in the history of American public education and the nature of the learning system. Until very recently, the prevailing mythos of public schools was the metaphor of the "melting pot," wherein a common "American" culture was created by conscientiously reducing the variety which a culturally heterogeneous population presented to the schools. The population which left the schools to become part of the schools' environment was (and for the most part still is) less varied than the population which entered the schools. The human environment which most schools inhabit is itself a product of the acculturation process of public schooling. For a long time, we felt that this was true of the field, too; school people tended to ignore those elements of the population who were not successful products of American schooling. The American dream of cultural homogeneity is no longer so firmly entrenched; "cultural Pluralism" and "human diversity" are becoming familiar slogans in schools, and I believe that many schools are fumbling their way towards making them more than slogans. Yet it would be a profound mistake to assume that schools' environments change as rapidly as schools may change. There is a built-in generation-lag; products of "heterogeneous" schools will not become significant parts of those schools' environments for several years. School boards, whether elected by majority or appointed by the community power structure, reflect the previous generation of schooled people, not the current generation. Adminstrators of schools, too, generally represent successful products of an earlier generation of schooling. This is less true of teacher candidates, although since teachers are usually selected by administrators, successful candidates - those who actually enter the classrooms - are generally less diverse in their characteristics than those who apply. Because learning systems tend to project their characteristics onto their environment (7.43) as well as map characteristics of their environment into their internal processes (7.36), the system and environment will generally resemble each other much more closely than will the environment and its field. Since the school is such a loosely-bounded system, the character of its environment can perhaps best be ascertained by observing the characteristics of the school rather than the characteristics of the field.

12.1.A.2 One more important point must be made in this section relating to schools as well as the next section relating to students. Because we are dealing with concrete systems whose variables must, in fact, exist concretely in time/space (5.4), the absence of a variable is not a variable of the system, and the absence of a parameter is not a parameter of the system. In the language of education, neither system nor environment can be characterized by its "needs." Certainly, the environment of a school may contain many statements and assertions about needs, and those statements may be part of the school's environment, but it is only the statement and not the need that the school can deal with. The reification of "needs" is one of the prevailing fallacies of much social science, and emenates from the confusion of abstracted systems which inhabit normative environments and concrete systems which only inhabit concrete environments. One of the simple tests of whether an analysis is dealing with concrete systems and concrete environments is the extent to which statements of "needs" enter into the analysis.

12.1.B.1 It is relatively easy to distinguish among classroom environments according to the three criteria described in 12.1. It would be fallacious, however, to assume that the environment of the student in the classroom necessarily resembled the classroom environment as the field. We can say that a rich, organized, dynamic classroom is more conducive to learning than a poor, unorganized, static classroom, but we cannot say that a student in the first type of classroom will necessarily inhabit an environment with those characteristics. It is easier for a student in a rich classroom to inhabit a poor environment than it is for a student in a poor classroom to inhabit a rich environment. Likewise, it is easier for a student in a loosely-structured classroom to inhabit a highly-structured environment than it is for a student in a highly-structured classroom to inhabit a loosely-structured environment. Rich, loosely-structured, dynamic classrooms can provide a greater range of concrete environments than poor, highly-structured, static classrooms, and are therefore more appropriate for learning systems. The more the classroom resembles the second type, the more the "successful" student's behavior will be adjustment behavior, although, as we have seen (11.9B), the student requires a certain degree of variety for learning to take place, and he must learn. Since the classroom is only a portion of the student's environment, it is not necessary that it provide this variety, although to the extent that it fails to do so the less relevance it will have to the rest of the student's life. The theory of concrete learning systems thus powerfully supports the movement towards greater classroom variety and less classroom structure as being conducive for a wide range of learning environments for particular students, without prescribing that these particular environments resemble the classroom as a field.

12.1.B.2 We must stress here as we did above (12.1A), that "needs" are not variables of either students or classrooms. A teacher may determine that a student may have a particular need and may attempt to structure the field accordingly. This determination thus may well affect the student's environment. Likewise, the student may well feel a "need," and this feeling becomes a significant variable, whether it is a need to eat, to love, to read, or to learn. It is the feeling, though, and not the need, which is the variable. We may state almost catagorically that a system's feelings of needs will result in particular behaviors (the only exception being when a particular need gratification is deferred because of other more pressing feelings of need). The only needs that can be generally ascribed to learning systems are the need for varied and loosely-joined environments and the need to learn, and we can only say this because we are attempting to develop a general theory. At any given time, a particular learning system may need less variety and more structure. What we commonly talk about as needs in this context are really "necessary conditions" of the same sort as physiological "needs."

12.2 <u>All concrete learning systems are well-adapted to their environment</u>. One of the consequences of adopting a non-normative analysis is the abandonment of the notions of maladaption and deviance (in its ethical sense). A learning system may deviate from its prior behavior but it cannot deviate from the way it ought to behave, since "oughts," like "needs," do not describe concrete parameters. This point of view allows us to divest ourselves of much cumbersome analytical baggage, and also significantly simplifies the analysis of complex systems by forcing the analyst to focus on actual behavior which does exist while relieving him of the obligation of inquiring into behavior which might exist, but does not. To this extent, at least, this approach conforms to a strict behaviorism which studies actual rather than desired behavior. (It departs from behaviorism, of course, by refusing to accept linear and causal explanations of the relationship between input and output.) Most important, however, it forces us to understand situations before we evaluate them. Perhaps the most significant contributions of post-war psychiatry have been the work of Laing,[3] Bateson and Ruesch,[4] Watzlawick, Beavin, and Jackson,[5] and their colleagues to remove familiar but inhibiting evaluative labels from human behavior and to examine that behavior in the social context in which it occurs. Such an examination reveals that behavior which we might ordinarily label "disturbed" is an understandable adaptation to an environment which manifests the same characteristics. The focus of investigation thus shifts from the "disturbed" behavior of the system to the relationship between the system and its environment. Just as an understanding of mental illness has been profoundly changed by this change in focus, so too, our understanding of other forms of disturbed behavior - crime, drug addiction, alcoholism - is slowly changing to the point where we are beginning to recognize all of these behaviors as adaptive rather than maladaptive. Recognizing behavior as adaptive does not require that we approve of it or that we should not desire to change it. To understand is not to justify. But to understand the situation makes it more likely that the situation can be changed, since

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[3] Self and Others; The Politics of Experience; Sanity, Madness and the Family (with Esterson); Interpersonal Perception (with Phillipson and Lee).

[4] Communication: The Social Matrix of Psychiatry.

[5] Pragmatics of Human Communication.

the field can play an important part in changing the environment and thus changing the behavior of the system we are looking steadily at.

12.2A Schools are well-adapted to their environments. It was, I believe, Jonathon Kozol who first made this observation several years ago in an article in the New York Times, in which he argued that the "problem" with American public schools was not that they worked so poorly but that they worked so well. One need not share Kozol's viewpoint to acknowledge the cogency of his position. The environment that most schools inhabit is the environment that they largely created and continue to perpetuate. We might wish that schools might have a larger and more creative vision of their place in the social order; we may think that schools should become agents of social and cultural change. What we are actually saying in this case is either that we wish the school were less well-adapted to its environment or that the school's environment could be expanded to include more of the variety in the field. It is ironic that so many critics and reformers who are willing to absolve the individual of responsibility for his anit-social acts are unwilling to absolve the school of responsibility for its behavior, and yet from a general systems viewpoint there is no difference; all learning systems are well-adapted to their environments. Whether this calls for sympathetic understanding or catagorical condemnation is purely a function of the observer's prejudices. The rapid development of alternative and free schools both within and outside the public school system is undoubtedly the healthiest and most encouraging acknowledgement of the proposition that different schools can inhabit very different environments within the same field.

12.2B Every student is well-adapted to his environment. If we start from this assumption, some remarkable changes in perception occur. We find, for example, that most of our vocabulary for talking about students disappears. There are no more "over-achievers" or "under-achievers," only achievers. There are, in fact, no "slow learners" or "fast learners," only learners inhabiting different environments with different degrees of variety and organization. We must emphasize that we are not suggesting that all students, as learning systems, have similar learning competence, for this is certainly not the case. We are saying, however, that each student's learning competence will serve to limit or extend the variety and organization of his environment, and that each student's competence and environment will be reciprocally well-adapted. Neither is fixed or predetermined; they will tend to expand and contract together.

12.2B.2 A further implication of this assumption is that when teachers choose or intend to change a student's behavior, either through teaching him something or through "behavior modification," he is dealing with behavior which is already well-adapted and functional. This is not to say that all behavior is optimally functional, but rather that it is minimally functional - it satisfies the minimal requirements for existing in its environment. If we choose to change behavior or to move a system towards an optimally functional behavior, we must treat the system as an adjusting system and make sure both that the inputs into the system are carefully controlled and that negative feedback loops are fully functioning. In other words, the variety in the environment must be significantly reduced, and the organization of the environment significantly increased, so that the behavior that was satisfactorily adapted to its original environment no longer is well-adapted to a contrived, more restricted environment. The assumption is that when the new behaviors are "learned" they can be used by the learning system in more expansive environments. This is the underlying assumption of schooling, and while the first part of it is probably true - learning systems are capable of adjustment behavior - the second part is questionable. We have said that adjusting systems cannot learn; whether learning systems can "transfer" adjustment behavior to less predictable environments is by no means clear. It is frequently the case that what a student "learns" in restrictive classroom environments is useful only in subsequent similar environments. Most people "forget" most of what they "learn" in school because the environments in which they exist are so unlike their classroom environments. For most people, "learned" algebra is useful only in algebra classes, "learned" history only useful in history classes, and so forth. If life was carried on in environments that resembled most school rooms, then sophisticated adjustment behavior would be the optimal kind of behavior. If, on the other hand, most schoolrooms more closely resembled the environments that the real world presents, adjustment behavior would be mal-adaptive since the environment would be much less predictable. At the same time, in such a classroom, the control of the students' behavior would rest much more with the student than with the teacher, and learning would be less likely to be the direct result of teaching.

12.2B.3 The modification of well-adapted learned behavior is therefore more likely to occur in open classrooms, whereas the modification of adjustment behavior is more likely to occur in restrictive classrooms. Since adjustment behavior is useful only in environments which repeat themselves with a high degree of regularity, we have theoretical grounds for questioning the efficacy of schooling in restrictive classrooms.

CHAPTER XIII

SYSTEM ORGANIZATION

13.1 "There is no such thing as 'good organization' in any absolute sense."[1] The relativity of this proposition has been implied throughout this paper, but it is well to make it explicit and to elicit the support of so rigorous an inductive theorist as Ashby in its behalf. He continues,

> I am prepared to assert that there is not a single mental faculty ascribed to Man that is good in the absolute sense. If any particular faculty is usually good, this is solely because our terrestrial environment is so lacking in variety that its usual form makes that faculty usually good. But change the environment, go to really different conditions, and possession of that faculty may be harmful . . . Here are some examples in illustration.
>
> The first is Memory. Is it not good that a brain should have memory? Not at all, I reply - only when the environment is of a type in which the future often copies the past; should the future often be the inverse of the past, memory is actually disadvantageous. . .
>
> As another example, what of the "organization" that the biologist always points to with pride - the development in evolution of specialized organs such as brain, intestines, heart and blood vessels. Is this not good? Good or not, it is certainly a specialization made possible only because the earth has an atmosphere; without it, we would be incessantly bombarded by tiny meteorites, any one of which, passing through our chest, might strike a large blood vessel and kill us. . .Thus the development of organs is not good unconditionally, but is a specialization to a world free from flying particles.[2]

In this spirit, then, we wish to stress that our typology and classification

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[1]Ashby, W. R., "Principles of the Self-Organizing System" in Buckley, Modern Systems Research for the Behavioral Scientist, (Chicago: Aldine, 1968), p. 112.

[2]Ibid., pp. 112-113.

of systems is descriptive and not evaluative. A learning system is in no absolute sense better than an adjusting system; a complex system is not better than a simple system. When we describe schools and students as learning systems, we are not patting them on the back or asserting that the things they learn will necessarily be true, good, or beautiful. We are merely saying that they have certain properties which distinguish them from other kinds of systems, and that it is useful to understand these properties if one is dealing with them.

13.1A Following Ashby's approach, we can say that there is no such thing as "good school organization," in an absolute sense, although we must be careful not to follow him too far down this road. If a school is intentionally attempting to reshape its environment, to be an "agent of social change," it may be that its internal organization is deliberately chosen to be at varience with the environment's organization. One thinks of the rural schools in North Dakota consciously creating classrooms distinctively richer and more complex than the social environments they serve. The impetus for this particular organization comes not from the immediate environments of the schools but rather from a localized intention of the New School at the University of North Dakota to "change" the environment by changing the schools which both create and reflect the environment they inhabit. There are many such examples of schools which intentionally create organization which appears maladapted to their particular environment, although in other environments they might appear highly adaptive. The survival of such schools over time is by no means assured, and not infrequently they succumb in a state of crisis and recrimination. Roland Barth describes an instance of several Harvard graduate students attempting to introduce open classrooms into an inner-city Boston school.[3] In retrospect, their failure can be ascribed to a combination of naivete, stupidity, and insensitivity, but even had they been more sophisticated, thoughtful, and sensitive it is unlikely that their efforts would have been successful, since they were so clearly an intrusion into a functioning system with a very different mode of organization which, for better or worse, was well-adapted to its environment. One is tempted to use the analogy of the body's rejection of an organ transplant, although it is not entirely apt. To the extent that some transplants are not rejected, the operation may be worth the risk in the light of the alternative, but the rate of success is not reassuring. The problem with so many major innovations in schools is that reformers assume that because schools are "bad" in some sense they are also mal-adapted to their environment; thus they see no need to make efforts to reduce the risks of rejection. Survival may not be the highest purpose the school reformers aspire to, but it is a necessary, if not sufficient, prerequisite if any higher purposes are to be served.

13.1B A thoughtful, if somewhat cynical, school superintendent once observed that the crucial turning point in a schoolchild's life is Christmas vacation of the second grade. It is at that point that the difference between work and play becomes crystal clear, and work becomes closely identified with reading. If he can read, he knows that if he works the chances of his future success in school are good; if he can't read, he realizes that there isn't much point in working; his chances for success

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[3] In a talk at a NESDEC Conference, Newton, Mass., March 23, 1972.

are minimal. For both the reader and the non-reader, reading, work, and school tend to go together, as do "not-reading," play, and vacation. Although this is an overstatement, I do not think it is wrong. We know that early readers are not necessarily better readers later in life, but it is probably true that children who learn to read before reading becomes the primary mode of learning in school will read more for pleasure and personal enrichment than those for whom reading is primarily associated with formal classroom learning. We know, too, that success in reading is highly correlated with success in school, and that success in school is highly correlated to subsequent success in school. One would like to think that success in school is also correlated to success in life, but this is a dubious proposition if one goes beyond measurements of income and status into more subjective areas. We would like to think that success in school is correlated with happiness, creativity, productivity, co-operation, and wisdom, but the evidence is not reassuring. The student who succeeds in school is not necessarily going to be happy, creative, productive, co-operative, or wise; he is likely to be able to read. As particular classrooms change their organization by emphasizing the importance of other input sources besides books and worksheets, and other output behaviors besides writing and speaking, they may, ironically, be increasing the likelihood of success in life while decreasing the likelihood of subsequent success in school. In any case, the successful student is a learning system who can adapt his level of organization to the requirements of his classroom.

13.2 Growing systems develop in the direction of: a) more differentiation of subsystems; b) more decentralization of decision-making; c) more interdependence of subsystems; d) more elaborate adjustment processes; and e) sharper subsystem boundaries.[4] Miller's criteria above pretty well characterize the notion of organized complexity. A system which manifests these characteristics is developing in the direction of increasing organization. A system which does not manifest these characteristics is probably not a learning system. A system which manifests the reverse characteristics, i.e. in which subsystems are becoming less differentiated, more independent, and less distinguishable, is moving towards decreasing organization, and, at a certain point, will no longer be a system. If one of the above characteristics is observable, it is likely that most of the other characteristics are also present. In other words, if the observer notices more differentiation of subsystems, he can expect to find that the subsystems are more interdependent - that the state of any given subsystem is constrained by the state of other subsystems. If he notices that subsystem boundaries are becoming sharper and more easily defined, he can expect to find that the decider subsystem of the whole system is laterally dispersed among many components and that, therefore, information input is subject to increasing numbers of boundary and filter processes and is subject to greater systematic distortion. One further implication of this proposition is that the more the system grows in the direction of organized complexity, the more difficult it becomes to have a sense of the system as a whole. The sharper the subsystem boundaries become, the vaguer and more diffuse

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[4] from Miller, J.G., "The Nature of Living Systems," Behavioral Science, vol. 16, 1971, p. 297.

the boundaries of the whole system become, and the more difficult it is for the analyst or change agent to deal with the system as a "thing" rather than a confederation of things. Conceptually, it becomes easier - and analytically it makes more sense - to treat the more sharply defined and differentiated subsystem as the system we are looking steadily at, and to treat the rest of the system as environment.

13.2A We shall in this section give brief examples of Miller's five characteristics as applied to schools.

a) more differentiation of subsystems - As schools grow in population and as knowledge increases, several kinds of increasing differentiation occur. Teachers become more specialized in subject areas, and schools become departmentalized into semi-autonomous departments. Specialists in administration, curriculum, and psychology become regular members of schools' hierarchial staffs. Business managers deal with matter-energy maintenance inputs and outputs.

b) more decentralization of decision-making - As subsystems become more differentiated, the decider subsystems play a greater role in determining what inputs to send to the decider subsystem of the whole system. If we assume that in most schools the decider subsystem is localized in the principal, the information he receives is increasingly selective and increasingly distorted. His decisions will be subject to the decisions of many others as to what information he should have and in what form that information should be transmitted to him. No matter how highly centralized the decisionmaking process may appear to be, and no matter how routinized the formal communication channels may be, the decentralization of decision-making is a necessary concomitant of increasing organized complexity.

c) more interdependence of subsystems - Specialization and interdependence develop concomitantly as schools grow more complex. However, we must keep in mind the distinction between components and subsystems when thinking about interdependence in schools; subsystems may be differentiated without being localized in particular individuals or groups of individuals. A school may consist of a number of self-contained classrooms and still manifest increasing interdependence of subsystems. As specialization increases, schools tend to place more emphasis upon the "inter-" and less emphasis upon the "-dependence." The plethera of specialists frequently has little actual effect upon the interactions taking place in schools, even though the "team" approach is frequently used to deal with curriculum and personnel. The increasing number of specialists requires increasing numbers of meetings of people increasingly unable to talk with one another using a common technical vocabulary. The concerns of the school psychometrist and the guidance counsellor and the classroom teacher become increasingly separated from one another. The classroom teacher accuses the counsellor of being unconcerned with a particular behavior problem she cannot cope with; the counsellor accuses the classroom teacher of being insensitive to the needs of the child; they both accuse the psychometrist of being concerned only with research and statistics. In schools, as in society as a whole, interdependence based upon specialization produces stress, conflict, misunderstanding, and resentment quite different from the abstracted picture of the team approach - happy specialists working together, sharing their expertise, and solving problems to their mutual satisfcation. It is not surprising that schools, as society as a whole, are currently undergoing a reaction against specialization. The movement towards "community" in schools is a movement away from increased diffentiation; all members of a community are expected to deal with the total range of inputs, both signal and maintenance. There are no domains reserved for administration or governance; the whole community becomes involved with such domains; expertise is an object of suspicion. From a systems point of view, this is a movement away from the interdependence of differentiated subsystems and towards the interdependence of undifferentiated components, each of which combines the subsystem process of the whole within itself. If all members of a school community are equally responsible for administrative and curricular decisions, for establishing priorities and policies, the physical and temporal proximity of the members becomes crucial, as does the size of the community. Communities of undifferentiated members must be relatively small, and closely bound in time and space, or interdependence is lost and the system as a whole becomes fragmented and factionalized. In human systems, then, personal knowledge and personal contact among components is essential when subsystem processes are shared and diffused, whether or not they are differentiated. Interdependence under these conditions is fragile and precarious. The more totipotential components become, the less they need or desire other components to survive. It is no wonder, then, that schools which attempt to diffuse subsystem processes laterally in the name of "community" are prone to fragmentation and conflict when their membership grows too large or too dispersed over space.

d) _more elaborate adjustment processes_ - We refer here not only to the adaptation of the school to its environment but also to the internal adjustment processes which must occur with increasing specialization and interdependence. A mundane example would be the problem of scheduling in a school wherein different individuals have special functions in dealing with a common school population. Not only is the creation of a schedule a specialized administrative function, but the schedule itself must reflect the special needs of the specialists. In a school where all classes regardless of subject or organization meet the same number of times and class periods are all the same length, this is merely a problem of avoiding as many conflicts as possible in scheduling classes. But when time itself is a variable - when different classes have different schedules - the internal adjustments become exceedingly complex, and frequently computers must be called upon to create a master schedule. In the interpersonal domain, too, adjustment processes must become more elaborate. As soon as schools acknowledge that both students and teachers have different learning, teaching, and personal styles, the process of "matching" these styles becomes very intricate. Ability grouping is a common adjustment process employed by schools when the population becomes large enought to allow such differentiation. Sex and age groupings are, of course, so common in schools that it may be difficult to see them as adjustment processes. All grouping, whether by subject, age, sex, ability, or interest, is an adjustment to the increasing complexity of system organization. That the rationale for various kinds of grouping are of questionable educational validity does not question their efficacy as internal adjustment processes. As the growth of the system makes <u>possible</u> greater variety of adjustment process, so does it <u>require</u> more elaborate adjustment processes to deal with the greater range of variety in the system. At the same time, this increased adjustment flexibility of the school as a whole is at the expense of diminished adjustment flexibility of the components, whether individuals, classes, or other groupings. A school consisting of undifferentiated, quasi-autonomous self-contained classrooms does not require elaborate adjustment processes, but the opportunity for elaborate adjustment processes within each of these classrooms is great. On the other hand, a school with highly differentiated and interdependent classes requires - and is capable of elaborate adjustment processes, while the adjustment processes of each of these classrooms is greatly constrained.

e) <u>sharper subsystem boundaries</u> - Schools have typically not sharpened their subsystem boundaries to the same extent that they have sharpened the distinctions among components. Particularly if the area of information subsystem processes, the school by necessity continues to combine and laterally disperse these processes among its components. Since we have dealt with this issue extensively in secs. 9.27 - 9.37, we shall not repeat it here. It is worth noting again, however, that the formal organization of the school as an institution, as reflected in organizational charts and job descriptions rarely reflects the actual organization of the school as a concrete system. The formal organization will frequently suggest sharper subsystem boundaries than in fact exist. While this is true to some extent of all human organizations, in few organizations is the functional infra-structure more at varience with the formal structure than it is in schools. Many analysts have seen this as pathological, and have attempted to reduce the inconcruence between the formal and functional organization of the school by sharpening subsystem boundaries. Whether or not this would be desireable, it does not seem possible without changing the school into an adjustment system. No human organization which attempts to deal with human beings as totipotential systems without itself being a totipotential system can do this. In this regard, it is instructive to compare the public school with other instructional or training contexts in which both formal and functional subsystem boundaries are sharper. The army provides such a context. It is a totipotential system which deals with human beings as partipotential systems. Its training is for immediate and specific purposes, and its hierarchial organization sharply defines subsystem boundaries. Soldiers are trained for very specific functions within the whole, and these functions are clearly related to specific subsystem processes. While all soldiers receive an initial basic training, subsequent training is highly specialized according to which subsystem process the individual is participating in. Typically, information processing and matter-energy processing are both hierarchically organized but are rarely combined. Personnel in the motor pool and the warehouse will have totally different jobs than personnel in the orderly room or intelligence office. In all subsystems, decision-making is highly localized, while at each echelon there is a specifically delineated sphere of responsibility and power. Those responsible for maintaining records have no responsibility for decoding or encoding the information in those records, and so forth. There is something seductive about such a highly organized system; it appears to be efficient and productive. Schools frequently aspire towards such a model in the name of efficiency and productivity. Without arguing the case as to whether the army is in fact efficient and productive, we can nonetheless state that its organization is based upon the assumption that its personnel are partipotential -

that they are trained to perform rigidly circumscribed functions, and that the individuality of the role incumbants, to the extent that it cannot be eliminated, is made irrelevant to the performance of their duties. This would appear to be a pre-requisite of sharply defined subsystem boundaries. In system terms, we can say that the more sharply defined these boundaries, the less the variey in the system, and the less the variety in the system, the less it will be able to adapt to increasing variety in the field. This is an essential reason why military and, for that matter, industrial models are inappropriate for comprehensive public schools which take seriously the job of educating individuals rather than role incumbants.

13.2B Most of the evidence in support of this proposition at the level of the organism comes from neuro-physiology and neuro-psychology and is beyond the competence of this paper to deal with. Moreover, that human beings develop in these directions is generally agreed upon by specialist and non-specialist alike. Since this is essentially a morphogenic process, one which follows inexorably from the organismic template, we shall not elaborate upon these characteristics here but shall accept them as "givens" and shall comment upon their implications for the student in secion 13.6B.

13.3 "The capacity of a complex organization to learn depends upon

a) the quantity and variety of information stored in the system;

b) the structure of the communications network;

c) the pattern of the subsystems within the whole;

d) the number, location, and function of negative feedback loops in the system and the amount of time-lag in them;

e) the nature of the system's memory facility;

f) the operating rules, or program, determining the system's structure and behavior, including:

1) rules . . .determining range of inputs,

2) rules responsible for the routing of information throughout the network,

3) rules about the identification, analysis, and classification of information,

4) priority rules for input, analysis, storage, and output,

5) rules governing feedback mechanisms,

6) instructions for storage in system's memory,

7) rules regarding the synthesis of information for the output of the system."[5]

Cadwallader's admirable synthesis provides a useful analytic tool for looking steadily at systems which manifest the characteristics noted in 13.2. Analysis is made easier by focusing strictly upon internal system organization and disregarding system-environment interaction. Analysis is made more difficult by the fact that in concrete systems each of these areas of focus is systemically related to all others and cannot really be analysed separately. Nonetheless, each of them suggests useful questions the analyst can ask, and we shall examine them seriatem.

13.4 The quantity and variety of information stored in the system. Deutsch suggests three kinds of information which a complex system must store if it is to be able to learn: 1) information of the world outside;

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[5] Cadwallader, Mervyn L., "The Cybernetic Analysis of Change in Complex Social Organizations," in Buckley, Modern Systems Research for the Behavioral Scientist, (Chicago: Aldine, 1968), p. 439.

2) information from the past, with a wide range or recall and recombination; and 3) information about itself and its own parts.[6] Information of the world outside comes from inputs; some inputs are acted upon immediately and produce outputs with little time-lag; some inputs are acted upon but are also stored for future use; some inputs are stored without being acted upon. Information from the past was originally brought into the system by the input transducers but was stored in either the long-term memory or external memory for future use (see sec. 13.8). It thus is the basis of the system's "image" (13.9) of reality, against which subsequent input is evaluated and upon which subsequent input is mapped. The range of recall and recombination will depend in large measure upon the ability of the systme to break up stored information into smaller discrete chunks. This is the job of the associator subsystem. The third kind of information is uniquely associated with human systems and implies a certain level of consciousness that does not exist in any non-living system and only in a few non-human systems. Awareness of "self" is essential for any system whose self-regulation extends beyond physiological homeostasis. Furthermore, systems which have the capacity for self-awareness must use this information if they are to learn and survive. As an example, we can point to the relationship between hunger and nutrition. All sentient systems will "feel" hunger and will eat to satiation. In systems without the capacity for self-awareness, diet and nutrition are homeostatically controlled; an animal will eat only what his system needs and only as much as his system needs. The same is true of human infants, to a large

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[6] mentioned by Buckley, Sociology and Modern Systems Theory, (Englewood Cliffs: Prentice-Hall, 1967), p. 56.

extent. However, as consciousness and self-awareness develop, human beings must apply them to this basic physiological area. Proper diet is no longer something which the body itself regulates. Human beings can overeat and can have nutritionally deficient diets. If a system, therefore, has the capacity for processing information about itself, it must do so.

13.4A The school stores a vast quantity and variety of information in a great many different forms. Each human component of the schools is a repository of information from the world outside; the school's library and archives contain large amounts of information from its past. The school also has a quantity of information about itself and its parts, although this information is so dispersed among the components that it is more difficult to identify. It is also difficult to validate this kind of information; the school's consciousness of itself may be at varience with the perceptions of its components or of those in its environment, just as an individual's view of himself may be at varience with the views others may have of him. Nonetheless, the school as a system acts upon the basis of its self-awareness, and anyone who would wish to change a school must first change the school's image of itself.

13.4B Of the student in the school we can say much the same as we have said of the school, although the range of individual differences will be greater than the range of differences among schools. All students process information from the world outside, although the range and variety of that information will vary significantly from student to student according to the acuity of their sensory apparatus. All students have memories which store information from the past. The capacity of the memory subsystem not only varies individually, but also varies with age, as does the associator subsystem. The capacity of the student to abstract properties of phenomena, essential to recombination, is developmental, and while all students will develop it, not all will develop equal facility or predisposition to do so. It is the third kind of information, again, that appears to be crucial. "Self-image" and "self-concept" have become such overused terms that it is important to emphasize that they have a specific place in systems thinking which extends beyound how a person "feels" about himself to what a person knows about himself. The two, of course, are closely related; the information a person receives about himself through his engagement with his social and physical environment will be the basis of both his thinking and feeling about himself. However, his ability to learn depends upon his consciousness of his self-concept, and the degree of consciousness will vary tremendously from person to person. "Self-consciousness" is not generally considered to be a desireable trait; the person who dwells excessively upon his self is frequently considered "poorly adjusted." Our culture prizes the extrovert over the introvert. This is particularly true of children, since self-consciousness in young children is unusual and frequently symptomatic of incipient pathology. We want children to have a "positive" self-image, but we do not want them to be conscious of it. Neither conceit nor inferiority seems appropriate for school-age children. Schools have thus stressed competence rather than identity as the basis for self-concept, and the information a student stores about his self is information about what he can do, rather than what he is. The effect of this frequently is to reinforce areas of greater competence and to constrain the development of areas of lesser competence. This approach to self-concept thus serves to constrain the range and variety of information from the outside world and from the past which is likely to be stored in the system.

13.5 The structure of the communication network - We have already seen (9.29) that the processing of information inputs depends upon the particular configuration of the network of channels, their capacities and characteristics. The capacity of a complex organization to learn depends upon its ability to regulate the flow of information and to monitor the reliability of its channels. Since complex organizations will have multiple overlapping channels, and since human organizations will have both formal and informal channels, such regulation will always be difficult and will never be total. Not only will the communication network be subject to systematic distortion, but the informal channels will frequently operate out of the range of awareness so that they are less controllable. Formal communication channels are generally verbal, oral or written, while informal channels are frequently non-verbal and non-intentional. If there is incongruence between the verbal and the non-verbal communications being sent simultaneously, we generally take the non-verbal communications more seriously, precisely because they are less subject to the conscious control of the sender. We familiarly recognize this discrepency by exhorting others to "do as I say, not as I do," but most of us still remain largely unaware of the discrepancies between our own verbal and non-verbal behavior.

13.5A Schools generally pay strict attention to the structuring of the formal, verbal communication network and pay very little attention to the informal, non-verbal communication network which overlaps the formal channels. "Official" communications are put forth in written memos or bulletins and disseminated to the appropriate individuals. Teachers regulate formal communication in classrooms by recognizing raised hands and by prohibiting unrecognized verbal communication. Communication networks in small groups have been extensively studied by social scientists, and while such networks as teacher talk in the Teacher's Lounge and student talk over the lunch table are not "official," their typologies have been so well documented by small-group theorists that they must be considered formal. It is the "silent language"[7] of non-verbal behavior which is so generally ignored in schools. All behavior communicates; it is impossible not to communicate. As Hall has persuasively pointed out, "time talks," and "space speaks;" how we organize time and space in schools is a potent form of non-verbal communication. We shall not enlarge upon this topic here, since it is so large, but we shall reiterate that the non-verbal communication in schools is so frequently at varience with the verbal communication that what is often described as a "lack" of communication is instead a multiplicity of overlapping, incongruent messages. As a consequence of this, the capacity of the school to act upon any specific information is constrained by the simultaneous transmission of contradictory or incongruent information. The resulting ambiguity vitiates the value of transmitted information. From a systems viewpoint, ambiguity inhibits learning; in any situation which allows a variety of interpretations of available information, the system will invariably select the interpretation which is most comfortable and familiar and which requires the least strain. Life may be full of ambiguous situations, but they do not tend to be the situations from which we learn.

13.5B The first job of the student in the classroom is to discover which of the myriad messages he receives simultaneously he should pay

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[7]Hall, Edward T., The Silent Language, (Greenwich: Fawcett, 1959).

attention to. He quickly learns that what the teacher says or does is more important than what his classmates say or do; he also learns that what the teacher says may or may not be more important than what the teacher does. Outside the classroom, the reverse is generally true; what his classmates say or do is more important than what his teacher has said or done. Likewise, in the classroom eyes and ears, rather than nose, tongue, or hand, will be the important input transducers; the student must learn to ignore information from these sense organs. The student is always processing information carried by multiple channels simultaneously. Messages are always tri-partite: they have a "content" dimension, a "metacommunication" dimension, and a "relationship" dimension. That is to say, they are about "something," they are about "themselves," and they are about the relationship between the sender and the receiver. Conventional discussions of communication processes concentrate on the "content" dimension. "Information," in its colloquial usage refers to the "something" the message purports to be about. The other two dimensions, however, are less frequently remarked upon, and because they are always present, they deserve close attention. Furthermore, because they are frequently non-verbal, they tend to be out of the sender's awareness, although not out of the receiver's awareness. Any theory which focuses on "intentional" message-sending and neglects "non-intentional" message sending is dealing with an abstracted notion of communications networks, not a concrete notion. Intentional and non-intentional messages are always sent simultaneously; the non-intentional messages are usually non-verbal, metacommunicational, and dealing with the relationship between sender and receiver. Metacommunication says of the message content that it is important or unimportant, serious or humorous, fact or opinion, certain or dubious, interesting or uninteresting, statement or question, demand or request, and so forth. Metacommunication is rarely verbal; we may occasionally preface a message with a metacommunicational comment, as when a teacher says "this is important," or when President Nixon says "let me make one thing perfectly clear," but more usually metacommunication is accomplished through inflection, intonation, stress, gesture, and timing. If the metacommunication is congruent with the content, it provides powerful reinforcement of that content; if it incongruent, it can lead to confusion and anxiety in the receiver. A joke told with a straight face may or may not be a joke; should one laugh? Sarcasm is a weapon in the arsenal of many a teacher. How is the student to interpret a sarcastic comment? A lecture full of brilliant insights delivered in a flat, monotonous style provides metacommunicational incongruence which students are quick to perceive. When there is incongruence between content and metacommunication, it is the latter which has the greater potency. The third dimension of messages, the relationship dimension, is equally potent. Every message implies a particular relationship between sender and receiver; relationships are construed either as symmetrical or complementary. In complementary relationships, one part holds the super-ordinate position and the other party hold the subordinate position. The two parties may or may not agree about the nature of their relationship, but every message sent between them will include their perceptions of their relationship. Again, this is rarely verbal or intentional, although in times of stress or crisis it may become so. If students question the authority of the teacher or dean, the content of their messages may in fact be their relationship, but more generally the relationship dimension of messages is implicit rather than explicit. The person making a demand of another is concomitantly asserting his right to make that demand. The other, by acquiescing, confirms the right of the first to make demands, or by not acquiescing, challenges that right. Leadership may be asserted by one party, but it may either be confirmed or rejected by the subordinate party. Students are continually processing all three dimensions of messages, whether or not intentional, and whether or not verbal. If they are incongruent, the student as a learning system may well learn more from the metacommunicational and relationship dimensions than from the content dimension.

13.6 The pattern of the subsystems within the whole - It will be helpful to think of two prototypical systems; in the first, subsystem processes are highly localized in discrete components, while in the second, subsystem processes are widely dispersed and combined among the components. It is easy to see both the advantages and the disadvantages of both kinds of organization. The first has the advantages of efficiency, speed, and uniformity. Each component, having a specialized subsystem function, can concentrate its energies on the performance of that function without being distracted. Decision-making for the whole system is highly centralized; decisions can be made quickly and disseminated with a high degree of accuracy. Both matter-energy and information inputs can be regulated and allocated with efficiency and dispatch. System malfunctions can be quickly identified, located, and repaired. Job descriptions can be specified with a minimum of confusion and ambiguity. When such a system is working well, it is working very well, indeed. The disadvantages, however, are concomitants of their advantages. Such systems rarely work well, since the malfunction of a single component will jeopardize the performance of a critical subsystem process. Highly specialized systems are so highly constrained that the performance of each subsystem is dependent upon the performance of all other subsystems, and when these subsystems are localized in single components, a malfunctioning component will affect the entire system. Such systems are, therefore, vulnerable and fragile; they are dependent upon maintenance inputs to maintain the components in working order and upon boundary processes to filter out any inputs which might jeopardize the functioning of the components. At the other extreme is the second propotypical system in which subsystem processes are widely dispersed and combined. This system has the advantages of dependability, flexibility, adaptability and durability. Because it is not dependent on discrete components for the performance of specific subsystem processes, the malfunction of particular components will not so easily jeopardize the performance of the system as a whole. Because individual components are involved in more than one subsystem process they can allocate their attention and energy to different tasks depending upon the exigencies of the moment. Such systems are capable of maintaining steady states in a wide variety of environmental conditions, since components will be capable of different lines of behavior. If the needs of the situation require extreme boundary vigilence, the system can deploy its components to boundary maintenance. If the needs of the situation require greater decoding capacity, the system's components can all participate in this process. Because the system has the flexibility to re-organize itself as needed, its ability to survive and function is enhanced; it can endure. Such systems have significant disadvantages, however. They tend to be inefficient; while they will dependably perform at a satisfactory level, they will rarely perform at an optimal level. The energies and attention of components are too diffused and changeable to allow for more than a portion of their time to be devoted to any given task. They tend to be slow; the decision-making process is the clearest example of this. When decision-making about the system as a whole is diffused among many components the process is cumbersome and time-consuming without any guarantee that the decision will be better for the situation at hand. Such systems, when they do malfunction, are difficult to repair. They are not susceptible to either analysis or testing, since the components are only minimally constrained. Any dysfunction might well reside in many places or in many relationships among the components. Finally, such systems have so many modes of critical interaction that they are less likely to adapt speedily to new situations presented by the environment. Their very cohesiveness mitigates against significant alteration in their internal organization. Most systems fall midway between the two extremes described above and will have, to some degree, the advantages and disadvantages of both. In terms of learning, it is not possible to give priority to one type of organization over the other. The first may have the advantage in terms of executive decision-making, while the second may be better able to integrate new patterns of behavior throughout the system. The first may have a more specialized and elaborate memory facility with a more efficient recall capacity, while the second may have an associator subsystem with greater creative potential. As we have seen in 13.2, as systems develop, they tend to become more like the first prototype. Whether or not this is desireable, or course depends upon the nature of the environment, as Ashby points out.

13.6A Schools vary widely in their patterns of sub-system allocation (9.16-9.34). To some extent, pattern of allocation will be correlated with size; a small school will necessarily tend towards more combined subsystems while a large school will tend towards more localized subsystems. The fabled one-room school house, in which the teacher would come in early in the morning to stoke the furnace, go out to drive the school bus and return to teach all subjects to all pupils, would be at one extreme of the continuum; the large comprehensive high school, highly departmentalized with a wide range of special services would be at the other end. However, as we have seen in Chapter Nine, regardless of how localized and specialized subsystem processes may appear to be from an organizational chart, the actual allocation of significant subsystem processes is highly combined and dispersed, moreso than in other kinds of human organizations with which schools are frequently compared and from which organizational theory is largely derived. As long as schools deal globally with comprehensive inputs and intend to transmit, as outputs, "educated men," their real organization as concrete systems will be at varience with their formal organizations. In terms of their defined functions, they will be partipotential systems, sharing the education of their students with the society as a whole. The effort to more closely relate the school to the larger community it serves is thus more than a rhetorical flourish; it is an expression of an educational reality. As long as the education of children takes place both in and out of schools, the school is only a <u>part</u> of the concrete educational system for any given child. What this means practically is that the techniques of management, planning, budgeting, and producing which are appropriate for organizations tending towards the first prototype will be less appropriate for schools. PPBS, for example, may be an excellent management tool for organizations whose subsystems are highly localized, but it will be exceedingly difficult to apply honestly to organizations in which these processes are combined and dispersed.

13.6B Physiologically, the human organism includes both combined and localized subsystem processes dealing with matter-energy inputs; psychologically, the same statement may be made about the processing of information inputs. In thinking about the student as a learning system, however, we shall be more interested with how he organizes the information he processes. We shall avoid a neuropsychological discussion not by choice but by necessity as beyond our competence at this time. It is possible to say, though, that there does appear to be neuropsychological evidence to support the important assertions made in this section.[8] We shall begin by suggesting that two types of learning must co-exist in a learning system. We shall call one type "reactive" learning and we shall call the other type "pro-active" learning. Reactive learning requires the existence in the environment of a stimulus which elicits some line of behavior not already in the system's repetoire. When the system discovers the behavior that reduces or eliminates the stress or strain presented by that stimulus, it has learned, and presumably whenever that stimulus reappears it will "trigger" the successfully learned behavior, unless the behavior has been forgotten, in which case it must be relearned. The frequency with which the stimulus reappears in the environment will in large measure determine whether or not the behavior is forgotten or stored

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[8] see Pribram, Karl H., Languages of the Brain, (Englewood Cliffs: Prentice-Hall, 1971).

in the system's memory. Reactive learning is stimulus-dependent; without the concrete presence of the stimulus in the environment the learning will not occur. Most formal schooling calls for reacive learning. The stimulus is provided by the teacher or curriculum materials; the student provides the appropriate line of behavior, whether novel or familiar. Reiteration of the stimulus elicits repetition of the successful behavior. Generalization and abstraction are developed as the student discovers that a given line of behavior will successfully respond to more than one stimulus, and that more than one line of behavior will successfully respond to a given stimulus. Depending upon the frequency with which stimuli are likely to recur in the environment, reactive learning can be a sufficient mode of adaptation for a learning system. It is essentially a problem-solving mode and is appropriate to situations which are problematical. One the other hand, "pro-active" learning occurs in the absence of concrete stimuli in the environment, and, as far as we know, is limited to only a few species of living systems. Most of what we refer to as "creativity" is pro-active learning. The interior life of the mind which deals not only with the here-and-now but also with the past and future, with imagination and fantasy, is pro-active. We have commented throughout this paper on the capacity of the learning system not only to map aspects of the concrete environment into its internal organization but also to project aspects of its interior representation on to the concrete environment. This is pro-active learning, and it is the way in which learning systems compensate for deficits in their environments. The propensity for investigation, invention, and discovery cannot adequately be explained by any theory of learning which is predicated upon the presence of concrete stimuli in the concrete environment. Von Bertalanffy, in his oft-repeated criticism of behaviorism, refers to the "robot model of human behavior"[9] and includes in his indictment the S-R theories of Pavlov and Skinner, the environmentalism of J. B. Watson, and even Freudian reductionism which explains adult behavior on the basis of early childhood experiences. Indeed, the theory of open systems was initially extended to human behavior as an alternative to the "robot model," just as in the biological sciences it was an alternative to the equilibrial assumptions of closed systems models. The question we must ask ourselves is what kind of system organization is most conducive to pro-active learning, one in which subsystem functions are highly localized or one in which they are highly combined and dispersed. We limit our discussion of information-processing, since matter-energy processing is regulated largely by homeostatic mechnaisms. We can point to two extreme kinds of information processing, similar to the two prototypes discussed in 13.6. In the first kind, in which subsystem processes are highly localized, all sorts of information enters the system. What reaches the memory are highly diverse and varied data which , depending upon the memory's storage capacity, are available to the associator and the decider subsystems for use in constructing the internal representation of reality. This internal representation is likely to be rich in detail and rich in potential for association. It is also likely to contain more information than, at any given time, the system is likely to use, although at any given time there is more information available for

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[9] von Bertalanffy, Ludwig, General System Theory, (New York: Braziller, 1968), p. 188.

use than is present in the immediate environment. There is more likelihood for unique associations of seemingly unrelated data and thus more likelihood for creative and fresh internal representations of reality. The student, therefore, who is capable of processing and storing a wide variety of potentially although not immediately useful or pertinant information is more likely to have that information available at a time when it is useful and relevant, even if it does not pertain to the environment as it exists at that time. Contrast this student with one at the other extreme. His input transducers are highly selective and admit only information pertinent to the situation at hand. He is a "focuser" not a "scanner." His senses are disciplined to exclude the extraneous. Sense-data are classified by the time they reach the brain. These built-in classification schemes restrict the data that the associator subsystem can process. The second student's memory may have just as great a capacity as the first student's has, and there may be just as much data stored in it. However, the data are so highly organized into such rigid classification schemes that the possibility of novel or fresh associations is minimal. While both of these examples are extreme, individuals do tend towards one extreme or the other. Those tending towards the first type are more likely to have the capacity for proactive learning than those tending towards the second. Curriculum in schools tends to be highly compartmentalized. Math is math, and reading is reading. They are taught in separate time periods and in different ways. The opportunity for the student to discover that they are both symbol systems, both languages, ordinarily does not exist in the classrooms. Even subjects that might seem to have an even greater natural affinity, like literature and social studies, are ordinarily presented as separate domains. Life's experiences, though, do not fall neatly into subject areas. The mind which is accustomed to processing pre-classified data will have difficulty in processing information which is not so neatly arranged.

13.7 The number, location, and function of negative feedback loops in the system and the amount of time-lag in them. We recall from 10.3 and 10.11 that negative feedback is a portion of the system's output which re-enters the system as information to regulate the system's subsequent performance. Both adjustment and learning systems require negative feedback, although while the adjustment system must act upon its feedback, the learning system may choose not to act upon it. Without feedback, however, the learning system could not distinguish between successful and less successful behavior; it could not change its line of behavior to accomodate a changing environment. Indeed, we are justified in claiming that the "feedback loop" is the basic behavioral element in a learning system. If we recall Pask's contention (11.10A) that the least distinguishable or describable component of an active control system is also an active control system, we are now in a position to identify this element as a feedback loop. We can think of a learning system with its critical subsystem processes as a set of interrelated feedback loops through which, at any level, information about performance flows. Miller, Galenter, and Pribram have called this feedback loop a TOTE unit, "TOTE" standing for "Test-Operate-Test-Exit."[10]

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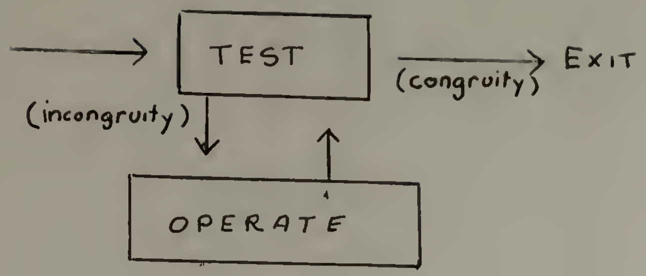
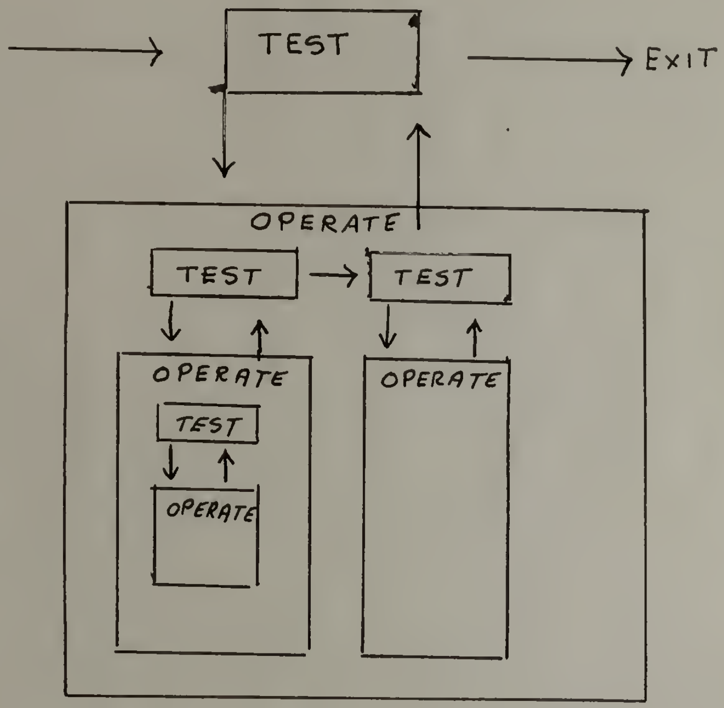
[10] Miller, George A., Galenter, Eugene, and Pribram, Karl H., Plans and the Structure of Behavior, (New York: Holt, Rinehart, and Winston, 1960), p. 27.



"The action is initiated by an 'incongruity' between the state of the organism and the state that is being tested for, and the action persists until the incongruity is removed."[11] The advantage of thinking of the feedback loop as a TOTE unit is that it can easily be applied to any hierarchial level by considering the "Operate" phase to include as many smaller TOTE units as is convenient for the inquiry.



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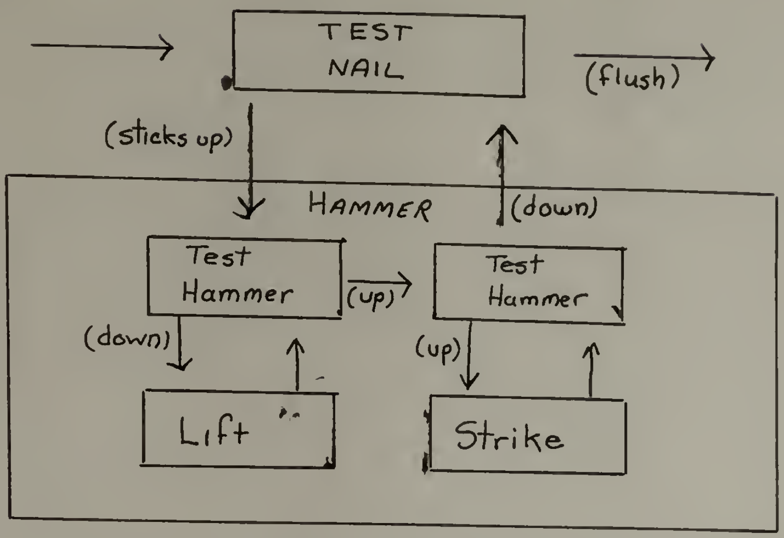
[11] _Ibid._, pp. 25-26.

Miller, Galenter, and Pribram use the simple act of hammering a nail to illustrate.[12]



Of course, if the major activity were conceived as building a bookcase, this whole TOTE unit would be one small part of the operational phase of a much larger TOTE unit. The TOTE unit has another great advantage; it need not be applied only to motor activities of the system. The "Test" phase can be construed as developing a plan for behaving and the "Operate" phase as executing that plan. Or the test phase can be construed as developing the program which generated plans, while the operate phase includes the plans thus generated. On whatever leve of generality we may choose to apply the TOTE analysis the important feature is the circular and reciprocal relationship between testing and operating. Over time, the sequence always looks like this:

. . .Test ⟶ Operate ⟶ Test ⟶ Operate ⟶ Test. . . .Exit

Two testing phases are always separated by an operational phase; two operational phases are always separated by a testing phase. The time-lag

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[12] _Ibid._, p. 36.

between the operational and testing phases thus becomes a crucial factor in the performance of the system. If the time-lag is too great - particularly between the operational and testing phases - the feedback will effectively disappear and the system must perform without information about the efficacy of its performance. There is no general rule to determine the effects of time-lag. In some situations, writing a dissertation, for example, a certain time-lag is inevitable and, while frustrating, managable. Too great a time-lag, though, is counter-productive and inefficient. In general, we can say that time-lag is least harmful in situations where subsequent operations can be deferred without jeopardizing the attainment of the desired state.

13.7A Schools do not lack feedback loops; what they lack in many instances is the capacity to improve their performance even with the information that feedback provides. In terms of student performance, too often the school will go through one TOTE cycle and then exit, regardless of the information that the student, or class, has not achieved the desired congruence with the goal. Learning systems, we know, may choose not to act upon feedback, although rarely do school people realize that they have, in fact, made this choice. Frequently, too, schools couch their goals and purposes in such global and amorphous terms that they make it impossible for themselves to test their operations. The performance objective movement has attempted to construe the learning process in terms of specific TOTE units, and this is all to the good, although proponents of this approach have too often focused so finely on specific overt behaviors and have construed the conditions under which those behaviors are to occur so narrowly that they make it difficult for success-

13.7A

ful behaviors to become part of future operational phases in other TOTE units. The main problem that schools have with feedback, then, is not the lack of it but the lack of means to apply it to subsequent performance.

13.7B The student in the school, on the other hand, has a very different sort of problem. Students learn very early that the important information is not feedback from their performance but feedback about their performance from another person, usually the teacher. Viewed one way, this inhibits the development of TOTE units, since the "test" of an operation is external to the system. Viewed another way, the test becomes - not the success of the operation - but the attitude of the teacher, the grade, or the gold star; the operation itself is externalized. The student learns first to distrust and second to suspend his own judgment or capacity to test his operations. What he has done is neither good nor bad, right nor wrong, successful nor unsuccessful, until the teacher has so indicated. Moreover, the pseudo-feedback the student receives from the teacher rarely occurs at a point when it can do him any good. Evaluation is too frequently at the end of a unit of instruction; tests may indicate that a student has performed poorly, but by then it is too late - the class has moved to another unit. The test phase of a TOTE unit is diagnostic; the test phase in schooling is all too often "terminal." Until students in schools can depend upon feedback from their performance, the assumption that specific behaviors are the result of learning is questionable at best.

13.8 The nature of the system's memory facility - Following Newell and Simon,[13] we postulate three kinds of memory, an internal Long-

[13]Newell, Allen and Simon, Herbert A., Human Problem Solving, (Englewood Cliffs: Prentice-Hall, 1972).

Term Memory (LTM), an internal Short-Term Memory (STM), and and External Memory (EM). The LTM has, as far as we can tell, an infinite capacity to store symbols and "chunks" (patterns of frequently associated symbols). Information stored in the LTM is quickly accessible, although the process of accession is not understood. The learning system evidently does not have to scan the LTM to have access to information stored in it.[14] Curiously, conscious attempts to scan the LTM, as when a person tries to find the precise word he wants, or has a name "on the tip of his tongue," usually do not work; focussing on symbols in the LTM seems to make them less accessible. Little is known about the capacity of information to remain over long periods of time in the LTM. If it can be accessed, it is, of course, there. If the human learning system is conscious of having "forgotton" something, it may or many not be there, but at least some chunk is there or the person would not know what it is he had forgotten. At one time, I had in my LTM the names and dates of all the ancient kings of Assyria. I no longer know them, but the fact that I was able to draw from my LTM the catagory "ancient kinds of Assyria" to use as an example here means that there is a residual chunk in my LTM. The names and dates could be re-entered with ease.

The STM is the learning system's working space. It has a very limited capacity. George Miller suggests that the STM has a capacity to store about seven symbols or chunks,[15] and even this small number is

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[14] Ibid., p. 793.

[15] Miller, George A., The Psychology of Human Communication, (Baltimore: Penguin, 1969).

reduced to about two if other information processes are interposed between presentation and recall.[16] Fortunately, information can be retrieved and returned to the LTM with ease and rapidity, so over time the information in the STM can be very great, even though at any given time it is very small. Information in the STM decays rapidly. Whether the decay is a time-dependent process, or whether it is due to the interference among symbols in the STM is a matter of controversy among psychologists.[17] There is no doubt, though, that the storing of information in the STM over time requires conscious rehearsal (what we call memorization), and that when the information is not needed it decays rapidly. It is not necessarily true that information processed in the STM is stored in the LTM even if it has been assiduously memorized. Nor does it appear to be true that all information stored in the LTM must enter it through the STM. We can, however, offer the hypothesis that as long as the information is being used in an uncompleted TOTE it will remain accessible to the STM. Put another way, as long as a system is executing a plan, the information it needs to execute that plan will remain available to it, even if the execution is interrupted or deferred. The capacity of a learning system to construe particular plans as sub-units of larger plans will thus inhibit the decay of information and maintain its accessibility.

External Memory (EM) resides outside the system and may be as simple as a piece of paper and pencil or as complex as the New York Public Library. EM is an auxilliary of the STM and compensates for the STM's

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[16] Newell and Simon, op. cit., p. 795.

[17] Ibid.

limited capacity. Certain kinds of tasks, which could be carried out by the LTM and STM exclusively are made much easier and quicker with the help of EM. As an example, the computation "7 x 6" can be retrieved from the LTM immediately whenever it is needed. The problem "42 x 6" can be worked out by the STM withou the aid of EM, although it will take more time and the probability of error is greater. The problem "252 x 46" could, with considerable difficulty be worked out without EM, although the difficulty in remembering the intermediate products illustrates the limited capacity of the STM. The problem-solver would have to work hard to remember the intermediate steps, since subsequent processing would tend to obliterate the previously arrived at product. The problem "11592 x 252" could probably not be accomplished without the aid of EM unless the problem-solver had a heuristic for reducing the over twenty-five separate products and sums to approximately seven. With paper and pencil, however, this becomes a trivial task. It is, of course, possible to store limitless information in the EM and transfer information from the STM to the EM. Retrieval of information from the EM depends upon the size of the relevant EM and its organization. A book without an index, or a library without a cross-referenced subject catalogue, makes information retrieval from the EM cumbersome and time-consuming. Newell and Simon point out that viewed functionally, the STM is both the internal STM _and_ that portion of the EM available to the system at any given time.[18] That is to say, that the system's memory facility should be construed to include the EM. To expect all information used by the STM to come from the LTM is foolish.

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[18] _Ibid._, p. 801.

13.8A Most schools are foolish. School people appear to feel that there is greater virtue in having the names and dates of the Assyrian monarchs in the LTM than having this information in the EM. Their folly is compounded by their assumption that the presence of such information in the STM at a given time (when the unit test is given, for example) indicates its presence in the LTM. In an age of such information overload, it seems ludicrous to expect learning systems to store vast data in their LTMs. What we can expect, and what schools should be helping students to learn, is to store accessing processes in the LTM so that when the need for particular information is present the learner can search the EM for it efficiently and effectively. This is, in effect, what schools as learning systems must do, for there does not seem to be anything analogous to the LTM at the supraorganismic level. Human organizations must rely on the EM to provide the function of the LTM in the organism. Individuals within the school, or course, will have LTMs, but since the school's memory subsystem is so widely dispersed, the individual LTMs taken collectively cannot be construed to constitute the LTM of the system. This is why minutes are taken of important meetings and why important decisions are written down and entered in policy books. The school, thus, must rely on EM for its information, and in a paradoxical sort of way this is probably a good thing. We have remarked elsewhere (9.33) that what schools may need is not more efficient memories but more efficient "forgetters." The existence of LTM may be dysfunctional in Ashby's sense (13.1) if the environment changes with great rapidity and tends not to repeat itself. That a school does not have an LTM means that it can more easily create new lines of behavior and is less fixated upon old behaviors that are no longer functional. It may reasonably be objected that many schools do appear to be fixated on dysfunctional behaviors - that this, in fact, is the "problem" of American schooling. It is true that schools act as though they had LTMs, but in fact the problem really lies with their reliance on an obsolete and dsyfunctional EM. The curriculum of the school resides in its textbooks and worksheets. An easy solution to the problem of an outmoded curriculum is to throw the books away. The fact that the EM is part of the environment means that it is more susceptible to external control than is the school itself. The reader may note a conceptual contradiction in considering the EM to be both part of the system's memory and part of the system's environment. This would seem to violate our practice of looking steadily at the system and not changing levels in mid-analysis. James Miller helps us out of this confusion by introducing the concept of an "inclusion."

> Sometimes a part of the enviornment is surrounded by a system and totally included within its boundary. That is an <u>inclusion</u> . . . The inclusion is a component or subsystem of the system if it carries out or helps in carrying out a critical process of the system; otherwise it is part of the environment.[19]

In other words, the EM is an example of an outwardly dispersed subsystem (9.15).

13.8B We have said that the STM, supplemented frequently by the EM, is the functional working space of the memory. We have also noted the

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[19] Miller, James G., "Living Systems: Basic Concepts" in Gray, Duhl, and Rizzo, <u>General Systems Theory and Psychiatry</u>, (Boston: Little, Brown, 1969), p. 106.

extremely limited capacity of the STM - on the order of seven symbols or chunks at any given time. We have finally observed that information in the STM can come either as input from the environment or from the LTM. The interesting question is what happens to the symbols or chunks when the work in the STM is completed? We know that they cannot remain in the STM. There appear to be three alternatives: they are stored in the LTM for future retrieval; they are stored in the EM for future retrieval; they decay. We can offer the following hypotheses related to these alternatives:

First, data stored in the EM are unlikely also to be stored in the LTM simultaneously, although they can subsequently enter the LTM via the STM. A student taking notes from a lecture will probably not remember the material in his notes, although after the lecture he can review his notes at his own pace and the material can enter the LTM. Underlining passages in a book is not an aid to remembering, it is an aid to subsequent access to the information underlined.

Second, data retrieved from the LTM are more likely to be returned to the LTM for storage than data from the environment. Likewise, the more frequently data are retrieved from the LTM the more likely thay are to be returned to it. If a student makes continued use of the names and dates of the ancient Assyrian kings he will be more likely to remember them.

Most important, data that are used in the execution of a plan will be returned to the LTM until that plan is either successfully executed or until it is relinquished. A plan, as we have said, is any process, or combination of processes, in the system which controls the sequence of behaviors which constitute the system's output. As we shall see in the next section, a plan is analogous to a computer's program. It is a set of rules or strategies which controls the sequence of TOTE units. At the same time it is itself a TOTE unit of a higher-order plan. Plans follow the same heirarchial principles of roganization that appear to be operative in the natural and social worlds. We shall soon be discussing the various types of higher order plans which are stored in the LTM. Here, we would only suggest that this hypothesis seems to argue against the construal of performance objectives to be such molecular units that the satisfactory attainment of the performance criteria leads to the relinquishing of the plan. The more self-contained a unit of instruction or a unit of learning, the less likely the student is to remember it once he has achieved it. If the purpose of learning the Assyrian kings is to pass a unit test, once the test is passed, the plan for learning the Assyrian kings is likely to decay rapidly. If, on the other hand, the study of ancient Assyria is part of a larger plan - to study comparative political forms or the process of political change or the relationship between political and religious beliefs, the information is likely to remain available in the LTM for future retrieval - at least until the end of the semester. If the semester of Ancient History can itself be related to other concerns of the student, the data will remain in the LTM even longer. In other words, the higher the order of the plan that that student is executing the less likely the successful execution of lower order TOTE units will result in the decay of the information used in their execution. In the language of schools, if the performance of particular objectives is construed as a step in the attainment of long-range goals, the skills developed in the performance of the objectives will remain in the student's repetoire. It stands to reason, of course, that the long-range goals must be the student's, not the teacher's or the school's or the community's.

13.9 The operating rules, or program, determining the system's structure and behavior - What Cadwallader calls rules or programs we have called "plans." They are the highest level plans, those that govern the processing of any and all information by the learning system. We shall discuss each of the briefly in this secion and then consider them together in sections 13.9A and 13.9B.

1) rules . . . determining range of inputs - The learning system has an internal representation of reality - an image of the way things are - and this image serves as a high order plan for determining the range of inputs into the system. Whether there is an objective reality to which this image corresponds either closely or loosely is an epistimological issue we shall skirt. We shall assert only that we act on the basis of how we think things are - our subjective knowledge of reality. Our image controls not only the way we act but also controls the range of messages we receive from the field. In other words, our image in large measure determines our environment. The presidential campaign of 1972 appears as though it is going to pit two radically different images of reality against one another. The views of President Nixon and Senator McGovern start from such different unquestioned assumptions about the way the world is that it is fair to say that they inhabit two different environments. The inputs that Senator McGovern and his supporters accept as

compelling messages from the environment will probably not be inputs into President Nixon or his supporters. Learning systems tend to accept inputs that are congruent with their images and tend to resist inputs which are incongruent. Sometimes these inputs enter the system and are then rejected by the decider subsystem. It is just as likely, though, that they will be outside the range of inputs which the system will accept. Because the learning system cannot deal with them, they are excluded from the system entirely.

2) rules responsible for the routing of information throughout the network - Particularly at the organization level there must be a plan for the internal transmission of information. The existence of multiple overlapping channels could lead to a hopelesss morass of messages if information flowed promiscuously over them. The capacity of the system to process information is not the sum of the capacities of its channels. The capacity of a channel is the upper limit of the bits of information it can handle, not the optimal limit. Given a network of channels of varying capacities, all of which must particiapte in the processing of information, the channel with the least capacity will determine the capacity of the network. In such a system, the communication network resembles a chain which is as strong as its weakest link. Other systems may operate with a "message dispatch center." All messages entering the system are routed through the dispatch center. It is then the capacity of the dispatch center which determines the capacity of the system. Some systems have alternate channels to relay messages if the principal channels are at their capacity. All of the above are examples of different plans for the routing of information within the system.

3) rules about the identification, analysis, and classification of information - The patterning of information into usable chunks is the job of the associator subsystem. Without such high level plans, the learning system would have no capacity for dealing with novel information or unfamiliar configurations of familiar symbols. The most compelling evidence for the existence of such plans has been oft cited in this paper: the human being's linguistic capacity to generate and understand entirely new sentences instantaneously. This linguistic competence is just such a high order plan. It is intriguing - and mystifying - to watch this competence developing in young children. The gradual realization that words have meanings, that meaning can be combined to produce new meanings, that language is a means of control over one's environment, that it is an active meaning-producing facility, that it is an act of volition, is testimony for the existence of a high-level plan in the LTM which, as a single chunk, can govern the associations and classification of particular data from the environment. We can hardly conceive of how the world might appear if we did not have such plans. It is not only that all phenomena would be unexpected and unfamiliar, it is also that we would not have the catagories "unexpected" and "unfamiliar" within which to classify them. Classification, indeed, can be considered the pre-eminent plan which learning systems must have; classification and re-classification, for if classification plans are not themselves subject to modification and alteration they can become rigid and ossified. When that happens, the internal representation of reality - the image - cannot be changed, it can only be shattered.

4) priority rules for input, analysis, storage and output - The

learning system's information processing is serial; it can deal with things only one at a time. Input into the system is not serial, but output is. One of the great advantages of chunking is that when the "one thing" that the system is dealing with is a chunk, it is really dealing with many related things at once. Nonetheless, the system must always have a plan for determining the priority of inputs which may impinge simultaneously upon the input transducers. It must, at the other end of the process, have a plan for determining in which order outputs will be extruded. This has, of course, implications for storage, for those inputs not immediately processed must be held in storage for future processing. If they are held in the STM they are taking up precious, limited space.

5) <u>rules governing feedback mechanisms</u> - We have tried to make the case for the importance of feedback; now we must add the importance of the selective use of feedback. Whereas in some areas time-lag in feedback would be fatal to the system or to its performance, in other areas simultaneous feedback is neither possible nor desireable. When the system is executing a high order plan, it must often do so without the knowledge of whether its intermediate steps are successful in meeting its goal. An author writes a book in the hopes that it will be published and reviewed favorably; a candidate runs for office in the hope of being elected; an administration institutes wage and price controls in the hopes of curbing inflation. All of these are long term plans which are not ordinarily susceptible to feedback control. The author may attempt to publish chapters of his book in magazines, but unless the book is essentially episodic the reaction to the parts will not be a reliable indicator of the reaction to the whole. The candidate may get "feedback"

from public opinion polls, but the feedback early in the campaign is not necessarily a reliable indicator of the feedback at the end of the campaign. Were he to adjust his campaign strategy every time a poll was published, the final result might well be more disasterous than had he stuck to his course. The long-term consequences of wage and price controls might well be contrary to their immediate consequneces. There are, in other words, large arenas of human affairs in which behavior cannot or should not be guided by feedback. Those who are too dependent upon immediate feedback - who will not take the second step until they are assured that the first step was successful - are considered overly cautious or compulsive. They are people who are dependent upon the opinion of others before they can have an opinion of themselves. They may have learned this in schools. Thus, the learning system must have a plan for determining when immediate feedback is possible and desireable and when feedback is inhibitory. Without such a plan, the system would be incapable of executing any other long-range plans.

6) Instructions for storage in the system's memory - The learning system must have plans both for entering and retrieving information in the system's memory, whether LTM or EM. These plans are themselves information, of course, so they must be guided by still higher-order plans which determine when and under what conditions the plans for storage are to be executed. The plans for storage in EM and LTM will have to be quite different. The plans for storage in EM are usually under the conscious control of the system. Both entering and retrieving information are time-consuming tasks. The LTM, on the other hand, need not be consciously controlled. The process of retrieval, particularly, seems

to be inhibited by consciousness. The harder we try to remember something, the more elusive it becomes. As Miller, Galenter, and Pribram put it, ". . . it is not storage, but retrieval, that is the real bottleneck in verbal learning. Building the connections seems to be far simpler than finding them later. . .The time and effort that goes into a job of memorization is devoted to ensuring that there will be some way to get access to the particular association we want when the time comes to revive it."[20]

7) rules regarding the synthesis of information for the output of the system - Analysis and synthesis are opposite and complementary processes requiring different plans. The process of synthesizing is really the process of forming new plans from the available bits and chunks of information. We must admit that we really don't know much about how this is done, but there is no doubt that it is done, by all learning systems all the time, and with skill and rapidity. No doubt some systems are better at it than others, and no doubt some systems actively attempt to shape their environments to minimize the necessity for creating new plans. Some systems will resist as long as possible the creation of new plans even when environmental parameters clearly call for them. Finally, there are some systems which refuse to create new plans, even though they could. There are individuals and organizations who, on principle, persist in following traditional lines of behavior, who choose not to adapt to a current environmental condition in the hopes that the condition itself will revert to a prior state. From the observer's viewpoint it

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[20] op. cit., pp. 137-138.

may appear that such systems are incapable of change - that they cannot formulate new plans to replace old ones. In a rapidly changing environment, however, such conservatism may make great good sense. It is often difficult to distinguish between passing fads and enduring fundamental changes. A system which adapts to every new condition which confronts it may be expending so much energy in accomodation that it forfeits its ability to play an active role in shaping the environment to its own goals and purposes.

In looking over the vast array of plans we have discussed in this section, two kinds of distinctions will be helpful in maintaining perspective. First of all, we will want to bear in mind that at the organismic level most of these plans are part of the genetic template, while at the organizational level there is nothing corresponding to a genetic template. Constitutions, charters and by-laws, which are the closest analogies, are still artifacts of the organization and may or may not accurately describe organizational processes. In the second place, we want to make a distinction between plans and the data plans control. We have resisted using Cadwallader's term "program" because it is too closely tied to a strictly cybernetic model of system processes. Because computer technology has developed the sophisticated capacity to simulate human learning, it is tempting to turn that around and to assume that human learning simulates computer processes. There is a great and fundamental difference, however. At some level, even the most sophisticated computer receives its program from the environment. Computers are <u>designed</u> in particular ways and are slaves to their designers. They may manifest remarkable abilities for self-control and program modification, but these abilities have been built into the system. The most amazing computer, as we have said, is an amazing adjustment system. Just the reverse is true of learning systems; at some level, even the most "adjustable" learning system controls its own plans. In the truest sense, learning systems can never be completely controlled from the environment and adjustment systems can never completely control their own plans.

13.9A Where does the observer find the operating rules, or programs, which determine the school's structure and behavior? He might begin by searching the school's EM for statements of policy and regulations, but this is a highly unreliable source of information which describes, not the actual operating rules, but the ideal operating rules. Just as the old-time civics books in describing how a bill becomes a law omit the actual back-room by-play which is an essentail part of the legislative process, so, too, the policies and the organizational procedures of a school omit the actual day-to-day processes of the school which may or may not resemble the abstracted regulations. The observer or analyst cannot assume that the school actually behaves the way it says it does; he must, instead, observe over time the way it actually behaves, and infer from its behavior what its plans must be. However, this task is made extremely difficult by the problem of deciding what, in fact, the school's behavior is. Because it is such a poorly-defined system, it is virtually impossible for the analyst to look steadily at it. It has been tempting throughout this paper to decide that the school is not a system, since we could resolve our analytical difficulties by ignoring them. But the school <u>is</u> a system; the fact that it is difficult to analyze - and difficult to change - does not mean that it does not act systemically.

The school has an internal representation of reality which functionally limits the range of inputs it can process. This image will set priorities which are easily observable. Which is more important to the school, reading or music, work or play, obedience or initiative? The answers to these questions can be gained by observation. How does information, in fact, travel through the school? If a person wants information treated confidentially, how does he go about it? If he wants information disseminated widely, how does he go about that? Where are the critical nodes of interaction in a school? Who are the people who always seem to know what's going on? Who represent the short-cuts which by-pass the formal channels? These are but a few of the questions that can reveal the plan which controls the routing of information. Plans for the classification of information are likewise ascertainable. In schools, information is frequently classified according to its source. Information from the textbook is true; it is the standard against which all other information is judged. Information from students is dubious unless it corresponds to textbook information. Information from the superintendent is supported by the power he has to control the destinies of others. Information in writing is treated as more definitive than information transmitted orally. The organization of the curriculum will also indicate the school's plan for classifying information, as will the sorts of records schools keep about student progress and behavior. The school is really a prisoner of its classification plans; they are the most difficult to change without a conscious decision on the school's part to change them. The school's rules for establishing priorities are evident in the school's allocation of time. When the school puts "first things first," what are the first things? The students know. The observer can ask them. Plans governing feedback mechanisms can be discovered first by asking whether the school really allows intrinsic feedback - feedback from performance - to occur, or whether students must await the teacher's evaluation, the teacher must await the principal's evaluation. Can - and do - members of the school community evaluate their own performance and have confidence in their own judgments? Can - and do - they establish their own criteria for assessing their performance? It is particularly easy to discover the plans for storage in the school's memory, since the school has no LTM and must store information in its EM which is accessible to the analyst. Pupil personnel records are one source of information about the school's plans for storage. Not only the kind of information in the records is significant but also who can have access to that information? When, if ever, is information discarded? Who makes the decisions about entering and retrieving information? Finally, the analyst can obtain information about the school's plans for formulating new plans. How does the school decide to do something different? How widespread, in fact, is the decision-making process? Who participates? Who is bound by the decision? How are subsystems restructured to facilitate the new plan?

We can thus see that even with a poorly-defined system it is possible to gain information both about its processes and about is plans for carrying out these processes. It is these processes and plans which constitute the system's organization.

13.9B With the student, our set of questions must be different. We can assume the existence of these plans, or operating rules, even though we cannot observe them. Because the student is a well-defined learning system, we can observe, analyze, and compare outputs at many different levels. We can make valid inferences about his plans from his behavior. What educators and school people must ask, is how students can be helped in developing plans for planning - how, to use the cliche, to "learn how to learn." Whatever their ideologies or personal biases, most thoughtful people would agree that our age is one of information overload, and that the purpose of education should be less the transmission of specific data and more the development of processes for acquiring, analysing and synthesizing relevant data. Most people would also agree that our times are perplexing and our perplexities are full of ambiguities and anxieties. The situations in which individuals find themselves are unlike the problems in school which have solutions. Schools may inhabit the realm of right answers, but most human beings do not. One of the reasons that so many people have difficulty in coping with life's perplexities may well be that their schooling prepared them only for dealing with unambiguous problems in the realm of right answers. In the face of uncertainty they become fearful, in the face of complexity they become frustrated, in the face of ambiguity they become immobilized. Some people, sustained by faith or conviction, manage to carve out sheltered realms of certitude, simplicity, and clarity to inhabit, but most of us cope as best we can, hoping to find in sharing a sense of community what we cannot find through mastery of the perplexities we face. Schools could be more helpful than most of them are in preparing students to cope with uncertainty, complexity, and ambiguity. They could, for example, move out of the realm of right answers and admit that any question that is important enough to ask has, as a legitimate answer, "I don't know," or "I'm not sure." For every question that can be answered "yest" or "no," "right" or "wrong," "true" or "false," there is always the possibility of "maybe," "both," or "neither." Schools could also admit that there is no datum so important that everyone must know it nor any datum so trivial that it could not reshape some student's image of the way things are. For the student, ideally, schooling should be a process of "making the strange familiar" and "making the familiar strange." The teacher, curriculum materials, peers, and other components of his environment can provide the inputs, but he himself must develop his plans. Schools can help him do so by making it important for him to be developing plans rather than merely processing data according to someone else's plan. To the extent that the plans he is executing are his, and the criteria for success are his, the student will be learning how to learn and will develop the capacity to face the unfamiliar with confidence and the familiar with wonder.

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For a general introduction to General System Theory the best sources are the anthologies listed in Part I of the Bibliography, and undoubtedly the best of the anthologies is the one edited by Walter Buckley. Many of the articles in the other anthologies are collected in Buckley's also. Of the books, Buckley's (25) and Berrien's (15) are probably the best starting points for the general reader. Ashby's two books (7, 8) are essential, although very demanding.

The chart below lists the references roughly according to their primary focus and their accessibility to the general reader. None of the references is particularly easy reading, but for the reader willing to make the effort, the dividends in intellectual excitement and insight are great.

	General Works Requiring no Specialized Knowledge	Advanced non-mathematical references	References requiring advanced math
General Theory	15, 19, 25, 70, 71	7, 8, 17, 39, 59, 60, 72	3, 41, 45, 49, 76, 83, 104
Psychology	2, 13, 14, 18, 47, 52, 53, 54, 65, 68, 89, 103	4, 6, 12, 22, 40, 55, 56, 61, 74, 81, 82, 94, 99, 100	75, 101
Biology and Physiology		16, 28, 35, 51, 73, 81, 106	97, 98
Organization Theory	1, 14, 46, 48, 95	27, 33, 64, 86	

Sociology	25, 32, 38, 42, 43, 77, 96	21, 24	
Cybernetics	5, 87, 88, 102, 105	7, 8, 9, 31, 78	75, 80
Communication Theory	13, 91, 103	29, 30, 36, 62, 63, 66, 67, 69, 79, 84, 90, 92	11, 93
Philosophy	20, 23, 37, 58, 95	26, 34, 44, 50, 57	
Mathematical System Theory			10, 85, 93

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The articles and selections listed in Part II of this Bibliography which are taken from the anthologies and collections listed below will use the code which follows for citation.

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