ACKOFF'S BEST

HIS CLASSIC WRITINGS ON MANAGEMENT

Russell L. Ackoff

John Wiley & Sons, Inc.
New York • Chichester • Weinheim • Brisbane • Singapore • Toronto

CHAPTER 1

OUR CHANGING CONCEPT OF THE WORLD

> *There is a certain relief in change, even though it is from bad to worse; as I have found in travelling in a stage-coach, that it is often a comfort to shift one's position and be bruised in a new place.*
>
> Washington Irving

Change itself is constantly changing. This is reflected in the widespread recognition of its accelerating rate. For example, the speed with which we can travel has increased more in our lifetimes than it has over all the time before our births. The same is true for the speed with which we can calculate, communicate, produce, and consume.

Change has always been accelerating. This is nothing new, and we cannot claim uniqueness because of it. There are, however, some aspects of the changes we are experiencing that are unique. These are responsible for much of our preoccupation with change.

First, although technological and social change have been accelerating almost continuously, until recently this has been slow enough to enable people to adapt, either by making small occasional adjustments or by accumulating the need to do so and passing it on to the next generation. The young have always found it easier than the old to make the necessary adjustments. Newcomers to power have usually been willing to make changes that their predecessors were unwilling to make.

In the past, because change did not press people greatly, it did not receive much of their attention. Today it presses hard and therefore is attended to. Its current rate is so great that delays in responding to it can be very costly, even disastrous. Companies and governments are going out

---

From *Creating the Corporate Future* (Wiley, 1981).

of business every day because they have failed to adapt to it or they have adapted too slowly. Adaptation to current rapid changes requires frequent and large adjustments of what we do and how we do it. As the eminent student of management Peter Drucker put it, managers must now manage discontinuities. The changes in management required to handle change have become a major concern to all those associated with it.

Human beings seek stability and are members of stability-seeking groups, organizations, institutions, and societies. Their objective may be said to be "homostasis," but the world in which this objective is pursued is increasingly dynamic and unstable. Because of the increasing interconnectedness and interdependence of individuals, groups, organizations, institutions, and societies brought about by changes in communication and transportation, our environments have become larger, more complex, and less predictable—in short, more turbulent. The only kind of equilibrium that can be obtained by a light object in a turbulent environment is dynamic—like that obtained by an airplane flying in a storm, not like that of the Rock of Gibraltar.

We can drive a car down a deserted turnpike in good weather with few changes of direction and acceleration; hence we do so without giving it much conscious thought. The worse the weather and the road, and the heavier the traffic (hence the more unpredictable the driving of others), the more we have to concentrate on our driving and the more frequently we have to change our direction and speed.

As Alvin Toffler pointed out, either we do not respond at all or we do not respond quickly enough or effectively enough to the changes occurring around us. He called our paralysis in the face of change-demanding change Future Shock. One of the objectives of this book is to overcome such paralysis.

The second unique characteristic of the changes we face is more subtle than the first and, perhaps, even more threatening. It was first brought to our attention by Donald A. Schön. To paraphrase his argument, as the rate of change increases, the complexity of the problems that face us also increases. The more complex these problems are, the more time it takes to solve them. The more the rate of change increases, the more the problems that face us change and the shorter is the life of the solutions we find to them. Therefore, by the time we find solutions to many of the problems that face us, usually the most important ones, the problems have so changed that our solutions to them are no longer relevant or effective; they are stillborn. In other words, many of our solutions are to problems that no longer exist in the form in which they were solved. As a result we are falling further and further behind our times.

Little wonder, then, that to many experts on change it appears critical that we learn how to forecast it more accurately and as early as possible, to prepare for it more effectively, and to respond to it more rapidly when we have not anticipated it. They see the solution to the problems created by accelerating change in improved forecasting, learning, and adaptation.

There is no doubt that such improvements would reduce some of the social pressure brought about by accelerating change, but it is neither the only path we can follow nor the best one. It is better to develop greater immunity to changes that we cannot control, and greater control over the others. Many changes that occur need not occur; and many that do not occur could have. Most of the changes that people worry about are consequences of what they have done or failed to do, however unintentionally.

Although change in general may be inevitable, particular changes are not. To those changes that do occur we must, of course, learn how to adapt more rapidly and effectively. Therefore, in this book considerable attention is given to learning and adaptation. However, because control of change is preferable to responsiveness to it, control receives even more attention.

Acceleration of change takes place in our minds as well as in our environment. There is no doubt that we have become increasingly sensitive to changes in our environment, and that we now perceive changes that once would have been ignored. We are, perhaps, more finely tuned to pick up change than any previous generation.

The most important change taking place, I believe, is in the way we try to understand the world, and in our conception of its nature. However, the large and growing literature on change and its management focuses on its objective rather than subjective aspects. It assumes that most of the managerial problems created by change derive from its rate. This may be true, but it is apparent that we cannot deal with change effectively unless we understand its nature. This means understanding it in general, not just in particular instances. One of my students, who was better at asking questions than at answering them, grasped this point and put it into a very succinct question: *What in the world is happening in the world?*

It is hard to conceive of a question that is easier to ask and harder to answer. Nevertheless, each of us frames an answer to it, consciously or unconsciously. Our answer constitutes our *Weltanschauung*, our view of the world. This view has either an implicit or explicit impact on just about everything we think and do.

Because the way I proceed in this book is itself greatly affected by my view of the world, I present it here. I do so with the hope that it will enable others to understand better where I am coming from, and that it will support my contention that we cannot cope effectively with change unless we develop a better view of the world. Any view of the world is necessarily hypothetical, and mine is no exception. My view, like any other, will have to stand tests of its effectiveness in developing ways of coping with both the rate and content of change.

About the time of World War II the age we were in began to end, and a new age began to take its place. We are still in the period of transition from one age to another, standing with one foot in each. As the two ages draw further apart we feel increasing strain, and will continue to do so until we place both feet firmly in the age we are entering. We can, of course, step the other way and try to live our lives in a dying age. By so doing, however, we accelerate the demise of the institutions and the culture that are affected by such maladaptive behavior.

By an *age* I mean a period of history in which people are held together by, among other things, use of a common method of inquiry and a view of the nature of the world that derives from its use. Therefore, to say we are experiencing a change of age is to assert that both our methods of trying to understand the world and our actual understanding of it are undergoing fundamental and profound transformations.

THE MACHINE AGE

I believe we are leaving an age that can be called the *Machine Age*. In the Machine Age the universe was believed to be *a machine that was created by God to do His work*. Man, as part of that machine, was expected to serve God's purposes, to do His will. This belief was combined with another even more ancient in origin, man had been created in the image of God. This meant that man believed himself to be more like God than anything else on Earth. This belief is reflected in the way God was depicted in the art of the age: in the image of man. In a sense, men were taken to be "demigods."

From these two beliefs—that the universe was a machine created by God to do His work, and that He had created man in His image—it obviously followed that *man ought to be creating machines to do his work*. The Industrial Revolution was a product of this inference. Not only did the idea of mechanization derive from the world view of the Machine Age, but all the important characteristics of the Industrial Revolution and the culture associated with it were derived from the methodology and basic doctrines on which this view rested. Let us see how.

In the Middle Ages the expected lifespan was short, between twenty and thirty-five years at different times. Infant and child mortality was very high. The population was frequently and devastatingly plagued. During their lives most people never traveled more than a few miles from their places of birth. There was little personal freedom. Poverty and deprivation were widespread. For these and many other reasons the intellectual life of the time focused on the inner spiritual life and afterlife. Let us listen to one witness, the historian Edward Maslin Hulme who illustrates the typicality of these views.

> The intellectual strength of the Middle Ages did not lie in scientific knowledge and achievement, but in a vivid quickening of the spiritual imagination. . . The medieval man had little ability to look things squarely in the face; he had no clear-eyed perception of the visible world. It was not his practice to deal in an objective way with the facts of the actual world about him. All things were veiled with a mist of subjectivity. . . The speculative life was held to be vastly more important than the practical life. The world was but a house of probation. (p. 124)

> The ideal life of the Middle Ages was one closed about with the circumscribing walls of a cloister. . . Its vision . . . ignored as much as possible the world of nature and the world of men, but it opened upon the infinite. (p. 60)

The art of the age reflected this orientation by focusing on man's spiritual and afterlife, not on the content and context of everyday life.

> In the Middle Ages painting was merely the hand maid of the Church. Its function was not to reveal to men the beauty of the present world, but to help him win salvation in the next. (p. 116)

Little wonder, then, that curiosity was not taken to be a virtue.

> In the age of faith curiosity was a cardinal sin. The idea that it is a duty or that it is a part of wisdom to find out the reality of things was quite foreign to the times. (p. 64)

The Renaissance that took place in the fourteenth and fifteenth centuries was a reawakening or, literally, a *rebirth*. In a sense man reentered the world of nature in which he lived by noticing it, becoming curious about it, and inquiring into it. In the Middle Ages

> Revelation was the sole source of truth. But when Peter the Hermit preached the first Crusade he unconsciously helped to set in motion forces that resulted in the Renaissance. Travel incited the curiosity of men. . . Men became filled with curiosity not only to know the civilization of other countries, but to learn something of men who had lived in distant ages and who had been activated by different ideals of life. This curiosity came to be a powerful and important force. . . It produced a revival of learning and research, it resulted in invention and discovery. . . It initiated the experimental method. It implanted in the hearts of men the desire to study and to know the world for themselves, unencumbered by the bonds of authority. (p. 64)

Renaissance men confronted nature with awe, wonder, and childlike curiosity. They tried to unravel its mysteries much as children do today, *analytically*. I do not mean that these intellectual ancestors were unsophisticated. I mean that their science was naive in a literal sense, "having natural or unaffected simplicity."

Analysis

Children given something they do not understand—a radio, a clock, or a toy—are almost certain to try to take it apart to see how it works. From an understanding of how the parts work they try to extract an understanding of the whole. This three-stage process—(1) taking apart the thing to be understood, (2) trying to understand the behavior of the parts taken separately, and (3) trying to assemble this understanding into an understanding of the whole—became the basic method of inquiry of the age initiated by the Renaissance. It is called *analysis*. No wonder that today we use *analysis* and *inquiry* synonymously. For example, we speak of "analyzing a problem" and "trying to solve a problem" interchangeably. Most of us would be hard pressed if asked to identify an alternative to the analytical method.

Commitment to the analytical method induces observation and experimentation, which, in fact, brought about what we think of today as modern science. Over time, the use of this method led to a series of questions about the nature of reality, the answers to which formed the world view of the Machine Age.

Reductionism

According to the viewpoint of the Machine Age, in order to understand something it has to be taken apart conceptually or physically. Then how does one come to understand its parts? The answer to this question is obvious: by taking the parts apart. But this answer obviously leads to another question: Is there any end to such a process? The answer to this question is not obvious. It depends on whether one believes that the world as a whole is understandable in principle, if not in practice. In the age initiated by the Renaissance it was generally believed that complete understanding of the world was possible. In fact, by the mid-nineteenth century many leading scientists believed that such understanding was within their grasp. If one believes this, then the answer to the second question must be yes. Given the commitment to the analytical method, unless there are ultimate parts, *elements*, complete understanding of the universe would not be possible. If there are such indivisible parts and we come to understand them and their behavior, then complete understanding of the world is possible, at least in principle. Therefore, the belief in elements is a fundamental underpinning of the Machine-Age view of the world. The doctrine that asserts this belief is called *reductionism:* all reality of our experience of it can be reduced to ultimate indivisible elements.

Formulated so abstractly, this doctrine may not appear to be familiar; but it is very familiar to most of us in its specific manifestations. In physics, for example, with the work of the nineteenth-century English chemist John Dalton, people generally came to accept a speculation of Democritus and other ancient Greek philosophers as well as the seventeenth century French philosopher Descartes: all physical objects are reducible to indivisible particles of matter, or *atoms*. These elements were believed to have only two intrinsic properties: mass and energy. Physicists tried to build their understanding of nature on a foundation of an understanding of these elements.

Chemistry, like physics, had its elements. They appeared in the familiar Periodic Table. Biologists believed that all life was reducible to a single element, the *cell*. Psychology was not so parsimonious; it postulated a number of elements at different times. It began with psychic atoms, *monads*, but gave them up in favor of *simple ideas* or *impressions*, later called *directly observables* and *atomic observations*. Fundamental *drives*, *needs*, and *instincts* were added. Later, however, Freud returned to psychic atoms to explain personality. He used three elements—the *id*, *ego*, and *superego*—and energy, the *libido*, to "explain" human behavior. Linguists tried to reduce language to indivisible elements of sound called *phonemes;* and so on and on.

In every domain of inquiry men sought to gain understanding by looking for elements. In a sense, Machine-Age science was a crusade whose Holy Grail was the element.

Determinism

Once the elements of a thing had been identified and were themselves understood it was necessary to assemble such understanding into an understanding of the whole. This required an explanation of the *relationships* between the parts, or how they interacted. It is not surprising that in an age in which it was widely believed that all things were reducible to elements it was also believed that one simple relationship, *cause-effect,* was sufficient to explain all interactions.

Cause-effect is such a familiar concept that many of us have forgotten what it means. It may be helpful, therefore, to review its meaning. One thing is said to be the cause of another, its effect, if the cause is both *necessary* and *sufficient* for its effect. One thing is necessary for another if the other cannot occur unless the first does. One thing is sufficient for another if the occurrence of the first assures the occurrence of the second. The program directed at explaining all natural phenomena by using only the cause-effect relationship led to a series of questions whose answers provided the remaining foundations for the Machine-Age view of the world.

First, the following question arose: Is everything in the universe the effect of some cause? The answer to this question was dictated by the prevailing belief in the possibility of understanding the universe completely. For this to be possible, everything had to be taken as the effect of some cause, otherwise they could not be related or understood. This doctrine was called *determinism.* It precluded anything occurring by either chance or choice.

Now, if everything in the universe is caused, then each cause is itself the effect of a previous cause. If we start tracing back through the chain of causes do we come to a beginning of the process? The answer to this question was also dictated by the belief in the complete understandability of the universe. It was yes. Therefore, a *first cause* was postulated and taken to be God. This line of reasoning was called the "cosmological proof of the existence of God." It is significant that this proof derived from the commitment to the cause-effect relationship and the belief in the complete understandability of the universe.

Because God was conceptualized as the first cause, He was taken to be the *creator.* As we will see, not all concepts of God attribute this function to Him, or even attribute individuality or "Himness" to Him.

The doctrine of determinism gave rise to yet another critical question to which philosophers of the Machine Age devoted much of their time. How can we explain free will, choice, and purpose in a deterministic universe? There was no generally accepted answer to this question, but this did not create a problem because there was widespread agreement on this much: the concept of free will or choice was not needed to explain any natural phenomenon, including the behavior of man.

Some held that free will was an illusion granted to us by a merciful God who realized how dull life would be without it. Man was thought to be like a fly who, riding on the trunk of an elephant, believes he is steering it. This belief makes the ride more interesting and the elephant does not mind.

Another important consequence of the commitment to causal thinking derives from the acceptance of a cause as sufficient for its effect. Because of this a cause was taken to explain its effect *completely.* Nothing else was required to explain it, *not even the environment.* Therefore, Machine-Age thinking was, to a large extent, *environment-free;* it tried to develop understanding of natural phenomena without using the concept of environment. For example, what does the word "freely" in the familiar "Law of Freely Falling Bodies" mean? It means a body falling in the absence of any environmental influences. The apparent universality of such laws (and there were many) does not derive from their applicability to every environment for, strictly speaking, they apply to none; it derives from the fact that they apply *approximately* to most environments that we experience.

Perhaps even more revealing of the environment-free orientation of Machine-Age science is the nature of the place in which its inquiry was usually conducted, the *laboratory.* A laboratory is a place so constructed as to facilitate exclusion of the environment. It is a place in which the effect of one variable on another can be studied without the intervention of the environment.

Mechanism

The concept of the universe that derives from the exclusive use of analysis and the doctrines of reductionism and determinism is *mechanistic.* The world was viewed *as* a machine, not merely like one. The universe was frequently compared to a hermetically sealed clock. This is a very revealing comparison, implying that it had no environment. Like a clock, its behavior was thought to be determined by its internal structure and the causal laws of nature.

The Industrial Revolution

This revolution had to do with the replacement of man by man-made machines as a source of work. Its two central concepts were *work* and *machine*. Whatever else was thought of work, it was believed to be *real*, particularly after the Reformation. Because all real things were believed to be reducible to atoms and atoms had only two intrinsic properties, mass (matter) and energy, work was conceptualized as the application of energy to matter so as to change its properties. For example, the movement of coal and its transformation into heat (energy) were considered to be work. Thought, however, was not taken to be work because it did not involve the application of energy to matter.

A machine was considered any object that could be used to apply energy to matter. Not surprisingly, it was believed that all machines were reducible to elementary machines: the lever, pulley, wheel and axle, and inclined plane (of which the wedge and screw are modifications).

The mechanization of work was greatly facilitated by reducing it to a set of simple tasks. Therefore, work was *analyzed* to reduce it to its *elements*. These elements were tasks so simple that they could only be done by one person—for example, tightening a screw or driving a nail. Then many of the work elements were mechanized. Not all were because either the technology required was not available or, although available, it was more costly than the use of human labor. Therefore, people and machines, each doing elementary tasks, were aggregated to do the whole job. The result was the industrialized production and assembly line that forms the spine of the modern factory.

The benefits of the Industrial Revolution are too obvious to dwell on here. They were many and significant. The same can be said of its costs. However, there is one cost which we have only recently become aware of, derived from what might be called the irony of the Industrial Revolution. In our effort to replace ourselves with machines as a source of energy, we reduced our work to elementary tasks designed to be simple enough to be done by machines, eventually if not immediately. In this way *we were reduced to behaving like machines*, doing very simple repetitive tasks. Our work became dehumanized. This is the source

of one of the most critical problems facing us today, our alienation from work.

The nature of the workplace developed during the Industrial Revolution was dictated by the application of the analytical method to work. If there were another way of thinking about work, it would be possible to conceive of another kind of workplace, one very different from the kind that we know today. This possibility is one that recently has been given much thought. I will return to it after we have seen what the alternative way of thinking is.

On Looking Backward and Forward

The Machine Age is largely history, but part of it still lives. The very brief account of its history that I have given is not a conventional one, hence it is subject to controversy. In contrast, the Systems Age lies largely in the future; nevertheless, my account of it is equally controversial. Such controversy, however, revolves around what we want it to be because, as I will argue, to a large extent the future can be what we want it to be. The Systems Age emerges from a new vision, a new mission, and a new method. Therefore, in describing it my rhetoric changes from narrative to persuasive as I try to convince the reader to share the vision, mission, and method with which I believe we can create this new age.

I present the Systems Age as emerging dialectically from the Machine Age. The Machine Age is a thesis, and its meaning and implications only become clear when its antithesis is fully developed. This development is taking place now, in the period of transition from one age to another, just as it took place for the Machine Age during the Renaissance. The Systems Age, as I see it, is a synthesis of the Machine Age and its antithesis, which is still being formulated. Their synthesis, however, has already begun to emerge and is being disclosed more clearly as time goes on.

The Systems Age is a movement of many wills in which each has only a small part to play, even those who are trying to shape it deliberately. It is taking shape before our eyes. It is still too early, however, to foresee all the difficulties that it will generate. Nevertheless, I believe the new age can be trusted to deal with them. Meanwhile there is much work to be done, much scope for greater vision, and much room for enthusiasm and optimism.

My account of the Machine Age was a hurried resume of the past because I am eager to face the future. The brevity of my account depreciates the magnificent efforts of the past four centuries to cope effectively with reality. The origins of the Systems Age lie in this past, hence the problems it confronts are inherited, but those of us who intend to have a hand in shaping the new age are trying to face them in a new way. Now let us see what that way is.

THE SYSTEMS AGE

No age has a starting point; it emerges imperceptibly in bits and pieces that eventually combine, first to produce an awareness that something fundamental is happening, then to provide a new world view.

Doubts about a prevailing world view usually begin with the appearances of *dilemmas.* A dilemma is a problem or question that cannot be solved or answered within the prevailing world view and therefore calls it into question (see Kuhn). We have already considered one such question: how can we account for free will in a mechanistic universe? In physics, Heisenberg's *Uncertaintly Principle* presented another such dilemma. He showed that within the prevailing paradigm in physics two critical properties of point particles could not be determined simultaneously; as the accuracy of the determination of one increases, the accuracy of the other decreases. This called into question the belief that the world is completely understandable, even in principle.

Then there was the dilemma that arose as all the king's men tried and failed to put Humpty Dumpty together again. Some things, once disassembled, could not be reassembled. The essential properties of other things could not be inferred from either the properties of their parts or their interactions, as for example, the personality or intelligence of a human being. More recently, in their studies of servomechanisms, machines that control other machines, Arturo Rosenblueth and Norbert Wiener argued that such machines could only be understood if they were assumed to display choice and goal-seeking behavior. Choice and mechanism, however, are incompatible concepts. This dilemma had a special significance which is discussed later in this chapter.

In the latter part of the last century and the early part of this one, dilemmas arose with increasing frequency in every field of inquiry. Investigators confronted with dilemmas in one field gradually became aware of those arising in other fields and the similarities among them. They also became aware of the fact that the prevailing mechanistic view of the world and the beliefs on which it was based were increasingly

being brought into question. This awareness was intensified by events that took place just before, during, and immediately after World War II.

This war took science and scientists out of their laboratories and into the "real world" in an effort to solve important problems arising in large, complex organizations—military, governmental, and corporate. Scientists discovered that the problems they faced could not be disassembled into ones that fit neatly into any one discipline and that the interactions of the solutions of disassembled parts were of greater importance than the solutions considered separately. This in turn led to the formation of interdisciplinary efforts. In the late 1930s, Operational Research, an interdisciplinary activity, emerged out of the British military establishment to deal with the management and control of its complex operations.

By the 1950s interdisciplinary scientific activities proliferated. These included the management sciences, decision sciences, computer sciences, information sciences, cybernetics, policy sciences, peace science, and many others. The overlap of interest among them and the similarities in their practices led to a search for a theme common to all of them.

By the mid-1950s it was generally recognized that the source of similarities of the interdisciplines was their shared preoccupation with the behavior of *systems.* This concept gradually came to be recognized as one that could be used to organize an increasingly varied set of intellectual pursuits. Of greater importance, however, was the fact that it revealed the fundamental dilemma of the Machine Age and suggested how its world view might be modified to escape the horns of that dilemma. It is for this reason that I refer to the emerging era as the *Systems Age.*

The Nature of a System

Before we can begin to understand the change in world view that the focus on systems is bringing about, we must first understand the concept of systems itself.

A system is a set of two or more elements that satisfies the following three conditions.

1. *The behavior of each element has an effect on the behavior of the whole.* Consider, for example, that system which is, perhaps, the most familiar to us: the human body. Each of its parts—the heart, lungs, stomach, and so on—has an effect on the performance of the whole. However, one part of the body, the appendix, is not known to have any such effect. It is not surprising, therefore, that it is called the appendix which means "attached to," not "a part of." If a function is found for the appendix, its name would probably be changed.

2. *The behavior of the elements and their effects on the whole are interdependent.* This condition implies that the way each element behaves and the way it affects the whole depends on how at least one other element behaves. No element has an independent effect on the system as a whole. In the human body, for example, the way the heart behaves and the way it affects the body as a whole depends on the behavior of the brain, lungs, and other parts of the body. The same is true for the brain and lungs.

3. *However subgroups of the elements are formed, each has an effect on the behavior of the whole and none has an independent effect on it.* To put it another way, the elements of a system are so connected that independent subgroups of them cannot be formed.

A system, therefore, is a whole that cannot be divided into independent parts. From this, two of its most important properties derive: every part of a system has properties that it loses when separated from the system, and every system has some properties—its essential ones—that none of its parts do. An organ or part of the body, for example, if removed from the body does not continue to operate as it did before removal. The eye detached from the body cannot see. On the other hand, people can run, play piano, read, write, and do many other things that none of their parts can do by themselves. No part of a human being is human; only the whole is.

The essential properties of a system taken as a whole derive from the *interactions* of its parts, not their actions taken separately. Therefore, *when a system is taken apart it loses its essential properties.* Because of this—and this is the critical point—*a system is a whole that cannot be understood by analysis.*

Realization of this fact is the primary source of the intellectual revolution that is bringing about a change of age. It has become clear that a method other than analysis is required for understanding the behavior and properties of systems.

Systems Thinking

Synthesis, or putting things together, is the key to systems thinking just as analysis, or taking them apart, was the key to Machine-Age thinking.

Synthesis, of course, is as old as analysis—Aristotle dealt with both—but it is taking on a new meaning and significance in a new context just as analysis did with the emergence of the Machine Age. Synthesis and analysis are complementary processes. Like the head and tail of a coin, they can be considered separately, but they cannot be separated. Therefore, the differences between Systems-Age and Machine-Age thinking derives not from the fact that one synthesizes and the other analyses, but from the fact that systems thinking combines the two in a new way.

Systems thinking reverses the three-stage order of Machine-Age thinking: (1) decomposition of that which is to be explained, (2) explanation of the behavior or properties of the parts taken separately, and (3) aggregating these explanations into an explanation of the whole. This third step, of course, is synthesis. In the systems approach there are also three steps:

1. Identify a containing whole (system) of which the thing to be explained is a part.
2. Explain the behavior or properties of the containing whole.
3. Then explain the behavior or properties of the thing to be explained in terms of its *role(s)* or *function(s)* within its containing whole.

Note that in this sequence, synthesis precedes analysis.

In analytical thinking the thing to be explained is treated as a whole to be taken apart. In synthetic thinking the thing to be explained is treated as a part of a containing whole. The former *reduces* the focus of the investigator; the latter *expands* it.

An example might help clarify the difference. A Machine-Age thinker, confronted with the need to explain a university, would begin by disassembling it until he reached its elements; for example, from university to college, from college to department, and from department to faculty, students, and subject matter. Then he would define faculty, student, and subject matter. Finally, he would aggregate these into a definition of a department, thence to college, and conclude with a definition of a university.

A systems thinker confronted with the same task would begin by identifying a system containing the university; for example, the educational system. Then such a thinker would define the objectives and functions of the educational system and do so with respect to the still larger social system that contains it. Finally, he or she would explain or define the university in terms of its roles and functions in the educational system.

These two approaches should not (but often do) yield contradictory or conflicting results: they are complementary. Development of this complementarity is a major task of systems thinking. Analysis focuses on *structure;* it reveals *how things work*. Synthesis focuses on *function;* it reveals *why things operate as they do*. Therefore, analysis yields *knowledge;* synthesis yields *understanding*. The former enables us to *describe;* the latter, to *explain*.

Analysis looks *into* things; synthesis looks *out of* things. Machine-Age thinking was concerned only with the interactions of the parts of the thing to be explained; systems thinking is similarly concerned, but it is additionally occupied with the interactions of that thing with other things in its environment and with its environment itself. It is also concerned with the *functional* interaction of the parts of a system. This orientation derives from the preoccupation of systems thinking with the *design* and *redesign* of systems. In systems design, parts identified by analysis of the function(s) to be performed by the whole are not put together like unchangeable pieces of a jigsaw puzzle; they are designed to fit each other so as to work together *harmoniously* as well as efficiently and effectively.

Harmony has to do not only with the effect of the interactions of the parts on the whole, but also with the effects of the functioning of the whole and the interactions of the parts on the parts themselves. It is also concerned with the effects of the functioning of the parts and the whole on the containing system and other systems in its environment. This concern with harmony has important implications in the management of systems—implications that are explored below.

There are considerable differences between what might be called analytical and synthetic management. To a large extent this book is devoted to illuminating these differences. One such difference is worth noting here. It is based on the following systems principle:

> If each part of a system, considered separately, is made to operate as efficiently as possible, the system as a whole will *not* operate as effectively as possible.

Although the general validity of this principle is not apparent, its validity in specific instances is. For example, consider the large number of types of automobile that are available. Suppose we bring one of each of these into a large garage and then employ a number of outstanding automotive engineers to determine which one has the best carburetor. When they have done so, we record the result and ask them to do the same for engines. We continue this process until we have covered all the parts required for an automobile. Then we ask the engineers to remove and assemble these parts. Would we obtain the best possible automobile? Of course not. We would not even obtain an automobile because *the parts would not fit together,* even if they did, *they would not work well together. The performance of a system depends more on how its parts interact than on how they act independently of each other.*

Similarly, an all-star baseball or football team is seldom if ever the best team available, although one might argue that it would be if its members were allowed to play together for a year or so. True, but if they became the best team it is very unlikely that all of its members would be on the new all-star team.

The current methodology of management is predominantly based on Machine-Age thinking. When managers are confronted with large complex problems or tasks, they almost always break them down into solvable or manageable parts; they "cut them down to size." Then they arrange to have each part solved or performed as well as possible. The outputs of these separate efforts are then assembled into a "solution" of the whole. Yet we can be sure that the sum of the best solutions obtained from the parts taken separately is *not* the best solution to the whole. Fortunately, it is seldom the worst.

Awareness of this conflict between parts and the whole is reflected in the widespread recognition of the need for *coordinating* the behavior of the parts of a system. At the same time, however, measures of performance are set for the parts that bring them into conflict. Formulation of these measures is commonly based on the assumption that the best performance of the whole can be reduced to the sum of the best performances of its parts taken separately. The systems principle, however, asserts that this is not possible. Therefore, another and more effective way of organizing and managing the parts is required. One is considered below.

The application of systems thinking, whether to management or the world, like the application of Machine-Age thinking, raises a number of fundamental questions. The answers to these questions provide the doctrines from which a systems view of the world derives. Let us see how.

Expansionism

In systems thinking, increases in understanding are believed to be obtainable by expanding the systems to be understood, not by reducing them to their elements. Understanding proceeds from the whole to its parts, not from the parts to the whole as knowledge does.

If the behavior of a system is to be explained by referring to its containing system (the suprasystem), how is the behavior of the suprasystem to be explained? The answer is obvious: by reference to a more inclusive system, one that contains the suprasystem. Then the fundamental question—Is there any end to this process of expansion? Recall that when the corresponding question arose in the Machine Age—Is there any end to the process of reduction?—the answer was dictated by the belief that, at least in principle, complete understanding of the universe was possible. In the early part of this century, however, this belief was shattered by such dilemmas as that formulated by Heisenberg. As a result, we have come to believe that complete understanding of anything, let alone everything, is an *ideal* that can be approached continuously but *can never be attained*. Therefore, there is no need to assume the existence of an ultimate whole which if understood would yield the ultimate answer.

This means that we are free to believe or not in an all-containing whole. Since our understanding will never embrace such a whole, even if it exists, it makes no practical difference if we assume it to exist. Nevertheless, many individuals find comfort in assuming existence of such a unifying whole. Not surprisingly, they call it God. This God however, is very different from the Machine-Age God who was conceptualized as an individual who had created the universe. God-as-the-whole cannot be individualized or personified, and cannot be thought of as the creator. To do so would make no more sense than to speak of man as creator of his organs. In this holistic view of things man is taken as a part of God just as his heart is taken as a part of man.

Many will recognize that this holistic concept of God is precisely the one embraced by many Eastern religions which conceptualize God as a system, not as an element. It is not surprising, therefore, that in the past two decades many of the young people in the West—products of the emerging Systems Age—turned to religions of the East.

The East has used the concept of a system to organize its thinking about the universe for centuries, but it has not thought about systems scientifically. There is some hope, therefore, that in the creation of systems sciences the cultures of the East and West can be synthesized. The twain may yet meet in the Systems Age.

The doctrine of expansionism has a major effect on the way we go about trying to solve problems. In the Machine Age, when something did not work satisfactorily, we looked for improvement by manipulating the behavior of its parts; we looked for solutions from within and worked our way out from the interior only when we failed there. In the Systems Age we look for solutions from without and work our way in when we fail there. The reasons for and effects of this reversal of direction will become apparent when we consider the differences between Machine-Age and Systems-Age planning.

Producer-Product

The Machine Age's commitment to cause and effect was the source of many dilemmas, including the one involving free will. At the turn of the century the American philosopher E. A. Singer, Jr., showed that science had, in effect, been cheating.* It was using two different relationships but calling both cause and effect. He pointed out, for example, that acorns do not cause oaks because they are *not* sufficient, even though they are necessary, for oaks. An acorn thrown into the ocean, or planted in the desert or an Arctic ice cap does not yield an oak. To call the relationship between an acorn and an oak "probabilistic" or "nondeterministic causality," as many scientists did, was cheating because it is not possible to have a probability other than 1.0 associated with a cause; a cause completely determines its effect. Therefore, Singer chose to call this relationship "producer-product" and to differentiate it from cause-effect.†

Singer went on to ask what the universe would look like if producer-product is applied to it rather than cause-effect. One might think of Singer's question in this way: an orange, when sliced vertically, yields a cross-sectional view that is very different from the view revealed when it is sliced horizontally. Yet both are views of the same thing. The more views we have of a thing, the better we can understand it. Singer argued similarly about the universe.

As Singer and Ackoff and Emery have shown, the view of the universe revealed by viewing it in terms of producer-product is quite different from that yielded by viewing it in terms of cause-effect. Because a producer is only necessary and not sufficient for its product, it cannot provide a complete explanation of it. There are always other necessary

---

* Singer showed this in a series of papers published between 1896 and 1904. His work is best presented in a posthumors publication, *Experience and Reflection*.

† Much after Singer, Sommerhoff independently came up with very similar results. What Singer called "producer-product," Sommerhoff called "directive correlation."

conditions, coproducers of its product. For example, moisture is a coproducer of an oak along with an acorn. These other necessary conditions taken collectively constitute the acorn's *environment*. Therefore, the use of the producer-product relationship requires the environment to explain everything whereas use of cause-effect requires the environment to explain nothing. Science based on the producer-product relationship is environment-*full*, not environment-*free*.

A law based on the producer-product relationship must specify the environment(s) under which it applies. No such law can apply in every environment, because if it did no environmental conditions would be necessary. Thus there are no universal laws in this view of the universe. For example, we have learned more recently that the law that everything that goes up must come down is not universally true. (Unfortunately, some things that we have put up with the intention that they not come down, nevertheless have done so.) Environmentally relative laws can use probabilistic concepts in a consistent and meaningful way. In an environment in which all the necessary coproducing conditions are not specified—hence may or may not be present—it is not only meaningful but it is useful to speak of the probability of production. For example, we can determine the probability of an acorn producing an oak in a specified environment in which some of the relevant properties are not known. Therefore, the probability determined is the probability that the unspecified but necessary environmental conditions are present.

Teleology

Singer showed by reasoning that is too complicated to reproduce here that in the producer-product-based view of the world, such concepts as choice, purpose, and free will could be made operationally and objectively meaningful. (See also Ackoff and Emery.) A system's *ends—goals, objectives, and ideals*—could be established as objectively as the number of elements it contained. This made it possible to look at systems *teleologically*, in an output-oriented way, rather than deterministically, in an input-oriented way.

Objective teleology does not replace determinism, which is an objective *a*teleology; it complements it. These are different views of the same thing, but the teleological approach is more fruitful when applied to systems.

Centuries ago Aristotle invoked teleological concepts to explain why things, inanimate as well as animate, behaved as they did; but he employed a *subjective* teleology. Among those who carry on in his spirit are some psychologists who try to explain human behavior by invoking such (unobservable, they claim) intervening variables as beliefs, feelings, attitudes, and drives which at best are only observable by those who have them. In an objective teleology, beliefs, feelings, attitudes, and the like are attributable to human beings because of *what they do;* hence are observable. These properties are derived from observed regularities of behavior under varied conditions. Such concepts do not lie behind behavior, but *in* it; hence are observable. In an objective teleology functional characteristics of systems are not treated as metaphysical forces, but as observable properties of the system's behavior.

The ideas and concepts developed by Singer were largely ignored for the first half of this century. Sommerhoff's were ignored as well, but for a shorter time. It was not until the concept of teleological mechanisms* and the dilemma contained in it came into the focus of science's attention that the work of Singer and Sommerhoff came to be recognized as significant. Their work solved this dilemma. A teleological system and a deterministic machine are two different aspects of the same thing. These antithetical points of view are synthesized in the concept of reality emerging in the Systems Age.

Systems-oriented investigators focus on teleological (goal seeking and purposeful) systems. In the Machine Age, even human beings were thought of as machines. In the Systems Age, even machines are thought of as parts of purposeful systems. We now believe that a machine cannot be understood except by reference to the purpose for which it is used by the purposeful system of which it is a part. For example, we cannot understand why an automobile is like it is without understanding the purposes for which it is used. Moreover, some machines, teleogical mechanisms, are seen to have goals, if not purposes, of their own.

Ordinary machines serve the purposes of others but have no purposes of their own. *Organisms* and *organizations* are systems that usually have purposes of their own. However, the parts of an organism (i.e., heart, lungs, brain) do not have purposes of their own, but the parts of an organization do. Therefore, when we focus on organizations we are

---

* Such mechanisms were brought to the attention of science by Frank et al.

concerned with three levels of purpose: the purposes of the system, of its parts, and of the system of which it is part, the suprasystem.

There is a functional division of labor among the parts of all types of systems. A set of elements or parts, all of which do the same thing, does not constitute a system; it is an aggregation. For example, a collection of people waiting for a bus does not constitute a system, nor does a collection of clocks all ticking away on the same shelf. Each part of a system has a function in the system, and some of these must differ. To organize a system, as we will see, is to divide its labor functionally among its parts and to arrange for their coordination.

The Postindustrial Revolution

To complete this account of the change of age that we are in, we should consider the effect of systems thinking on the Industrial Revolution.

The conversion of the Industrial Revolution into what has come to be called the *Postindustrial Revolution* has its origins in the last century. Scientists who explored the use of electricity as a source of energy found that it could not be observed easily. Therefore, they developed such *instruments* as the ammeter, ommeter, and voltmeter to observe it for them. The development of instruments exploded in this century, particularly after the advent of electronics and sonar and radar. Look at the dashboard of a large commercial airplane, or even one in an automobile. These instruments *generate symbols* that represent the properties of objects or events. Such symbols are called *data*. Instruments, therefore, are observing devices, but they are not machines in the Machine-Age sense because they do not apply energy to matter in order to transform it. The technology of instrumentation is fundamentally different from that of mechanization.

Another technology with this same characteristic emerged when the telegraph was invented in the last century. It was followed by the telephone, wireless, radio, television, and so on. This technology, like that of instrumentation, has nothing to do with mechanization; it has to do with the *transmission of symbols*, or *communication*.

The technologies of observation and communication formed the two sides of a technological arch that could not carry any weight until a keystone was dropped into place. This did not occur until the 1940s when the *computer* was developed. It too did no work in the Machine-Age sense; *it manipulated symbols logically*, which, as John Dewey pointed out, is the nature of *thought*. It is for this reason that the computer is often referred to as a thinking machine.

Because the computer appeared at a time when we had begun to put things back together again, and because the technologies of observation, communication, and computation all involve the manipulation of symbols, people began to consider systems that combine these three functions. They found that such systems could be used to *control* other systems, to *automate*. Automation is fundamentally different from mechanization. Mechanization has to do with the replacement of *muscle;* automation with the replacement of *mind*. Automation is to the Postindustrial Revolution what mechanization was to the Industrial Revolution.

Automations are certainly not machines in the Machine-Age sense, and they need not be purposeless. It was for this reason that they came to be called teleological mechanisms. However, automation is no more an essential ingredient of the systems approach than is high technology in general. Both come with the Systems Age and are among its producers as well as its products. The technology of the Postindustrial Revolution is neither a panacea nor a plague; it is what we make of it. It generates a host of problems and possibilities that systems thinking must address. The problems it generates are highly infectious, particularly to less-technologically developed cultures. The systems approach provides a more effective way than previously has been available for dealing with both the problems and the possibilities generated by the Postindustrial Revolution, but it is by no means limited to this special set of either or both.

CONCLUSION

Well, there it is: a tentative answer to the question—what in the world is happening in the world? My response to it is an attempt to make some sense out of what is going on and to equip us to cope with it more effectively. In particular, I hope to show that this response has important and useful implications to managers. Curiously, I have found managers more willing to embrace the systems approach and its implication than academics. Managers are more inclined than academics to try something new and judge it on the basis of its performance. Their egos are not as involved as the academics' in the acceptance or rejection of a view formulated by another. Academic evaluations tend to be based on the subjective opinions of peers, not on any objective measure of performance.