CHAPTER

I

Tools for Thinking: The General Nature of Theory and Models

The history of many fields of science shows a characteristic pattern. There is a time in which the science goes through a philosophic stage in its development; the emphasis is on theory, on general concepts, and on the questioning of the fundamental assumptions and methods by which knowledge has been accumulated. At the end of such a philosophic stage often stands an agreement on some basic assumptions and methods—though not necessarily on all of them—and a shifting of interest to the application of these methods to the gathering of detailed facts. The philosophic stages in the development of science define the main lines of interest; in the empirical stages these interests are followed up. Philosophic stages in the development of a particular science are concerned with strategy; they select the targets and the main lines of attack. Empirical stages are concerned with tactics; they attain the targets, or they accumulate experience indicating that the targets cannot be taken in this manner and that the underlying strategy was wrong.[1]

In any case, every empirical stage ends with the need for a revision of fundamental concepts and underlying strategy. If these were inadequate, the revision must come soon. If they were adequate for a time, the revision must nevertheless come later, for the very success of the concepts, methods, and interests adopted will lead in time to an accumulation of data and problems that will point beyond the interests and methods by which they were discovered. In the end, every empirical stage will have bitten off more facts than it can chew, and scientists will have to turn to a new philosophic stage for more powerful analytic equipment.

The test of this conceptual equipment must be twofold: it must be operational, that is, it must lead to inferences capable of being confirmed or refuted by repeatable physical operations; and it must be fruitful, that is, it must lead to new observations and experiments, and eventually to further developments in theory.[2] The stage of philosophic or conceptual emphasis must again lead to empirical progress, and the progress eventually leads once more to new fundamental problems.

The social sciences today perhaps are approaching another "philosophic crisis"—an age of re-examination of concepts, methods, and interests, of search for new symbolic models and/or new strategies in selecting their major targets for attack. At the same time, their data have increased in quantity, and selection has become ever more imperative. To understand and describe in full detail the political process even in a single country may well take the work of a lifetime. To do the same for several countries means to multiply the amount of possible data to be looked for and of possible questions to be asked.

Clearly, selection is of the essence. What are the data most worth getting? What are the questions most worth asking? What are the propositions most worth verifying or disproving? Our answers to these questions will determine the shape of any investigation and may do much to determine the value of the outcome. But to say that we must choose our questions is another way of saying that we must choose our concepts or models.

We obtain the answers to these questions by our preliminary "understanding" of the situation we propose to study. But we could perhaps obtain better answers if we had a better critical grasp of the vague process of "understanding" to which we commit so much of our professional fortunes.[3]

This process of understanding, from its early stages to the final theory or strategy of inquiry, is carried on by means of symbolic models that all of us use in our thinking. It may be worth our while to gain a clearer picture of this process of choosing models and of using them, and we may end with more and sharper intellectual tools than were available to past generations. To be sure, a master sometimes may accomplish more with crude tools than could a novice with better technical equipment. Even so, there may be some usefulness in a brief survey of the nature of conceptual models, and a discussion of a few more recently developed models of this kind in terms of their possible usefulness to comparative political studies.

KNOWLEDGE AND MODELS IN SOCIAL SCIENCE

To discuss some of the recent models in the field of political science, we must recall briefly the role of any model in the pursuit of knowledge. In order to "know" a process, we must use symbols that we match in some way against the distribution of some aspects of the process we study, much as we match the distributions of symbols on a map against the distributions of coastlines, rivers, or roads in the landscape to be pictured. To know thus always means to omit and to select. In this sense, no knowledge is completely "objective."

But to know also means to match our standards of selection, explicit or implied, against the practical requirements of the action for which this knowledge is to be used. If we want to drive a car, we can omit offshore sandbanks from our map, but we must not omit roads. (If we want to sail a boat, some of the sandbanks may have to be included.) In this sense, no knowledge can be completely "nonobjective," if it is to be applied.

Knowledge depends on four things:

1. the selective interests of the knower;
2. the actual characteristics of the situation to be known;
3. the selective operations by which these characteristics can in fact be experienced or measured; and

4. the system of symbols and physical facilities by which the data selected in stages 1 and 3 are recorded and used for later application.

Knowledge is thus a process in which subjective and objective elements inevitably meet. Its first stage is subjective: the interests and needs of the knower. Its second stage—the existing characteristics of the situation—is objective to the extent that these characteristics are not significantly changed by the effects of observation. The third and fourth stages involve both elements: an objectively existing repertory of available measuring operations, and of encoding and recording facilities; and a set of subjective choices of items from this available repertory for use in actual operations. Moreover, the selection, in terms of interest or the asking of questions (stage 1), and in terms of measurability or the getting of relevant data for answers (stage 3), need not coincide: we may be interested in things for which we may at present have no operations of measurement. We may be interested, as it were, in color, but may find ourselves limited by our equipment to line drawings or black-and-white photography.

Pictures, photographs, and maps are simple models of situations in space. Various geopolitical maps and crude diagrams of political or social structures have been used by social scientists for a number of years.

Sometimes we are interested in mapping the performance of some thing or process over time. Here, again, the success of such mapping or diagraming over time will depend on the four stages of the process of knowing: the criteria of interest selected, the actual characteristics of the process to be studied, the operations of measurement employed, and the symbols and symbol systems used for recording and using the results. Curves of the growth of population, of production in particular industries or of votes for a particular party, or of membership in labor unions, are examples of such mapping over time.

Maps, as well as time diagrams, can do more than summarize existing knowledge. They can suggest ways of looking for new knowl-

edge, and help to predict regularities that may or may not be confirmed by later experience or measurement. We can do these things through the operation of *prediction*. This operation consists in noting the pattern of the distribution of a set of known data, and extending tentatively a similar pattern into some area of space, or some period of time, from which we have as yet no firsthand data. In this manner we may guess at least something of the features of an unexplored country by noting the distribution of rivers and mountains leading to the edges of the "white patch" on our map. Nineteenth-century explorers did use such reasoning to guide their search for the sources and tributaries of the river Nile.

In making predictions over time, we must similarly collect series of selected data for the past, abstract from them some pattern, and extend or "extrapolate" that pattern tentatively into the future. As in the case of the map, this procedure may yield two kinds of predictions: (1) general predictions of interest (for example, does the future seem likely to contain data of interest to us, in terms of our criteria of interest assumed at the outset?); and (2) specific predictions of distribution (for example, what relevant events seem likely to occur in the future, and when do they seem likely to occur?). General predictions of interest are related to the *heuristic* functions of models; they tell us where to go to look for *something* interesting. Specific predictions of distributions are predictive in the narrower sense of the word; they tell us just what we should expect to find. Heuristic as well as predictive forecasts—for example, of future population growth, of anticipated market changes or needs for raw materials, of business cycles, or of changes in military potential or political stability—are all well known to social scientists.

By extending several time series tentatively into the future, side by side, we may make a guess as to what might happen if the peaks or valleys of several such series, let us say, of industrial strikes and agrarian unrest, or exports and domestic credits, should happen to coincide at some date in the future, even if they did not do so in the past. Natural scientists can predict in this manner the likelihood of rip tides, when the time of flood, the phase and position of the moon, and a strong onshore wind may combine to maximum effect. Students of social and political science might similarly become able to appraise the likelihood of rip tides of social change, when several normally separate processes making for social stress might coincide so as to exercise their greatest force. Thus, if in each of, say, one hundred countries there were at work three mutually independent stress-producing processes—such as agrarian revolts, industrial unrest, and foreign military conflict—and if each of these processes should tend to become acute, or to reach a peak about once every ten years, then the chances would be better than even that these three peaks would coincide, and the "rip-tide effect" would shake or even overthrow the government in at least one of these countries within the next ten years.

Our discussion of the nature of knowledge has clear implications for the functions of models. We may think of models as serving, more or less imperfectly, four distinct functions: the organizing, the heuristic, the predictive, and the measuring (or mensurative).

By the *organizing* function is meant the ability of a model to order and relate disjointed data, and to show similarities or connections between them that had previously remained unperceived. To make isolated pieces of information fall suddenly into a meaningful pattern is to furnish an esthetic experience; Professor Paul Lazarsfeld once described it as the "Aha!-experience" familiar to psychologists.[4] Such organization may facilitate its storage in memory, and perhaps even more its recall.

If the new model organizes information about unfamiliar processes in terms of images borrowed from familiar events, we call it an *explanation*. The operational function of an explanation is that of a training or teaching device that facilitates the transfer of learned habits from a familiar to an unfamiliar environment. If it actually does help us to transfer some familiar behavior pattern to a new problem, we may feel that the explanation is "satisfactory," or even that it "satisfies our curiosity," at least for a time. Such an explanation might be subjectively satisfying without being predictive; it would satisfy some persons but not others, depending on each person's memories and habits. Since it yields no predictions that can be tested by physical operations, it would be rejected by some scientists as a "mere explanation" that would be operationally meaningless.[5]

Certainly, such "mere explanations" are models of a very low order. It seems, however, that explanations almost invariably imply some predictions. Moreover, even if these predictions cannot be verified by techniques practicable at the present time, they may yet serve as *heuristic* devices leading to the discovery of new facts and new methods.[6] This heuristic function of making discoveries more probable has already been discussed above. Here, it is mainly important for us to remember that the heuristic function of a model may be independent to a considerable degree from its orderliness or organizing power, as well as from its predictive and mensurative performance.

Little need be added to our earlier discussion of the *predictive* function of a model, beyond the well-known requirement of verifiability by physical operations. There are different kinds of prediction, however, that form something of a spectrum. At one extreme we find simple yes-or-no predictions; at higher degrees of specificity we get qualitative predictions of similarity or matching, where the result is predicted to be of this kind or of that kind, or of this particular delicate shade; and at the other extreme we find completely quantitative predictions that may give us elaborate time series that may answer the questions of "When?" and "How much?"[7]

At this extreme, models become related ~~to measurement~~. If the model is related to the thing modeled by laws that are not clearly understood, the data it yields may serve as indicators. If it is connected to the thing modeled by processes clearly understood, we may call the data obtained with its help a *measure*—and measures again may range all the way from simple rank orderings to full-fledged ratio scales.[8]

The effectiveness of our predictions will depend in all cases upon the four elements of the process of knowledge we listed earlier. One of these elements is never completely under our control: the actual structure of the process that we are trying to know in the present and to predict for the future. If this structure happens to have sufficiently large discontinuities in its performance, all our guesses and extrapolations may remain mistaken.

The other three elements of knowledge, however, are under our control to a greater degree. Our selective interests develop with our increasing experience and knowledge, and with our expanding range of needs and of things we are able to do. Our operations of observation and measurement develop with the growth of our technology, and with the introduction of new instruments or methods of inquiry in the social as well as in the natural sciences. Finally, the range and effectiveness of our symbols and symbol systems increase, and accompany increases in our power to select and abstract, to store and recall, to analyze and recombine the sets of data we obtain, to extend them for prediction, to transfer them easily for communication, to submit them to operational tests for verification, and to apply them to behavior. Progress in the effectiveness of symbols and symbol systems is thus basic progress in the technology of thinking and in the development of human powers of insight and action.

A *symbol* is an order to recall from memory a particular thing or event, or a particular set of things or events. Any physical work or event that functions repeatedly as such a command can thus function as a symbol. If we use several symbols, so as to be able to recall several different things, we must connect our symbols with some operating rules. Together, the set of symbols and the set of operating rules form a *symbol system* or a *model.*

Any language is such a symbol system. Roughly speaking, it is a set of socially standardized words, or shorter sound patterns or "phonemes" with a set of rules of grammar and syntax, which specify their combinations. A system of geometry or arithmetic, a logical calculus, a game like chess or poker, or a model, physical or abstract, of some process, or a "conceptual scheme" in a natural or social science are all symbol systems of this kind.[9]

If the system has been chosen for purposes of play, as in choosing a game, the symbols or rules adopted need only be such as to give the player such thrills or challenges for his talents as he desires. If the system has been chosen for purposes of knowledge of the existing world, as in scientific models and conceptual schemes, and in applied mathematics, then it is desirable that the symbols and rules should match as well as possible the distributions and sequences of events in the process of which knowledge is desired. If the model actually matches the reality, then the outcome of operations on the model may be used to predict the outcome of operations in reality, where such operations might be difficult or costly.

Models can be formal or material. In the case of formal models, such as mathematical or geometric models, both symbols and rules are themselves abstract, and are recorded by means of signs that can be set down on paper. Some models of this kind may be quite unsuited to visual representation. The "consumption function" and the "production function" in John Maynard Keynes' system of economics give precise quantitative predictions that can be represented on a graph, but the mathematical model from which this graph is derived is almost as difficult to imagine visually as are some of the mathematical models used in quantitative physics.

Other formal models may seem more familiar to us, since they are at least loosely connected with some familiar pictures from everyday experience—even though these pictures may fail to give the content of the models much precision. In this manner, the Ionian philosophers transferred the familiar models of "law" and "cause" from social life into the world of nature,[10] but the precise formal content of the concept of "strict causality" in either nature or society remained a subject of discussion for many centuries.

In the case of material models, symbols may be tangible objects (as in the parts of a model airplane) or unseen processes (as electric currents in a network analyzer). The operating rules are then given by the physical properties of the resulting system.

In all cases, models must be tested for their *relevance:* do they match those aspects of the empirical process in which we are interested to a degree of accuracy sufficient for our purposes? Whether or not a model matches reality must be established by some *critical process,* that is, some physical process, simple or complex, that has one kind of outcome if the matching is close enough, and another outcome if it is not.[11]

It seems clear, from what has been said thus far, that we all use models in our thinking all the time, even though we may not stop to notice it. When we say that we "understand" a situation, political or otherwise, we say, in effect, that we have in our mind an abstract model, vague or specific, that permits us to parallel or predict such changes in that situation of interest to us.

When we say that we "understand" a person, we may mean one of two things. Either we mean that we understand his *situation,* and can "put ourselves into his place," that is, that we have a model of the conditions under which he is acting that permits us to conclude that we, with our memories and values, would act very similarly in that situation as he does with his memories and his values. Or we mean that we understand his *outlook;* that is, we can imagine a model of his mind, with his memories and values, that is sufficiently accurate for us to predict—and perhaps to experience emotionally by empathy—how he would act with his mind and his personality under conditions in which we ourselves might act quite differently.

The first type of understanding, which built models of different situations but treated human nature as essentially uniform, was prominent in the political science of Hobbes and Locke. The search for the second type of understanding, which seeks for models of different personality, culture, and value patterns so as to retrace or predict their choice of goals and goal-oriented actions, has become prominent in the "understanding sociology" (*verstehende Soziologie*) of Max Weber and in the work of modern anthropologists.[12]

This kind of understanding of individuals and groups "from the inside," as it were, can again be visualized in two broad ways: as a rational reconstruction of the personality, culture, or cognitive map of the actors concerned, or an act of empathy or role-playing, that is, an emotional simulation of their feelings by an imaginative manipulation of our own minds. This type of understanding by empathy has been stressed and elaborated by Wilhelm Dilthey and his followers,[13] but its basic idea is simple: can we in our imagination feel as the other person feels, value what he values, experience his inner tensions as if they were our own—regardless of whether we approve

or disapprove of his purposes? This is the understanding of what the sociologist Talcott Parsons would call the "evaluative" and the "cathectic" aspects of the other person's actions.[14]

If we suggest that understanding of impersonal situations, as well as personal actions, is possible by means of models, and perhaps only by means of models, we are apt to meet with two kinds of objections.

The first objection is based on the fact of uncertainty. Since many events in politics and social life are uncertain until the moment they occur, would not a prediction based on models introduce an unwarranted bias in favor of some assumed strict causality or determinism? This objection, where it still persists, is based on ignorance or, more charitably put, on a preoccupation with obsolete models. There is no need to put more "causality" or "determinism" into our symbolic models than we have reason to expect to find in the situations we intend to investigate with their aid. Models can be set up in terms of probability, and they can be revised in line with the probability distributions found in the empirical data. Our entire discussion of prediction was in terms of a repeatable operation, and not in terms of any construct of "causality." The pitfalls of the notion of causality have been pointed out for the natural sciences by P. W. Bridgman[15] and for the social sciences by R. M. MacIver.[16] Political scientists can very well seek out and test possible regularities and probabilities without becoming entangled in the metaphysics of any absolute causality concept.

The second objection comes from a seemingly opposite viewpoint. The most important events, it claims, are not merely uncertain; they are unique. They can, therefore, be indicated by symbols, but not described by them, regardless of their arrangement in any system, language, or model whatever. Such events are thus ineffable. At most (and only if we exempt the nerve cells of the human brain from the limitations of all other symbol-carrying structures), they can be understood by solitary individuals through incommunicable intuition. In a less extreme version of this argument, comparability is not denied, but is limited to the unimportant aspects of each situation, leaving intact the "essential uniqueness" of each historical event.

Well.—

This theory of uniqueness rests on unexamined assumptions regarding the nature of knowledge. As we have seen, no knowable object can be completely unique: if it were radically unique it could be neither observed nor recorded, nor could it be known. Any object or event that can interact with others sufficiently to make a relevant difference to their outcome must have sufficient structural similarities to permit such interaction. Anything that can interact with events important for us must have some structural similarities with them, and to a lesser extent with us; and once it has structure, there seems to be no a priori reason why it could not be matched by suitable symbols. Of course, our current models of many particular events may be too crude to permit the effective mapping of the probabilities involved, or the effective prediction of any probable results that would be important for us. But to conclude from this that these events cannot be effectively paralleled for such purposes by any symbol system requires either metaphysical convictions or a sweeping prediction of the entire future course of social science.

In current social science, our problems are more practical. All political processes and institutions we observe contain combinations of similarities and differences, and thus become accessible to our knowledge. Indeed, it is only against a background of similarities that differences can be recognized. It is only later, as a second step, that new symbols can be assigned to those groups of aspects that remain different from those previously familiar, and different from each other, and that these new data become part of our experience. In the course of this process, political scientists—like other men—must use comparisons of the relatively simple and familiar as stepping-stones to the gradual conquest of the relatively complex and unique.

This is in fact what they have done. From the comparative study of universal traits, anthropologists have gone on to the first steps in the study of particular configurations of culture. Psychologists have used general schemes, such as those proposed by Sigmund Freud, Abraham Kardiner, and others, as the background against which they could try to evaluate the particular personality problems of

individual patients. Economists began their work with the search for uniform laws governing the relations between supply and demand, or the changes in the wealth of nations, and are now gradually progressing to the study of the "propensity to consume" (J. M. Keynes) or "propensity to innovate" (W. W. Rostow) in particular periods and countries;[17] and of the performance, stability, and growth of particular national or regional economies.

THE STUDY OF POLITICAL SYSTEMS

Political scientists are finding themselves to an increasing degree moving in the same direction. In recent years they have been less often asked to compare merely the technical details of single political institutions or devices, such as "ministerial responsibility," "proportional representation," "judicial review," or "the power of dissolution," in several countries. More often they have been asked to say how a particular law or institution of this kind was functioning in the context of a particular political and social system, or how it could be expected to function if transferred into the context of some other system. Such questions of comparative political science have thus tended indirectly to become questions concerning the partial or over-all performance of the entire political systems of different countries.

Increasingly often political scientists also are asked direct questions about political system characteristics and system performance. What are the prospects for political stability in a country? What are the present political and military capabilities of its government? What are its abilities and inclinations to fulfill its international obligations? Are its present political institutions compatible with rapid economic growth? Is its present political regime capable of making effective use of large-scale financial or military aid from abroad? Can it make effective use of technological information under some technical-assistance program? All these, and many similar questions, have been asked, and are being asked currently, by many agencies of government as well as by nongovernmental organizations.

None of these questions can be answered by merely saying that each country is "unique," and political events in it "ineffable" or "unpredictable." Rather, political scientists have made what comparisons they could, in order to point out with the help of such comparisons the particular prospects of each situation. In so doing, they have drawn on many social sciences. Many of them steeped themselves in the study of particular geographic or cultural areas; and all had to use more or less explicit conceptual schemes, that is, symbolic models, in order to give order and context to their questions.

With the present trend in the social sciences, political scientists have thus found it increasingly hard to rest content with partial models of isolated traits or situations. Increasingly, they have found themselves in need of models capable of representing the behavior of whole decision systems. This need, in turn, has made acute the problem of choosing the most suitable models from all those that could be constructed.

THE CHOICE OF MODELS

Since there may be many models that match a given empirical situation to the required extent, we may have to choose among them. The first criteria that come to mind are two: relevance and economy of representation. In order to be *relevant* (or "realistic") the model must resemble the empirical system in those aspects with which we shall have to deal in order to do the things we are interested in doing. In order to be *economical*, the model must be in some respect "simpler" than the situation modeled; that is, its construction and operation must require less of those factors (such as material resources, physical or intellectual labor, calculating steps, and so on) that happen to be in short supply at the time and place of our work.[18] "Simplicity" or economy is thus often relative: something

is being economized, usually at the cost of spending a little more of something else. Sometimes there are models that are significantly simpler in every relevant dimension than are their closest competitors, but more often a great gain in simplicity in one particularly important direction may have to be paid for by a loss of economy in another, less important one.[19]

In addition to considerations of economy and relevance, models are also chosen to suggest new predictions and new lines of investigation. The *predictive* performance of a model involves the three properties of rigor, combinatorial richness, and extended relevance or organizing power. The *rigor* of a model (as well as of any game, calculus, or logical or mathematical system) consists in its ability to give unique answers at each step of the calculation, or more broadly speaking, at each step of applying the operating rules. The *combinatorial richness* of a model is measured by the range of combinations or patterns that can be generated from it. The extended relevance or *organizing power* of a model consists in the degree of its correspondence to other empirical processes beyond the range of those in respect to which its relevance was first established.[20] A physicist's model of an "ideal liquid" usually has little relevance for the behavior of water above 100 degrees centigrade, but it may nevertheless be applicable to many other liquids and temperatures in addition to the ones for which it was first tested. Similarly, such social science concepts as "the family," "the economic multiplier," or "the state" may be evaluated in terms of their relevance for different epochs and cultures. Organizing power in this sense is indicated by the range of additional situations for which the model would be relevant, and by the precision and specificity of each relevance in each class of such cases.

The different models that are applicable to a given situation usually are not equally probable; that is, they are not equally likely to be produced by combinations of their elements, and thus not equally likely to be found or invented within a limited time. Models or symbolic schemes that are highly probable are called in everyday language "trite" or "obvious." The *originality* of a model could therefore be measured by its improbability within the ensemble of possible models at a given time and place. If models or symbolic schemes have a high degree of originality, simplicity, relevance, and organizing power, they often are said to be works of genius, and yield esthetic satisfaction.

It may be noted that all these dimensions can be measured to some extent, but also that each of them may vary with time, place, culture and personality, since the set of memories to be organized or empirical processes to be matched will vary with each of these. Discussions about the "beauty," "elegance," "interest," and "timelessness" of a mathematical theorem, a work of art, or a conceptual scheme in the social sciences is likely to show in each case a characteristic mixture of impersonal and measurable criteria with relative historical, cultural, and personal standards. It is thus not surprising that people can never quite agree about matters of elegance, interest, and beauty, and yet can never quite stop arguing about them.

Despite this irremovable element of relativity, there is a strong objective element in judgments of this kind. At any given time or place, and even across many times and places, there are certain sets of models that are highly probable and others that are not. There are certain costs, such as the effort of changing familiar habits, or of carrying out repetitive steps of tedious intellectual labor, which most men at most places will want to minimize; and there may be common areas of past memories and present interest from which common standards of relevance and organizing power can be derived.

Conceptual schemes or models can thus be compared and evaluated to some extent on an objective basis, as long as the historical and cultural facts underlying that basis are not forgotten. Political scientists need not content themselves, therefore, with using a different model for each special purpose, to be discarded for another with every shift in the particular topic of their questions. Rather, they may seek models of more general usefulness for the study of politics in different countries and cultures.

THE UNITY OF HUMAN KNOWLEDGE

We have talked thus far about knowledge in the social sciences, and we shall continue to focus our interest on the social sciences throughout this book. But it is worth remembering that the process of knowledge applies to our understanding of the physical universe as well as to our understanding of human actions. The viewpoint of this book is that of the essential unity of the process of knowing—not by making human beings look overly simple but by bringing out the richness and the sense of wonder in all knowledge everywhere.

We have seen that men think in terms of models. Their sense organs abstract the events that touch them; their memories store traces of these events as coded symbols; and they may recall them according to patterns they learned earlier, or recombine them in patterns that are new. In all this, we may think of our thought as consisting of symbols that are put in relations or sequences according to operating rules. Both symbols and operating rules are acquired, in part directly from interaction with the outside world, and in part from elaboration of this material through internal recombination. Together, a set of symbols and a set of rules may constitute what we may call a calculus, a logic, a game, or a model. Whatever we call it, it will have some structure, that is, some pattern of distribution of relative discontinuities, and some "laws" of operation.

MODELS, KNOWLEDGE, AND STRUCTURE

If this pattern and these laws resemble, to any relevant extent, any particular situation or class of situations in the outside world, then to that extent these outside situations can be "understood," that is, predicted—and perhaps even controlled—with the aid of the model. Whether any such resemblance exists cannot be discovered from the model, but only from a physical process of *verification*, that is, physical operations for matching some of the structure of the outside situation—this we might call "taking information off" the outside situation—followed by some *critical process*, that is, further physical operations that depend in their outcome on the degree of correspondence between the structure proposed from the model and the structure derived from the outside facts.

Models of this kind may unify the thinking of their users. If clearly retained, they make mental operations repeatable: they confer on them the property of *retraceability* that is essential for reason. If used by several persons with identical results they add another characteristic of reason: *cogency*. They will do this whether their actual correspondence to events in nature is close or not.

In one sense, all these models are physical. They consist of symbols that are states of physical objects, and traces of physical processes, whether in brain cells, ink marks, magnetic dots, electric charges, or whatnot. Similarly, the operating rules, according to which these symbols are to be permutated or combined, and new symbols derived from them, are constraints on physical processes.

In this sense, knowledge is a physical process, or rather a particular configuration of physical processes. It is the process in which at least three other physical processes are incompletely matched: one, the "outside" process, which undergoes relatively little change in the matching (such as a stone we look at); a second, the "inside" process, which undergoes a great deal of change during the matching (such as the rods and cones in our retina, and the nerve cells in our brain that retain the image, or like the film in a camera); and a third, in which this stored "information" is recalled in more or less modified form, and reapplied to a new interaction with some outside process, more or less loosely related to the first; and the results of all these different processes of reapplication again are noted and compared for even more comprehensive verification.

Knowledge in general depends, therefore, on physical structure. If anything is to be knowable by *any* physical process, there must be in it some unevenness of distribution. What we call "evenness," as well as "randomness," can be treated as special cases of such distributions. If anything is to be knowable by *a particular process*,

however, it must have not merely structure, but a particular structure corresponding to that of the "observing" process, at least to a relevant degree.

Unevenness, structure, and distribution are fundamental physical properties of everything—all matter, all energy, all processes—in the universe we know, and even in any universe we can imagine. Indeed, this unevenness is the physical condition of all knowledge, all observation, and all representation by symbols, of all imagination and all understanding. Yet this argument is not wholly circular nor perhaps wholly trivial. For it suggests that whatever can be at all experienced or observed, indeed whatever can at all interact with anything in the universe we know, must therefore have itself some relative discontinuities, and hence some structure. It must therefore be capable of being known. What interacts has structure. And what has structure can be known.

"The most incomprehensible thing about the world is that it is comprehensible," Albert Einstein has been quoted as saying.[21] Perhaps we may now venture to differ from this suggestion of incomprehensibility. Any universe uneven enough to be observed by us—or to sustain life in it—is uneven enough to be known, potentially though incompletely, by some processes and by some knowing agent. Any universe uneven enough to sustain the life of a flatworm should perhaps be uneven enough to be eventually known by man.

There is still reason, however, for a sense of wonder and surprise, as the physicist Victor F. Weisskopf pointed out to this writer: that the universe should be known in so many of its aspects so readily, in terms of patterns of such simplicity and generality as modern physics has discovered.

That the universe is knowable in general, at some time, by some processes, is then perhaps not surprising. That so much of it has become known to us so soon is a significant aspect of human history. And the particular models that men have used in their thinking in the course of their history may have had something to do with the outcome.

CHAPTER

2

Some Classic Models in the History of Thought

Image As Theory

Throughout history, men have thought in images—rich, imprecise, but suggestive. Some scientists, and some scientific traditions, have excelled in the creation of images that could be imagined visually, that is, in patterns closely related to those familiar from previous visual experience. Such images had many advantages. They were clear, vivid, in part familiar, emotionally relevant, and well suited to simultaneous inspection, so that different parts or aspects could be surveyed at the same time, or so nearly so that they immediately compared and correlated in memory, thus permitting many such correlations, or previously hidden aspects, to become suddenly "visible," or visualizable, to men's imaginations. The classic natural science of the Greeks, in particular, was carried on in large part in terms of such clarifying visual images.[1]

Another type of scientific imagery tends to be verbal, or else numerical and computational. Often it involves the precise knowledge of ~~highly abstract~~ symbols that have no close or obvious visual counterparts, and it may further involve their prolonged manipulation in sequences of steps of abstract reasoning or computation without the aid of visual imagery, perhaps somewhat similar to the unerring pursuit of Ariadne's thread through the darkness of the

Labyrinth.[2] This type of scientific competence and relatively nonvisual imagination, together with extreme competence in computing, seems to have characterized some modern mathematicians, such as the Indian, Ramanujan, and in earlier times, the scientific tradition of the ancient Babylonians. Western science, and its offshoot, modern science, it has been persuasively argued, have derived from the marriage, in Hellenistic times, of the visual imagination of classic Greek science with the computational skills of the Babylonians; and the ever-renewed union of new feats of visualization with computations that ever since has accompanied the development of mathematics, and of all the sciences.[3]

In the course of this joint development of science, involving both the powers of visualization and of calculation, men's images became increasingly refined. As these images became more abstract and consistent, they turned into models.

Images and models thus form two ends of one spectrum. Formal or "idealized" models shade off by successive steps of abstraction from the images of the rich material situations from which they were borrowed or derived.

THE USE OF MATERIAL MODELS AS RESOURCES OF THOUGHT

Ontology

The models referred to so far have been *formal* models, sets of symbols and operating rules, carried largely in people's heads. Arturo Ros~~enblueth and~~ Norbert Wiener have discussed the concept of the *material model*; they have defined it as "the representation of a ~~complex system by~~ a system which is assumed simpler and which is also assumed to have some properties similar to those selected for study in the original complex system," pointing out, at the same time, that this "presumes that there are reasonable grounds for supposing a similarity between the two situations; it thus presupposes the possession of an adequate formal model, with a structure similar to that of the two material systems."[4]

In this view every material model implies a formal model behind it, or perhaps we might say that to compare two material situations and to use one of them as a model for the other is, at least, to abstract some more generalized formal model from the two.

What may count in intellectual history, then, is not only the actual properties of a physical or social process that people accept at some time as a material model for some other process, but rather the idealized or implied properties they ascribe to the implied formal model behind it. Not exactly what clocks actually were, nor even only what Newton's mechanics necessarily implied, but also what they seemed to imply to the classic "Age of Reason" (c. A.D. 1650–1790) made up that classic concept of "mechanism" that looms so large in the history of thought.

SOME MODELS IN EARLIER THOUGHT

Since early times, men have tended to order their thoughts in terms of pictorial models. The model itself was usually drawn from something in their immediate experience, available from their technology, and acceptable to their society and culture. Once adopted, it served, more or less efficiently, to order and correlate men's acquired habits and experiences, and perhaps to suggest a selection of new guesses and behavior patterns for unfamiliar situations.

Thus men used the image of their own society (where men influence one another's behavior by talking to each other) as a model for physical nature that was pictured as a society of animated objects that could be magically influenced by talking to them through the right kind of incantations. Later models were derived by men from the work of their hands, which they themselves could put together and take to pieces and which they therefore could analyze and elaborate more adequately in terms of parts and interrelations.

There is the simple model of the potter who shapes clay. It is assumed, in this model, that things have neither will nor mind but are simply inert products made by an invisible craftsman. Speech

seems useless when directed to things, but promising when directed to the craftsman.

More complex models become available as men learn to produce more complex contrivances, and when the fruits of their labor can be piled up into houses, towns, and pyramids, which dwarf the individuals beholding them. The impersonal plan or law of the city may then come to serve as a model for an assumed impersonal plan or law of nature, and the structure of this impersonal law or architecture appears to remain effective regardless of the subsequent activities of any invisible architect or lawgiver who might have originated it. These new models permit a clear and more specific correlation of experience. They imply rigid and often immovable arrangements in space, which lend themselves readily to pictorial representation. In this manner, the Egyptian pyramid, with its rigorous order of a very few stones at its apex and the many stones bearing all the burden at the bottom, has served as a model for the conception of a "social pyramid," or, more generally, of a "hierarchy," whether of priests or army officers, or of ideas, values, and purposes, such as in Aristotelian philosophy.

Two other simple models involve at least some movement, and therefore some implication of time. The first of these is the *wheel.* In its simple rotary motion, elevating and casting down each ~~part of~~ its circumference in regular succession, it has been conceived of as a model of human affairs and human history. Whether as "wheel of fortune," "wheel of fate," or Fortune standing on a ball, in each case the model suggests the instability of the parts with a stability of over-all performance; and this model was projected to the skies in the spheres, cycles, and epicycles of Ptolemaic astronomy.

The second of these models is the *balance,* the pair of scales that yields the concept of stable ~~equilibrium, with~~ its implication that the adverse reactions must be the greater, the more the true position of balance has been disturbed. The notion of *diké*, of "nothing too much," of the golden mean, and the statue holding the scales of justice in front of many Western lawcourts all testify to its suggestive power. Both wheel and balance suggest movement that eventually returns to the original position. "The more it changes, the more it stays the same."

Other simple technological operations began to yield models that implied notions of process, progress, and history in the simplest, most elementary form. An outstanding model here is the *thread* taken from spinning, whether as the thread of fate or the thread of an argument or the thread of a human life. A *web* woven from these threads is an obvious extension of this model, implying now, however, the notion of interaction. The German word for reality, *Wirklichkeit*, is related to the word denoting such a textile operation. Goethe has embodied this picture in the words of the Earth Spirit in *Faust:*

> So steh' ich am sausenden Webstuhl der Zeit
> Und wirke der Gottheit lebendiges Kleid.[5]

However, the partial continuity of thread and skein and warp and woof makes these textile models unsuitable for analysis.

THE CLASSIC MODEL OF MECHANISM

Only with the development of far more complex mechanical operations toward the end of the Middle Ages did there emerge mechanical models of greater complexity, and thus slightly less inadequate for describing the world around us. *Mechanisms* can be taken apart and reassembled. This is crucial for the new models. The growing knowledge of mechanical pumps finally enabled Harvey to write his scientific classic on the motion of the heart, *De Motu Cordis,* using the analogy of valves and pumps for the first adequate description of the circulation of the blood.[6]

The development of clockwork, under progress ever since the thirteenth century, yielded the classic model of a "mechanism"—a model applied to a description of the stars in the system of Newton; to government in the writings of Machiavelli and Hobbes; to theories of the "balance of power" and "checks and balances" by Locke, Montesquieu, and the founding fathers of the American

Constitution; and to the human body by such eighteenth-century writers as La Mettrie, author of the book *Man a Machine*. It was extended to joy in Schiller's lyric "Ode to Joy" as the "watchspring of the universe," and to God as the "first mechanic" by Thomas Paine.

The classic concept of mechanism differed from the actual mechanisms that inspired it. It was to have in theoretical perfection those properties for which the designers of admittedly imperfect machinery were striving in practice. This assumption of a perfect mechanism was made more plausible by the success of gravitational astronomy, where the movements of the planets, isolated from each other by vast distances, proved well suited to mechanical interpretations—though they have turned out to be quite unrepresentative of much of the rest of nature.[7]

Classic mechanism implied the notion of a whole that was completely equal to the sum of its parts, that could be run in reverse, and that would behave in exactly identical fashion no matter how often those parts were disassembled and put together again, and irrespective of the sequence in which the disassembling or reassembling would take place. It thus implied the notion that the parts were never significantly modified by each other, nor by their own past, and that each part once placed into its appropriate position, with its appropriate momentum, would remain in place and continue to fulfill its completely and uniquely determined function.

As this model implied certain assumptions, so it excluded others. The notions of irreversible change, of growth, of evolution, of novelty, and of purpose all had no place in it.

The classic notion of mechanism was a metaphysical concept. Nothing strictly fulfilling these conditions has ever been found anywhere. The more complicated a modern mechanical device becomes in practice, the more important become the mutual interaction of its parts through wear and friction, and the interdependence of all those parts with their environment, in regard to temperature, moisture, magnetic, electrical, and other influences. The more exacting we make the standards for the performance of a real "mechanism," the less "mechanical" in the classic sense does it become. Even an automobile engine must be "broken in," and a highly accurate timing device depends so much on its environment that it must be assembled in carefully air-conditioned workrooms by workers with dry fingertips.

To be sure, highly idealized clockwork was not the only model that could have been developed from the facts available to scientists and philosophers during those centuries. It was, however, the model that they did develop, and that fitted well into their notions of perfection carried over into philosophy from technological and social practices.

To this model corresponded a characteristic analytic method: to seek a set of simple, unchanging elements acting by simple, unchanging laws. Scientists and philosophers discovered such simple elements as atoms, corpuscles, or waves in physics; as molecules and elements in chemistry; as "economic men" in economics; and as "increments of pain or pleasure" in the ethics and philosophy of Jeremy Bentham, and these last perhaps in turn have left some lingering echoes in the far more refined formulations of "indulgences" and "deprivations" by Harold Lasswell and Abraham Kaplan.[8]

Professor Philipp Frank has suggested that Newtonian mechanics and the later classic electrodynamics could have been used to describe considerably more sophisticated mechanisms than the idealized clockwork that predominated during that epoch. "There is nowhere in La Mettrie and contemporary materialists the idea," says Professor Frank, "that a 'mechanism' *has to be* of the simple character of a clockwork and that the parts of a mechanism *cannot* be rearranged by the operation of the mechanism."[9]

This situation is different, Frank suggests, from the "breakdown of the mechanism as a model in the twentieth century . . . due to the impossibility of constructing a mechanism for the phenomena within the atom" which required "the new physical theories like relativity and the quantum theory."[10]

If I understand this correctly, Professor Frank suggests that Newtonian physics did not, in itself, force upon scientists and philosophers the narrow mechanical model they adopted. The point

seems, however, that this was the model they did adopt. To the extent that actual machinery resembled such idealized clockwork, isolated from its environment, unmodified by time and interaction, to that extent it was considered to be nearer perfection; for that age saw perfection in that classic mechanism we described above.

It is that kind of mechanism, too, that we find in the social sciences of the period. It is still an age preoccupied with discovery of lands, of laws of nature, and of laws of conduct. Nature is to be conquered by being obeyed, in Francis Bacon's view, but nature herself is not expected to change in the process. Similarly, for Machiavelli, the nature of princes and the laws governing their prudent conduct do not change; rather, to the author of *The Prince*, they seem as permanent as the political apathy of the masses of the people, which is so fundamental among Machiavelli's assumptions. Thomas Hobbes, a century and a revolution later, drops this assumption of apathy. In the world of the *Leviathan* all men are intensely and deplorably active, being like wolves unto each other. It is this frantic activity that is now held to be unchanging; whenever the restraints of government break, the "war of all against all" will be the state of nature. Hobbes and Machiavelli hold almost exactly opposite views about the political behavior of the large majority of the populations about whom they write; yet each asserts his view as an objective description of unchanging human nature.

The hallmark of the age of classic mechanism in social science was, perhaps, this attempt to discover a set of simple, unchanging elements that act according to simple, unchanging laws. From these, then, the simple, unchanging rules of prudent conduct in politics, economics, psychology, morality, religion—or indeed even in writing poetry—can be deduced by reasoning and verified by observation. The elements of the system may be the foxy princes of Machiavelli or the wolfish commoners of Hobbes; the prudent businessmen of Adam Smith; the abstract and "inalienable rights" of Thomas Jefferson—but whatever they are, they are as unchanging as the heavenly bodies in Newton's solar system before Kant's introduction of historical evolution into the latter.

This introduction of evolution by Kant, and later by Laplace, through their account of the origin of the planets, is relevant to our point. For it shows the directions in which men might have struck out from the Newtonian framework if they had seen the opportunity, or had wanted to see it. Kant saw it well. His famous sketch of 1787 for a "Universal History"[10] began with interaction and mutual modification between men and their institutions, and arrived at a succession of historical periods, each characterized by different patterns of behavior and leading by necessary steps to a future world government by scientists—a government strikingly different from the institutions Kant accepted as existing in his own time.[11]

Perhaps the reasons that kept most of Kant's contemporaries from continuing successfully his analytic approach to evolution were social at least as much as technical or scientific. Yet if the classic notion of mechanism had dominated much of the epoch's thinking up to his time, the classic notion of organism was to challenge it for the next few generations.

THE CLASSIC CONCEPT OF ORGANISM

Conspicuous breakdowns of the concept of mechanism became most obvious in the social sciences and in biology. Attacks on the inadequacy of mechanistic thinking form a major part of the political writings of Edmund Burke. The emphasis on wholeness, interrelations, growth and evolution—proclaimed in literature and education by Rousseau, and in politics by Burke—was then powerfully reinforced in the nineteenth century through the growth of the biological sciences, resulting in the wide popularity of the concept of "organism" in its classic nineteenth century form as the proper model for reality.

An organism, according to this classic view, cannot be analyzed, at least in some of its essential parts. It cannot be taken apart and put together again without damage. Each part of a classic organism, insofar as it can be identified at all, embodies in its structure the particular function to which it has been assigned. As a rule, these parts cannot be put to any other functions without destroying the

organism.[12] The classic organism's behavior is irreversible. It has a significant past and a history—two things the classic mechanism lacks—but it is only partly historical, because it was believed to follow its own peculiar "organic law" that governs its birth, maturity, and death and that cannot be analyzed in terms of clearly identifiable mechanical "causes." It did have something like "purpose": a state of maturity or a function of reproduction, toward which earlier phases seemed to lead, and the attainment of which was followed usually first by continuation or repetition, and sooner or later by decomposition.

The similarity between this "mature phase" and Aristotle's *telos* was obvious, but neither Aristotle nor the nineteenth-century "organicists" or "vitalists" could analyze successfully the process by which this "mature" state (and no other) was achieved; nor could they analyze the process that after maturity seemed to turn all further change into repetition or degeneration; nor, even less, could they suggest any detailed process by which any such cycle with its supposedly inherent goals could undergo some fundamental change.

Here, again, the modern biologists' approach to the study of actual organisms has been far less restrictive than the classic organismic model. A modern discussion of the organism speaks of its "table of organization," "decision points," "feedback loops," "flow paths," and the like, as well as of "innovative behavior," "goals," and an "information model"—in short, it is finding a common language with the modern models of communication and control processes discussed later in this book.[13] It was not, however, the increasingly sophisticated redefinition of the organismic concept by working scientists that was adopted in the thinking of most historians, philosophers, and humanistically oriented writers on politics or economics. Rather, if such men thought of any organismic model, they accepted the classic model of organism with all its crippling restrictions.

"Organism" seemed a more subtle concept than "mechanism." It seemed subtle because it made two justified assumptions: that there was vastly more intricate structural detail, and that there were many more different kinds of structure, than could be found in the crude mechanics and the undeveloped sciences of the age.

Yet the classic organism was in many ways a mechanism with restrictions. It implied restrictions on the possibility of analysis into separate parts, and of reassembly from them; and restrictions on the extent of possible changes in structure or function of either the parts or the whole. Perhaps the most severe restriction was the postulate that certain parts of the organism could never be known: the imponderables," routed from physics and chemistry during the eighteenth century, reappeared as "vital force" or "vital spirit"[14] in later "organismic" thinking. The implied sharp separation between these mysterious "miracle parts" and the ordinary knowable elements of the system, and usually, also, the presumed static characteristics of both the knowable and the "imponderable" elements, then led to the classic picture of an "organism" with certain parts eternally mysterious, and with no chance of fundamental rearrangement of its elements.

Organismic models served a useful purpose in biology, in educational psychology, and even in economics, by directing men's attention to problems of interdependence and growth. But their successes were narrowly limited. While "organismic" models might sometimes help to balance the one-sidedness of a "mechanical" approach, biologists have failed to derive significant predictions or experiments from the supposed "life force" of nineteenth-century "vitalists." Most biologists by now have given up assertions about "imponderables," and have replaced them by sustained efforts at structural analysis and quantitative measurement, with impressive and fruitful results.

The inadequacies of organismic theories of society or history have been even more conspicuous. In one aspect organismic notions could be used to draw attention to processes of growth: organisms, after all, were supposed to grow before they reached maturity, though not afterward. In educational psychology and in the "infant industry" argument of economics, organismic notions perhaps facilitated contributions to social science.[15] But if they sug-

gested respect for the child's innate ability to grow in mind and body, they also encouraged some men to assert innate inequalities between races. In economics the analogy between a steel mill behind a tariff wall and a baby in a crib led to bewildered questions as to why heavy industries so rarely if ever grew up, instead of leading to nonbiological investigations of economic growth.

Neither mechanism nor organism, in their classic forms, could explain well the peculiar social cohesion found in many societies, cultures, or peoples. Organismic views took this cohesion for granted or ascribed it to some "common blood," at the price of increasing difficulties with the facts. Mechanistic explanations in terms of "habits" found it hard to explain why sojourn under one crown or government should implant habits of political cohesion between Englishmen and Scotsmen, but not between Englishmen and Irishmen, nor between Czechs and Germans in Bohemia, nor between Frenchmen and Arabs in Algiers.

In political thought, classic models of *organism* appear in the writings of Edmund Burke, Adam Müller, Friedrich List, Oswald Spengler, and many later writers. These organismic models stressed the interdependence of all parts of a system in their structures and functions, but they excluded all possibilities of major internal reorganization, and of any evolution beyond a final goal of "maturity," prefigured from the outset of each type of organism by its peculiar "organic law."[16]

Even though organismic models are now obsolete in economics, poetic images of "mature" and "immature" political systems sometimes still persist in political science. Their cognitive value has been small. Few correlations have been found between the number of centuries a state has existed and its political processes at any given time. "Maturity" is not a helpful concept in distinguishing among the political institutions of France in the 1760's, the 1860's, and the 1960's, or between the politics of Germany in any two major periods of her history from Charlemagne to Konrad Adenauer. Neither has there been much confirmation for the prediction implied in the "maturity" concept that each political system must either stagnate or else develop through a specific sequence of stages to a particular state of "maturity," which can only be followed by repetition or by overripeness and decay.

The same doubts apply to the second implication of "maturity" —that it is an all-round stage, enabling a people or government to be equally "mature" in dealing with, let us say, constitutional problems, domestic race relations, and foreign policy. Of more relevance here is the level of experience and competence available for each of these subjects in particular, since a government may easily appear "naïve" in dealing with one problem, while appearing "mature" in dealing with another. Although the word "immature" has been plausibly applied to political situations in which the participants seemed to be conspicuously lacking in experience and tradition, such terms as "poor in relevant tradition" or "unconsolidated by relevant experience" could describe the facts without misleading organismic connotations.

Neither of these classic concepts of mechanism and organism could easily be used to deal with the process of learning. Nor are they easy to apply to the problem of knowledge; nor to the way qualitative judgments are made; nor to predictions in many social situations, or for longer trends in history; nor to the problems dealt with by esthetics, ethics, or religion.

To be sure, no mere invention of suitable concepts, schemes of investigation, or testing operations can be a substitute for the actual work of investigation in finding answers to these problems, or in producing coherence among such answers as are found. But perhaps we may yet come to recognize that the deep cleavage between the "natural" and the "social" sciences; between "reason" and "intuition," or "reason" and "wisdom"; between the search for the truth and the search for goodness—perhaps we may come to recognize how ~~much these~~ cleavages were amplified and exaggerated in the thought of many good ~~men between the times of~~ Galileo and those of Einstein, by particular historical and social conditions in the Western world, and perhaps by the rather unwieldy intellectual equipment ~~available during that~~ period.

CONCEPTS DRAWN FROM HISTORY

A third group of models was developed out of the experiences of the dialogue, of struggle, and of historical process. All these suggested, in varying degree, a connection between conflict and communication. From these were then developed various notions of *process:* an interplay of changes that might be irreversible—"You cannot step twice into the same river" (Heraclitus)—yet analyzable into unchanging or more slowly changing discrete elements (which might themselves be complex subprocesses or patterns of action) arranged in a specific *structure*—though it, too, might be changing —and with discoverable laws governing their interplay. "This world . . . is an ever-living Fire, *with measures* kindling and *measures* going out."[17] This implied notion of structure is as essential to the models of processes as is their well-known emphasis on change.

In particular, the social sciences themselves produced an approach that was analytical to some degree, and emphasized development and growth. It was the approach of history, particularly after history became thought of not as a mere cycle of events, but as a succession of steps in a pattern leading in a discoverable direction. This view of history, as R. G. Collingwood has shown,[18] was introduced by Christianity, though it may already have had certain roots in Judaism. The notion of a distinction between "genuine" and "false" progress in this sense is explicitly stated in the writings of Vincent of Lerinum about A.D. 434.[19] In the eighteenth and nineteenth centuries the notions of the historical process were developed by Kant, Hegel, and Marx, and by a whole series of "historical schools" that used history as the central notion for interpreting anything from law to economics. Contemporary writers such as A. J. Toynbee and Eugen Rosenstock-Huessy testify to the continuing vigor and diversity of the tradition.[20]

Some of these historical views contained notions of irreversible change, of evolution through conflicts, and of some underlying relations between conflict and harmony. From Heraclitus' vision of war as "the father of all things," to Kant's *Idea of a Universal History* of 1787, and Burke's idealized vision of the continuous growth of civilization, on to Hegel's notion of "dialectical" progress from opposite to opposite, and further to the directed time of Bergson, the "instability forward" which J. C. Smuts saw in racehorses and civilizations, and the "challenge and response" of A. J. Toynbee, men have searched in history for models for the processes of growth, of evolution, of the emergence of novelty, and of creation.

Yet the striking parallels and suggestive insights that they offered remained empty of inner structure. Heraclitus said, "That which opposes, fits." He did not say *how* it fits. His *logos* meant "word" or "language," and so in a sense "structure": the world to him was "an ever-living Fire, with measures kindling and measures going out." But neither this *logos* nor these "measures" could he measure or describe. Both Kant's "unsocial sociality of man" and Hegel's "dialectics" are qualitative notions that disclose little detailed structure behind them. Carlyle's "great men," as well as Toynbee's "creative minorities," are unanalyzed vessels of a creativity that itself has no intrinsic details that could be described and understood.[21]

Nor did an appeal to biology help matters. Creativity as a process remained just as blank and structureless when it was enclosed in a human body labeled "genius," or in groups of such bodies labeled "superior race." Ununderstood patterns of organization found little aid from the ununderstood chemistry of proteins.

As with biology, so with economics. The notions of economic "creativeness" and "innovation" were emphasized by Joseph Schumpeter as central in the process of economic growth, but for a long time little could be said about the inner structure of these processes. They represented labels, as it were, on bottles that remained opaque. Even when their qualitative importance was conceded, as it was by such an authority on national income measurement as Simon Kuznets,[22] their relationship to the rest of the process of economic growth seemed to defy measurement.

When they tried to be more specific, proponents of theories of process often fell back into mechanical analogies. They spoke of evolution as an "unfolding," that is, as of a bringing to light of

pre-existing patterns. Others, following a philosophical tradition from Aristotle to Kant, spoke of the "fulfilling of potentialities," that is to say, the presumably exhaustive working out of an already existing, small combinatorial ensemble made up of unchanging elements and laws, disregarding the infinitesimally small probabilities that many of these "potential" combinations might have in any larger universe of elements.

It should have been possible to imagine a process of genuine growth or evolution, involving fundamental rearrangements of the elements, and even of the laws and probabilities of the ensemble. Such changes could also have included explicitly changes in kinds of the interactions of the system with its environment, so as to transform the original system into a new one, with long-run properties not predictable from its previous states. Genuine evolution in this sense involves the possibility of sudden change and genuine novelty, including both internal change within the system and its interaction with the environment. The recent formulation of a distinguished Catholic anthropologist seems instructive here:

> Everything, in some extremely attenuated extension of itself, has existed from the very first. . . . But to have realized . . . that each new being has . . . a *cosmic embryogenesis* in no way invalidates the reality of its *historic birth.*
>
> In every domain, when anything exceeds a certain measurement, it suddenly changes its aspect, condition or nature. . . . Critical points have been reached, rungs on the ladder, involving a change of state—jumps of all sorts *in the course* of development.[23]

In the view of many scientists such evolution does not necessarily lead to one fixed goal, nor does it have to approximate any such single goal ever more closely. Rather, it is an open-ended process, containing the possibility of self-disruption or self-destruction, as well as of a change of goals. Such a possibility seemed at least hinted at in the words of the New Testament, "Now are we the sons of God, and it doth not yet appear what we shall be."[24] Yet if this had been a hint of growth with no definite end, most theories of organization persisted in not taking it.

What all these notions were trying to describe were processes of organization: self-sustaining or self-controlling or self-enlarging or self-transforming processes, as the case might be. Yet the only model they used to describe these processes was human society itself, changing throughout history, of infinite complexity, and baffling to those who tried to understand it while participating in its conflicts. Few of the aids of the natural sciences were available to the social scientists: neither the simplified and yet analogous model, offering the powerful aid of relevant and reproducible patterns; nor the controlled experiment; nor any relative ease of analysis of the interplay between observer and object; nor concepts permitting mathematical treatment; nor the mathematical techniques fitting much of the material. Against the background of these difficulties it appears an even greater accomplishment that the greatest of the social scientists achieved what they did.

In their interplay, all three models contributed to scientific growth. Models of classic mechanism contributed, within their limits, the possibility of rigorous and quantitative treatment. Models of classic organisms permitted greater complexity and some very limited development, but they left no room for consciousness or will, which were assumed powerless to change the organism's inner laws.[25] All qualitative changes in a classic organism were assumed preformed from the start, with no room for problems of choice or decision. Models of historical process left room for direction, for qualitative changes, for influences by consciousness, for genuine novelty. Yet they remained essentially qualitative; they aided in the recognition of certain patterns, but furnished little aid in measuring or counting, and no quantitative predictions over space or time. What was needed were models applicable to problems involving both quantity and quality; and facilitating the recognition of patterns, together with measurement and verifiable predictions.

CHAPTER

3

Some Recent Models in the Social Sciences

Some contemporary mathematical models in the social sciences appear to be the intellectual offspring of the classic mechanistic style of thinking. In these models it is not so much the rigid limitations of the classic image of mechanism that have been preserved, but rather the propensity to make extremely simple assumptions about the basic elements of the models—assumptions that are then subjected to more or less sophisticated mathematical techniques.

Such mathematical models in the social sciences may lose much of their usefulness through their overly naïve assumptions, or through the introduction of pseudoconstants, that is, magnitudes represented as constants in the mathematical equations but incapable of being checked by independent and impersonal operations.

SOME APPROACHES BY RASHEVSKY, ZIPF, SIMON, AND RICHARDSON

An example of sophisticated mathematical techniques whose usefulness is limited by regrettably naïve assumptions is found in Professor Nicholas Rashevsky's discussion of changing levels of activity in