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ABSTRACT

This paper presents a conceptual framework for the future study and development of new structures for organizing education in metropolitan areas. Intended as a step toward development of general organizational rules, it attempts to (1) refine and reduce to a general rule the concepts of organization, organizational change, and organizational improvement; and (2) link these concepts to human organization. (Hard copy may reproduce poorly because of marginal legibility.) (LLR)

ORGANIZATION, ORGANIZATIONAL CHANGE, AND ORGANIZATIONAL IMPROVEMENT IN EDUCATION

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I

Considerable quantities of ink have been spilled in recent years in attempts to answer such questions as, "How can one bring about organizational change in education?" and, "How can educational organization be improved?" Here, in this seminar, we're exchanging views on a companion question, "How can we organize education in metropolitan areas?" Unfortunately, few persons seem to realize the "fact" that the conceptual confusion surrounding the terms, "organization," "organizational change," "organizational improvement," and "organize," makes it impossible, or at any rate difficult, to answer these questions in anything approaching a rigorous manner. Lacking a clear specification of what it is that one means by "organization," one cannot even decide whether or not an organizational change has occurred, much less how to bring one about. Unless one chooses to mean by organization, "anything that goes on within the collections to which we refer as organizations" (which implies that any event in such a collection which differs from preceding events is an organizational change), he has no way of discriminating between organizational and other sorts of changes. And, lacking a clear understanding of what we mean by "organized," one has only vague, intuitive grounds for deciding when something is organized and when it is not.

Clear evidence concerning the ambiguity of these terms is provided in a recent article by Robbins and Miller.[1] In their review of the empirical and analytical literature pertaining to the concept "school structure," these authors identify as the central issue the validation of the concept and its association with educational output. Defining school structure as "the set of essential organizational arrangements that distinguish one type of school from another and schools as a class from all other formal institutions," Robbins and Miller concluded that the concept is not validated by empirical or theoretical analysis. Here, school structure is defined as "essential organizational arrangements, but the key question of what can be meant by the phrase "essential organizational arrangements" is never raised, either by the authors or, so far as one can determine from the review, by the investigators whose work is reviewed. In short, Robbins and Miller have concluded that a concept, the meaning of which is provided by an undefined concept, has not been validated.

Obviously, we know a great deal more about organizing and about organization than the preceding remarks suggest. The problem is not that we know so little, but that our knowledge is so fragmented. The various items in our fund of knowledge are independent, isolated entities. Perhaps an analogy will clarify the point. Probably everyone here knows a considerable amount of logical reasoning, certainly enough to arrive at logically valid conclusions much of the time in the course of day-to-day activities. Still, unless I am badly mistaken, there are few among us for whom logic is a consciously used tool of analysis and argument. We can, in many cases, produce logically valid arguments as well as recognize both valid and invalid arguments when we encounter them. But, however many valid arguments we are able to produce, and however many valid and invalid arguments we can identify, each of them is an independent, separately recalled case.

In matters of logical argument, the logician has a tremendous advantage over the non-logician. For him the vast number of specific arguments are special cases of a limited number of general rules. It is as though the body of specific arguments had been examined and divided into groups, all members of each group being specific examples of a single general rule. The logician is like the scientist who, having the rule $s = 16t^2$, can generate an infinite number of specific statements like, a body which falls for 4 seconds will travel a distance of 256 feet. The non-logician is like the individual without the rule who has to remember each separate statement.

Although we may be a long time in getting there, what we need to work toward in the field of organization is a limited set of general rules to use as a conscious tool of analysis and action. This paper is intended as a tentative step in that direction. On the basis of an examination of a number of specific cases of organization, we shall attempt first to reduce to a general rule, and second, to refine, the concepts of organization, organizational change, and organizational improvement. Finally, we shall attempt to link these highly generalized concepts with a more specific interpretation of direct relevance to human organization.

II

Although subsequent discussion will lead to modifications, let us begin with the notion of a set of elements, each of which is associated with its own set of alternative actions, states, or properties which may or may not be different from element to element. The state of collection of elements at a given time is determined by noting the alternative state exhibited by each element of the set at that time. There are, of course, as many states of the collection as there are ways of selecting one alternative each from the sets of alternatives associated with the several elements. Thus, with two coins, there are four possible ways of selecting one alternative each, head or tail, from the two: HH, TT, HT, TH. Now, a set of elements may be said to be organized if the number of states of the collection which actually occurs is less than that which might conceivably occur. As Rothstein has noted, "The essential point is that choices from [or occurences in] one set [of element alternatives] are not independent from choices made [or occurrences] in other sets."[2] Zero organization, then, is the condition characterized by independence between the occurrence of element alternatives.

Thus, given a set, called the set of collection states, formed by multiple occurrences, one occurrence from each set of alternatives associated with the elements, any correlation, interaction, constraint which yields a reduction of the set of conceivable collection states below the maximum constitutes an instance of organization. In the situation in which only one state of the collection occurs, maximum organization is present. Consider as a concrete example of organization, an over-simplified thermostatic heating system including three elements, a fuel valve, a thermocouple, and a heater. The alternatives associated with the valve are open and closed; those associated with the thermocouple are the same, and those associated with the heater are on and off. The set of conceivable collection states is $2^3 = 8$. The set of actual collection states is two, (1) valve closed, thermocouple open, heater off, and (2) valve open, thermocouple closed, heater on.

In a less dramatic and temporally immediate way, the same notions can be applied to collections of living organisms. A bee hive is organized in the sense that with each type of bee there is associated a set, or repertoire, of alternative behaviors, and states. In the long run the state of each type depends on the state of other types. The drone cannot forage, produce food, and hence its survival is dependent on the behaviors of workers. Only the drone can fertilize the eggs of the queen, however, so her states (and the state of the hive) depend on the states of drones. A more dramatic illustration, of course, is the dependence between the dance of the returning worker bee and the behavior of workers witnessing the dance. Another is the tendency of bees in a hive to fan their wings when the temperature of the hive rises above a level compatible with the survival of the brood.

The latter illustration above serves to introduce the sometimes useful, but from the point of view of organization alone, arbitrary distinction between internal and external. The distinction is arbitrary in the sense that organization, as defined above, deals with relations among collections of elements without regard to the nature of those elements. Thus from the point of view of organization, there is no basis for the distinction between bees and air. The distinction is made by introducing the criteria which enable one to sort organisms from organisms, and these from their environment.

It should be apparent now that what we mean by organized is the existence of contingent relations among variables. It should also be apparent that under the heading of "variable" we include not only those properties of elements capable of metrical treatment, but any discriminable change of state associated with an element. Differences between nominal, ordinal, interval, and ratio measurement scales are irrelevant at this point. Moreover, by elements we do not mean only physically isolated entities. In the thermostatic example we can include the air and the set of alternative temperature values associated with it. Thus, if an element is capable of behaving in more than one way, or of exhibiting more than one value on a dimension, then its behavior is a variable, e.g., the heater can be on or off, hence it is a two-value variable. Now, the identification of the heater as an element which has as one of the states available to it the production of heat, presupposes a further contingency a further element of organization. As noted at the outset, the heater must exhibit some relatively constant properties which permit its repertoire of alternatives to include heating, i.e., there must be a contingent relation between the presence of those properties and having as one of the states available to it the production of heat. What we need to do here is to differentiate between two sorts of variables: (1) those in terms of which the momentary states of elements are described, and (2) those in terms of which the elements are differentiated from one another. For a given element, only the first is a variable. The second is a constant, and becomes a variable only across elements. In other words, there are two sorts of contingencies involved: (1) contingencies between the properties of elements and the alternative states available to the elements; and, (2) contingencies between the states of the several elements. (Also, when the element exhibits variations on two or more dimensions, there may be contingencies among these.)

The significant consequence of the introduction of both sorts of contingencies into a collection of elements is the reduction of uncertainty or variety. To make this point clear, suppose in a collection of four elements, four activities occur. To make the illustration concrete, let the elements be a heater (h), a valve (v), the air in a room (a), and a thermocouple (t); and let the activities be heat production (p), controlling the flow of fuel (c), measuring temperature variations (m), and exhibiting temperature variations (x). In a state of zero organization, the probability that element (h), (v), (a), or (t) will be observed to engage in activity (p), (c), (m), and (x) is .25, .25, .25, and .25 respectively. In short, every element is equally likely to be observed engaging in any of the four activities. (Note that the problem of an observer in this situation is not too far removed from that of one attempting to predict who will make a certain decision in an organization.) The situation here is the exact analogy the probability of getting a head and a tail on the toss of a fair coin. When there are four tosses of the coin there are K^n possible outcomes (where K = the number of outcomes of a single toss, and n = the number of tosses), i.e., 2^4 = 16 joint outcomes. With four unorganized elements and our activities in which they may engage, there are 4^4 = 256 possible joint outcomes, and no one of them is any more probable than another. Obviously, thermostatic heating systems do not operate in this manner. The heater produces heat, the valve controls the flow of fuel, and so on. Of the 256 possible outcomes, the contingencies introduced by the designer permit only one to occur.

At this point a most intriguing prospect presents itself. Recent developments in the field of communication and information have made available a means of quantifying organization as defined above. The amount of organization present in the thermostatic set can be measured by finding the difference between the potential variety of joint outcomes, and the actual variety of joint outcomes. Suppose that all we know about the set is that it consists of the four elements and the four activities listed. How great is the variety of outcomes that might conceivably occur? Or, put another way, how great is our uncertainty with respect to what can occur? All we know about the heater is that when it does something, it will either produce heat, measure temperature, control the flow of fuel, or exhibit temperature variations. By the Shannon-Weiner measure (which has been interpreted on occasion as a measure of information, a measure of entropy, a measure of variety, and a measure of uncertainty) var t in binary digits, or bits, is $\log_2$ of K, where K is the number of alternative outcomes. By this measure, variety with respect to the conceivable actions of the heater is $\log_2$ of 4 = 2 bits. Sin the situation is the same with respect to the thermometer, th valve, and the air, the total variety is 2 + 2 + 2 + 2 = 8 bits. (Note that 8 is $\log_2$ of 256, the number of joint outcomes referred to above.) As we know, in functioning thermostatic sets there is no ariety in the performances of the elements. Hence, there is zero variety, and, by definition, 8 bits of organization or constraint are present.

It is easy to see that this aspect of organization is the familiar notion of differentiation among elements in terms of their actions, performances, or states. Thus, if we were to observe a collection o five persons in which 10 different activities were performed, d noted that each of the five was equally likely to engage in any one of the 10 activities, we should say that it was unorganized. It is worth noting here that the potential for organization in a collection depends on the variety in the collection, i.e., the potential number of joint element-activity outcomes, which in turn is a function of the number of elements and the number of activities. The collection with four elements and four activities can exhibit at most eight bits of organization. If we add an element, then the number of conceivable outcomes is 4^5 = between 10 and 11 bits of organization. Given a fully organized collection, organization can be increased only by increasing variety.

The thermostatic collection provides a useful illustration to follow further. The heater always produces heat, the valve always controls the flow of fuel,and so on. In the context of element differentiation, organization is at a maximum relative to the potential variety. We do not sometimes find the heater acting as a valve, and sometimes as a thermometer. In another sense, however, there is variety in the set. Each element of the set has two states from which selections can be made, or which can occur. The heater can select on or off; the valve, open or closed; the thermocouple, open or closed, and so on. Can we measure the amount of constraint holding among the states of the several elements? The answer is "Yes." With four elements, each having two possible states (one bit of variety), there are 16 conveivable combinations of one selection from each element. In a state of maximum variety, zero constraint, or independence, we are equally likely to witness all combinations of element states, including the case in which the switch selects closed, the valve selects open, and the heater selects off. In short, maximum variety is the situation in which there are no contingent relations between the selections of the elements in the set. The action of each element is wholly independent of the action of every other element. In a "properly" functioning heating system, however, such is not the case. There are only two combinations of selections that occur. One is temperature above, thermocouple open, valve closed, and heater off. The other is temperature below, thermocouple closed, valve open, and heater on. With two possible outcomes the variety is one bit, hence three bits of organization have been imposed on the set.

It is worth noting at this point that a maximally organized set i.e., one in which only one combination of element states is possible, or one in which there is no variety, is by definition incapable of variation and cannot possibly vary as a function of, or be organized in relation to, other conditions. Neither can it produce any such variations. A heating system in which the only possible combination is the second one given above can only produce heat even if the room temperature is 150°.

Since the selections of the elements of a thermostatic collection vary in a perfectly obvious way as a function of variations in air temperature, and since the selections of elements vary as a function of the selections of other elements, we can say that the selections of the thermocouple are controlled by the selections of the air, the selections of the valve are controlled by the selections of the thermocouple, and so on. Under these circumstances we are justified in calling the collection a system. The problem which presents itself now is one of identifying what it is to which we refer as the organization of the system. The reason for this being a problem is that when we speak of reorganizing the system, of organizational change, or of organizational improvement, we need to know what is being reorganized, changed or improved. It does not seem useful to speak of alternations between the possible configurations of element states as organizational change. In the case of the thermostatic system these are no more than repetitive changes from one configuration to another, and then back to the first. It seems more useful to speak of these as changes in the state of the system.

From what has been said above, it is clear that we have been concerned with variables (variations in the actions or states of elements) which change as a function of changes on other variables (variations in the actions or states of other elements) e.g., the fuel valve is a two-value variable the state of which is a function of the state of the thermocouple. But the state of the valve <u>is</u> a function of the state of the thermocouple, rather than now a function of this and then a function of that. That is to say, the pattern of relations among elements is constant. Likewise, the properties which make an element the kind of element it is are constant. The heater does not change capriciously from a heater to a thermocouple; nor are there variations in the number of states available to the heater--it can be on or off. <u>It is to these element and inter-element constants that we refer herewhen we speak of the organization of the system, and by definition, a change of organization (whether it is considered an improvement or not) is a change in one of the two kinds of constants</u>. In the case of the bee-hive, for example, if at a given time the activity of foraging was not an alternative in the behavioral repertoire of the drone bee, and at a subsequent time it was, then we would speak of a change in the organization of the hive. Interestingly enough, changes of this kind do occur in bee-hives. Typically, the older worker bees tend to engage in foraging (those from 20-40 days old), while activities such as keeping the brood warm, feeding the older grubs, feeding the queen, etc., are performed by other age groups within the class of worker bees. If, however, there is an unusually low proportion of older workers in the hive, then there is a tendency for much younger worker bees to also engage in foraging.[3]

The variables, then, are the alternative states in the repertoires of the elements (which fluctuate in the normal course of events). We shall not wish to speak of the closing and opening of the switch, the opening of the valve, or the fanning of the bee's wings as organizational changes. Rather, we shall refer to these as changes in the states of elements, and to changes from one configuration of element states to another as change in the state of the system. If we wish to be more succinct, we may speak of them as system dynamics. Obviously, in the thermostatic context, dynamics are functions of changes in temperature conditions, and vice versa.

The notion of constants as the organization of a system has been mentioned briefly by Ashby[4], and illustrated in the example of a matrix of beads linked together and fastened to a rigid framework with elastic bands. Such a device may be regarded as a system in the sense that, if we displace the matrix from its position at rest by stretching the bands, its motion when released will describe a determinate trajectory. That is, given the values of certain variables at a given time, the values of those same variables can be predicted for subsequent times. As Ashby points out, underlying these system variables are the system constants. In the matrix the system constants are the masses of the beads, the arrangement of the beads, and the elasticity of the bands. The constants are those properties of the individual elements (beads) and the relations among them which, if altered, would change the trajectory of the system, i.e., would change the dynamics of the system. Thus, a change in the masses of the beads, or a change in the elasticity of the connecting bands would change the motion of the matrix, but a change in the color of the beads, or a change in the composition of the bands (if independent of elasticity) would not. Hence mass and elasticity are constants, while color and composition are not. The organization of the system consists in those properties of the elements and their relations on which system dynamics are dependent.

From the present point of view, then, a change is an organizational change only if it is associated with a change in dynamics, and the two major kinds of organizational change are (1) change in the properties of the elements (which include number of alternatives available and those properties which make it the kind of element it is), and (2) change in the relations among elements. Another could be the addition of new elements, but again the criterion is change system dynamics. A corollary of this proposition is the proposition that any change in system dynamics must necessarily involve an organizational change. A change in dynamics, of course, is a change which goes beyond the normal alternation between system states. It must involve the occurrence of states different from those which occurred before.

We considered above the matter of degree of organization with respect to one kind of constant, i.e., the differentiation of element states. Can we now analyze the degree of organization in the context of relational constants in the same terms? Again, the answer is "Yes." Consider the collection of three elements--a thermocouple (t), a heater (h), and a valve (v), and the relation "controls." Among these three members there are $n(n-1) = 6$ conceivable relations among pairs of elements. These may be listed as in Figure 1. If each of these relations can be either present or absent, (as in Figure 2), in which the numeral (0) represents absent, and the numeral (1) represents present then there are $2^6 = 64$

conceivable patterns of control among the three elements. All 64 patterns of relations can be diagrammed in the manner of the examples in Figure 3.

TV VT TH HT VH HV

Figure 1
Pair Relations Among Three Elements

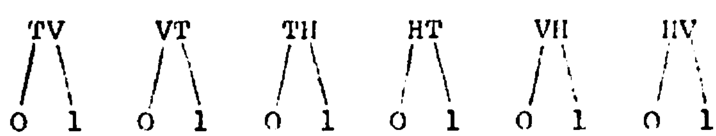
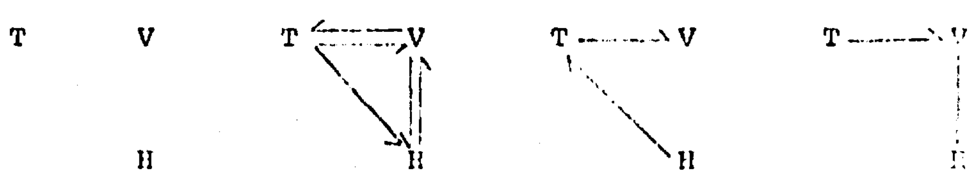


Figure 2
Relations as Elements with Two Values



000000	111111	100100	100010
(a)	(b)	(c)	(d)

Figure 3
Illustrative Relational Patterns

Diagram (a) in Fig. 3 represents the case in which no element controls any other element; diagram (b) represents that in which each controls every other, and diagram (d) that which we find in thermostatic heating systems. Since the 64 conceivable patterns have been reduced to one in the heating system, we can say that the variety has been reduced from 6 bits to zero bits. Hence, there are 6 bits of organization present in the context of inter-element relations. Some idea of the enormous complexity of the organizational problem can be gained by noting that, with five elements joined by a single relation, there are $2^{n(n-1)} = 2^{20} \cong$ 1,000,000 possible relational patterns.

Our analysis thus far has exposed the problem of organization as an enormously complex one, so complex that one wonders how we cope with it as well as we do. Perhaps some simplification can be achieved by answering the question, "What can be meant by the phrase, 'organizational improvement'?" If improvement implies change, and if we define organizational change as we have above, then organizational improvement can only be a change from one set of constants to another set that is in some sense better. For example, given the simple case of five elements and 1,000,000 possible relational patterns, to improve the relational aspect of organization means to select from the 1,000,000 possibilities a pattern of relations that is preferred over that which existed before. How can such a selection be made? Two possibilities may be suggested. One is that the pattern is preferred in its own right. It needs no justification. The other is that it is preferred because it has consequences that are preferred. That is to say, the selection is made on the basis of some criterion variable concerning which we have preferences. In the case of thermostatic systems one selects pattern (d) because it can be related to the additional element, air, in such a way that its temperature variations are a partial function of the variations in the states of the system, and variations in the states of the system are a function of variations in air temperature. (See Fig. 4.)

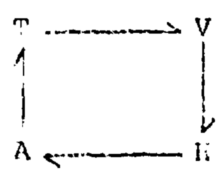


Figure 4

Thus, at least one thing we can mean by organizational improvement is a change in the properties of, or the relations among elements such that an organization good in its own right is achieved. Another is a change such that system dynamics more nearly suit our preferences. Whether we begin with an established, organized system that we wish to improve, or with an assortment of elements that we wish to organize, quite generally we are dealing not simply with systems, but systems-for-something, and that something is usually the maintenance of a relatively constant value on a given variable (which may be a rate of change). The heating system is not simply a system-for-producing-variations-in-air-temperature: it is a system-for-maintaining-constant-air-temperature. From this point of view, organizational improvement can mean any organizational change which accomplishes that objective with greater effectiveness. And by effectiveness we mean the degree to which it limits variation around the desired level on the criterion variable. This is an enormous simplification because it gives us some basis for selecting from among the great number of alternatives.

In order to consider more fully what might be involved in organizational improvement in this sense, let us examine a primitive system-for-maintaining-constant-temperature. Instead of the thermostatically controlled heating system with which we are now familiar, imagine a situation in which we have a coal or wood fired stove which person X feeds by hand when the temperature becomes uncomfortably cool, and damps down when it becomes uncomfortably warm. Under these conditions it is clear that the temperature level will vary greatly. Much of the time the temperature will be either uncomfortably cool or uncomfortably warm. The reasons for this are not difficult to identify. First, it takes a considerable amount of time to get a heater of this kind burning strongly enough to produce heat, and, once it is gotten going, it takes a considerable amount of time to reduce its heat output. Second, the human individual is not a very sensitive temperature measuring instrument: by the time he has become aware of discomfort due to either high or low temperature, a considerable amount of temperature change has already occurred. Third, the human individual is involved as an element in a number of systems other than the one for maintaining constant temperature, and it often happens that participation in one system interferes with participation in another. All these shortcomings can be treated under the headings of excessive lag and excessive gain. Lag is the time lapse between the initiation and completion of corrective action.

Gain is the magnitude of the corrective action taken.

Some improvement could be achieved in this situation by relieving X of all responsibilities other than that of maintaining a constant temperature level, which is to say we could reduce the variety with respect to the number of alternatives in X's repertoire. Since these eliminated activities presumably vary as a function of variations on other variables, and since X's performance in the heating situation varies in accordance with their variations, we can also regard this as a reduction of variety with respect to the number of systems in which X is an element. But given X's multiple responsibilities in connection with maintaining a constant temperature, it is very likely that two things will occur. First, the fact that he can be in only one place at a time will limit the effectiveness of the organization. Second, the performance in one function will interfere with the performance of another. Hence, still more improvement could be achieved by adding persons Y and Z. Then X could remain in the room noting temperature changes sufficient to cause discomfort, calling to Y when he became too warm or too cool. Y could then add fuel to a fire that he maintained at a level which resulted in the least number of signals of discomfort from X. Z, of course, could stand by the window ready to throw it open when X indicated that he was uncomfortably warm.

This is a ridiculous example. But, what makes it ridiculous is the fact that the system is terribly inefficient. We have three persons devoting all their time to a relatively ineffective system-for-maintaining-constant-temperature. Efficiency, however, introduces an additional variable, and it is clear that a system-for-maintaining-constant-temperature effectively is not necessarily the same as a system-for-maintaining-constant-temperature efficiently. It is not at all uncommon to find that maximizing the one entails an unacceptable sacrifice on the other.

Ridiculous as it may seem, the above illustration seems to point toward the conclusions: (1) organizational improvement can be achieved by reducing variety with respect to the activities in which elements are engaged, i.e. by reducing variety with respect to the number of systems in which the element is active (specialization again); (2) organizational improvement can be achieved by reducing the variety with respect to the number of functions in which an element is involved in a given system; and (3) the second type of improvement can be gained only by adding elements, a procedure which increases the variety of conceivable relational patterns.

One point needs clarification before we proceed further. In the discussion thus far we have spoken of the repertoire of alternative states available to elements without distinguishing clearly between alternative functions in which the element may be a term, on the one hand, and alternative values of the element as a variable in a given function, on the other. The reason for raising this point is that an important kind of organizational change involves increasing the variety of values available to an element as a variable in a given function. Consider the case of a ship's helmsman. Here we have the ship, the compass, the helmsman, the wheel, and the rudder as elements of a system-for-maintaining-constant-direction. Imagine the unlikely situation in which the compass can take on only three values instead of 360°, say, on-course, off-course-to-the-left, and off-course-to-the-right. Here the number of alternative states available to the compass is a constant which limits the number of alternative states available to the system. Under these conditions it is clear that even if the activity of the helmsman is infinitely variable in terms of the amount that he is capable of turning the wheel, he is effectively only a three-value variable. He can only turn the wheel left, turn it right, or not turn it at all, and his responses to a 45° deviation from course will probably be the same as his responses to a 180° deviation from course. Two obvious consequences of this situation are (1) the ship will oscillate around the desired course with a great deal of instability, and (2) the helmsman will be forced to concentrate all his energy and attention on the task of steering. The system is both ineffective and inefficient.*

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*To put the above example in the terms of the preceding discussion, let us consider only the compass and the helmsman, each of which is a three-value variable. If the two variables are independent there are nine conceivable configurations of values, one value from each variable. If the variables are perfectly correlated, then only three of these nine configurations actually occur, and the variety in the collection has been reduced from 3.17 to 1.59 bits, a reduction of 1.58 bits. Now, if we increase the number of values which each variable has available to it to seven, then there are 49 conceivable configurations of values with a variety of 5.62 bits. With a perfect correlation the variety is reduced to seven configurations, or 2.81 bits. By adding variety we obtain a gain of 2.81 minus 1.59, or 1.22 bits of organization. The addition of values to each variable, along with the correlation between them, means that the response of the helmsman is now scaled to the deviation from course, and we now have a far more effective, and probably efficient, organization-for-maintaining-constant-direction. Hence, an additional approach to organizational improvement is through the increase of the number of values available to elements as terms in organizational functions. Or, as the mathematician might say, by increasing the range and the domain of the functions.

In each of the areas examined thus far, the bee-hive, the heating system, and the helmsman, we considered a set of elements in which: (1) the several elements were capable of exhibiting two or more states; (2) the properties of elements and the relations among elements were constant; (3) the set of elements exhibited one of a number of conceivable numbers of relational patterns among elements; (4) the set of elements exhibited a number of configurations of element states smaller than the number of conceivable states; (5) the dynamics of the organization were functions of variations in environmental conditions; and (6) the dynamics of the organization tended to hold one or more variables at a relatively constant level. Terminology is far from stabilized in these areas, but systems exhibiting these characterisitcs tend to be identified as "self-regulating" systems, self-regulation referring specifically to characteristics (5) and (6). Since the term "dynamics" carries no necessary connotation of a tendency to return to a given system state following environmental variations, i.e., of equilibrium maintenance, homeostasis, or self-regulation, it seems more appropriate to substitute the term "system regulation" for the term "system dynamics." We need to consider more fully now just what sort of leverage the "for-something"characteristic of systems provides.

III

The defining characteristic of self-regulating systems is goal-directedness. Following MacKay, we define the statement "System A seeks goal X" as follows:

> Let the current state of A (plus its environment) be defined as Y. Let X define that state of A - plus environment which we term the goal of A. Then the statement above (A seeks goal X) implies that the activity of A in a defined group of circumstances is such as inter alia to minimize the discrepancy between X and Y.[5]

We have considered several examples in which this condition is met, including the heating system, in which Y is the current air temperatures and X is the pre-set temperature; the navigational system in which Y is the current heading of the ship, and X is the planned course; and, the bee-hive in which Y is the current air temperature in the hive and X is the air temperature compatible with survival of the brood. One might list any number of additional examples, such as the current and desired production levels of a business firm, the current and desired rate of growth of an economy, the current and desired educational level of a society, and so on. In each case, the central feature is self-regulation in the sense of minimizing the discrepancy between X and Y, i.e., the maintenance of a relatively constant value on some variable.

The essential features of any organization that is to show such activity are shown in Figure 5, where X and Y are represented as points on line F.

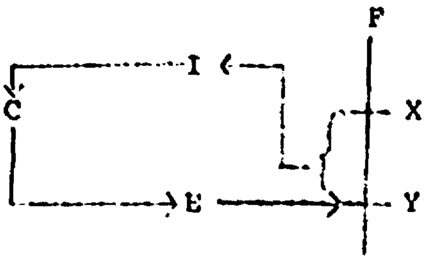

Figure 5
Essential Features of Self Regulation
(After McKay, see footnote #5)

Included are (1) an effector element, E, with a repertoire of activities capable of altering state Y; (2) a control element, C, which selects from moment to moment what E shall do next out of the range of possibilities in its repertoire, and (3) an indicator element, I, from which C receives information about the XY interval. In the simplest case, C receives only a match or a mismatch signal from I. In this situation C can only keep E randomly or systematically running through its repertoire of activity until the mis-match signal disappears. Consider again the case of the helmsman. If the compass indicates only "on-course" or "off-course," then given an "off-course" signal all the helmsman can do is turn the wheel left and right until the compass indicates "on-course." Since more time will be spent in searching than in a goal state, this blindly groping sort of system barely qualifies for the title "self-regulating." A vast improvement can be made, however, if the indicator is capable of providing information concerning the direction and degree of the discrepancy, i.e., if greater variety is provided on the indicator variable. From one point of view, this can be treated as a matter of refining measurement. Thus, a compass which indicates discrepancies on a scale of 360 degrees is a vastly more refined measuring device than one which indicates only on-course and off-course. Hence, to increase the variety on a given variable is to increase the refinement of measurements. Given more refined measurements, the effector action can be selected by the control in accordance with the requirements of the situation reported by the indicator. That is, the action of the effector selected by the control is calculated on the basis of the discrepancy.

It is of some interest to consider more fully the business of measurement and calculation. The basis of calculation is measurement, and by measurement we mean any process of indication the outcome of which is the discrimination of one alternative among a number of possibilities. From this point of view, the identification of an animal as a homo sapien is as much a measurement as the identification of a temperature level as 70 degrees. The first places an object in the category of homo sapiens, and the second places a temperature in the category of 70 degree temperatures. Both are instances of placing an object or phenomenon in a class with like objects or phenomena. The fact that one category has a verbal name and the other a numerical name should not obscure the identity of the processes. Numerical measurement is simply a highly refined way of identifying likenesses, or of categorizing. The difference between the two examples is not that one is classification and the other is measurement; both are classifications and both are measurements. The difference is in the degree of discrimination possible and what can be done on the basis of the measurement, for measurement is a prerequisite to the application of calculation to phenomena.

Calculation, however, cannot be performed with measurements alone. It requires the inclusion of operations and relations. The measurements which specify the cost of one object as $10.00, the cost of another as $7.00 and one's current assets as $13.00 cannot, by themselves, be used to calculate anything. One has to include such operations as "add," "subtract," "divide," and such relations as "equal to," "more than," "less than," and so on. Given these, one can calculate ($10.00 + $7.00 = $17.00, $17.00 - $13.00 = $4.00) the amount of money one must acquire (add) in order to make both purchases. Similarly, the identification of an animal as a homo sapien, and another as a reptile provides a basis for calculation only in conjuction with such relations and operations as specified in the theory of evolution, i.e., is the ancestor of, and interbreeds. The identification of an object as having the monetary value of $10.00 means that that object stands in all the relations to other objects similarly measured that 10 stands to other numbers. In the same way, the identification of an animal as a homo sapien means that that object stands in all the relations to other objects identified in terms of the biological taxonomy that the term homo sapiens stands to other terms in the taxonomy specified by the theory of evolution.

Returning to the groping helmsman, we can see that making the indicator provide the direction of the discrepancy affords the opportunity to ascertain relations abetween two sets of measurements, and to calculate the operations required to yield a given measurement. That is, he can now discover (1) that certain positions of the wheel are associated with the on-course signal; (2) that certain positions of the wheel are associated with the off-course-to-the-left signal; (3) that certain positions of the wheel are associated with the off-course-to-the-right signal; (4) that altering the position of the wheel to the right on the appearance of an off-course-to-the left signal is followed more quickly by an on-course signal than altering the position of the wheel to the left; (5) that altering the position of the wheel to the left on the appearance of an off-course-to-the-right is followed more quickly by an on-course signal than altering the position of the wheel to the right. Then the helmsman can calculate in exactly the same sense that one calculates with numbers. To say that one must add $4.00 to $13.00 to get $17.00 is precisely the same as saying that one must turn the wheel to the right from its present position to get from an off-course-to-left signal to an on-course signal.

A minimum degree of calculation is present even in the organization in which the control merely has the effector run through its repertoire until the mis-match signal disappears. The calculation is of the form, given a mis-match signal, activity is more likely to lead to its disappearance than is inactivity. But recognition of the fact that we can conceive of varying degrees of calculation suggests several things. One is that simply adding variety to a variable, or adding to the number of states available to an element, is no guarantee of organizational improvement. To be useful, refined measurement must be accompanied by calculation. Thus, it would be pointless to increase the physician's diagnostic skill if, having made the diagnosis, he did not know what to do to alter the situation. Another is that we can now conceive of the organization which has the capacity to profit from past experience, and hence the capacity to improve its self-regulation. Refining measurements, or adding values on a variable, would seem to constitute a change in the properties of the element.

This point can be clarified by reconsidering the thermostatic example. In that example the collection consisted of four elements, the air, the thermocouple, the valve, and the heater. Each element was capable of appearing in two states, and the total conceivable configurations of element states was 16. In the operating system, however, that number was reduced to two, one in which the temperature was high, the thermocouple was open, the valve was closed, the heater was off, and one in which the reverse was true. Now, if, on receipt of a mis-match signal, the control (in this area the valve) does not select on as the activity of the heater, but instead keeps the heater alternately trying on and off, then we no longer have only two possible system states, i.e., configurations of element values. There are now three possible states, since the heater can be either on or off when the mis-match signal is present. What permits us to reduce the number of states to two is our ability to calculate, our knowledge that given a low temperature, the way to increase it is to turn up the heater. If we extend this kind of thinking to human affairs, in which we are far less able to base selections on calculation, it is obvious that the effectiveness of a given organization can be increased through the acquisition of more information about what operations yield what effects in a given set of circumstances. Ultimately, it seems to come to this; all we can do here is to indicate what is involved in organization, organizational change, and organizational improvement. Though this is an essential prerequisite, what we really need is more knowledge about what kinds of operations lead to the desired outcomes. In the case of the heating system improvements could be made because we knew (1) what outcome was desired, (2) what operations were required to produce that outcome, and (3) the sequence in which those operations had to be performed. From that point on improvement was a matter of progressive mechanization, i.e., the development of more sensitive measuring devices, the development of more specialized components, and the development of better control relations among components. When we turn to educational affairs we encounter difficulties on all these counts. We are not all certain what outcomes are desired. We know altogether too little about the operations required to yield those outcomes. We know altogether too little about how operations might best be sequenced. And, finally in human affairs the problem of control is very, very different from that in mechanical systems.

IV

In each of the situations considered thus far, system regulation has, apart from the discussion of calculation, been treated as unproblematic. That is, we considered cases in which the uncertainty with respect to which a number of alternative configurations of element states could occur was reduced from some conveivable maximum to some smaller number, e.g., in the thermostatic example only two out of a conceivable 16 configurations were seen to occur, and the regulatory activities of the organization consisted in alternations between those two states of the organization.

While it may be safe to assume that a high degree of organization exists in mechanical collections, the same assumption with respect to human elements is obviously questionable, and, if we consider any human organizations, we are likely to agree that it is by no means certain that only two configurations of element selections are possible, or even highly probable. But the reason for this is not necessarily inability to calculate, very often the operations required are known and the problem is to get the components to perform them. This brings us to the central process of self-regulating organizations, namely, the flow of information.

Figure 5 may be regarded as an information flow map, where information is said to flow from I to C when an event, action, or situation at I selects, or determines, the form of some action at C without necessarily supplying the energy for it. For example:

> When the front door button (A) is pressed and the bell (B) rings in the kitchen, it makes sense in terms of information theory to say that the information flows from door to kitchen, even though the energy to ring the bell comes from a transformer which is in the kitchen. We can draw a simple map showing a line from A to B say that information flows from A to B no matter what may be the flow of energy involved--where it comes from or how much is required.

In much the same way, we can draw a map showing the

> lines of information flow (or communication) between the units of an army and headquarters regardless of whether the messages are conveyed by radio, or telephone, or signal lamp. The lines of our map are not meant to show what happens to the energy transmitted, but to depict the flow of information, in the sense in which information theory uses the term (i.e., in the sense that information may be said to have flowed from A to B when an action at A selects or determines which of a number of alternative actions occurs at B).[6]

The point to be emphasized here is that the pattern of relations among elements discussed earlier may be viewed as channels through which information flows. And, if we now speak of these relations, or the flow of information, in terms of probability instead of mere presence or absence, then it is clear that the number of possible patterns of relations is increased fantastically. Consider the following example, a domestic oven with the following elements: (1) a burner, (2) a valve controlling the flow of fuel to the burner, (3) a thermometer indicating the air temperature in the oven, (4) the air in the oven, and (5) a housewife. With five elements there are $n(n-1) = 20$ conceivable pair relations among pairs of elements, and if each of these relations can be either present or absent, then there are 2^{20} conceivable relational patterns. However, if we allow that each relation can have a probability of occurrence in tenths from 0.0 to 1.0 (instead of absent or present, which is the case of 0.0 and 1.0 probability) then the number of conceivable relational patterns is $n^{n(n-1)} = 10^{90}$. Even if the direction of information flow among the five elements listed above is specified, as in Figure 6, there are still 10^5 patterns of relations based on the probability of information flow, clearly, this is a more realistic representation of the situation when the elements of the collection are human individuals, and it reveals that a major context in which organizational improvement may be sought is in changing the probabilities of information flow among elements. Perhaps a more useful way to treat the matter is to say that information may be said to have flowed from A to B when an action at A alters the probabilities of occurrence of the alternatives available at B.

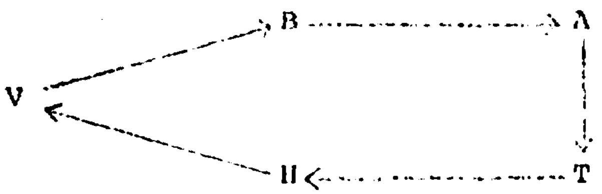

Figure 6

However, it should not be assumed that providing for the flow of information from element to element (in the sense of happenings at A altering the probabilities of occurrence of the several alternatives available at B) is a guarantee of increased stability in the goal variable. There are at least two reasons for this. First, it is conceivable that certain information flow channels impede, rather than facilitate, the stabilization of the goal variable. Second, if say in Figure 6, H can only manipulate V in such a way as to keep B in random activity, then there is no reason to suppose that information flow from T to H will have a pronounced stabilizing effect on A. The flow of information, or control, must be accompanied by calculation. That is, there is little to be gained by having events at T determine the probabilities of events at H if we do not know what events at H will reduce the discrepancy which determined the action of T. To speak of the physician again, it would be pointless to have his actions determine the probabilities of events in the patient's physiology if he cannot calculate the events to be determined on the basis of their effect on the illness in question.

To summarize the discussion thus far, we have (1) defined organization as the particular set of element and inter-element constants exhibited by a collection; (2) defined organizational change as a change in one or more of these constants; (3) defined organizational improvement as a change in one or more of these constants which yields more effective control of a criterion variable; (4) defined effectiveness as the degree to which the value of a criterion variable is stabilized; (5) differentiated organizational change from system regulation; and, (6) identified organizational change and change in system regulation as distinct approaches to increased organizational effectiveness. More specifically, we have identified within the category of organizational change, the following approaches, (1) differentiation among elements; (2) changes in the number of states available to elements, i.e., refined measurements; (3) changes in the probability of information flow among elements; (4) changes in the capacity to calculate; and, (5) changes in the capacity of events at A to alter the probabilities of alternative events at B. <u>All these may be summarized by indicating that the essential ingredients of self-regulating systems are measurement, calculation, and the transmission of information.</u>

In order to bring the discussion more directly to bear on the organization of human collections, we need to consider several additional points. First, the examples utilized above may suggest that self-regulating systems are simple, unitary entities, simple in the sense that they exhibit only two states (active when a disrepancy exists, inactive when no discrepancy exists) and unitary in the sense that they may be regarded as single undifferentiated systems, having a single organization. For all practical purposes this may sometimes be so, but the more important case is that in which a regulatory system is superimposed on a lower order system which is engaged in a relatively continuous process of some kind. In the helmsman illustration, for example, there are at least two distinct systems, each with its own organization. There are (1) the system which produces the motion of the vessel; and (2) the system which controls the direction of motion, the latter being activated only when a discrepancy occurs. For certain purposes the several systems may be regarded as elements in the organization of a single more inclusive system, but misleading results can be obtained when one relates variations in the organization of one sub-system to variations in the output of another without being aware he is doing so.

A further point is that in most of the illustrations utilized we have considered single purpose sytems, e.g., a system-for-maintaining-constant-temperature, and a system-for-maintaining-constant-direction. While these sytems are useful for illustrative purposes, they do not correspond well with the systems of human collections in which it is typical for a number of potentially conflicting goals to be sought. In order to represent this situation, Figure 5 would have to be expanded to include lines of activity F_1, F_2, F_3 and so on, as well as an additional element designed to establish priorities among the several goals. Even more important for present purposes is the fact that a detailed analysis would require that each of the elements in the simplified representation of a self-regulating system (Fig. 5) be treated as a system in its own right with its constituent element and relational constants. Thus, the effector element would need to be conceived as an effector system capable of being changed and improved upon.

V

Our discussion thus far has taken us through a number of steps. We first made a distinction between system organization and system dynamics, or regulation, a distinction which provided a specific meaning for the term organizational change. Following that we noted that a considerable reduction in the apparently insurmountable complexity of the task of organizing a system is achieved by virtue of the fact that we organize systems for something. Organizational improvement was then seen to be an organizational change preferred in its own right, or preferred because of its consequences for a criterion variable. Thereafter we considered some of the more obvious ways of improving the organization of a system, including the reduction of variety, refining measurement, improving calcula and so on, arriving ultimately at the conclusion that the ba ingredients of self-regulating systems are measurement, calc , and the flow of information. Measurement is involved in a two major contexts, that of specifying objectives, and that fining the means of establishing the degree and direction c tions from the goal state. Calculation consists in the uti n of measurements, operations, and relations to determine in the consequences of those operations, given those measurements, or alternatively, the determination of the operations required to bring about a given change. Hence, in order to make improvements in the organization of the educational organization we need three things (1) a more precise statement of what variables we are attempting to control; (2) more discriminative means of measuring the existing state on those variables; and; (3) an increased capacity to calculate the operations necessary to reduce discrepancies.

What it comes to is this; we cannot make improvements in the organization of education unless we know more about the relation between organization and the dynamics. We must first specify more clearly what variables we wish to control, and then identify the system in which they are embedded. Given the definition of organization as the unit and relational constants which, if altered, alter the dynamics of the system, only then can we investigate systematically the relation between organization and dynamics. In order to see how this might be done let us consider the scientist studying the matrix of beads referred to earlier. He knows that he can predict the position of the matrix from the position and momentum at a previous time, i.e., he knows the dynamics of its motion. Now suppose he wants to devise a matrix which moves faster. What he needs to know is what are the constants underlying this system. How can he discover what they are? The standard scientific procedure is to examine each possibility in turn while holding other things constant. Keep everything else the same and alter the color of the beads, then the shape, then the weight, and so on. The process is simplified, of course, by formulating and testing alternative hypotheses, but this is the standard approach of experimental science.

Another possibility can be illustrated by the matrix example. If one displaced the matrix farther and farther from its rest position, the elastic bands would eventually break, or perhaps a bead would fly off, and the dynamics of the system would be altered drastically. By definition, this is an organizational change. Thus, another way of identifying the organization underlying a system is to push it to the breaking point.

Neither of these two approaches seems very realistic. Most of us would rule out the possibility of pushing the educational system to the breaking point just to see how it is organized, even if we knew how to do it. The shortcomings of the first alternative are more complex. As a number of commentators have noted, the range of phenomena to which the "vary-one-thing-at-a-time" approach is applicable is relatively restricted. While there may be a number of suitable applications, it is difficult to see how it might be applied to a systematic examination of organizational alternatives in a large scale collectively. It might be argued that most of the difficulties encountered can be overcome, or at least minimized, through the use of statistical controls across large sample. This too is questionable, for the variability of the organization of existing educational systems is much less than we would wish to study.

We have reached a conclusion here which many others reached long ago. It is a conclusion often asserted, but never demonstrated, at least in terms that I can comprehend. But having myself worked through, however superficially, the enormous complexity of the question of system organization, I am forced to concede that the analytical approach cannot be applied successfully to the phenomena in question. By analytic approach, I mean the scientific procedure of resolving an entity into its "atomic" units, or component parts, which may then be examined in isolation from one another, and of experimentally varying configurations of these units to identify their effects. Perhaps the simplest illustration of the impossibility of this approach is this: given a number of points between each pair of which a line may be drawn, the number of ways of connecting the points is $2^{n(n-1)}$. If the number of points is five, then $2^{5(5-1)} = 1,048,576$. In other words, there are more than a million possible patterns of a single relation between five persons. How long would it take us to explore all these alternatives? But the problem is not strictly one of numbers. Examining one element in isolation while others are held constant requires that the system be relatively closed, i.e., immune to external influences and that effects among elements within the system be negligible. If the system is open to external influences, then one may have great difficulty in holding things constant. And, if elements are interdependent, then the behavior of the element in isolation will bear little resemblance to its behavior in the system. Neither of these conditions obtain in many of the phenomena with which the life and social sciences are concerned.

Number of alternatives, openness, and interdependence are limiting factors, but they may not be the most important. The analysis of phenomena into elementary components works well when the system is an aggregate of components. In the contexts which concern us, however, this is seldom the case. The living organism, for example is not a simple aggregation of cells, and cells themselves are not simple aggregations of atoms. Atoms are organized into molecular compounds, molecules into macro-molecules, macro-molecules into organelles, organelles into cells, cells into tissues, tissues and organs, and so on. One simply cannot view the organism as an aggregate of particles. If one begins with the cell and attempts to describe the organism as an aggregation of these he immediately encounters the fact cells in brain tissue do not behave in the same way as cells in muscle tissue. It is not that the individual cells are different, it is a case of them being organized differently. The organism is not an aggregation of elementary particles, but a hierarchy of sub-assemblies. On one level, the cell is a relatively self-contained unit from which higher-order units may be assembled. At the same time, it is an assembly of lower-order units. In the human collections to which we refer as organizations we find the same thing. The organization is not an aggregation of units, but a hierarchy of hierarchically-ordered sub-assemblies. Each level operates according to its own laws, and the laws of one level cannot be deduced from a knowledge of the laws of another level.

The significance of this conclusion for the investigation and improvement of educational organization is this. The examination of all possible alternatives, either in controlled scientific experimentation, or in less rigorous field experimentation simply is not a realistic possibility. Even if we find it possible to identify what may be usefully called the elementary units of organization, and even if we find it possible to identify succession of levels on which these are organized, we cannot hope to study experimentally even a major part of the organizational options on a given level. Suppose, for example, that we have the following; we begin with six five-unit assemblies, each of which can be organized in more than a million different ways. Given the organization of the first-order assemblies; there is an even larger number of ways of organizing them into one or more second-order assemblies. If we choose to create one six-unit second-order assembly there are 2^{30} possibilities. Or, we may decide to create three two-unit second-order assemblies, in which case there are 64 ways of organizing them.

The problem is not quite as complex as we have made it appear. In organizing five persons to achieve a given result, we eliminate a great number of the more than one million possibilities on the basis of common sense. We know that some things have to be done before others, and that the nature of the technical task rules out some alternatives. Even so, the number of options remaining is very large, especially when we consider the problem of organizing hundreds of thousands of persons, and the question remains, what is the most feasible approach to organizational improvement. Since we are concerned about the present and the immediate future I think we can rule out for the time being such potentially useful approaches as those which are emerging under the broad heading of "systems theory," e.g., operations research, systems engineering, systems analysis, decision theory, game theory, etc. However useful these may be in the future, they seem to provide little practical assistance at the present moment, at least in education.

The most promising approach that I can see at the present time is to try to establish the conditions which enable us to take advantage of the properties of historically successful complex systems. Successful systems, as the term is used here, are those which have not only survived, but which have also maintained a sufficient degree of flexibility in their internal organization to permit further evolution in response to a continuously evolving environment. Thus, the koala bear has survived, but could not be considered successful, since the organization of its digestive system permits only a diet of a certain kind of leaves. It is at an evolutionary dead-end.

The notion of an evolving environment is a rather novel one, but as von Foerster[7] points out, the inanimate world has evolved in the same general direction as the animate. Following von Foerster, we may think of the environment as constrained in spatial, temporal, and a variety of other senses. A world without temporal constraints is one in which transitions from any state to any other state can occur, anything can follow anything. A world without spatial constraints is one in which there are no enduring objects, entities, or substances. In the absence of temporal constraints, rocks could change into feathers, and feathers into trees. In the absence of spatial constraints there would be no identifiable rocks, feathers, or trees.

Clearly, the simplest world is one in which there is the maximum amount of both sorts of constraint, so that everything that is remains perpetually as it is. Less simple, but still relatively so, is a deterministic world, i.e., one in which there is absolute certainty with respect to what events can be neighbors to one another in time. Presumably life on Earth began in the primordial seas in which there was relatively little variation in the kinds of spatial constraints present, and in which temperature and chemical transitions were minimal. From that point on the history of the Earth is one of not only the evolution of complex forms of life from simple forms, but also the evolution of a complex environment from a simple environment. From this point of view, successful systems are those whose organizations contain a sufficient amount of variety, uncertainty, or flexibility to keep pace with the increasing complexity of the environment.

In the broad sense, the characteristics of such systems are reasonably well known. The account which follows is due primarily to Koestler.[8] These (1) systems (2) internally-selective, (3) self-repairing, (4) open, (5) multi-leveled, (6) branching, (7) hierarchies of (8) semi-autonomous, (9) interactive, (10) rule-governed, (11) strategically-flexible, (12) self-regulating, (13) organized subsystems. Each of the numbered terms in the preceding sentence identifies a characteristic feature of what Koestler refers to as "open hierarchical systems." The term "system" is itself numbered in order to emphasize the inter-dependence of parts. A system may be likened, with many qualifications, to a set of inter-locking gears. Each gear is, to some degree, locked in, or meshed with, one or more contiguous gears. As a consequence there are limits to the degree that one gear can be changed independently of others. Some kinds of change can be made only by making corresponding changes through-out the entire set of inter-locking elements, and when a change in a part is made it usually produces effects that affect the entire mechanism. Such a mechanism has an internal harmony which permits the persistence of only those changes which fit the pattern. Within a system selective controls operate to eliminate incompatible changes and to coordinate acceptable ones. For example, embryonic development,

> . . . is a many-levelled hierarchic process, and this leads one to assume that selective and regulative controls operate on several levels to eliminate harmful mutations and to coordinate acceptable ones. Various authors have suggested that this screening process might start at the very base of the hierarchy, on the level of molecular chemistry of the gene-complex. Mutations are chemical changes, presumably caused by the impact of cosmic radiations and other factors on the germ cells. The changes consist in alterations in the sequence of chemical units in the chromosomes--the four letters of the genetic alphabet. Mostly they are the equivalent of misprints. But there seems to be again a hierarchy of correctors and proof readers at work to eliminate these; 'The struggle for survival of mutations begins at the moment mutation occurs' writes L.L. Whyte. 'It is obvious that entirely arbitrary changes will not be chemically or functionally stable . . . . Only those changes which result in a mutated system that satisfies certain stringent chemical and functional conditions will be able to survive . . . .' All others will be eliminated either by the death of the mutated cell and its offspring at an early stage or, as we shall presently see, by the remarkable self-repairing properties of the gene-complex as a whole. (131-32)

The relevant point in the present context is that an educational agency is most appropriately regarded as a patterned system with an internal coherence with which certain kinds of changes are compatible but with which others are not. When functioning in accordance with the principles of internal selection it eliminates incompatible changes, and accepts only those changes which will affect the whole system in a harmonious way. Changes which are accepted tend to be those made possible by the possibility of simultaneous alteration of a number of parts. In terms of implications for educational improvement, this means, look for the pattern of linkages between elements, make changes compatible with the pattern, and be prepared to trace the implications of a given change through a succession of interlocking elements.

It is not always the case that only beneficial changes occur, however, and it is here that the "self-repairing" properties of open hierarchical systems become operative. However, metaphysical the notion may seem, such systems seem to function in accordance with an over-all plan so that deviations from it, if not disasterous, tend to be corrected automatically. The fruit fly, for example, has a recessive, mutant gene which, when paired in the fertilized egg, produces an eye-less fly. If only eyeless flys interbreed, then a species of eyeless flys is produced. But, strangely enough,

> . . . within a few generations, flies appear in the inbred 'eyeless' stock with eyes that are perfectly normal. The traditional explanation of this remarkable phenomenon is that the other members of the gene-complex have been 'reshuffled and recombined in such a way that they deputize for the missing normal eye-forming gene.' Now reshuffling, as every poker player knows is a randomizing process. No biologist would be so perverse as to suggest that the new insect eye evolved by pure chance, thus repeating within a few generations an evolutionary process which took hundreds of millions of years. Nor does the concept of natural selection provide the slightest help in this case. The recombination of genes to deputize for the missing gene must have been coordinated according to some over-all plan which includes the rules of genetic self-repair after certain types of damage by deleterious mutations. But such coordinative controls can operate only on levels higher than that of individual genes. Once more we are driven to the conclusion that the genetic code is not an architect's blueprint; that the gene-complex and its internal environment form a remarkably stable, closely knit, self-regulating micro-hierarchy; and that mutated genes in any of its [sub-assemblies] are liable to cause corresponding reactions in others, coordinated by higher levels.[10] (133-34)

In order for either the internal-selection or self-repairing mechanism of a system to function at all, there must obviously be opportunity for changes to occur from the lowest to the highest levels in the hierarchy. There must be opportunities for variation. But variations which are arbitrary or unstable must be eliminated while variations that affect the whole system in a harmonious way must be coordinated by higher levels in the hierarchy.

Openness identifies, for any given system, its irreducability to ultimate particles on the one hand, and its inclusion in a higher-order system on the other. Every system is constituted by parts which are also systems, and every system is a part of some higher order system. Wherever man looks in the animate and inanimate worlds he finds not ultimate indivisible particles, but particles within particles, within particles, on an ever diminishing scale. Organisms consist of muscles, bones, tissues, and organs. These in turn consist of cells, cells consist of organelles, organelles of molecules, molecules of atoms, and so on to the nucleus and the increasing variety of sub-atomic particles therein. In the other direction, each divisible element combines with other elements of its kind to form higher order elements in infinite hierarchical regress.

The multi-leveled, branching, hierarchical nature of organized systems was touched upon immediately above. The picture is one of an inverted tree, with the trunk dividing into branches, branches into twigs, a world geneological table, as it were. The whole, which is never a whole in any absolute sense, is not an aggregation of elementary units or particles, but an organized system of stable, organized sub-assemblies, a hierarchy of hierarchies, of parts within parts. One cannot treat the organism as an aggregation of cells, for cells are organized differently into different sorts of tissues. The behavior of a cell, for example, cannot be explained, or predicted, solely in terms of the characterisitcs of the cell itself. Its behavior is, in part, a function of its relations with other cells. The organization of sub-sub-particles into sub-particles, and the sub-particles into particles is a factor which must be taken into account. The behavior of each level is lawful, but each level behaves in accordance with its own rules. The rules or laws governing the interaction of atoms are not the same as those governing sub-atomic particles, and vice-versa. Moreover, neither can be derived from the other. Much common-sense thinking about the educational system, and other agencies as well, is fundamentally atomistic. We tend to view each member of an organization as a fully autonomous unit(s) the behavior of which can be attributed solely to its (their) individual characteristics. We attribute difficulties to the recalcitrance of individuals and in attempting to improve situations, focus on changing this individual. The more relistic view would seem to be one in which the individual is seen as linked with other individuals on the same level, and in which levels are linked with one another.

The implication for the organization of the educational system is not that some fundamental changes are required, for the above simply describes what seems to be the case. The implication is that in a system functioning explicitly in accordance with these princiiples, we would devote less time to talking about the conservatism of teachers, about the bureaucratic characteristics of principals, about the political characteristics of superintendent, and more time to examining the linkages within and between levels to identify the sources of such behavior.

Each level in the hierarchy constitutes a stable, organized semi-autonomous whole, discontinuous from higher levels in certain respects, yet still an interactive part of a larger whole. In certain respects the individual cell is an autonomous unit but in other respects it is subordinated to the tissue of which it is a part. Thus, there is no ultimate building block, only building blocks constructed from lower-order building blocks. Although each level functions in accordance with fixed limiting rules, there are available flexible strategies governed by environmental feedbacks. Each part constitutes a lawfully constrained self-regulating system, triggered into action by higher levels in the hierarchy, spelling out the implications of the triggering message in accordance with its own rules under the guidance of environmental feedbacks.

Taken as a whole, the action of a system consists in triggering commands originating at the apex undergoing step-wise elaboration, concretization, and specification at each successive level, each superordinate level leaving the immediately subordinate level to spell out the implications of the command in terms of the flexible strategies available to it in accordance with environmental conditions. Each sub-assembly possesses multi-potential capacity within the constraints governing its action. The future state of a cell, for example, cannot be predicted from its states at a previous time. Up to a point, a cell can develop in any number of different directions depending on its surroundings.

> The process has been compared to the development of the embryo: the fertilized egg contains all the potentialities of the future individual; these are then spelled out in successive stages of differentiation. It could also be compared to the way a military command is executed: the generalized order, "Eighth Army will advance in direction of Tobruk," issued from the apex of the hierarchy, is concretized in more detail at each of the lower echelons.[11] (41)

In the opposite direction we are presented with an ascending hierarchy of filters or scanners which successively collect, analyze abstract and transmit information to the level above. Koestler illustrates the general process with the specific example of perceptual screening and abstraction. Human perception is highly selective, transmitting to the level of consciousness only a fraction of the sensations impinging on the senses. One is not ordinarily aware of the multitude of sounds, visual details, or odors present in a given setting. Moreover, the information delivered to higher levels is not the same as that received by the sense organs themselves. The retinal images of two persons at different distances from an observer in a room vary in size, yet the observer "sees" the two persons as the same size. Finally, in many cases it is not detailed, unorganized elementary bits of information that is transmitted, but patterns, abstracted universals.

> Thus at the series of relay stations through which the input stream must pass, it is subjected to filtering, scanning and analyzing processes, which strip it of irrelevancies extract stable configurations from the flux of sensations, analyze and identify patterns of events in space and time.[12]

Koestler compares the combined processes to a military operation:

> The General in Command issues an order which contains the plan of action in broad outlines: this is transmitted from Divisional Headquarters to Brigade Headquarters, and so on; at each successive echelon the plan is more elaborated until the last detail is filled in. The reverse process takes place in collecting information on the movements of the enemy and the lie of the land. The data are collected on the lowest, local levels by patrols reconnoitring the terrain. They are then stripped of irrelevant detail, condensed, filtered and combined with data from other sources at each higher echelon, as the stream of information flows upward along the converging branches of the hierarchy.[13] (77)

The central feature of the system as a whole is an equilibrium between constraint and autonomy.

> . . . it is essential for the stability and efficient functioning of the [system] that each of its subdivisions should operate as an autonomous, self-reliant unit which, though subject to controls from above, must have a degree of independence and take routine contingencies in its stride, without asking higher authority for instructions.[14] (55)

The preceding portrays the dynamics of the organized system from a static point of view. That is, we have presented a cross-sectional view of its normal operation as it might appear during a given period of time. Our main concern, however, is organizational change and improvement. Hence, we are interested not only in the characteristics associated with adequate functioning during a given period of time, but also in those associated with adequate development in response to an environment characterized by increasing uncertainty. The environment of the educational system of a few decades ago was relatively simple both with respect to its spatial* and temporal aspects. The clientel of the school was relatively homogeneous, and there was relatively little uncertainty with respect to what events would be neighbors in time to existing ones. Today's

* "Spatial complexity" here refers to the hetrogeniety environmental "objects."

educational system faces an increasingly hetrogeneous, and an increasingly uncertain environment. More to the point, the rate of change is itself increasing, and there is little reason to believe that that pattern will change. Hence, our question is not only "What characteristics are associated with adequate functioning at a given point in time," but also, "What characteristics are associated with adequate development in the face of increasing environmental complexity?"

But in its most direct form, the question is this: "On the assumption that neither you, nor I, nor the social scientists, can devise an educational system capable of fully fulfilling present demands, not to mention future demands, what kind of educational system is most likely to evolve its own evolving design?" The most plausible answer to that question seems to be, "One patterned after an open hierarchical system as characterized above." In order to see this, we need to turn the branching hierarchy on its side and view it as a process of development extending through time, a process not unlike morphogenisis in embryonic development. As Koestler points out:

> It takes fifty-six generations of cells to produce a human being out of a single, fertilized egg-cell. This is done in a series of steps, each of which involves (a) the multiplication of cells by division, and the subsequent growth of daughter cells; (b) the structural and functional specialization of cells (differentiation); and; (c) the shaping of the organism (morphogenesis).[15] (117)

The shaping of the organism proceeds in accordance with the hierarchical principles outlined above, i.e., through successive stages of articulation in which semi-autonomous sub-assemblies develop under the inducement of biochemical triggers within the constraints of fixed physical-chemical laws, in accordance with biochemical environmental feedbacks. Although governed by fixed rules, embryonic tissues have the capacity to differentiate into the kind of organ best suited to the tissue's position in the growing organism. Thus, if a particular portion of the developing eye of a frog is transplanted under the belly skin of a frog embryo, the skin over the eye will develop into a lens. Embryonic tissues thus have multipotential development capacity, but only to a point. In later stages of development, specialization reduces and eventually eliminates flexibility. Specialization yields a decrease in further developmental capacity.

A second illustration used by Koestler comes from the field of,phsycholinguistics. From the point of view of the naive observer, the generation of spoken or written messages by the human individual is a formidable achievement. Both the apparent problem of speech generation and the human solution to it, are quite exact parallels of the problem of the design of organizations and the human solution to it. The English language is based on 45*elementary units called phonemes, from which higher-order units called morphemes are constructed. Morphemes are the smallest meaningful language units (corresponding to simple words and syllables). The apparent problem of speech generation is this: from 45 elementary units it is possible to construct a staggering number of higher-order units. If we consider only four unit compounds (morphemes) there are millions of possibilities. The same problem is repeated on a succession of higher levels, in the organization of morphemes

* There seems to be some disagreement on the number. One author sets it at 41.

into words, the organization of words into phrases, phrases into sentences, sentences into paragraphs, and so on. When viewed as a process of organizing in terms developed earlier in this paper, the generation of speech seems to present inurmountable complexities. How does one know which combinations are admissable and which are not?

The psycholinguist's account of the mechanisms for dealing with this complexity parallel very closely the biologist's account of the mechanisms of embryonic development. Each level in the hierarchy is governed by its own set of fixed rules which are for the speaker, implicit. Speech is not, in many of its aspects, a matter of deliberate selection from among alternatives, but the perpetuation of received practices. The individual speaker is never actually confronted with the problem of selecting the relatively small number of admissible morphemes from the staggering number of possibilities. The problem was solved for him in the course of evolution. His degrees of freedom are constrained by the "decisions" of his ancestors many generations removed, and his language is a given. The "adoption" of a rule concerning the formation of morphemes from phonemes was an essential step, but it necessarily entailed the foreclosure of certain alternatives. For subsequent generations of speakers, certain alternatives are eliminated. Still, the "selections' made allow a wide variety of possibilities. On any given level prior selections establish broad limits within which a very great number of alternatives is available, and a "living" language is sufficiently flexible to permit one to encode almost any conceivable message.

The actual generation of speech is believed to follow a pattern very much like th t of embryonic development. Starting at the apex of a hierarchy represented by a situation that one wishes to represent, there follows a step-wise process of specification, each level functioning within the constraints imposed by the action taken at the higher level and by its own rules. Figure 7 present the general procedure in diagramatic form. Here the pattern of semi-autonomous

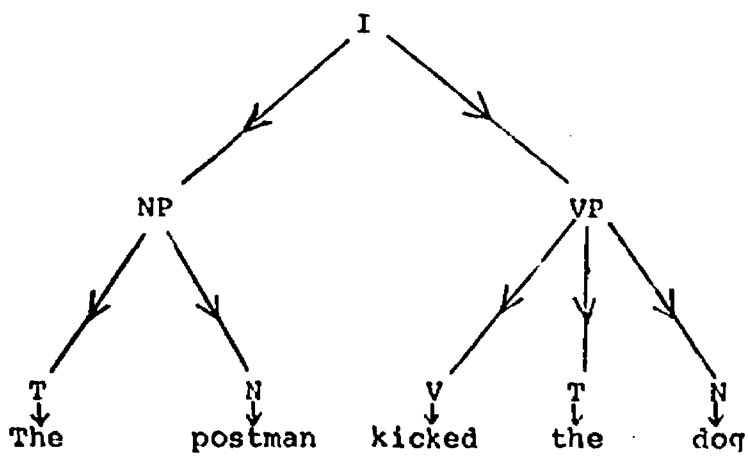

Figure 7

I: idea. NP: noun phrase. VP: verb phrase. T: article. N: noun. V: verb (After Koestler, p.30)

levels constrained by their own rules and by the triggering action of higher levels is clear. Given the state of affairs to be encoded, only certain noun and verb phrases are admissable, and so on down the hierarchy. In a more extended example, say an individual preparing a speech for presentation, one could illustrate the operation of environmental feedbacks, judgments concerning the appropriateness of the presentation for the audience, etc.

The points of direct relevance for our consideration of the organizational system are these. First, the decisions made at one point in time at any given level in the hiearchy should foreclose as few lines of development for subsequent designs as possible. There is no escape from the necessity for making selections, but selections which leave sufficient flexibility to permit the system to cope with a wide variety of situations are preferable to those which impose excessive constraint. Second, selections made at one level in the hierarchy at any given time, should leave open to lower levels the maximum number of alternatives.

Ideally, the function of any given level in relation to lower levels is to make "triggering" decisions which set in train downward through the branching hierarchy, and forward into the future, a sequence of decisions which brings to bear on the problem at hand a far greater degree of intelligence than that possessed by the initiating level. Beer[16] has referred to the "management" of an organization as a "selection amplifier" in which a selection from among alternatives on one level "triggers" on a succession of lower levels further selections from among alternative consequences of the previous selection. Each level brings to bear a knowledge of alternatives not shared by other levels, selections are made by those who have the greatest amount of information about the alternatives available, and who are not likely to select the most appropriate alternative.

We might borrow a term from Ashby[17] and term the system organized in this way an "intelligence amplifier." Ashby regards the capacity to select correctly from among alternative solutions to problems as the epitome of intelligence. Thus, while the highest levels of government may select from among a variety of alternatives the option of putting men on the moon, it would be unintelligent in the extreme for that same level to make the strategic and technical selections required to implement it. From this point of view a considerable amount of educational decision making is sadly lacking in intelligence. The tendency of city school systems toward detailed and uniform policies is too well known to require comment. In British Columbia the only difference is the much greater degree of involvement of the provincial government.

Two final points concerning the characteristics of open hierarchical systems need to be made before we bring this already overlong paper to a close. Both are most easily illustrated in the context of the theory of evolution, in which early thought placed the main causative factor in the selective procedure of the environment. In this view an "active" environment selects the most fit from among randomly produced mutations. More recent thought, still somewhat controversial according to Koestler, while not abandoning the concept of environmental selection, emphasizes the importance of initiative on the part of the organism. Taking note of widespread exploratory behavior on the part of animals, some biologists have been led to postulate an exploratory drive as basic as hunger and sex. The connection made between this and evolution is that animals discover new ways of living, new sources of food which are spread by imitation and which only subsequently receive "genetic endorsement."

> One might call this the 'progress by initiative,' or do-it-yourself theory of evolution. It does not do away with chance mutations, but further narrows down the part

> played by them to that of a lucky hit at a pre-set target, which is sooner or later bound to occur. Once it has occurred, the spontaneously acquired habit or skill becomes hereditary, incorporated into the animal's native repertoire: it no longer has to be invented or learned, it has become an instinct, endorsed by the gene-complex.[18] (155)

This is the first of the points mentioned above. Its significance is that it contradicts the popular version of "systems" theory which holds that change must be externally induced. The second point concerns the capacity of organisms which find themselves in an evolutionary blind alley to re-trace their steps, undoing some of the organizing that has gone before, to start anew on a more promising path. The most common developmental trend leading toward an evolutionary dead-end is over-specialization; the koala bear again. The phylogenetic mechanism through which this eventuality is sometimes avoided is known as neoteny.

> Its result is that the animal begins to breed while still displaying larval or juvenile features; and it frequently happens that the fully adult stage is never reached--it is dropped off the life cycle.[19] (164)

> This tendency towards a 'prolonged childhood' with the corresponding squeezing out of the final adult stage, amounts to a rejuvination and de-specialization of the race--an escape from the cul-du-sac in the evolutionary maze.[20] (164)

Just what might constitute the homologous mechanism in organized human systems is not entirely clear, but several possibilities may be suggested. The most apparent organizational homologue of reproduction for a given organization is the recruitment and on-the-job training of personnel. The most obvious interpretation is that the recruitment of personnel for a school system and their orientation to the system might well be conducted by persons who are still at a "juvenile" stage in their professional careers. The same would seem to apply to the profession as a whole. Perhaps schools of education should be appointing "juvenile professionals" to posts in teacher and administrator training programs. It seems that something of this sort has actually been occurring in administration. Fewer and fewer newly appointed professors have served for lengthy periods of time as practicing administrators prior to their appointment. This may also be the case in teacher training programs. I do not know.

Another possibility is suggested by the following quote from Koestler. "The creative act, in so far as it depends on unconscious resources, presupposes a relaxing of controls and a regression to modes of ideation which are indifferent to the rules of logic, unperturbed by contradiction, untouched by the dogmas and taboos of so-called common sense. At the decisive stage of discovery the codes of disciplined reasoning are suspended--as they are in the dream, the reverie, the manic flight of thought, when the stream of ideation is free to drift, by its own creational gravity, as it were, in an apparently lawless fashion." (Arthur Koestler, The Act of Creation, Macmillan Co. 1967, p. 178.) The key words and phrases here are "relaxing of controls," "regression," "indifferent to rules," "unperturbed by contradiction," "codes of disciplined reasoning are suspended," "lawless." Taking a cue from V. Bertalanffy, who in the article "A Biologist Looks at Human Nature," regards the "revolt of the masses" as a regression from rational, symbol-governed reasoning, to emotional, signal-governed conditioned reflexes, one can speculatively re-write Koestler's statement as follows. The creative collective act, in so far as it depends on ___?___ resources, presupposes a relaxing of social controls and a regression to modes of social interaction which are indifferent to established rules, unperturbed by conflict, untouched by the dogmas and taboos of so-called "good practice." At the decisive stage of social invention the codes of disciplined behavior are suspended as they are in the revolt, when the stream of behavior is free to drift by its own emotional gravity, as it were, in an apparently lawless fashion. Distasteful as the thought is, it is a highly suggestive analogy.

VI

This paper was prepared in response to the invitation to contribute a "conceptual framework" which would "have utility for the future study and development of new structures for organizing education in metropolitan areas. Although it would be immodest, and inaccurate, to assert that this paper itself makes a significant contribution, I think the ideas on which it is based have profound implications. Perhaps the best way to summarize and highlight these implications is to recount a bit of the history of this paper. This paper did not turn out as it was supposed to, and it represents for me, a radical reorientation of thought. The program outlined in the opening pages called for a systematic analysis of the concept of organization, and the allied concepts of organizational change and organizational improvement. The obvious, though unstated, implication being that such an analysis was an essential prerequisite to the study and implementation of organizational change. It seemed painfully obvious at that point that real progress could be made only when we devised a satisfactory way of characterizing the organization of the school. Only then could we specify an initial state, an intervention, a subsequent state and the consequences of that change of state for the relevant variables. Given these prerequisites, we could have done with the unhappy and messy business of "tinkering" with the machinery, and get on with the task of experimenting with various alternatives.

By borrowing a bit here and a bit there, I found to my delight that it was possible to think more sharply about organization, organizational change, and organizational improvement than I had previously been able to do. But delight turned to dismay when, at a point well into the paper, I discovered that I have worked myself into my own cul-du-sac. Having exposed the full complexity of the problem of organization, I found that it did not "go anywhere." The first attempt at extrication tacked on a functional analysis of the educational system and a discussion of metropolitan problem couched in those terms. Despite the encouragement provided by the Seminar Director, the result was far from satisfactory. It simply did not hang together. Only later did I come to realize that these are two entirely different, cross-cutting modes of analysis, both of which are probably essential.

In time I came to see the relevance of Koestler's discussion of open hierarchial systems, but it was only recently, while reading Bertalanffy's General System Theory,[21] that the significance of the cul-du-sac, and of the relevance of Koestler's discussion, became clear. The problem of organization was simply insoluable within the approach that I had adopted. Research of the kind that I had envisioned simply could not cope with the over-whelming complexity of whole systems. While traditional approaches to research undoubtedly remain useful for dealing with limited problems within and between sub-assemblies, it seems impossible to deal simultaneously with multiple factors on multiple levels.

It is important that the point I am making concerning the inadequacy of traditional experimental scientific approaches not be misunderstood. Hence, one last comment on the matter may not be out of order. As Simon[22] has put it, much of the activity of basic science is an application of the paradigm, given a description of some natural phenomena, find the equations, rules, or natural laws for processes that will produce the phenomena. Thus the problem of the social scientist with respect to the broad question of organization (which is very different from specific questions concerning leadership, morale, and so on) is first, describe organizations, and second to find the rule for the processes which generate them. Similarly, much of the activity of applied science is an application of the paradigm, "given the rule for the processes which produce the phenomena, and given control of some of the variables, change the values of those variables in such a way that we produce a state more to our liking."

Now the question at issue here is not one of whether or not the social scientist can describe organizations, but one of whether or not he can find the rules for the processes which generate organizations. In order to accomplish this he must be able to do one of two (possibly three) things. Either he must be able to observe the phenomena as they occur in nature over a sufficient period of time and over a sufficient range of variation, (as astronomers have done in relation to the solar system) to have some confidence in the laws derived, or he must systematically manipulate certain variables while holding others constant. In the realm of human organization neither of these approaches seems possible. In the first context, there seems no basis for assuming that the rather wide range of empirical variability in organizations anywhere near exhausts the possibilities. In the second context, enough has been said about the immense number of possible ways of organizing a collection of elements to discourage even the most optomistic from embarking on an experimental program to assess the consequences of available alternatives.

Nor are these the only reason for skepticism. Another can be put in this way: the task of the social scientist in finding the rule for the processes which generate a given organization (or class of organizations) is the exact parallel of the task of a psycholinguist finding the rule for the processes which generate a particular spoken or written message (or class of messages). The point to be made here is that the psycholinguist would not even try to find such a rule. He would insist that the given message is one of a very large number of messages which can be generated not by a rule, but by sets of rules operating in a multi-leveled hierarchy with sufficient flexibility to permit the generation of a wide variety of alternatives at each level. Thus, even if one knew the general nature of the message a speaker wished to convey (the analogy of an organization goal) and the rules governing the formation of sentences, phrases, complex words, and morphemes, he could not possibly predict the specific content of the message. Given the same information to be conveyed the rules at each level are sufficiently loose to permit the generation of a variety of messages. The very best the psycholinguist could hope to do would be to develop a decision tree and assign conditional probabilities to the several alternatives at each level in the branching hierarchy.

Finally, even if it proves possible for the social scientist to describe organizations and to write sets of rules for the processes which generate them, as psycholinguists seem to have done, we are still a very long way from having solved the applied problem. The reason for this is that the paradigms of applied science in the social and physical areas are very different. While the paradigm for the latter is "change the values of the variables," the paradigm for the former is that plus, "change the rules of the game." Given the rules governing physical processes, we have no choice but to work within those rules. Not so in human organization. Thus, many of the rules can be repealed. In principle, it is within the capacity of the applied psycholinguist to write entirely new rules, to completely reorganize the language. Here again, however, we encounter the insurmountable problem of complexity. Given the number of levels involved, and the number of conceivable possibilities at each level, a program to determine experimentally the "best" possible set of rules for a given purpose, though possible in principle is not possible in practice with available techniques. In the field of organization the situation is very much the same, only more complex.

From these conclusions followed the further conclusion that, at least for the immediately forseeable future, the most promising approach to the improvement of educational organization, metropolitan or otherwise, lay not in bringing to bear the research skills and special knowledge of outside experts, but in attempting to enhance the problem-solving capacities inherent in the educational system itself. Although the preceding discussion probably raises more questions than it answers, the most promising approach to this seems to be through approximating the general characteristics of open hierarchical systems. At this point I am as convinced of this as one can be who has just found it necessary to abandon one of his most firmly held convictions.

FOOTNOTES

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