122

MANAGEMENT SCIENCE
Vol. 17, No. 11, July, 1971
Printed in U.S.A.

TOWARDS A SYSTEM OF SYSTEMS CONCEPTS*

RUSSELL L. ACKOFF

University of Pennsylvania

The concepts and terms commonly used to talk about systems have not themselves been organized into a system. An attempt to do so is made here. *System* and the most important types of system are defined so that differences and similarities are made explicit. Particular attention is given to that type of system of most interest to management scientists: *organizations*. The relationship between a system and its parts is considered and a proposition is put forward that all systems are either variety-increasing or variety-decreasing relative to the behavior of its parts.

Introduction

The concept *system* has come to play a critical role in contemporary science.[1] This preoccupation of scientists in general is reflected among Management Scientists in particular for whom the *systems approach* to problems is fundamental and for whom *organizations*, a special type of system, are the principal subject of study.

The systems approach to problems focuses on systems taken as a whole, not on their parts taken separately. Such an approach is concerned with total-system performance even when a change in only one or a few of its parts is contemplated because there are some properties of systems that can only be treated adequately from a holistic point of view. These properties derive from the *relationships* between parts of systems: how the parts interact and fit together. In an imperfectly organized system even if every part performs as well as possible relative to its own objectives, the total system will often not perform as well as possible relative to its objectives.

Despite the importance of systems concepts and the attention that they have received and are receiving, we do not yet have a unified or integrated set (i.e., a system) of such concepts. Different terms are used to refer to the same thing and the same term is used to refer to different things. This state is aggravated by the fact that the literature of systems research is widely dispersed and is therefore difficult to track. Researchers in a wide variety of disciplines and interdisciplines are contributing to the conceptual development of the systems sciences but these contributions are not as interactive and additive as they might be. Fred Emery [3] has warned against too hasty an effort to remedy this situation:

> It is almost as if the pioneers [of systems thinking], while respectfully noting each other's existence, have felt it incumbent upon themselves to work out their intuitions in their own language, for fear of what might be lost in trying to work through the language of another. Whatever the reason, the results seem to justify the stand-offishness. In a short space of time there has been a considerable accumulation of insights into system dynamics that are readily translatable into different languages and with, as yet, little sign of divisive schools of thought that for instance marred psychology during the 1920s and 1930s. Perhaps this might happen if some influential group of scholars prematurely decide that the time has come for a common conceptual framework (p. 12).

Although I sympathize with Emery's fear, a fear that is rooted in a research perspective, as a teacher I feel a great need to provide my students with a conceptual

* Received June 1970.

[1] For excellent extensive and intensive discussions of 'systems thinking', see F. E. Emery [3] and C. W. Churchman [2].

framework that will assist them in absorbing and synthesizing this large accumulation of insights to which Emery refers. My intent is not to preclude further conceptual exploration, but rather to encourage it and make it more interactive and additive. Despite Emery's warning I feel benefits will accrue to systems research from an evolutionary convergence of concepts into a generally accepted framework. At any rate, little harm is likely to come from my effort to provide the beginnings of such a framework since I can hardly claim to be, or to speak for, "an influential group of scholars".

The framework that follows does not include all concepts relevant to the systems sciences. I have made an effort, however, to include enough of the key concepts so that building on this framework will not be as difficult as construction of the framework itself has been.

One final word of introduction. I have not tried to identify the origin or trace the history of each conceptual idea that is presented in what follows. Hence few credits are provided. I can only compensate for this lack of bibliographic bird-dogging by claiming no credit for any of the elements in what follows, only for the resulting system into which they have been organized. I must, of course, accept responsibility for deficiencies in either the parts or the whole.

Systems

1. A *system* is a set of interrelated elements. Thus a system is an entity which is composed of at least two elements and a relation that holds between each of its elements and at least one other element in the set. Each of a system's elements is connected to every other element, directly or indirectly. Furthermore, no subset of elements is unrelated to any other subset.

2. An *abstract system* is one all of whose elements are concepts. Languages, philosophic systems, and number systems are examples. *Numbers* are concepts but the symbols that represent them, *numerals*, are physical things. Numerals, however, are not the elements of a number system. The use of different numerals to represent the same numbers does not change the nature of the system.

In an abstract system the elements are created by defining and the relationships between them are created by assumptions (e.g., axioms and postulates). Such systems, therefore, are the subject of study of the so-called 'formal sciences'.

3. A *concrete system* is one at least two of whose elements are objects. It is only with such systems that we are concerned here. Unless otherwise noted, 'system' will always be used to mean 'concrete system'.

In concrete systems establishment of the existence and properties of elements and the nature of the relationships between them requires research with an empirical component in it. Such systems, therefore, are the subject of study of the so-called 'non-formal sciences'.

4. The *state of a system* at a moment of time is the set of relevant properties which that system has at that time. Any system has an unlimited number of properties. Only some of these are relevant to any particular research. Hence those which are relevant may change with changes in the purpose of the research. The values of the relevant properties constitute the state of the system. In some cases we may be interested in only two possible states (e.g., off and on, or awake and asleep). In other cases we may be interested in a large or unlimited number of possible states (e.g., a system's velocity or weight).

5. The *environment of a system* is a set of elements and their relevant properties,

which elements are not part of the system but a change in any of which can produce[2] a change in the state of the system. Thus a system's environment consists of all variables which can affect its state. External elements which affect irrelevant properties of a system are not part of its environment.

6. The *state of a system's environment* at a moment of time is the set of its relevant properties at that time. The state of an element or subset of elements of a system or its environment may be similarly defined.

Although concrete systems and their environments are *objective* things, they are also *subjective* insofar as the particular configuration of elements that form both is dictated by the interests of the researcher. Different observers of the same phenomena may conceptualize them into different systems and environments. For example, an architect may consider a house together with its electrical, heating, and water systems as one large system. But a mechanical engineer may consider the heating system as a system and the house as its environment. To a social psychologist a house may be an environment of a family, the system with which he is concerned. To him the relationship between the heating and electrical systems may be irrelevant, but to the architect it may be very relevant.

The elements that form the envirомment of a system and the environment itself may be conceptualized as systems when they become the focus of attention. Every system can be conceptualized as part of another and larger system.

Even an abstract system can have an environment. For example, the metalanguage in which we describe a formal system is the environment of that formal system. Therefore logic is the environment of mathematics.

7. A *closed system* is one that has no environment. An *open system* is one that does. Thus a closed system is one which is conceptualized so that it has no interaction with any element not contained within it; it is completely self-contained. Because systems researchers have found such conceptualizations of relatively restricted use, their attention has increasingly focused on more complex and 'realistic' open systems. 'Openness' and 'closedness' are simultaneously properties of systems and our conceptualizations of them.

Systems may or may not change over time.

8. A system (or environmental) *event* is a change in one or more structural properties of the system (or its environment) over a period of time of specified duration; that is, a change in the structural state of the system (or environment). For example, an event occurs to a house's lighting system when a fuse blows, and to its environment when night falls.

9. A *static* (*one-state*) *system* is one to which no events occur. A table, for example, can be conceptualized as a static concrete system consisting of four legs, top, screws, glue, and so on. Relative to most research purposes it displays no change of structural properties, no change of state. A compass may also be conceptualized as a static system because it virtually always points to the Magnetic North Pole.

10. A *dynamic* (*multi-state*) *system* is one to which events occur, whose state changes over time. An automobile which can move forward or backward and at different speeds is such a system, or a motor which can be either off or on. Such systems can be con-

[2] One thing (x) can be said to produce another (y) in a specified environment and time interval if x is a necessary but not a sufficient condition for y in that environment and time period. Thus a producer is a 'probabilistic cause' of its product. Every producer, since it is not sufficient for its product, has a coproducer of that product (e.g., the producer's environment).

ceptualized as either open or closed; closed if its elements react or respond only to each other.

11. A *homeostatic system* is a static system whose elements and environment are dynamic. Thus a homeostatic system is one that retains its state in a changing environment by internal adjustments. A house that maintains a constant temperature during changing external temperatures is homeostatic. The behavior of its heating subsystem makes this possible.

Note that the same object may be conceptualized as either a static or dynamic system. For most of us a building would be thought of as static, but it might be taken as dynamic by a civil engineer who is interested in structural deformation.

System Changes

12. A *reaction* of a system is a system event for which another event that occurs to the same system or its environment is sufficient. Thus a reaction is a system event that is deterministically caused by another event. For example, if an operator's moving a motor's switch is sufficient to turn that motor off or on, then the change of state of the motor is a reaction to the movement of its switch. In this case, the turning of the switch may be necessary as well as sufficient for the state of the motor. But an event that is sufficient to bring about a change in a system's state may not be necessary for it. For example, sleep may be brought about by drugs administered to a person or it may be self-induced. Thus sleep may be determined by drugs but need not be.

13. A *response* of a system is a system event for which another event that occurs to the same system or to its environment is necessary but not sufficient; that is, a system event produced by another system or environmental event (the *stimulus*). Thus a response is an event of which the system itself is a coproducer. A system does not have to respond to a stimulus, but it does have to react to its cause. Therefore, a person's turning on a light when it gets dark is a response to darkness, but the light's going on when the switch is turned is a reaction.

14. An *act* of a system is a system event for the occurrence of which no change in the system's environment is either necessary or sufficient. Acts, therefore, are self-determined events, autonomous changes. Internal changes—in the states of the system's elements—are both necessary and sufficient to bring about action. Much of the behavior of human beings is of this type, but such behavior is not restricted to humans. A computer, for example, may have its state changed or change the state of its environment because of its own program.

Systems all of whose changes are reactive, responsive, or autonomous (active) can be called reactive, responsive, or autonomous (active), respectively. Most systems, however, display some combination of these types of change.

The classification of systems into reactive, responsive, and autonomous is based on consideration of what brings about changes in them. Now let us consider systems with respect to what kind of changes in themselves and their environments their reactions, responses, and actions bring about.

15. A system's *behavior* is a system event(s) which is either necessary or sufficient for another event in that system or its environment. Thus behavior is a system change which initiates other events. Note that reactions, responses, and actions may themselves constitute behavior. Reactions, responses, and actions are system events *whose antecedents are of interest*. Behavior consists of system events *whose consequences are of interest*. We may, of course, be interested in both the antecedents and consequences of system events.

TABLE 1
Behavioral Classification of Systems

Type of System	Behavior of System	Outcome of Behavior
State-Maintaining	Variable but determined (reactive)	Fixed
Goal-Seeking	Variable and chosen (responsive)	Fixed
Multi-Goal-Seeking and Purposive	Variable and chosen	Variable but determined
Purposeful	Variable and chosen	Variable and chosen

Behavioral Classification of Systems

Understanding the nature of the classification that follows may be aided by Table 1 in which the basis for the classification is revealed.

16. A *state-maintaining system* is one that (1) can react in only one way to any one external or internal event but (2) it reacts differently to different external or internal events, and (3) these different reactions produce the same external or internal state (outcome). Such a system only reacts to changes; it cannot respond because what it does is completely determined by the causing event. Nevertheless it can be said to have the *function* of maintaining the state it produces because it can produce this state in different ways under different conditions.

Thus a heating system whose internal controller turns it on when the room temperature is below a desired level, and turns it off when the temperature is above this level, is state-maintaining. The state it maintains is a room temperature that falls within a small range around its setting. Note that the temperature of the room which affects the system's behavior can be conceptualized as either part of the system or part of its environment. Hence a state-maintaining system may react to either internal or external changes.

In general, most systems with 'stats' (e.g., thermostats and humidistats) are state-maintaining. Any system with a regulated output (e.g., the voltage of the output of a generator) is also state-maintaining.

A compass is also state-maintaining because in many different environments it points to the Magnetic North Pole.

A state-maintaining system must be able to *discriminate* between different internal or external states to changes in which it reacts. Furthermore, as we shall see below, such systems are necessarily *adaptive*, but unlike goal-seeking systems they are not capable of learning because they cannot choose their behavior. They cannot improve with experience.

17. A *goal-seeking system* is one that can respond differently to one or more different external or internal events in one or more different external or internal states and that can respond differently to a particular event in an unchanging environment until it produces a particular state (outcome). Production of this state is its goal. Thus such a system has a *choice* of behavior. A goal-seeking system's behavior is responsive, but not reactive. A state which is sufficient and thus deterministically causes a reaction cannot cause different reactions in the same environment.

Under constant conditions a goal-seeking system may be able to accomplish the same thing in different ways and it may be able to do so under different conditions. If it has *memory*, it can increase its efficiency over time in producing the outcome that is its goal.

For example, an electronic maze-solving rat is a goal-seeking system which, when it runs into a wall of a maze, turns right and if stopped again, goes in the opposite direction, and if stopped again, returns in the direction from which it came. In this way it can eventually solve any solvable maze. If, in addition, it has memory, it can take a 'solution path' on subsequent trials in a familiar maze.

Systems with automatic 'pilots' are goal-seeking. These and other goal-seeking systems may, of course, fail to attain their goals in some situations.

The sequence of behavior which a goal-seeking system carries out in quest of its goal is an example of a process.

18. A *process* is a sequence of behavior that constitutes a system and has a goal-producing function. In some well-definable sense each unit of behavior in the process brings the actor closer to the goal which it seeks. The sequence of behavior that is performed by the electronic rat constitutes a maze-solving process. After each move the rat is closer (i.e., has reduced the number of moves required) to solve the maze. The metabolic process in living things is a similar type of sequence the goal of which is acquisition of energy or, more generally, survival. Production processes are a similar type of sequence whose goal is a particular type of product.

Process behavior displayed by a system may be either reactive, responsive, or active.

19. A *multi-goal-seeking* system is one that is goal-seeking in each of two or more different (initial) external or internal states, and which seeks different goals in at least two different states, the goal being determined by the initial state.

20. A *purposive system* is a multi-goal-seeking system the different goals of which have a common property. Production of that common property is the system's purpose. These types of system can pursue different goals but they do not select the goal to be pursued. The goal is determined by the initiating event. But such a system does choose the means by which to pursue its goals.

A computer which is programmed to play more than one game (e.g., tic-tac-toe and checkers) is multi-goal-seeking. What game it plays is not a matter of its choice, however; it is usually determined by an instruction from an external source. Such a system is also purposive because 'game winning' is a common property of the different goals which it seeks.

21. A *purposeful system* is one which can produce the same outcome in different ways in the same (internal or external) state and can produce different outcomes in the same and different states. Thus a purposeful system is one which can change its goals under constant conditions; it selects ends as well as means and thus displays *will*. Human beings are the most familiar examples of such systems.

Ideal-seeking systems form an important subclass of purposeful systems. Before making their nature explicit we must consider the differences between goals, objectives, and ideals and some concepts related to them. The differences to be considered have relevance only to purposeful systems because only they can choose ends.

A system which can choose between different outcomes can place different values on different outcomes.

22. The *relative value of an outcome* that is a member of an exclusive and exhaustive set of outcomes, to a purposeful system, is the probability that the system will produce that outcome when each of the set of outcomes can be obtained with certainty. The relative value of an outcome can range from 0 to 1.0. That outcome with the highest relative value in a set can be said to be *preferred*.

23. The *goal* of a purposeful system in a particular situation is a preferred outcome that can be obtained within a specified time period.

24. The *objective* of a purposeful system in a particular situation is a preferred outcome that cannot be obtained within a specified period but which can be obtained over a longer time period. Consider a set of possible outcomes ordered along one or more scales (e.g., increasing speeds of travel). Then each outcome is closer to the fina one than those which precede it. Each of these outcomes can be a goal in some time period after the 'preceding' goal has been obtained, leading eventually to attainment of the last outcome, the objective. For example, a high-school freshman's goal in his first year is to be promoted to his second (sophomore) year. Passing his second year is a subsequent goal. And so on to graduation, which is his objective.

Pursuit of an objective requires an ability to change goals once a goal has been obtained. This is why such pursuit is possible only for a purposeful system.

25. An *ideal* is an objective which cannot be obtained in any time period but which can be approached without limit. Just as goals can be ordered with respect to objectives, objectives can be ordered with respect to ideals. But an ideal is an outcome which is unobtainable in practice, if not in principle. For example, an ideal of science is errorless observations. The amount of observer error can be reduced without limi but can never be reduced to zero. Omniscience is another such ideal.

26. An *ideal-seeking system* is a purposeful system which, on attainment of any o its goals or objectives, then seeks another goal and objective which more closely approximates its ideal. An ideal-seeking system is thus one which has a concept o 'perfection' or the 'ultimately desirable' and pursues it systematically; that is, in interrelated steps.

From the point of view of their output, six types of system have been identified state-maintaining, goal-seeking, multi-goal-seeking, purposive, purposeful, and ideal seeking. The elements of systems can be similarly classified. The relationship between (1) the behavior and type of a system and (2) the behavior and type of its elements is not apparent. We consider it next.

Relationships Between Systems and Their Elements

Some systems can display a greater variety and higher level of behavior than can any of their elements. These can be called *variety increasing*. For example, consider two state-maintaining elements, A and B. Say A reacts to a decrease in room temperature by closing any open windows. If a short time after A has reacted the room temperature is still below a specified level, B reacts to this by turning on the furnace Then the system consisting of A and B is goal-seeking.

Clearly, by combining two or more goal-seeking elements we can construct a multi goal-seeking (and hence a purposive) system. It is less apparent that such elements can also be combined to form a purposeful system. Suppose one element A can pursu goal G_1 in environment E_1 and goal G_2 in another environment E_2; and the othe element B can pursue G_2 in E_1 and G_1 in E_2. Then the system would be capable c pursuing G_1 and G_2 in both E_1 and E_2 if it could select between the elements in thes environments. Suppose we add a third (controlling) element which responds to E by 'turning on' either A or B, but not both. Suppose further that it turns on A wit probability P_A where $0 < P_A < 1.0$ and turns on B with probability P_B wher $0 < P_B < 1.0$. (The controller could be a computer that employs random number for this purpose.) The resulting system could choose both ends and means in tw environments and hence would be purposeful.

A system can also show less variety of behavior and operate at a lower level tha at least some of its elements. Such a system is *variety reducing*. For example, conside a simple system with two elements one of which turns lights on in a room wher ever the illumination in that room drops below a certain level. The other element turns the lights off whenever the illumination exceeds a level that is lower than that provided by the lights in the room. Then the lights will go off and on continuously. The system would not be state-maintaining even though its elements are.

A more familiar example of a variety-reducing system can be found in those groups of purposeful people (e.g., committees) which are incapable of reaching agreement and hence of taking any collective action.

A system must be either variety-increasing or variety-decreasing. A set of elements which collectively neither increase nor decrease variety would have to consist of identical elements either only one of which can act at a time or in which similar action by multiple units is equivalent to action by only one. In the latter case the behavior is nonadditive and the behavior is redundant. The relationships between the elements would therefore be irrelevant. For example, a set of similar automobiles owned by one person do not constitute a system because he can drive only one at a time and which he drives makes no difference. On the other hand a radio with two speakers can provide stereo sound; the speakers each do a different thing and together they do something that neither can do alone.

Adaptation and Learning

In order to deal with the concepts 'adaptation' and 'learning' it is necessary first to consider the concepts 'function' and 'efficiency'.

27. The *function(s)* of a system is production of the outcomes that define its goal(s) and objective(s). Put another way, suppose a system can display at least two structurally different types of behavior in the same or different environments and that these types of behavior produce the same kind of outcome. Then the system can be said to have the function of producing that outcome. To function, therefore, is to be able to produce the same outcome in different ways.

Let C_i $(1 \leq i \leq m)$ represent the different actions available to a system in a specific environment. Let P_i represent the probabilities that the system will select these courses of action in that environment. If the courses of action are exclusive and exhaustive, then $\sum_{i=1}^{m} P_i = 1.0$. Let E_{ij} represent the probability that course of action C_i will produce a particular outcome O_j in that environment. Then:

28. The *efficiency* of the system with respect to an outcome O_j which it has the function of producing is $\sum_{i=1}^{m} P_i E_{ij}$.

Now we can turn to 'adaptation'.

29. A system is *adaptive* if, when there is a change in its environmental and/or internal state which reduces its efficiency in pursuing one or more of its goals which define its function(s), it reacts or responds by changing its own state and/or that of its environment so as to increase its efficiency with respect to that goal or goals. Thus adaptiveness is the ability of a system to modify itself or its environment when either has changed to the system's disadvantage so as to regain at least some of its lost efficiency.

The definition of 'adaptive' implies four types of adaptation:

29.1. *Other-other adaptation:* A system's reacting or responding to an external change by modifying the environment (e.g., when a person turns on an air conditioner in a room that has become too warm for him to continue to work in).

29.2. *Other-self adaptation:* A system's reacting or responding to an external change by modifying itself (e.g., when the person moves to another and cooler room).

29.3. *Self-other adaptation:* A system's reacting or responding to an internal change by modifying the environment (e.g., when a person who has chills due to a cold turns up the heat).

29.4. *Self-self adaptation:* a system's reacting or responding to an internal change by modifying itself (e.g., when that person takes medication to suppress the chills). Other-self adaptation is most commonly considered because it was this type with which Darwin was concerned in his studies of biological species as systems.

It should now be apparent why state-maintaining and higher systems are necessarily adaptive. Now let us consider why nothing lower than a goal-seeking system is capable of learning.

30. To *learn* is to increase one's efficiency in the pursuit of a goal under unchanging conditions. Thus if a person increases his ability to hit a target (his goal) with repeated shooting at it, he learns how to shoot better. Note that to do so requires an ability to modify one's behavior (i.e., to display choice) and memory.

Since learning can take place only when a system has a choice among alternative courses of action, only systems that are goal-seeking or higher can learn.

If a system is repeatedly subjected to the same environmental or internal change and increases its ability to maintain its efficiency under this type of change, then it *learns how to adapt*. Thus adaptation itself can be learned.

Organizations

Management Scientists are most concerned with that type of system called 'organizations'. Cyberneticians, on the other hand, are more concerned with that type of system called 'organisms', but they frequently treat organizations as though they were organisms. Although these two types of system have much in common, there is an important difference between them. This difference can be identified once 'organization' has been defined. I will work up to its definition by considering separately each of what I consider to be its four essential characteristics.

(1) An organization is a purposeful system that contains at least two purposeful elements which have a common purpose.

We sometimes characterize a purely mechanical system as being well organized, but we would not refer to it as an 'organization'. This results from the fact that we use 'organize' to mean, 'to make a system of', or, as one dictionary puts it, "to get into proper working order", and "to arrange or dispose systematically". Wires, poles, transformers, switchboards, and telephones may constitute a communication system, but they do not constitute an organization. The employees of a telephone company make up the organization that operates the telephone system. Organization of a system is an activity that can be carried out only by purposeful entities; to be an organization a system must contain such entities.

An aggregation of purposeful entities does not constitute an organization unless they have at least one common purpose: that is, unless there is some one or more things that they all want. An organization is always organized around this common purpose. It is the relationships between what the purposeful elements do and the pursuit of their common purpose that give unity and identity to their organization.

Without a common purpose the elements would not work together unless compelled to do so. A group of unwilling prisoners or slaves can be organized and forced to do something that they do not want to do, but if so they do not constitute an organization even though they may form a system. An organization consists of elements that have and can exercise their own wills.

(2) An organization has a functional division of labor in pursuit of the common purpose(s) of its elements that define it.

Each of two or more subsets of elements, each containing one or more purposeful elements, is responsible for choosing from among different courses of action. A choice from each subset is necessary for obtaining the common purpose. For example, if an automobile carrying two people stalls on a highway and one gets out and pushes while the other sits in the driver's seat trying to start it when it is in motion, then there is a functional division of labor and they constitute an organization. The car cannot be started (their common purpose) unless both functions are performed.

The classes of courses of action and (hence) the subsets of elements may be differentiated by a variety of types of characteristics; for example:

(a) by *function* (e.g., production, marketing, research, finance, and personnel, in the industrial context),

(b) by *space* (e.g., geography, as territories of sales offices), and

(c) by *time* (e.g., waves of an invading force).

The classes of action may, of course, also be defined by combinations of these and other characteristics.

It should be noted that individuals or groups in an organization that *make* choices need not *take* them; that is, carry them out. The actions may be carried out by other persons, groups, or even machines that are controlled by the decision makers.

(3) The functionally distinct subsets (parts of the system) can respond to each other's behavior through observation or communication.[3]

In some laboratory experiments subjects are given interrelated tasks to perform but they are not permitted to observe or communicate with each other even though they are rewarded on the basis of an outcome determined by their collective choices. In such cases the subjects are *unorganized*. If they were allowed to observe each other or to communicate with each other they could become an organization. The choices made by elements or subsets of an organization must be capable of influencing each other, otherwise they would not even constitute a system.

(4) At least one subset of the system has a system-control function.

This subset (or subsystem) compares achieved outcomes with desired outcomes and makes adjustments in the behavior of the system which are directed toward reducing the observed deficiencies. It also determines what the desired outcomes are. The control function is normally exercised by an executive body which operates on a feed-back principle. 'Control' requires elucidation.

31. An element or a system *controls* another element or system (or itself) if its behavior is either necessary or sufficient for subsequent behavior of the other element or system (or itself), and the subsequent behavior is necessary or sufficient for the attainment of one or more of its goals. Summarizing, then, an 'organization' can be defined as follows:

32. An *organization* is a purposeful system that contains at least two purposeful elements which have a common purpose relative to which the system has a functional division of labor; its functionally distinct subsets can respond to each other's behavior through observation or communication; and at least one subset has a system-control function.

Now the critical difference between organisms and organizations can be made

[3] In another place, Ackoff [1], I have given operational definitions of 'observation' and 'communication' that fit this conceptual system. Reproduction of these treatments would require more space than is available here.

explicit. Whereas both are purposeful systems, organisms do not contain purposeful elements. The elements of an organism may be state-maintaining, goal-seeking, multi-goal-seeking, or purposive; but not purposeful. Thus an organism must be variety increasing. An organization, on the other hand, may be either variety increasing or decreasing (e.g., the ineffective committee). In an organism only the whole can display will; none of the parts can.

Because an organism is a system that has a functional division of labor it is also said to be 'organized'. Its functionally distinct parts are called 'organs'. Their functioning is necessary but not sufficient for accomplishment of the organism's purpose(s).

Conclusion

Defining concepts is frequently treated by scientists as an annoying necessity to be completed as quickly and thoughtlessly as possible. A consequence of this disinclination to define is often research carried out like surgery performed with dull instruments. The surgeon has to work harder, the patient has to suffer more, and the chances for success are decreased.

Like surgical instruments, definitions become dull with use and require frequent sharpening and, eventually, replacement. Those I have offered here are not exceptions.

Research can seldom be played with a single concept; a matched set is usually required. Matching different researches requires matching the sets of concepts used in them. A scientific field can arise only on the base of a system of concepts. Systems science is not an exception. Systems thinking, if anything, should be carried out systematically.

References

1. Ackoff, R. L., *Choice, Communication, and Conflict*, a report to the National Science Foundation under Grant GN-389, Management Science Center, University of Pennsylvania, Philadelphia, 1967.
2. Churchman, C. W., *The Systems Approach*, Delacorte Press, New York, 1968.
3. Emery, F. E., *Systems Thinking*, Penguin Books Ltd., Harmondsworth, Middlesex, England, 1969.