Scott & Davis (2007)

CHAPTER **4**

Organizations as Open Systems

> That a system is open means, not simply that it engages in interchanges with the environment, but that this interchange is an essential factor underlying the system's viability.
>
> WALTER BUCKLEY (1967)

The open system perspective emerged as a part of the intellectual ferment following World War II, although its roots are much older. This general movement created new areas of study, such as cybernetics and information theory; stimulated new applications, such as systems engineering and operations research; transformed existing disciplines, including the study of organizations; and proposed closer linkages among scientific disciplines. The latter interest was fostered especially by general system theory. Its founder, biologist Ludwig von Bertalanffy, was concerned about the growing compartmentalization of science:

> The physicist, the biologist, the psychologist and the social scientist are, so to speak, encapsulated in a private universe, and it is difficult to get word from one cocoon to another. (Bertalanffy, 1956: 1)

Bertalanffy and his associates argued that key concepts could have relevance across a broad spectrum of disciplines.[1] In particular, they pointed out that many of the most important entities studied by scientists—nuclear particles, atoms, molecules, cells, organs, organisms, ecological communities, groups,

[1]In a similar fashion, a half-century later, another biologist, Edward O. Wilson (1998), has proposed that all knowledge is intrinsically unified, that behind disciplines as diverse as physics and sociology lie a small number of natural laws, stemming largely from biological principles.

organizations, societies, solar systems—are all subsumable under the general rubric of *system.*[2]

SYSTEM LEVELS

All systems are characterized by an assemblage or combination of parts whose relations make them interdependent. While these features underlie the similarities exhibited by all systems, they also suggest bases for differences among them. The parts of which all systems are composed vary from simple to complex, from stable to variable, and from nonreactive to reactive to the changes in the system to which they belong. As we move from mechanical through organic to social systems, the parts of which systems are composed become more complex and variable. In addition, relations among the parts varies from one type of system to another. In this connection, Norbert Wiener, the founder of cybernetics, notes; "Organization we must consider as something in which there is an interdependence between the several organized parts but in which this interdependence has degrees" (1956: 322). In mechanistic systems, the interdependence among parts is such that their behavior is highly constrained and limited. The structure is relatively rigid, and the system of relations determinant. In organic systems, the connections among the interdependent parts are somewhat less constrained, allowing for more flexibility of response. In social systems, such as groups and organizations, the connections among the interacting parts are relatively loose: less constraint is placed on the behavior of one element by the condition of the others. Social organizations, in contrast with physical or mechanical structures, are *complex* and *loosely coupled* systems (see Ashby, 1968; Buckley, 1967: 82–83).

Also, as we progress from simple to complex and from tightly to loosely coupled systems, the nature and relative importance of the various flows among the system elements and between the system and its environment change. The major types of system flows are those of materials, energy, and information. And, as Buckley notes:

> Whereas the relations among components of mechanical systems are a function primarily of spatial and temporal considerations and the transmission of energy from one component to another, the interrelations characterizing higher levels come to depend more and more on the transmission of information. (1967: 47)

The notion of types or levels of systems that vary both in the complexity of their parts and in the nature of the relations among the parts has been usefully elaborated by Boulding, who devised a classification of systems by their level of complexity. Boulding identifies nine system types (see Table 4–1).

[2]In his monumental book *Living Systems,* Miller (1978) identifies seven basic levels: the cell, the organ, the organism, the group, the organization, the society, and the supranational system.

TABLE 4–1 Boulding's System Types

1. ***Frameworks:*** systems comprising static structures, such as the arrangements of atoms in a crystal or the anatomy of an animal.
2. ***Clockworks:*** simple dynamic systems with predetermined motions, such as the clock and the solar system.
3. ***Cybernetic systems:*** systems capable of self-regulation in terms of some externally prescribed target or criterion, such as a thermostat.
4. ***Open systems:*** systems capable of self-maintenance based on a throughput of resources from their environment, such as a living cell.
5. ***Blueprinted-growth systems:*** systems that reproduce not by duplication but by the production of seeds or eggs containing preprogrammed instructions for development, such as the acorn-oak system or the egg-chicken system.
6. ***Internal-image systems:*** systems capable of a detailed awareness of the environment in which information is received and organized into an image or knowledge structure of the environment as a whole, a level at which animals function.
7. ***Symbol-processing systems:*** systems that possess self-consciousness and so are capable of using language. Humans function at this level.
8. ***Social systems:*** multicephalous systems comprising actors functioning at level 7 who share a common social order and culture. Social organizations operate at this level.
9. ***Transcendental systems:*** systems composed of the "absolutes and the inescapable unknowables."

Source: Adapted from Boulding (1956: 200–207).

Boulding's typology is illuminating in several respects. It quickly persuades us of the great range and variety of systems present in the world. Levels 1 to 3 encompass the physical systems, levels 4 to 6 the biological systems, and levels 7 and 8 the human and social systems. Progressing from level 1 to 8, each successive system becomes progressively more complex, more loosely coupled, more dependent on information flows, more capable of self-maintenance and renewal, more able to grow and change, and more open to the environment. Boulding adds level 9 so that the schema will not be closed, but open to new possibilities not yet envisioned.

Although the nine levels can be distinctly identified and associated with specific existing systems, they are not meant to be mutually exclusive. Indeed, each higher-level system incorporates basic features of those below it. For example, it is possible to analyze a social organization as a framework, a clockwork, a cybernetic system, and so on up to level 8, the level that captures the most complex, the higher-level, processes occurring in organizations. Boulding argues that because each level incorporates those below it, "much valuable information and insights can be obtained by applying low-level systems to high-level subject matter." At the same time, he reminds us that "most of the theoretical schemes of the social sciences are still at level 2, just rising now to 3, although the subject matter clearly involves level 8" (1956: 208).

In 1980, Daft reviewed all of the theoretical and empirical papers published between 1959–1979 in *Administrative Science Quarterly,* the leading outlet for organizational studies during that period. Classifying articles by the "level of complexity" at which organizational systems were treated using Boulding's typology, Daft (1980) noted that it was not until after 1969 that articles began to drift toward greater complexity, although no articles published during that period reached Boulding's higher levels. This suggests that Boulding's conclusion continued to be applicable for many years and constitutes an important criticism of reigning theoretical models of organizations throughout this period.

The most systematic introduction of open systems concepts and models into organization theory was provided by Katz and Kahn (1978) in the first edition (1966) of their influential text. Buckley (1967) also served as a useful guide for many sociologists.

SPECIAL EMPHASES AND INSIGHTS

Enormous benefits have been realized by students of organizations simply in elevating their conceptual level from 1 and 2, frameworks and clockworks, up to level 3, where organizations are viewed as cybernetic systems, and to level 4, where they are viewed as open systems. Along with our consideration of organizations as cybernetic and open systems, we take note of two other concepts associated with this perspective: organizations as loosely coupled systems and organizations as hierarchical systems.

Organizations as Cybernetic Systems

Systems functioning at Boulding's level 3 are capable of self-regulation. This important feat is attained through the development of specialized parts or subsystems related by certain processes or flows. Consider the mechanical example of the thermostat related to a source of heat. As Figure 4–1 illustrates, the system contains differentiated parts: a component for converting inputs into outputs—in this case, a heater that converts fuel and oxygen into heat; and a component for comparing the actual and desired temperatures—the thermostat. The parts are interrelated: the heater produces changes in temperatures detected by the thermostat; the thermostat controls a switch on the heater turning it on or off based on information provided by comparing the actual and desired temperatures.

The key mechanism that effects the control process, that renders the system capable of self-regulation, however, is the *program.* Beniger provides an illuminating discussion of programs which he defines as "any prearranged information that guides subsequent behavior" (1986: 39). He continues:

> Programs control by determining decisions. . . . the process of control involves comparison of new information (inputs) to stored patterns and instructions (programming) to decide among a predetermined set of contingent behaviors (possible outputs). (p. 48)

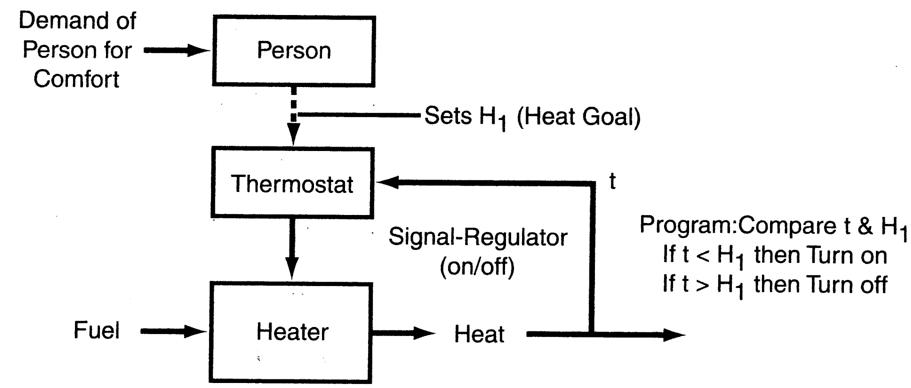

FIGURE 4–1 Illustration of a Cybernetic System: The Thermostat and the Heater.
Source: Adapted from Swinth (1974: Figure 2–1, p. 18).

The identification of programs that exercise control through information processing and decision making circumvents the problem of teleology: the attempt to explain present activities by reference to their future consequences.[3] Programs "must exist prior to the phenomena they explain"; "their effects precede rather than follow their causes" (Beniger, 1986: 40).

Figure 4–1 also depicts a person who sets the standards in terms of which the cybernetic system functions. The person is capable of altering the system by reprogramming it, that is, by changing the desired temperature level. However, the person is not a component in the basic cybernetic system, which is, in its simplest manifestation a closed system consisting, in the current example, of simply an existing program governing the thermostat, the heater, and their interconnections.[4] If the standard-setting and programming functions are included as a part of the system, then the model is transformed into a powerful, general model of control, depicted in Figure 4–2, a type of control that is widely employed in organizational settings.

To view an organization as a cybernetic system is to emphasize the importance of the operations, control, and policy centers, and the flows among them (Swinth, 1974). The policy center sets the goals for the system. This activity occurs in response to demands or preferences from the environment (flow 1 in Figure 4–2), some of the environmental demands take the form of orders (flow 2) from, for example, customers or from a higher-level organizational system. Note that the setting of goals is based on

[3]Functional arguments, described in Chapter 3, suffer from the difficulties of teleological explanation.

[4]Not too surprisingly, the founder of cybernetics, Norbert Wiener, insists that the subject is broader in scope than indicated by Boulding. Wiener defines cybernetics as the "study of messages and the communication facilities that belong to it . . . [including] messages between man and machines, machines and man, and between machines and machines" (1954: 16).

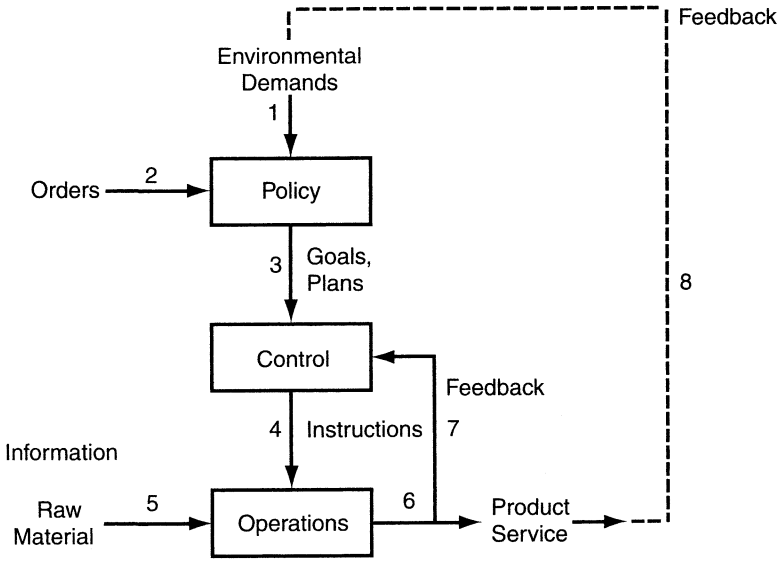

FIGURE 4–2 Abstract Model of Cybernetic System.
Source: Adapted from Swinth (1974: Figure 2–4, p. 23).

information received from the environment so that favorable exchanges between the environment and organization can occur. The policy center transmits goals or performance standards (flow 3) to the control center. This unit applies its program(s) to the operations level (flow 4), where raw materials are transformed into products and services (flows 5 and 6). It is also the task of the control center to monitor the outputs, comparing their quality and/or quantity with the standards set by the policy center (flow 7). Discrepancies are the occasion for corrective actions as prescribed by the program. The figure also displays a second feedback loop (flow 8) to illustrate the possibility that reactions to the system's outputs by those outside the system, for example, customers, may lead the organization to revise its goals. Ashby (1952) points out that in such double feedback systems, the primary loop handles disturbances in "degree," applying existing decision rules, while the secondary loop handles disturbances in "kind," determining whether it is necessary to redefine the rules controlling the operating levels. Argyris (1982) labels such adaptive behaviors that result not simply in different activities but in different rules for choosing activities "double-loop learning." Monitoring environmental feedback on the system's past performance—for example, a company reviewing records on sales by product lines—is an important mechanism of adaptation for any open system, although many organizations do not avail themselves of such occasions for learning.

Buckley stresses that cybernetic systems result in behavior that is "goal *directed* and not merely goal-*oriented*, since it is the deviations from the

goal-state itself that direct the behavior of the system, rather than some predetermined internal mechanism that aims blindly" (1967: 53). Further, a feedback mechanism detects departures from the established goals no matter what their cause, an important control characteristic as systems become so complex that all the potential sources of disturbance cannot be identified in advance (see Beer, 1964: 29–30).

The cybernetic model places great emphasis on the operational level of the organization—the level at which the production processes of the system are carried out. The analysis of these technical flows—inputs, throughputs, and outputs—is regarded as vital to an understanding of the system; indeed, the control and policy centers are examined chiefly in terms of their impact on these technical flows. In keeping with this de-emphasis on formal structure and attention to how the organization actually does its work, Mintzberg and Van der Heyden (1999) propose that organizations would be well advised to discard their organization charts and replace them with "organigraphs." These diagrams, composed of "sets" (items such as materials or machines), "chains" (linear connections among sets), "hubs" (coordination centers), and "webs" (networks), emphasize flows and other relations among the component parts of organizations.

The cybernetic framework can be applied to the organization as a whole or to any of its subsystems. It can be used, for example, to analyze the operation of a company's personnel subsystem, which must meet the demands of other subsystems for trained employees and must control the recruitment and training of new workers and monitor their turnover (Carzo and Yanouzas, 1967: 345–47). Or it can be used to examine the working of an entire organization, for example, a company producing, distributing, and exercising quality control over its products and attempting to monitor past sales and customer preferences so as to keep abreast of a changing marketplace.

Organizations as Loosely Coupled Systems

The cybernetic model gives the impression of a taut system—an arrangement of parts such that each is highly responsive to changes in the others. Such system relations are certainly found within organizations, but we should guard against overgeneralization. One of the main contributions of the open systems perspective is the recognition that many systems—especially social systems—contain elements that are only weakly connected to others and capable of fairly autonomous actions (Ashby, 1968; Glassman, 1973; Weick, 1976).

This insight can be applied to many different components or elements of organizations and their participants. Thus, we have seen that from the standpoint of the natural system analysts, the normative structure of an organization is only loosely coupled with its behavioral structure. Rules do not always govern actions: a rule may change without affecting behavior, and vice versa. At the social psychology level, analysts have noted that an individual's goals or intentions may be only weakly linked to his or her actions (March and

Olsen, 1976). Often there is, at best, a weak connection between "talk" and "action" in organizations (Brunsson, 1989). Executives and managers may talk convincingly about the total quality management (TQM) programs in their organizations, but researchers may find little or no evidence of such activities in production and service departments (Cole and Scott, 2000). Pfeffer and Sutton (2000) provide much evidence of this sort of "knowing-doing" gap in organizations. The concept of loose coupling can also be applied to the relationship among structural units such as work groups or departments. Some may be tightly coupled while others are, at best, loosely connected, and still others, virtually independent. Inspection of official organizational charts can convey the impression that these units are all highly interrelated and closely coordinated, whereas observation of their actual behavior may reveal that they are only slightly or occasionally connected.

A particularly important application of the loose coupling image is that proposed by Cyert and March (1963) and adopted by Pfeffer and Salancik (1978). As noted in Chapter 1 in describing the open system definition of the concept of organization, these theorists propose to view the key participants in organizations not as a unitary hierarchy or as an organic entity, but as a loosely linked coalition of shifting interest groups. According to Pfeffer and Salancik:

> The organization is a coalition of groups and interests, each attempting to obtain something from the collectivity by interacting with others, and each with its own preferences and objectives. (1978: 36)

Rather than being rigidly oriented to the pursuit of consistent, common objectives, these coalitions change

> their purpose and domains to accommodate new interests, sloughing off parts of themselves to avoid some interests, and when necessary become involved in activities far afield from their stated purposes. (1978: 24)

The relation between dominant coalitions and goal setting is further discussed in Chapter 8.

Another important application of the loose-coupling concept is the argument that formal administrative structures within organizations are often de-coupled from production systems. We discuss this argument, developed by institutional scholars, in Chapter 10.

Contrary to first impressions and to rational system assumptions, open system theorists insist that loose coupling in structural arrangements can be highly adaptive for the system as a whole (see Orton and Weick, 1990; Weick, 1976). It appears that loose coupling need not signify either low moral or low managerial standards.

On the other hand, the loose coupling of organizational elements no doubt contributes to what has been termed, the "productivity paradox," the situation in which a great many organizations have made enormous investments in information-processing technologies without appreciable effects on the overall rate of productivity growth in this country (see Harris, 1994). Enhancement in the productivity of individual workers does not quickly or easily translate into gains in productivity assessed at the departmental or firm level, let alone that of the industry.

The Characteristics of Open Systems

Organizations may be analyzed as cybernetic systems, but they also function at higher levels of complexity (review Table 4–1). They operate as open systems. *Open systems* are capable of self-maintenance on the basis of throughput of resources from the environment. As Buckley (1967: 50) observes, this throughput is essential to the system's viability. Note that the heating unit, one of the components in our example of a cybernetic system, is not an open system as we have defined the concept. Although the heater receives inputs such as fuel from its environment and emits heat and various waste products to the environment, it is not capable of using the fuel to replace or repair its own elements. It cannot transform its inputs in such a way as to prolong its own survival or self-maintenance. Organic systems, including plants and animals, have this capacity, as do human and social systems.

Some analysts have mistakenly characterized an open system as having the capacity for self-maintenance *despite* the presence of throughput from the environment. Their assumption is that because organizations are open, they must defend themselves against the assaults of the environment. This view is misguided and misleading, since interaction with the environment is essential for open system functioning. As Pondy and Mitroff argue, rather than suggesting that organizational systems be protected "against environmental complexity," we should realize that "it is precisely the throughput of nonuniformity that preserves the differential structure of an open system" (1979: 7).

This is not to say that open systems do not have boundaries. They do, of course, and must expend energy in boundary maintenance. But it is of equal importance that energies be devoted to activities that span and, more recently, redraw boundaries. Because of the openness of organizations, determining their boundaries is always difficult and sometimes appears to be a quite arbitrary decision. Does a university include within its boundary its students? Its alumni? Faculty during the summer? The spouses of students in university housing? Pfeffer and Salancik (1978: 30) propose to resolve this type of problem by reminding us that individual persons are not enclosed within the boundaries of organizations, only certain of their activities and behaviors. Although this interpretation helps, we all know that many actions have relevance for more than one system simultaneously. For example, a sale from the standpoint of one system is a purchase when viewed from another, and an act of conformity for one system can be an act of deviance for another. (Boundaries are considered in more detail in Chapters 7, 9, 11, and 14.)

Moreover, as will be emphasized, all systems are made up of subsystems and are themselves subsumed in larger systems—an arrangement that creates linkages across systems and confounds the attempt to erect clear boundaries around them. Ultimately, our determination of whether a system is open is itself a matter of how the boundaries of the system are defined. As Hall and Fagen note:

> whether a given system is open or closed depends on how much of the universe is included in the system and how much in the environment. By adjoining to the system the part of the environment with which an exchange takes place, the system becomes closed. (1956: 23)

General systems theorists elaborate the distinction between closed and open systems by employing the concept of *entropy*: energy that cannot be turned into work. According to the second law of thermodynamics, all systems spontaneously move toward a state of increasing entropy—a random arrangement of their elements, a dissolution of their differentiated structures, a state of maximum disorder. But open systems, because they are capable of importing energy from their environment, can experience negative entropy, or "negentropy." By acquiring inputs of greater complexity than their outputs, open systems restore their energy, repair breakdowns in their organization, and may improve their structures and routines. Bertalanffy concludes, "such systems can maintain themselves at a high level, and even evolve toward an increase of order and complexity" (1962: 7).[5]

To emphasize these twin properties of open systems, Buckley (1967: 58–62) distinguishes between two basic sets of system processes: morphostasis and morphogenesis. The term *morphostasis* refers to those processes that tend to preserve or maintain a system's given form, structure, or state. Morphostatic processes in biological systems would include circulation and respiration; in social systems, socialization and control activities. *Morphogenesis* refers to processes that elaborate or change the system—for example, growth, learning, and differentiation. In adapting to the external environment, open systems typically become more differentiated in form, more elaborate in structure. Thus, in biological systems, organs whose sensitivities to external stimuli are coarse and broad are succeeded, over time, by more specialized receptors capable of responding to a wider range and finer gradations of stimuli. Biological organisms move toward greater complexity through the process of evolution: individual organisms are little affected, but over time, as mutations occur and are selected for their survival value, species are gradually transformed. Social organizations, more variable and loosely coupled than biological systems, can and do fundamentally change their structural characteristics over time. The General Motors of today bears little structural resemblance to the company of the same name fifty years ago. Indeed, social organizations exhibit such an amazing capacity to change their basic structural features that researchers who study organizations over time have difficulty determining when the units they are studying are the same organizations with reorganized structures and when they represent the birth of new organizations (see Chapters 10 and 13).

To repeat, the source of system maintenance, diversity, and variety is the environment. From an open system point of view, there is a close connection between the condition of the environment and the characteristics of the systems within it: a complex system cannot maintain its complexity in a simple environment. Open systems are subject to what is termed the *law of limited variety*: "A system will exhibit no more variety than the variety to which it has been exposed in its environment" (Pondy and Mitroff, 1979: 7). Great universities do not arise in deserts or other sparsely inhabited areas. Although the processes by which such "laws" operate are not clearly understood, most of this volume is devoted to explicating and illustrating the interdependence of organizations and environments.

Organizations as Hierarchical Systems

General systems theorists also stress that hierarchy is a fundamental feature of complex systems—not hierarchy in the sense of status or power differences, but hierarchy as a mechanism of clustering. Systems are composed of multiple subsystems, and systems are themselves contained within larger systems. This is such a common feature of virtually all complex systems that it is easily overlooked. Books like this one are made up of letters, words, sentences, paragraphs, sections and chapters. The U.S. political system is constituted of precincts, special districts, counties, and states, all contained within the nation-state. And organizations are made up of roles clustered into work groups, departments, and divisions. Many organizations are themselves subsystems of larger systems, of corporate structures, associations, or a branch of government. And an increasing number of

[5]Information theorists posit a close relation between the concepts of organization and entropy: they are viewed, in effect, as opposite states. If entropy is a state of randomness, or zero organization, it is also the state that provides maximum variety, maximum information, to someone observing a set of elements. As organization develops, constraints and limitations grow, restricting the number of states that may be present among the elements. Miller elaborates this point:

> A well-organized system is predictable—you know what it is going to do before it happens. When a well-organized system does something, you learn little that you didn't already know—you acquire little information. A perfectly organized system is completely predictable and its behavior provides no information at all. The more disorganized and unpredictable a system is, the more information you get by watching it. (1953: 3)

Based on such reasoning, information theorists Shannon and Weaver (1963) have proposed a measure of information, H, which assesses the amount of entropy present in a set of elements—their variation, their relative frequency of occurrence, and their interdependence. The higher the H level, the more information and the less organization are present (see also Buckley, 1967: 82–89).

organizations are connected into wider collaborative networks and alliances with other organizations (see Chapter 11).

Combining the notion of hierarchy with that of loose coupling, we grasp an important feature of complex systems. The connections and interdependencies within a system component are apt to be tighter and of greater density than those between system components. In a well-written book, for example, the ideas expressed in a single paragraph are more closely interrelated than those expressed in different paragraphs. Similarly, interactions within a given academic department of a university are likely to be more frequent and more intense than those occurring between departments. Indeed, as will be discussed in Chapter 6, this generalization provides the basis for an important principle of organizational design.

When subsystems take the form of "stable subassemblies"—units capable of retaining their form without constant attention from superior units—then hierarchical forms have a significant survival advantage over other systems (Simon, 1962). Many seemingly complex organizational systems are made up of, and depend for their stability on, units that are highly similar and capable of relatively autonomous functioning—for example, work teams, departments, franchise units, or chain stores. From this perspective, the apparent complexity of many systems is significantly reduced. Everything is *not* connected to everything else; connections are loose or missing, and many components of systems are identical or nearly so (see Aldrich, 1979: 75–80).

To this point, we have emphasized that all systems are composed of subsystems. Of equal significance is the observation that all systems are subsumed by other, more encompassing systems. This suggests that to understand the operation of a system, it may be as important to look outside the system of interest to examine its context as to look inside the system at its component units. Schwab (1960) has termed this perspective "rationalism," the opposite of reductionism. In rationalism, explanation entails looking outside an entity to the environment or a higher system in which it is embedded (see also McKelvey, 1982: 5). In these many ways, the open systems perspective points to the significance of the wider environment.

SELECTED SCHOOLS

As with our discussion of the previous perspectives, we consider several schools that exemplify the open systems approach. We briefly describe the systems design approach; contingency theory (closely related to systems design), and Weick's social psychological model of organizing. Although open systems approaches to organizations were the last of the three perspectives to emerge, they have spread very rapidly and have had an enormous effect on organization theory. We discuss in this section only selected early developments; in Chapter 5 and later chapters we consider other approaches embodying open systems assumptions and insights.

Systems Design

A large and growing number of organization theorists look to general systems theory as a source of ideas to improve the design of organizations—determining proper work flows, control systems, information processing, planning mechanisms, knowledge transfer, and their interrelations (see Burton and Obel, 2004; Carzo and Yanouzas, 1967; Huber and Glick, 1993; Khandwalla, 1977; Mintzberg, 1979; Nissen, 2006; Sternman, 1994). Unlike some schools devoted to the study of organizations, the orientation of this group is pragmatic and applied: design theorists seek to change and improve organizations as viewed from a managerial perspective, not simply to describe and understand them.

Levels of System Complexity. Many of the analysts applying systems ideas to organizations are aware both of the great complexity of organizations as one type of system and of the danger of misapplying or overextending analogies based on the operation of other, less complex systems. Beer (1964) proposes a classification of systems ranging from those that are both simple and deterministic (e.g., the behavior of a block and tackle system) to those that are complex and probabilistic (e.g., the operation of an assembly line in a factory), to those that are "exceedingly complex" and probabilistic (e.g., an entire organization such as GM). Complex probabilistic systems, whose behavior can be generally described and predicted with statistical procedures, are the province of operations research. Efforts to understand exceedingly complex probabilistic systems have given rise to the fields of cybernetics and systems design (Beer, 1964: 18). Because of their great complexity, the latter systems currently defy conventional mathematical modeling approaches. Instead, the most widely employed analytic technique is to simulate the operation of the system. "Here, all the variables and relationships of interest are linked as understood into a model and then the manager-analyst-researcher manipulates certain ones and observes how others change as the simulation of the system plays itself out" (Swinth, 1974: 11). This approach emphasizes the importance of treating the system as a system—as more than the sum of its component elements.

Recent branches of systems theory, termed "complexity" and "chaos" theory, currently pursued with most vigor by scientists at the Santa Fe Institute for Study of Complexity in New Mexico, examine the behavior of nonlinear dynamic systems. These theories were developed to account for the behavior of the flow of fluids or the behavior of mental balls suspended over two or more magnets in which "a single set of deterministic relationships can produce patterned yet unpredictable outcomes" (Levy, 1994: 168). Scholars have explored the applicability of such models to the study of highly complex, probabilistic, nonlinear social systems, such as the economy or the behavior of a firm. Chaos theorists insist that much "order emerges naturally because of unpredictable interaction" and that far from "being meaningless void, chaos is the source of creativity and construction in nature and in social dynamics" (Marion, 1999: xi–xii). Nonlinear dynamics systems can reach three types of equilibrium: systems governed by negative feedback loops such that after a time, the system returns to its initial state; systems driven by positive feedback loops which amplify the initial disturbances so that small changes over time lead to explosive outcomes; and complex systems in which the interaction of positive and negative feedback loops gives rise to unpredictable but patterned outcomes (Thietart and Forgues, 1995). Since organizations are systems that combine elements that suppress variation (e.g., control systems) and elements that create and amplify variation (e.g., diversity of personnel, R&D units), they appear to be likely candidates for chaos and complexity models.

No complex system can be understood by an analysis that attempts to decompose the system into its individual parts so as to examine each part and relationship in turn. This approach, according to Ashby, one of the founders of the general systems movement,

> gives us only a vast number of separate parts or items of information, the results of whose interactions no one can predict. If we take such a system to pieces, we find that we cannot reassemble it! (1956: 36)

Simulation techniques are popular with systems analysts because they are consistent with this "wholistic" image of a unit whose behavior can be understood only as the resultant of complex and probabilistic interactions among its parts. They also support the systems view that to understand organizations it is essential to focus on the operational level of the organization. Thus, a systems design analyst would be more interested in obtaining diagrams depicting the flows of information, energy, and materials throughout the organization than in inspecting the formal table of organization. In examining a football team, for example, such an analyst would seek out the play books—the programs—governing the activities of the various players during the course of a game rather than the formal authority arrangements among the players, coaches, managers, and owners of the club. Current investigators are successful in simulating actions and interactions among actors performing interdependent tasks, including processes of attention, capacity allocation, and communication. Outputs assessed include project duration, costs, and coordination quality and costs (e.g., Levitt et al., 1994). These results can then be compared and contrasted with similar "real-world" situations. Similations are also used as learning exercises, as microworlds are created that "simulate the real world with sufficient fidelity that decisions and actions within the simulation produce the same kinds of results and consequences that would be expected in the real world" (Nissen, 2006: 62).

It is consistent with the holistic emphasis of the systems analyst that the approach can incorporate parts of systems whose detailed structure and

operation are unknown. These parts are treated as so-called "black boxes" (Haberstroh, 1965: 1174). For the purposes of systems analysis, all the information that is required is a description of the inputs to and the outputs from each of these parts (or the relation between the inputs and the outputs). It is not necessary to know the internal working of these system components to understand or simulate the workings of the larger system.

Normal Accidents versus Reliable Organizations. An important characteristic of exceedingly complex, probabilistic systems is that the whole is more than the sum of its parts in the pragmatic sense that given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the behavior of the larger system. As a consequence, it is virtually impossible to predict and protect against all the ways in which such systems can fail—for example, move rapidly toward an explosive state. When the systems are characterized by high levels of interactive complexity and tight coupling—for example, nuclear power plants—then, as Perrow argues, many of the accidents that occur should be regarded as "normal." The odd term *normal accident* is meant to signal that, given the system characteristics, multiple and unexpected interactions of failures are inevitable (1984: 5). From an in-depth analysis of the near-disaster at the Three Mile Island nuclear plant in Pennsylvania, Perrow acknowledges the role of such ever-present problems of design and equipment failures and operator error but emphasizes the effects of "negative synergy."

> "Synergy" is a buzz word in business management circles, indicating that the whole is more than the sum of its parts, or in their congenial familiarity, two plus two equals five. But minus two plus minus two can equal minus five thousand in tightly-coupled, complex, high risk military and industrial systems . . . where complex, unanticipated, unperceived and incomprehensible interactions of off-standard components (equipment, design, and operator actions) threaten disaster. (Perrow, 1982: 18)

Gall identifies concisely the dilemma posed by these systems: "When a fail-safe system fails, it fails by failing to fail safe" (1978: 97).

A lively debate has developed between analysts adopting the normal accidents view and others who insist that it is possible to develop "high reliability" organizations. Both camps agree the hallmark of these systems is the combination of interactive complexity and tight coupling, but the latter insist that high reliability can be achieved by constructing redundant systems, relying on extensive training and simulation of crisis situations, and creating a "culture of safety" (LaPorte 1982; Roberts, 1990; Weick, 1987). Those insisting that accidents cannot be completely avoided point to our inability to anticipate all the ways in which complex systems can fail and noting that excessive concern for perfection can cause lower-level personnel to cover up inevitable lapses and shortcomings, so that safety is undermined by procedures designed to insure its attainment (Sagan, 1993; Vaughan, 1996). More recently, the terrorist incident of September 11, 2001, and the natural disaster of Hurricane Katrina on the Gulf coast in September 2005, indicate that major system failures are difficult to predict, to prepare for, and to deal with the aftermath.

Information Flows. Among the various flows connecting system elements, the flow of information is the most critical. The gathering, transmission, storage, and retrieval of information are among the most fateful activities of organizations, and design theorists devote much attention to them (Burton and Obel, 2004). We described in Chapter 2 Simon's views on the cognitive limits of decision makers. From the perspective of systems design, Simon is calling attention to the limitations of individuals as information processors. Viewing individuals in this manner, Haberstroh asserts that they exhibit "low channel capacity, lack of reliability, and poor computational ability." On the other hand, individuals possess some desirable features: "The strong points of a human element are its large memory capacity, its large repertory of responses, its flexibility in relating these responses to information inputs, and its ability to react creatively when the unexpected is encountered" (Haberstroh, 1965: 1176). The challenge facing the system designers is how to create structures that will overcome the limitations and exploit the strengths of each system component, including the individual participants.

Recent developments in information and community technologies (ICT) have transformed many aspects of the workplace, as we describe in Chapter 6 and elsewhere. Observers like Burton and Obel assert that "these new media for information exchange may be viewed as a new phase of automation similar in importance as the industrial revolution in the beginning of the 20th century" (2004: 5). Although in many organizational sectors, such a conclusion sounds greatly exaggerated, there is no doubt that these developments have spawned a whole new assemblage of networked organizational forms, as discussed in Chapter 11.

Of course, not all environments place the same demands on organizations and their participants for information processing. Since individual participants are limited in their capacity to process complex information, organization designers endeavor to construct structures capable of assisting participants to deal with these shortcomings. Recognition of these variable information-processing demands has given rise to a special perspective known as contingency theory, which we briefly summarize next.[6]

[6]Some economists, especially Arrow (1974) and Williamson (1975; 1985), also place great emphasis on the cognitive inadequacies of individuals confronted by complex situations. They view these conditions, however, not simply as posing special problems for organizational designers, but also as a general explanation for the existence of organizations. Their arguments are considered in Chapter 9.

Contingency Theory

As a branch of systems design, contingency theory emphasizes that design decisions depend—are contingent—on environmental conditions. Contingency theory is guided by the general orienting hypothesis that organizations whose internal features match the demands of their environments will achieve the best adaptation. The challenge facing those who embrace this orientation is to be clear about what is meant by "the organization's internal features," "the demands of their environments," "best adaptation," and, most difficult of all, "best fit." Details of attempted answers to these questions will be postponed to later chapters, but the general arguments developed by Lawrence and Lorsch are briefly described to illustrate the directions pursued within this theoretical tradition.

Paul Lawrence and Jay Lorsch (1967), who coined the label "contingency theory," argue that different environments place differing requirements on organizations. Specifically, environments characterized by uncertainty and rapid rates of change in market conditions or technologies present different challenges—both constraints and opportunities—to organizations than do placid and stable environments (see also, Burns and Stalker, 1961). They conducted empirical studies of organizations in the plastics manufacturing, food processing, and standardized container industries to assess the relation between these environments—ranging from high to low uncertainty—and the internal features of each type of organization. They also suggest that different subunits within a given type of organization may confront different external demands. Thus, within plastics manufacturing companies, the research and development units face a more uncertain and rapidly changing environment than do the production departments. To cope with these various challenges, organizations create specialized subunits with differing structural features. For example, some subunits may exhibit higher levels of formalization, be more centralized in decision making, or be oriented to longer planning horizons than others. The more varied the types of environments confronted by an organization, the more differentiated its internal structure needs to be. Moreover, the more differentiated the organizational structure, the more difficult it will be to coordinate the activities of the various subunits and the more bases for conflict will exist among participants. Hence, more resources and effort must be devoted to coordinating the various activities and to resolving conflicts among members if the organization is to perform effectively.

In sum, Lawrence and Lorsch propose that the match or coalignment of an organization with its environment occurs on at least two levels: (1) the structural features of each organizational subunit should be suited to the specific environment to which it relates; and (2) the differentiation and mode of integration characterizing the larger organization should be suited to the overall complexity in the environment in which the organization must operate (see Chapter 6).

Over time, contingency theory has become greatly elaborated, partly as analysts discover more and more factors on which the design of organizations is, or should be, contingent. In a recent review article, Lawrence (1993) provides a partial list of factors that one or another theorist has considered important. They include size or scale, technology, geography, uncertainty, individual predispositions of participants, resource dependency, national or cultural differences, scope, and organizational life cycle. Such an elaboration of the conditions on which structural design is dependent indicates both the broadening interests of scholars as well as the looseness of many versions of contingency theory. In spite or, perhaps, because of this expansion of concerns, contingency theory remains "the dominant approach to organization design" (Lawrence 1993: 9) as well as the most widely utilized contemporary theoretical approach to the study of organizations (see Donaldson 1985; 1996). We revisit this approach in succeeding chapters, particularly Chapters 5 and 6.

Weick's Model of Organizing

Weick defines *organizing* as "the resolving of equivocality in an enacted environment by means of interlocked behaviors embedded in conditionally related process" (1969: 91). Let us attempt to unpack this dense definition. Weick argues that organizing is directed toward information processing generally and, in particular, toward removing its equivocality. He explains that

> The basic raw materials on which organizations operate are informational inputs that are ambiguous, uncertain, equivocal. Whether the information is embedded in tangible raw materials, recalcitrant customers, assigned tasks, or union demands, there are many possibilities, or sets of outcomes that might occur. Organizing serves to narrow the range of possibilities, to reduce the number of "might occurs." The activities of organizing are directed toward the establishment of a workable level of certainty. (1969: 40)

In short, Weick asserts that "human beings organize primarily to help them reduce the information uncertainty they face in their lives" (Kreps, 1986: 111).

Organizational activities become structured as sets of "interlocked behaviors"—repetitive, reciprocal, contingent behaviors that develop and are maintained between two or more actors" (Weick, 1969: 91). The activities involved in organizing are carried on in three stages: enactment, selection, and retention.[7] *Enactment* is the active process by which individuals, in interaction, construct a picture of their world, their environment, their situation. Weick argues that

[7]It is instructive to note that these three stages are Weick's translation of the three phases of evolution—variation, selection, and retention—as formulated by Campbell (1969b; see also Chapter 5). Weick is one of the earlier theorists to employ evolutionary arguments; others are considered in subsequent chapters. Weick substitutes the term "enactment" for Campbell's label of "variation" for the first stage to emphasize the active role played by individuals—and organizational participants—in defining the environments they confront.

> Since human beings actively create the world around them through perception, organization members do not merely react to an objectively accepted physical environment but enact their environment through information and the creation of meaning. (Kreps, 1987: 116)

The concept of enactment emphasizes the role of perception but also recognizes that organizational members not only selectively perceive but also directly influence the state of their environments through the cognitive frames they utilize as well as by their own actions, which can alter the state of the environment.

"The activities of organizing are directed toward the establishment of a workable level of certainty" (Weick, 1969: 40). Participants selectively attend to their environments and then, in interaction, make collective sense of what is happening. "Making sense" entails not only developing a common interpretation or set of common meanings, but also developing one or more agreed-upon responses that are *selected* from among the many possibilities. Among responses that are selected, some are more useful and robust than others and it is these which are *retained* in the form of rules or routines. In this manner communal sense making gives rise to a repertory of repeated routines and patterns of interaction—which constitute the process of organizing. As an example, Weick discusses the gradual emergence among physicians of the construction of a "battered child syndrome," to account for the otherwise inexplicable incidents of injuries to children appearing in medical clinics. Lacking this construct, physicians were unable to "make sense" of what they were seeing; with the aid of the new model, explanations, routines, and counteractive remedies could be crafted (Weick, 1995).

Although the objective of the entire process is to reduce equivocality, some ambiguity does and must remain if the organization is to be able to survive into a new and different future. In other words, "organizations continue to exist only if they maintain a balance between flexibility and stability" (Weick, 1979: 215). The information received and selected by the organization must be both credited (retained) and discredited or questioned if the organization is to safely face a future that may resemble, but must inevitably differ from, its past.

Weick's major concern is to spell out the implications of the open systems perspective when applied at the social psychology level—to the behavior of individual participants and the relationships among them. The semiautonomy of the individual actors is stressed: the looseness and conditionality of the relationships linking them is emphasized. Attention and interpretative processes are highlighted. And whereas conventional wisdom asserts that goals precede activities, that intention precedes action, Weick (1969: 37) insists that behavior often occurs first and then is interpreted—given meaning. Rationality is often retrospective. In these and related ways, Weick attempts to "open up" our conception of organizational structure and behavior. More generally, Weick was the first organization theorist to substitute a process- for a structure-based conception of organizations. In this sense, he anticipated later developments in the evolution of organization theory.

Many other theories emerging after the 1960s have expanded the range of insights and implications based on the open systems perspective, but we reserve discussion of them to later chapters.

SUMMARY AND TENTATIVE CONCLUSIONS

The open systems perspective developed later than the rational and natural system views, but it has gained adherents rapidly and profoundly altered our conception of organizations and their central features and processes. The open systems view of organizational structure stresses the complexity and variability of the parts—both individual participants and subgroups—as well as the looseness of connections among them. Parts are viewed as capable of semiautonomous action; many parts are viewed as, at best, loosely coupled to other parts. Further, in human organizations, as Boulding emphasizes, the system is "multi-cephalous": many heads are present to receive information, make decisions, direct action. Individuals and subgroups form and leave coalitions. Coordination and control become problematic. Also, system boundaries are seen as amorphous and transitory; the assignment of actors or actions to either the organization or the environment often seems arbitrary and varies depending on what aspect of systemic functioning is under consideration.

Open system scholars emphasis process over structure. Also, evolutionary theory is introduced to support studies of change, as new elements are introduced, selected or rejected, and retained. The cultural and cognitive dimensions of social life loom large in the open systems perspective. Great attention is devoted to information flows and sense-making activities. Organizations create, but also, appropriate knowledge, know-how, and meaning from their environments.

In this and other ways, the interdependence of the organization and its environment receives primary attention in the open systems perspective. Rather than overlooking the environment, as tends to be true of most early rational and natural system theories, or viewing it as alien and hostile, as is true of some early theories, the open systems perspective stresses the reciprocal ties that bind and relate the organization with those elements and flows that surround and penetrate it. The environment is perceived to be the ultimate source of materials, energy, and information, all of which are vital to the continuation of the system. Indeed, the environment is seen to be the source of order itself.

With the arrival of open system arguments in the 1960s, it quickly became clear that, to the extent that previous perspectives were grounded on closed systems views of organizations, they would need to be radically revised. To remain credible, all subsequent theories have had to take into account the openness of organizations to their environments. So did these developments signal the end of rational and natural system models? Have these early perspectives been consigned to the dustbins of history? Hardly! As discussed in the next chapter, they have continued to flourish as viable perspectives, by moving into the halls of open systems.