

General systems theory: The skeleton of science

Kenneth E. Boulding

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The second of this issue's two classical papers was written by Kenneth E. Boulding back in 1956 and published in one of the earliest issues of *Management Science* which is currently celebrating its fiftieth anniversary (Hopp, 2004). Congratulations to the team at *Management Science*.

Boulding is a peer of a number of great systems thinkers that introduced and developed the general systems movement in the early fifties. Such thinkers include Ludwig von Bertalanffy, Talcott Parsons, C. West Churchman, Alfred Emerson, Anatol Rapoport, and many more - it is likely that selected writings from these thinkers will appear in future issues of *E:CO*.

For those readers not familiar with the general systems movement (from which complexity thinking arguably emerged) Boulding starts his paper with a brief description:

"General Systems Theory is a name which has come into use to describe a level of theoretical model-building which lies somewhere between the highly generalized constructions of pure mathematics and the specific theories of the specialized disciplines."

This description of GST is very important as many complexity theorists still talk of a theory of complexity, or of a theory of management as if all the complexities and ambiguities of our perceived realities could somehow be reduced to a neat little theoretical package much akin to the physicists' quest for a theory of everything, or as Boulding puts it a "general theory of practically everything". In Boulding's mind GST was to be a tool that would enable mankind to effectively move back and forth between the perfectly describable Platonic world of theory and the fuzzy world of practice. Boulding rightly points out that any claims to any sort of theory of everything are misguided as "[s]uch a theory would be almost without content, for we always pay for generality by sacrificing content, and all we can say about practically everything is almost nothing."

Boulding's *General systems theory* is a sort of manifesto for the systems movement, much of which can be seen to be valid for complex systems theory today. A major role for any GST was to facilitate communication between disparate fields of interest, i.e., to provide a common language with which to discuss systemic problems. A lexicon of complexity science is also emerging, containing concepts such as *emergence*, *self-organization*, *chaos*, *bifurcation*, *exaptation*, etc. (some of which were also contained in the GST lexicon), which also aims to facilitate cross-disciplinary dialogue (though I personally doubt whether such an all-embracing way to express complexity is possible - there are an infinity of ways to talk about complexity and all of them should be allowed, initially at least).

The modern complexity movement is in some ways quite different from the general systems movement (although to many writers the two seem almost synonymous), but there is a lot to be learnt from the journey general systems theory has taken. Complex systems thinkers share a lot of the aims and ambitions of the original general systems movement, such as the need for cross-disciplinary communication and the development of analytical tools and processes to interact with, and intervene in, a modern complex (systemic) world. In this paper Boulding not only describes the need and role of a general systems framework but also offers a skeleton of what that framework might look like. Some readers may be surprised as to how fresh this paper still is.

Kurt Richardson

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GENERAL SYSTEMS THEORY—THE SKELETON OF SCIENCE

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General Systems Theory¹ is a name which has come into use to describe a level of theoretical model-building which lies somewhere between the highly generalized constructions of pure mathematics and the specific theories of the specialized disciplines. Mathematics attempts to organize highly general relationships into a coherent system, a system however which does not have any necessary connections with the "real" world around us. It studies all thinkable relationships abstracted from any concrete situation or body of empirical knowledge. It is not even confined to "quantitative" relationships narrowly defined—indeed, the developments of a mathematics of quality and structure is already on the way, even though it is not as far advanced as the "classical" mathematics of quantity and number. Nevertheless because in a sense mathematics contains all theories it contains none; it is the language of theory, but it does not give us the content. At the other extreme we have the separate disciplines and sciences, with their separate bodies of theory. Each discipline corresponds to a certain segment of the empirical world, and each develops theories which have particular applicability to its own empirical segment. Physics, Chemistry, Biology, Psychology, Sociology, Economics and so on all carve out for themselves certain elements of the experience of man and develop theories and patterns of activity (research) which yield satisfaction in understanding, and which are appropriate to their special segments.

In recent years increasing need has been felt for a body of systematic theoretical constructs which will discuss the general relationships of the empirical world. This is the quest of General Systems Theory. It does not seek, of course, to establish a single, self-contained "general theory of practically everything" which will replace all the special theories of particular disciplines. Such a theory would be almost without content, for we always pay for generality by sacrificing content, and all we can say about practically everything is almost nothing. Somewhere however between the specific that *has no meaning* and the general that *has no content* there must be, for each purpose and at each level of abstrac-

¹ The name and many of the ideas are to be credited to L. von Bertalanffy, who is not, however, to be held accountable for the ideas of the present author! For a general discussion of Bertalanffy's ideas see *General System Theory: A New Approach to Unity of Science*, *Human Biology*, Dec., 1951, Vol. 23, p. 303-361.

tion, an optimum degree of generality. It is the contention of the General Systems Theorists that this optimum degree of generality in theory is not always reached by the particular sciences. The objectives of General Systems Theory then can be set out with varying degrees of ambition and confidence. At a low level of ambition but with a high degree of confidence it aims to point out similarities in the theoretical constructions of different disciplines, where these exist, and to develop theoretical models having applicability to at least two different fields of study. At a higher level of ambition, but with perhaps a lower degree of confidence it hopes to develop something like a "spectrum" of theories—a system of systems which may perform the function of a "gestalt" in theoretical construction. Such "gestalts" in special fields have been of great value in directing research towards the gaps which they reveal. Thus the periodic table of elements in chemistry directed research for many decades towards the discovery of unknown elements to fill gaps in the table until the table was completely filled. Similarly a "system of systems" might be of value in directing the attention of theorists towards gaps in theoretical models, and might even be of value in pointing towards methods of filling them.

The need for general systems theory is accentuated by the present sociological situation in science. Knowledge is not something which exists and grows in the abstract. It is a function of human organisms and of social organization. Knowledge, that is to say, is always what somebody knows: the most perfect transcript of knowledge in writing is not knowledge if nobody knows it. Knowledge however grows by the receipt of meaningful information—that is, by the intake of messages by a knower which are capable of reorganizing his knowledge. We will quietly duck the question as to what reorganizations constitute "growth" of knowledge by defining "semantic growth" of knowledge as those reorganizations which can profitably be talked about, in writing or speech, by the Right People. Science, that is to say, is what can be talked about profitably by scientists in their role as scientists. The crisis of science today arises because of the increasing difficulty of such profitable talk among scientists as a whole. Specialization has outrun Trade, communication between the disciples becomes increasingly difficult, and the Republic of Learning is breaking up into isolated subcultures with only tenuous lines of communication between them—a situation which threatens intellectual civil war. The reason for this breakup in the body of knowledge is that in the course of specialization the receptors of information themselves become specialized. Hence physicists only talk to physicists, economists to economists—worse still, nuclear physicists only talk to nuclear physicists and econometricians to econometricians. One wonders sometimes if science will not grind to a stop in an assemblage of walled-in hermits, each mumbling to himself words in a private language that only he can understand. In these days the arts may have beaten the sciences to this desert of mutual unintelligibility, but that may be merely because the swift intuitions of art reach the future faster than the plodding leg work of the scientist. The more science breaks into sub-groups, and the less communication is possible among the disciplines, however, the greater chance there is that the total growth of knowledge is being slowed down by the

loss of relevant communications. The spread of specialized deafness means that someone who ought to know something that someone else knows isn't able to find it out for lack of generalized ears.

It is one of the main objectives of General Systems Theory to develop these generalized ears, and by developing a framework of general theory to enable one specialist to catch relevant communications from others. Thus the economist who realizes the strong formal similarity between utility theory in economics and field theory in physics² is probably in a better position to learn from the physicists than one who does not. Similarly a specialist who works with the growth concept—whether the crystallographer, the virologist, the cytologist, the physiologist, the psychologist, the sociologist or the economist—will be more sensitive to the contributions of other fields if he is aware of the many similarities of the growth process in widely different empirical fields.

There is not much doubt about the demand for general systems theory under one brand name or another. It is a little more embarrassing to inquire into the supply. Does any of it exist, and if so where? What is the chance of getting more of it, and if so, how? The situation might be described as promising and in ferment, though it is not wholly clear what is being promised or brewed. Something which might be called an "interdisciplinary movement" has been abroad for some time. The first signs of this are usually the development of hybrid disciplines. Thus physical chemistry emerged in the third quarter of the nineteenth century, social psychology in the second quarter of the twentieth. In the physical and biological sciences the list of hybrid disciplines is now quite long—biophysics, biochemistry, astrophysics are all well established. In the social sciences social anthropology is fairly well established, economic psychology and economic sociology are just beginning. There are signs, even, that Political Economy, which died in infancy some hundred years ago, may have a re-birth.

In recent years there has been an additional development of great interest in the form of "multisexual" interdisciplinary. The hybrid disciplines, as their hyphenated names indicate, come from two respectable and honest academic parents. The newer interdisciplinary have a much more varied and occasionally even obscure ancestry, and result from the reorganization of material from many different fields of study. Cybernetics, for instance, comes out of electrical engineering, neurophysiology, physics, biology, with even a dash of economics. Information theory, which originated in communications engineering, has important applications in many fields stretching from biology to the social sciences. Organization theory comes out of economics, sociology, engineering, physiology, and Management Science itself is an equally multidisciplinary product.

On the more empirical and practical side the interdisciplinary movement is reflected in the development of interdepartmental institutes of many kinds. Some of these find their basis of unity in the empirical field which they study, such as institutes of industrial relations, of public administration, of international

² See A. G. Pikler, *Utility Theories in Field Physics and Mathematical Economics*, *British Journal for the Philosophy of Science*, 1955, Vol. 5, pp. 47 and 303.

affairs, and so on. Others are organized around the application of a common methodology to many different fields and problems, such as the Survey Research Center and the Group Dynamics Center at the University of Michigan. Even more important than these visible developments, perhaps, though harder to perceive and identify, is a growing dissatisfaction in many departments, especially at the level of graduate study, with the existing traditional theoretical backgrounds for the empirical studies which form the major part of the output of Ph.D. theses. To take but a single example from the field with which I am most familiar. It is traditional for studies of labor relations, money and banking, and foreign investment to come out of departments of economics. Many of the needed theoretical models and frameworks in these fields, however, do not come out of "economic theory" as this is usually taught, but from sociology, social psychology, and cultural anthropology. Students in the department of economics however rarely get a chance to become acquainted with these theoretical models, which may be relevant to their studies, and they become impatient with economic theory, much of which may not be relevant.

It is clear that there is a good deal of interdisciplinary excitement abroad. If this excitement is to be productive, however, it must operate within a certain framework of coherence. It is all too easy for the interdisciplinary to degenerate into the undisciplined. If the interdisciplinary movement, therefore, is not to lose that sense of form and structure which is the "discipline" involved in the various separate disciplines, it should develop a structure of its own. This I conceive to be the great task of general systems theory. For the rest of this paper, therefore, I propose to look at some possible ways in which general systems theory might be structured.

Two possible approaches to the organization of general systems theory suggest themselves, which are to be thought of as complementary rather than competitive, or at least as two roads each of which is worth exploring. The first approach is to look over the empirical universe and to pick out certain general *phenomena* which are found in many different disciplines, and to seek to build up general theoretical models relevant to these phenomena. The second approach is to arrange the empirical fields in a hierarchy of complexity of organization of their basic "individual" or unit of behavior, and to try to develop a level of abstraction appropriate to each.

Some examples of the first approach will serve to clarify it, without pretending to be exhaustive. In almost all disciplines, for instance, we find examples of populations—aggregates of individuals conforming to a common definition, to which individuals are added (born) and subtracted (die) and in which the age of the individual is a relevant and identifiable variable. These populations exhibit dynamic movements of their own, which can frequently be described by fairly simple systems of difference equations. The populations of different species also exhibit dynamic interactions among themselves, as in the theory of Volterra. Models of population change and interaction cut across a great many different fields—ecological systems in biology, capital theory in economics which deals with populations of "goods," social ecology, and even certain problems of sta-

tistical mechanics. In all these fields population change, both in absolute numbers and in structure, can be discussed in terms of birth and survival functions relating numbers of births and of deaths in specific age groups to various aspects of the system. In all these fields the interaction of population can be discussed in terms of competitive, complementary, or parasitic relationships among populations of different species, whether the species consist of animals, commodities, social classes or molecules.

Another phenomenon of almost universal significance for all disciplines is that of the interaction of an "individual" of some kind with its environment. Every discipline studies some kind of "individual"—electron, atom, molecule, crystal, virus, cell, plant, animal, man, family, tribe, state, church, firm, corporation, university, and so on. Each of these individuals exhibits "behavior," action, or change, and this behavior is considered to be related in some way to the environment of the individual—that is, with other individuals with which it comes into contact or into some relationship. Each individual is thought of as consisting of a structure or complex of individuals of the order immediately below it—atoms are an arrangement of protons and electrons, molecules of atoms, cells of molecules, plants, animals and men of cells, social organizations of men. The "behavior" of each individual is "explained" by the structure and arrangement of the lower individuals of which it is composed, or by certain principles of equilibrium or homeostasis according to which certain "states" of the individual are "preferred." Behavior is described in terms of the restoration of these preferred states when they are disturbed by changes in the environment.

Another phenomenon of universal significance is growth. Growth theory is in a sense a subdivision of the theory of individual "behavior," growth being one important aspect of behavior. Nevertheless there are important differences between equilibrium theory and growth theory, which perhaps warrant giving growth theory a special category. There is hardly a science in which the growth phenomenon does not have some importance, and though there is a great difference in complexity between the growth of crystals, embryos, and societies, many of the principles and concepts which are important at the lower levels are also illuminating at higher levels. Some growth phenomena can be dealt with in terms of relatively simple population models, the solution of which yields growth curves of single variables. At the more complex levels structural problems become dominant and the complex interrelationships between growth and form are the focus of interest. All growth phenomena are sufficiently alike however to suggest that a general theory of growth is by no means an impossibility.³

Another aspect of the theory of the individual and also of interrelationships among individuals which might be singled out for special treatment is the theory of information and communication. The information concept as developed by Shannon has had interesting applications outside its original field of electrical engineering. It is not adequate, of course, to deal with problems involving the semantic level of communication. At the biological level however the informa-

³ See "Towards a General Theory of Growth" by K. E. Boulding, *Canadian Journal of Economics and Political Science*, 19 Aug. 1953, 326-340.

tion concept may serve to develop general notions of structuredness and abstract measures of organization which give us, as it were, a third basic dimension beyond mass and energy. Communication and information processes are found in a wide variety of empirical situations, and are unquestionably essential in the development of organization, both in the biological and the social world.

These various approaches to general systems through various aspects of the empirical world may lead ultimately to something like a general field theory of the dynamics of action and interaction. This, however, is a long way ahead.

A second possible approach to general systems theory is through the arrangement of theoretical systems and constructs in a hierarchy of complexity, roughly corresponding to the complexity of the "individuals" of the various empirical fields. This approach is more systematic than the first, leading towards a "system of systems." It may not replace the first entirely, however, as there may always be important theoretical concepts and constructs lying outside the systematic framework. I suggest below a possible arrangement of "levels" of theoretical discourse.

(i) The first level is that of the static structure. It might be called the level of *frameworks*. This is the geography and anatomy of the universe—the patterns of electrons around a nucleus, the pattern of atoms in a molecular formula, the arrangement of atoms in a crystal, the anatomy of the gene, the cell, the plant, the animal, the mapping of the earth, the solar system, the astronomical universe. The accurate description of these frameworks is the beginning of organized theoretical knowledge in almost any field, for without accuracy in this description of static relationships no accurate functional or dynamic theory is possible. Thus the Copernican revolution was really the discovery of a new static framework for the solar system which permitted a simpler description of its dynamics.

(ii) The next level of systematic analysis is that of the simple dynamic system with predetermined, necessary motions. This might be called the level of *clock-works*. The solar system itself is of course the great clock of the universe from man's point of view, and the deliciously exact predictions of the astronomers are a testimony to the excellence of the clock which they study. Simple machines such as the lever and the pulley, even quite complicated machines like steam engines and dynamos fall mostly under this category. The greater part of the theoretical structure of physics, chemistry, and even of economics falls into this category. Two special cases might be noted. Simple equilibrium systems really fall into the dynamic category, as every equilibrium system must be considered as a limiting case of a dynamic system, and its stability cannot be determined except from the properties of its parent dynamic system. Stochastic dynamic systems leading to equilibria, for all their complexity, also fall into this group of systems; such is the modern view of the atom and even of the molecule, each position or part of the system being given with a certain degree of probability, the whole nevertheless exhibiting a determinate structure. Two types of analytical method are important here, which we may call, with the usage of the economists, comparative statics and true dynamics. In comparative statics we compare two equilibrium positions of the system under different values for the

basic parameters. These equilibrium positions are usually expressed as the solution of a set of simultaneous equations. The method of comparative statics is to compare the solutions when the parameters of the equations are changed. Most simple mechanical problems are solved in this way. In true dynamics on the other hand we exhibit the system as a set of difference or differential equations, which are then solved in the form of an explicit function of each variable with time. Such a system may reach a position of stationary equilibrium, or it may not—there are plenty of examples of explosive dynamic systems, a very simple one being the growth of a sum at compound interest! Most physical and chemical reactions and most social systems do in fact exhibit a tendency to equilibrium—otherwise the world would have exploded or imploded long ago.

(iii) The next level is that of the control mechanism or cybernetic system, which might be nicknamed the level of the *thermostat*. This differs from the simple stable equilibrium system mainly in the fact that the transmission and interpretation of information is an essential part of the system. As a result of this the equilibrium position is not merely determined by the equations of the system, but the system will move to the maintenance of any *given* equilibrium, within limits. Thus the thermostat will maintain *any* temperature at which it can be set; the equilibrium temperature of the system is not determined solely by its equations. The trick here of course is that the essential variable of the dynamic system is the *difference* between an “observed” or “recorded” value of the maintained variable and its “ideal” value. If this difference is not zero the system moves so as to diminish it; thus the furnace sends up heat when the temperature as recorded is “too cold” and is turned off when the recorded temperature is “too hot.” The homeostasis model, which is of such importance in physiology, is an example of a cybernetic mechanism, and such mechanisms exist through the whole empirical world of the biologist and the social scientist.

(iv) The fourth level is that of the “open system,” or self-maintaining structure. This is the level at which life begins to differentiate itself from not-life: it might be called the level of the *cell*. Something like an open system exists, of course, even in physico-chemical equilibrium systems; atomic structures maintain themselves in the midst of a throughput of electrons, molecular structures maintain themselves in the midst of a throughput of atoms. Flames and rivers likewise are essentially open systems of a very simple kind. As we pass up the scale of complexity of organization towards living systems, however, the property of self-maintenance of structure in the midst of a throughput of material becomes of dominant importance. An atom or a molecule can presumably exist without throughput: the existence of even the simplest living organism is inconceivable without ingestion, excretion and metabolic exchange. Closely connected with the property of self-maintenance is the property of self-reproduction. It may be, indeed, that self-reproduction is a more primitive or “lower level” system than the open system, and that the gene and the virus, for instance, may be able to reproduce themselves without being open systems. It is not perhaps an important question at what point in the scale of increasing complexity “life” begins. What is clear, however, is that by the time we have got to systems which both reproduce

themselves and maintain themselves in the midst of a throughput of material and energy, we have something to which it would be hard to deny the title of "life."

(v) The fifth level might be called the genetic-societal level; it is typified by the *plant*, and it dominates the empirical world of the botanist. The outstanding characteristics of these systems are first, a division of labor among cells to form a cell-society with differentiated and mutually dependent parts (roots, leaves, seeds, etc.), and second, a sharp differentiation between the genotype and the phenotype, associated with the phenomenon of equifinal or "blueprinted" growth. At this level there are no highly specialized sense organs and information receptors are diffuse and incapable of much throughput of information—it is doubtful whether a tree can distinguish much more than light from dark, long days from short days, cold from hot.

(vi) As we move upward from the plant world towards the animal kingdom we gradually pass over into a new level, the "animal" level, characterized by increased mobility, teleological behavior, and self-awareness. Here we have the development of specialized information-receptors (eyes, ears, etc.) leading to an enormous increase in the intake of information; we have also a great development of nervous systems, leading ultimately to the brain, as an organizer of the information intake into a knowledge structure or "image". Increasingly as we ascend the scale of animal life, behavior is response not to a specific stimulus but to an "image" or knowledge structure or view of the environment as a whole. This image is of course determined ultimately by information received into the organism; the relation between the receipt of information and the building up of an image however is exceedingly complex. It is not a simple piling up or accumulation of information received, although this frequently happens, but a structuring of information into something essentially different from the information itself. After the image structure is well established most information received produces very little change in the image—it goes through the loose structure, as it were, without hitting it, much as a sub-atomic particle might go through an atom without hitting anything. Sometimes however the information is "captured" by the image and added to it, and sometimes the information hits some kind of a "nucleus" of the image and a reorganization takes place, with far reaching and radical changes in behavior in apparent response to what seems like a very small stimulus. The difficulties in the prediction of the behavior of these systems arises largely because of this intervention of the image between the stimulus and the response.

(vii) The next level is the "human" level, that is of the individual human being considered as a system. In addition to all, or nearly all, of the characteristics of animal systems man possesses self consciousness, which is something different from mere awareness. His image, besides being much more complex than that even of the higher animals, has a self-reflexive quality—he not only knows, but knows that he knows. This property is probably bound up with the phenomenon of language and symbolism. It is the capacity for speech—the ability to produce, absorb, and interpret *symbols*, as opposed to mere signs like

the warning cry of an animal—which most clearly marks man off from his humbler brethren. Man is distinguished from the animals also by a much more elaborate image of time and relationship; man is probably the only organization that knows that it dies, that contemplates in its behavior a whole life span, and more than a life span. Man exists not only in time and space but in history, and his behavior is profoundly affected by his view of the time process in which he stands.

(viii) Because of the vital importance for the individual man of symbolic images and behavior based on them it is not easy to separate clearly the level of the individual human organism from the next level, that of social organizations. In spite of the occasional stories of feral children raised by animals, man isolated from his fellows is practically unknown. So essential is the symbolic image in human behavior that one suspects that a truly isolated man would not be "human" in the usually accepted sense, though he would be potentially human. Nevertheless it is convenient for some purposes to distinguish the individual human as a system from the social systems which surround him, and in this sense social organizations may be said to constitute another level of organization. The unit of such systems is not perhaps the person—the individual human as such—but the "role"—that part of the person which is concerned with the organization or situation in question, and it is tempting to define social organizations, or almost any social system, as a set of roles tied together with channels of communication. The interrelations of the role and the person however can never be completely neglected—a square person in a round role may become a little rounder, but he also makes the role squarer, and the perception of a role is affected by the personalities of those who have occupied it in the past. At this level we must concern ourselves with the content and meaning of messages, the nature and dimensions of value systems, the transcription of images into a historical record, the subtle symbolizations of art, music, and poetry, and the complex gamut of human emotion. The empirical universe here is human life and society in all its complexity and richness.

(ix) To complete the structure of systems we should add a final turret for transcendental systems, even if we may be accused at this point of having built Babel to the clouds. There are however the ultimates and absolutes and the inescapable unknowables, and they also exhibit systematic structure and relationship. It will be a sad day for man when nobody is allowed to ask questions that do not have any answers.

One advantage of exhibiting a hierarchy of systems in this way is that it gives us some idea of the present gaps in both theoretical and empirical knowledge. Adequate theoretical models extend up to about the fourth level, and not much beyond. Empirical knowledge is deficient at practically all levels. Thus at the level of the static structure, fairly adequate descriptive models are available for geography, chemistry, geology, anatomy, and descriptive social science. Even at this simplest level, however, the problem of the adequate description of complex structures is still far from solved. The theory of indexing and cataloging, for instance, is only in its infancy. Librarians are fairly good at cataloging books,

chemists have begun to catalogue structural formulae, and anthropologists have begun to catalogue culture trails. The cataloguing of events, ideas, theories, statistics, and empirical data has hardly begun. The very multiplication of records however as time goes on will force us into much more adequate cataloguing and reference systems than we now have. This is perhaps the major unsolved theoretical problem at the level of the static structure. In the empirical field there are still great areas where static structures are very imperfectly known, although knowledge is advancing rapidly, thanks to new probing devices such as the electron microscope. The anatomy of that part of the empirical world which lies between the large molecule and the cell however, is still obscure at many points. It is precisely this area however—which includes, for instance, the gene and the virus—that holds the secret of life, and until its anatomy is made clear the nature of the functional systems which are involved will inevitably be obscure.

The level of the "clockwork" is the level of "classical" natural science, especially physics and astronomy, and is probably the most completely developed level in the present state of knowledge, especially if we extend the concept to include the field theory and stochastic models of modern physics. Even here however there are important gaps, especially at the higher empirical levels. There is much yet to be known about the sheer mechanics of cells and nervous systems, of brains and of societies.

Beyond the second level adequate theoretical models get scarcer. The last few years have seen great developments at the third and fourth levels. The theory of control mechanisms ("thermostats") has established itself as the new discipline or cybernetics, and the theory of self-maintaining systems or "open systems" likewise has made rapid strides. We could hardly maintain however that much more than a beginning had been made in these fields. We know very little about the cybernetics of genes and genetic systems, for instance, and still less about the control mechanisms involved in the mental and social world. Similarly the processes of self-maintenance remain essentially mysterious at many points, and although the theoretical possibility of constructing a self-maintaining machine which would be a true open system has been suggested, we seem to be a long way from the actual construction of such a mechanical similitude of life.

Beyond the fourth level it may be doubted whether we have as yet even the rudiments of theoretical systems. The intricate machinery of growth by which the genetic complex organizes the matter around it is almost a complete mystery. Up to now, whatever the future may hold, only God can make a tree. In the face of living systems we are almost helpless; we can occasionally cooperate with systems which we do not understand: we cannot even begin to reproduce them. The ambiguous status of medicine, hovering as it does uneasily between magic and science, is a testimony to the state of systematic knowledge in this area. As we move up the scale the absence of the appropriate theoretical systems becomes ever more noticeable. We can hardly conceive ourselves constructing a system which would be in any recognizable sense "aware," much less self-conscious. Nevertheless as we move towards the human and societal level a curious

thing happens: the fact that we have, as it were, an inside track, and that we ourselves *are* the systems which we are studying, enables us to utilize systems which we do not really understand. It is almost inconceivable that we should make a machine that would make a poem: nevertheless, poems *are* made by fools like us by processes which are largely hidden from us. The kind of knowledge and skill that we have at the symbolic level is very different from that which we have at lower levels—it is like, shall we say, the “knowhow” of the gene as compared with the knowhow of the biologist. Nevertheless it is a real kind of knowledge and it is the source of the creative achievements of man as artist, writer, architect, and composer.

Perhaps one of the most valuable uses of the above scheme is to prevent us from accepting as final a level of theoretical analysis which is below the level of the empirical world which we are investigating. Because, in a sense, each level incorporates all those below it, much valuable information and insights can be obtained by applying low-level systems to high-level subject matter. Thus most of the theoretical schemes of the social sciences are still at level (ii), just rising now to (iii), although the subject matter clearly involves level (viii). Economics, for instance, is still largely a “mechanics of utility and self interest,” in Jevons’ masterly phrase. Its theoretical and mathematical base is drawn largely from the level of simple equilibrium theory and dynamic mechanisms. It has hardly begun to use concepts such as information which are appropriate at level (iii), and makes no use of higher level systems. Furthermore, with this crude apparatus it has achieved a modicum of success, in the sense that anybody trying to manipulate an economic system is almost certain to be better off if he knows some economics than if he doesn’t. Nevertheless at some point progress in economics is going to depend on its ability to break out of these low-level systems, useful as they are as first approximations, and utilize systems which are more directly appropriate to its universe—when, of course, these systems are discovered. Many other examples could be given—the wholly inappropriate use in psychoanalytic theory, for instance, of the concept of energy, and the long inability of psychology to break loose from a sterile stimulus-response model.

Finally, the above scheme might serve as a mild word of warning even to Management Science. This new discipline represents an important breakaway from overly simple mechanical models in the theory of organization and control. Its emphasis on communication systems and organizational structure, on principles of homeostasis and growth, on decision processes under uncertainty, is carrying us far beyond the simple models of maximizing behavior of even ten years ago. This advance in the level of theoretical analysis is bound to lead to more powerful and fruitful systems. Nevertheless we must never quite forget that even these advances do not carry us much beyond the third and fourth levels, and that in dealing with human personalities and organizations we are dealing with systems in the empirical world far beyond our ability to formulate. We should not be wholly surprised, therefore, if our simpler systems, for all their importance and validity, occasionally let us down.

I chose the subtitle of my paper with some eye to its possible overtones of

meaning. General Systems Theory is the skeleton of science in the sense that it aims to provide a framework or structure of systems on which to hang the flesh and blood of particular disciplines and particular subject matters in an orderly and coherent corpus of knowledge. It is also, however, something of a skeleton in a cupboard—the cupboard in this case being the unwillingness of science to admit the very low level of its successes in systematization, and its tendency to shut the door on problems and subject matters which do not fit easily into simple mechanical schemes. Science, for all its successes, still has a very long way to go. General Systems Theory may at times be an embarrassment in pointing out how very far we still have to go, and in deflating excessive philosophical claims for overly simple systems. It also may be helpful however in pointing out to some extent *where* we have to go. The skeleton must come out of the cupboard before its dry bones can live.