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The Technological Revolution: Notes on the Relationship of Technology, Science, and Culture

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THE STANDARD ANSWER to the question: What brought about the explosive change in the human condition these last two hundred years, is " The Progress of Science." This paper enters a demurrer. It argues that the right answer is more likely: " A fundamental change in the concept of technology." Central to this was the re-ordering of old technologies into systematic public disciplines with their own conceptual equipment, e. g., the " differential diagnosis " of nineteenth century medicine. In the century between 1750 and 1857 the three main technologies of Man–Agriculture, the Mechanical Arts (today's Engineering), and Medicine–went in rapid succession through this process, which resulted almost immediately in an agricultural, an industrial, and a medical " revolution " respectively.

This process owed little or nothing to the new knowledge of contemporary science. In fact, in every technology the practice with its rules of thumb, was far ahead of science. Technology therefore became the spur to science; it took, for instance, 75 years until Clausius and Kelvin could give a scientific formulation to the thermodynamic behavior of Watt's steam engine. Science could indeed have had no impact on the Technological Revolution until the transformation from craft to technological discipline had first been completed.

But technology had an immediate impact on science which was transformed by the emergence of systematic technology. The change was the most fundamental one–a change in science's own definition and image of itself. From being " natural philosophy " science became a social institution. The words in which science defined itself remained unchanged: " the systematic search for rational knowledge." But " knowledge " changed its meaning from being " understanding," i. e., focused on man's mind, to being " control," i. e., focused on appli-

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cation in and through technology. Instead of raising, as science had always done, fundamental problems of metaphysics, it came to raise, as it rarely did before, fundamental social and political problems.

It would be claiming too much to say that technology established itself as the paramount power over science. But it was technology that built the future home, took out the marriage license, and hurried a rather reluctant science through the ceremony. And it is technology that gives the union of the two its character; it is a coupling of science *to* technology, rather than a coupling of science and technology.

The evidence indicates that the key to this change lies in new basic concepts regarding technology, that is, in a genuine Technological Revolution with its own causes and its own dynamics.

I

Of all major technologies medicine alone has been taught systematically for any length of time. An unbroken line leads back for 1000 years, from the medical school of today to the medical schools of the Arab Caliphates. The trail, though partly overgrown, goes back, another 1400 years, through the School of Alexandria to Hippocrates. From the beginning medical schools taught both theoretical knowledge and clinical practice, engaged simultaneously therefore in "science" and "technology." Unlike any other technologist in the West, the medical practitioner has continuously enjoyed social esteem and position.

Yet, until very late—1850 or thereabouts—there was no organized or predictable relationship between scientific knowledge and medical practice. The one major contribution to health care which the West made in the Middle Ages was the invention of spectacles. The generally accepted date is 1286; by 1290 the use of eyeglasses is fully documented.[1] This invention was, almost certainly, based directly upon brand-new scientific knowledge, most probably on Roger Bacon's optical experiments. Yet Bacon was still alive when spectacles came in—he died in 1294. Until the nineteenth century there is no other example of such all but instantaneous translation of new scientific knowledge into technology—least of all in medicine. Yet Galen's theory of vision which ruled out any mechanical correction was taught in the medical schools until 1700.[2]

Four hundred years later, in the Age of Galileo, medicine took its next big step—Harvey's discovery of the circulation of the blood, the first major new knowledge since the ancients. Another hundred years, and Jenner's smallpox vaccination brought both the first specific treatment and the first prevention of a major disease.

Harvey's findings disproved every single one of the theoretical assumptions that underlay the old clinical practice of bleeding. By 1700 Harvey's findings were taught in every medical school and repeated in every medical text. Yet bleeding remained the core of medical practice and a universal panacea for another hundred years, and was still applied liberally around 1850.[3] What killed it finally was not scientific knowledge—available and accepted for 200 years—but clinical observation.

In contrast to Harvey, Jenner's achievement was essentially technological and without any basis in theory. It is perhaps the greatest feat of clinical observation. Smallpox vaccination had hard sledding—it was, after all, a foolhardy thing deliberately to give oneself the dreaded pox. But what no one seemed to pay any attention to, was the complete incompatibility of Jenner's treatment with any biological or medical theory of the time, or of any time thereafter until Pasteur, 100 years later. That no one, apparently, saw fit to try explaining vaccination or to study the phenomenon of immunity appears to us strange enough. But how can one explain that the same doctors who practiced vaccination, for a century continued to teach theories which vaccination had rendered absurd?

The only explanation is that science and technology were not seen as having anything to do with one another. To us it is commonplace that scientific knowledge is being translated into technology, and vice versa. This assumption explains the violence of the arguments regarding the historical relationship between science and the "useful arts." But the assumptions of the debate are invalid: the presence of a tie proves as little as its absence—it is our age, not the past, which presumes consistency between theory and practice.

The basic difference was not in the content but in the focus of the two areas. "Science" was a branch of philosophy, concerned with understanding. Its object was to elevate the human mind. It was misuse and degradation of science to use it—Plato's famous argument. Technology, on the other hand, was focused on use. Its object was increase of the human capacity to do. Science dealt with the most general, technologies with the most concrete. Any resemblances between the two was "purely coincidental." [4]

II

There are no hard and fast dates for a major change in an attitude, a world view. And the Technological Revolution was nothing less. We do know, however, that it occurred within the half century 1720 to 1770—the half century that separates Newton from Benjamin Franklin.

Few people today realize that Swift's famous encomium on the man who makes two blades grow where one grew before, was not in praise of the scientists. On the contrary, it was the final, crushing argument in a biting attack on them, and especially against the august Royal Society. It was meant to extol the sanity and benefits of non-scientific technology against the arrogant sterility of an idle enquiry into nature concerned with understanding; this is against Newtonian Science, for Swift was, as always, on the unpopular side. But his basic assumption—that science and application were radically different and worlds apart—was clearly the prevailing one in the opening decades of the eighteenth century. No one scientist spoke out against the weirdest technological "projects" of the South Sea Bubble of 1720, even though their theoretical infeasibility must have been obvious to them. Many, Sir Isaac Newton taking the lead, invested heavily in them.[5] And while Newton, as Master of the Royal Mint, reformed its business practices, he did not much bother with its technology.

Fifty years later, around 1770, Dr. Franklin is the "philosopher" par excellence and the West's scientific lion. Franklin though a first-rate scientist, owed his fame to his achievements as a technologist—"artisan" in eighteenth century parlance. He was a brilliant gadgeteer, as witness Franklin stove and bifocals. Of his major scientific exploits, one—the investigation of atmospheric electricity—was immediately turned into useful application: the lightning rod. Another, his pioneering work in oceanography with its discovery of the Gulf stream, was undertaken for the express purpose of application, viz., to speed up the transatlantic mail service. Yet the scientists hailed Franklin as enthusiastically as did the general public.

In the fifty years between 1720 and 1770—not a particularly distinguished period in the history of science, by the way—a fundamental change in the attitude towards technology, both of laity and of scientists, must have taken place. One indication is the change in English attitude towards patents. During the South Sea Bubble they were still unpopular and attacked as "monopolies." They were still given to political favorites rather than to an inventor. By 1775 when Watt obtained his patent, they had become the accepted means of encouraging and rewarding technological progress.

We know in detail what happened to technology in the period which includes both the Agricultural Revolution and the opening of the Industrial Revolution. Technology as we know it today, that is, systematic, organized work on the material tools of man, was born then. It was produced by collecting and organizing existing knowledge, by applying it systematically, and by publishing it. Of these steps the last one was both the most novel—craft skill was not for nothing called a " mystery "—and the most important.

The immediate effect of the emergence of technology was not only rapid technological progress: it was the establishment of technologies as systematic disciplines to be taught and learned and, finally, the re-orientation of science towards feeding these new disciplines of technological application.

Agriculture [6] and the mechanical arts [7] changed at the same time, though independently.

Beginning with such men as Jethro Tull and his systematic work on horse-drawn cultivating machines in the early years of the seventeenth century and culminating towards its end in Coke of Holkham's work on balanced large-scale farming and selective live-stock breeding, agriculture changed from a " way of life " into an " industry." Yet this work would have had little impact but for the systematic publication of the new approach, especially by Arthur Young. This assured both rapid adoption and continuing further work. As a result, yields doubled while manpower needs were cut in half—which alone made possible that large-scale shift of labor from the land into the city and from producing food to consuming food on which the Industrial Revolution depended.

Around 1780, Albrecht Thaer in Germany, an enthusiastic follower of the English, founded the first agricultural college—a college not of " farming " but of " agriculture." This in turn, still in Thaer's lifetime, produced the first, specifically application-focused new knowledge, namely, Liebig's work on the nutrition of plants, and the first science-based industry, fertilizer.

The conversion of the mechanical arts into a technology followed the same sequence and a similar time table. The hundred years between the 1714 offer of the famous £20,000 prize for a reliable chronometer and Eli Whitney's standardization of parts was, of course, the great age of mechanical invention—of the machine tools, of the prime movers, and of industrial organization. Technical training, though not yet in systematic form, began with the founding of the *École des Ponts et Chaussées* in 1747. Codification and publication in organized form goes back to Diderot's *Encyclopédie*, the first volume of which appeared in 1750. In 1776—that miracle year that brought the Declaration of Independence, *The Wealth of Nations*, Blackstone's *Commentaries*, and Watt's first practical steam engine—the first modern technical university opened: the *Bergakademie* (Mining Academy) in Freiberg, Saxony. Significantly enough, one of the reasons for its establishment was the need for technically trained managers created by the increasing use of the Newcomen steam engine, especially in deep-level coal mining.

In 1794, with the establishment of the *École Polytechnique* in Paris, the profession of engineer was established. And again, within a generation, we see a re-orientation of the physical sciences—organic chemistry and electricity begin their scientific career, being simultaneously "sciences" and "technologies." Liebig, Woehler, Faraday, Henry, Maxwell were great scientists whose work was quickly applied by great inventors, designers, and industrial developers.

Only medicine, of the major technologies, did not make the transition in the eighteenth century. The attempt was made—by the Dutchman Gerhard Van Swieten,[8] not only a great physician but politically powerful as advisor to the Hapsburg Court. Van Swieten attempted to marry the clinical practice which his teacher Boerhaave had started at Leyden around 1700, with the new scientific methods of such men as the Paduan Morgagni whose *Pathological Anatomy* [9] (1761) first treated diseases as afflictions of an organ rather than as "humours." But—a lesson one should not forget—the very fact that medicine (or rather, something by that name) was already respectable and organized as an academic faculty defeated the attempt. Vienna relapsed into medical scholasticism as soon as Van Swieten and his backer, the Emperor Joseph II, died.

It was only after the French Revolution had abolished all medical schools and medical societies that a real change could be effected. Then another court physician, Corvisart, Napoleon's doctor, accomplished, in Paris around 1820, what Van Swieten had failed in. Even then opposition to the scientific approach remained powerful enough to drive Semmelweis out of Vienna and into exile when he found, around 1840, that traditional medical practices were responsible for lying-in fever with its ghastly death toll. Not until 1850, with the emergence of the "modern" medical school in Paris, Vienna, and Wuerzburg, did medicine become a genuine technology and an organized discipline.

This too happened, however, without benefit of science. What was codified and organized was primarily old knowledge, acquired in practice. Immediately *after* the re-orientation of the practice of medicine, the great medical scientists appeared—Claude Bernard, Pasteur, Lister, Koch. And they were all application-focused, all driven by a desire to do, rather than by a desire to know.

We know the results of the Technological Revolution, and its impacts. We know that, contrary to Malthus, food supply in the last two hundred years has risen a good deal more than an exploding human population. We know that the average life-span of man a hundred fifty years ago, was still close to the " natural life span ": the 25 years or so needed for the physical reproduction of the species. In the most highly developed and prosperous areas, it has almost tripled. And we know the transformation of our lives through the mechanical technologies, their potential, and their dangers.

Most of us also know that the Technological Revolution has resulted in something even more unprecedented: a common world civilization. It is corroding and dissolving history, tradition, culture, and values throughout the world, no matter how old, how highly developed, how deeply cherished and loved.

And underlying this is a change in the meaning and nature of " knowledge " and of our attitude to it. Perhaps one way of saying this is that the non-Western world does not want Western science primarily because it wants better understanding. It wants Western science because it wants technology and its fruits. It wants control, not understanding. The story of Japan's " Westernization " between 1867 and her emergence as a " modern nation " in the Chinese War of 1894, is the classical, as it is the earliest, example.[10]

But this means that the Technological Revolution endowed technology with a power which none of the " useful arts "—whether agricultural, mechanical, or medical—had ever had before: impact on man's mind. Previously, the " useful arts " had to do only with how man lives and dies, how he works, plays, eats, and fights. How and what he thinks, how he sees the world and himself in it, his beliefs and values, lay elsewhere—in religion, in philosophy, in the arts, in science. To use technological means to affect these areas was traditionally " magic "—considered at least evil, if not asinine to boot.

With the Technological Revolution, however, application and cognition, matter and the mind, tool and purpose, knowledge and control have come together for better or worse.

III

There is only one thing we do not know about the Technological Revolution—but it is essential: What happened to bring about the basic change in attitudes beliefs, and values which released it? " Scientific progress," I have tried to show, had little to do with it. But how responsible was the great change in world outlook which, a century earlier, had brought about the great Scientific Revolution? What part did the rising capitalism play? And what was the part of the new, centralized national state with its mercantilistic policies on trade and industry and its bureaucratic obsession with written, systematic, rational procedures everywhere? (After all, the eighteenth century codified the laws as it codified the useful or applied arts.) Or do we have to do here with a process, the dynamics of which lie in technology? Is it the " progress of technology " which piled up to the point when it suddenly turned things upside down, so that the " control " which nature had always exercised over man now became, at least potentially, " control " which man exercises over nature?

This should be, I submit, a central question both for the general historian and for the historian of technology.

For the first, the Technological Revolution marks one of the great turning points—whether intellectually, politically, culturally, or economically. In all four areas the traditional—and always unsuccessful—drives of systems, powers, and religions for world domination is replaced by a new and highly successful world-imperialism, that of technology. Within a hundred years, it penetrates everywhere and puts, by 1900, the symbol of its sovereignty, the steam engine, even into the Dalai Lama's palace in Lhasa.

For the historian of technology, the Technological Revolution is not only the cataclysmic event within his chosen field; it is the point at which such a field as " technology " emerges. Up to that point there is, of course, a long and exciting history of crafts and tools, artifacts and mechanical ingenuity, slow, painful advances and sudden, rapid diffusion. But only the historian, endowed with hindsight, sees this as " technology," and as belonging together. To contemporaries, these were separate things, each belonging to its own sphere, application, and way of life.

Neither the general historian nor the historian of technology has yet, however, concerned himself much with the Technological Revolution. The first—if he sees it at all—dismisses technology as the bastard child of science. The only general historian of the first rank (excepting only that keen connoisseur of techniques and tools, Herodotus) who devotes time and attention to technology, its role and impact is, to my knowledge, Franz Schnabel.[11] That Schnabel taught history at a technical university (Karlsruhe) may explain his interest. The historians of technology, for their part, tend to be historians of materials, tools, and techniques rather than historians of technology. The rare exceptions tend to be non-technologists such as Lewis Mumford or Roger Burlingame who, understandably, are concerned more with the impact of technology on society and culture than with the development and dynamics of technology itself.

Yet technology is important today precisely because it unites both the universe of doing and that of knowing, connects both the intellectual and the natural histories of man. How it came thus to be in the center—when it always before had been scattered around the periphery—has yet to be probed, thought through, and reported.

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[1] E. Rosen, "The Invention of Eye Glasses," *Journal for the History of Medicine*, 11 (1956), pp. 13-46, 183-218.

[2] It was among the great Boorhaave's many "firsts" to have taught the first course in opthalmology and to examine in it actual eyes—in 1708 in Leyden. Newton's *Optics* was the acknowledged inspiration. (See George Sarton, "The History of Medicine versus the History of Art," *Bulletin of the History of Medicine*, 10 (1941), pp. 123-35.)

[3] Bleeding actually reached a peak in the 1820's when it was touted as the universal remedy by no less an authority than Broussais, the most famous professor at the Paris Academy of Medicine. According to Henry E. Sigerist (*The Great Doctors*, New York, 1933), it became so popular that in the one year, 1827, 33 million leeches were imported into France.

[4] There was, to be sure, one famous dissent, one important and highly effective approach to science as a means to doing and as a foundation for technology. Its greatest spokesman was St. Bonaventure, the thirteenth century antiphonist to St. Thomas Aquinas (see especially St. Bonaventura's *The Reduction of all Arts to Theology*). A hundred years earlier the dissenters actually dominated in the twelfth century Platonism of the theologian—technologist schools of St. Victoire and Chartres, builders alike of mysticism and of the great cathedrals. On this see Charles Homer Haskin, *The Renaissance of the 12th century* (Cambridge, Mass., 1927); Otto von Simson *The Gothic Cathedral* (New York, 1956); and *Abbot Suger and the Cathedral Church of St. Denis*, edited by Erwin Panofsky (Princeton, 1946).

The dissenters did not, of course, see material technology as the end of knowledge; rational knowledge was a means towards the knowledge of God or at least His glorification. But knowledge, once its purpose was application, immediately focused on material technology and purely worldly ends—as St. Bernard pointed out in his famous attack on Suger's "technocracy" as early as 1127.

The dissent never died down completely. But after the Aristotelian triumph of the thirteenth century, it did not again become respectable, let alone dominant until the advent of Romantic Natural Philosophy in the early nineteenth century, well *after* the Technological Revolution and actually its first (and so far only) literary offspring. It is well known that there was the closest connection between the Romantics—with Novalis their greatest poet, and with Schelling their official philosopher—and the first major discipline which, from its inception, was always both science and technology: organic chemistry. Less well known is the fact that the Romantic movement, its philosophers, writers, and statesmen came largely out of the first technical university, the Mining Academy in Freiberg (Saxony) that had been founded in 1776.

[5] J. Carswell, *The South Sea Bubble* (Stanford, 1959).

[6] G. E. Fussel, *The Farmer's Tools 1500-1900* (London, 1952); A. J. Bourde, *The Influence of England on the French Agronomes* (Cambridge, 1953); A. Demolon, *L'Evolution Scientifique et l'Agriculture Francaise* (Paris, 1946); R. Krzymowski; *Geschichte der deutschen Landwirtschaft* (Stuttgart, 1939).

[7] A. P. Usher, *History of Mechanical Inventions* (Rev. Ed., Cambridge, Mass., 1954); also the same author's "Machines & Mechanisms" in Volume III of Singer, *et al.*, *A History of Technology* (Oxford, 1957); J. W. Roe, *English and American Tool Builders* (New Haven, 1916); K. R. Gilbreth; "Machine Tools," in *A History of Technology*, Vol. IV (Oxford, 1958); on early technical education see: Franz Schnabel, *Die Anfaenge des Technischen Hochschulwesens* (Freiburg, 1925).

[8] The standard biography of van Swieten is W. Mueller, *Gerhard van Swieten* (Vienna, 1883); On the organised resistance of academic medicine to the scientific approach, see G. Strakosch-Grassmann,*Geschichte des oesterreichischen Unterrichtswesens* (Vienna, 1905).

[9] This is the name commonly used for the work. Its actual title was *De Sedibus et causis morborum per anatomen indigatis*; the first English translation appeared in 1769 under the title *The Seats and Causes of Diseases Investigated by Anatomy.*

[10] This is brought out most clearly in William Lockwood, *The Economic Development of Japan, 1868-1938* (Princeton, 1954).

[11] Franz Schnabel, *Deutsche Geschichte im 19. Jahrhundert* (4 vols., Freiburg, 1929-1937); the discussion of technology and medicine is found chiefly in Vol. III.

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THE NEW PHILOSOPHY COMES TO LIFE

How we are gradually developing a new view of the world to replace the philosophy which we have used for three centuries—and which no longer fits either the science or the society of our times.

IN THE early fall of 1956 two brothers—intelligent, well-educated graduate students in their twenties—went to see "Inherit the Wind," the play based on the notorious Scopes "Monkey" Trial of 1925, in which a schoolteacher in rural Tennessee was convicted for teaching evolution, and in which the great nineteenth-century "conflict between science and religion" reached a climax of absurdity. When they came home they said they were much impressed by the acting but rather baffled by the plot. What, they wanted to know, was all the excitement about? Their father, at their age, had been so deeply stirred by the trial that he gave up the ministry and became a lawyer; but when he tried to explain its meaning and excitement to his sons, they replied, "You are making this up. It makes no sense at all."

The point of this story is that one of the sons is a graduate geneticist, the other a theological student in a Presbyterian and strictly Calvinist seminary. Yet the "conflict between science and religion" could not even be explained to either of them.

It is indeed frightening how fast the obvious of yesteryear is turning incomprehensible. An intelligent and well-educated man of the first "modern" generation—that of Newton, Hobbes, and Locke—might still have been able to understand and to make himself understood up to World War II. But it is unlikely that he could still communicate with the world of today, only fifteen years later. We ourselves, after all, saw in the last election campaign how rapidly the issues, slogans, and alignments of as recent a period as the 'thirties have become irrelevant, if not incomprehensible.

But what matters most for us—the first "post-modern" generation—is the change in fundamentals. We still profess and teach the world view of the past three hundred years. But we no longer see it. We have as yet no name for our new way of looking at things—no tools, no method. But a world view comes first; it is the foundation for philosophical terms and technical vocabulary. And that new foundation is something we have acquired, all of a sudden, within the past fifteen or twenty years.

SUM OF THE PARTS

THE world view of the past three hundred years can perhaps be summed up in a word as "Cartesian." Few professional philosophers during these years have followed René Descartes, the early seventeenth-century Frenchman, in answering the major problems of systematic philosophy. Yet the modern age has taken its important cues from him. More than Galileo or Calvin, Hobbes, Locke, or Rousseau, far more even than Newton, Descartes influenced the minds of three centuries—what problems would appear important or even relevant, what would be the scope of men's vision, their assumptions about themselves and their universe, and above all, their concept of what was rational and plausible.

His was a twofold contribution. First he gave to the modern world its basic axiom about the intelligibility of the universe. The best known formulation is that in which the Académie

Française, a generation after Descartes' death, defined "science" as "the certain and evident knowledge of things by their causes." Expressed less elegantly and less subtly, this says that "the whole is the sum of its parts"—the oversimplification that might be made by an ordinary man who is neither scientist nor philosopher.

Second, Descartes provided the method to make his axiom effective in organizing knowledge. Whatever the mathematical significance of his "Analytical Geometry," it established the new concept of a world unified in simple quantitative relations that could deal efficiently with motion and change, the flow of time, and even the invisible. The perfecting of this mathematics, and its widespread adoption as a universal symbolic language, made it possible for Lord Kelvin two hundred years later to re-assert the principles of Cartesianism by saying, "I know what I can measure."

The statement that the whole is equal to the sum of its parts also implies that the whole is determined by its parts, that the behavior of the whole is caused by the motion of the parts, and that there is no such thing as wholeness apart from the different sums, structures, and relationships of the parts. These statements are likely to sound obvious today since they have been taken for granted for so long, even though they were radical innovations when first propounded. But though most of us still respond to the familiarity of these assertions, there are no longer many scientists who would accept the definition of the Académie Française—at least not for what they call "science" in their own field. Virtually every one of our disciplines now relies on conceptions which are incompatible with the Cartesian axiom, and with the world view we once derived from it.

PATTERN AND CONFIGURATION

BIOLOGY shows this dramatically. Its tremendous development in the past fifty years has resulted directly from our applying the strict "Cartesian" methods to the study of the living organism. But the more "scientific" the biologist has become, the more he has tended to talk in terms such as "immunity" and "metabolism," "ecology" and "syndrome," "homeostasis" and "pattern"—each of them essentially an aesthetic term describing not so much a property of matter or quantity as of a harmonious order.

The psychologist talks about *"Gestalt,"* "ego," "personality," or "behavior"—terms that could hardly be found in serious works before 1910. The social sciences talk about "culture," about "integration," or about the "informal group." The aesthetician talks about "form." These are all concepts of pattern or configuration. Whether one searches for the "drives" in a personality, the complex of chemical, electrical, and mechanical actions in a metabolism, the specific rites and customs in a culture, or the particular colors and shapes in a non-objective painting—all can be understood, explained, or even identified only from their place in a pattern.

Similarly, we have a pattern at the center of our economic life, the business enterprise. "Automation" is merely an ugly word to describe as an entity a new view of the process of production. "Management" is a similar term. In government we talk about "administration" or "political process"; the economist talks about "national income," "productivity," or "economic growth" much as the theologian talks about "existence." Even the physical sciences and engineering, the most Cartesian of all our disciplines, talk about "systems" or—the most non-Cartesian term of all—about "quanta" in which, with one measurement, are expressed mass and energy, time and distance, all absorbed into a single entity.

The most striking change is perhaps to be found in our approach to the study of speech and language. Despite the anguished pleas of teachers and parents, we talk less and less about "grammar"—the study of *parts* of speech—and more and more about "communication." It is the *whole* of speech, including not only the words left unsaid but the atmosphere in which words are said and heard, that "communicates." One must not only know the whole of the "message," one must also be able to relate it to the pattern of behavior, personality, situation, and even culture with which it is surrounded.

ALL these terms are brand-new. Not one of them had any scientific standing fifty years ago in the vocabulary of scholars and scientists. And all of them are *qualitative*. Quantity does not characterize them; a "culture" is not defined by the number of people who belong to it, nor is a "business enterprise" defined by its size. Quantitative change matters in these configurations only when it becomes qualitative—when, in the words of the old Greek riddle, the grains of sand have become a sand-pile. This is not a continuous but a discontinuous event, a sudden jump over a qualitative threshold at which sounds turn into recognizable melody, words and motions into behavior, procedures into a management philosophy, or the atom of one element into that of another. And, finally, none of these configurations as such is measurable or capable of being expressed—except in the most distorted manner—through the traditional symbols of quantitative relationship.

None of these new concepts, let me emphasize, conforms to the axiom that the whole is the result of its parts. On the contrary, all conform to a new, and by no means as yet axiomatic, assertion that the parts exist in contemplation of, if not for the sake of, the whole.

THE PURPOSEFUL UNIVERSE

MOREOVER, none of these new concepts has any causality to it. Einstein was thoroughly "modern" in saying that he could not accept the view that the Lord plays dice with the universe. But what Einstein was criticizing was the inability of the physicists—including himself—to visualize any other kind of order except causality; that is, our inability to free ourselves from our Cartesian blinders. Underlying the new ideas, including those of modern physics, is a unifying order, but it is not causality; it is purpose.

Each of these new concepts I have mentioned expresses a purposeful unit. One might even say, as a general "modern" principle, that the elements (for we no longer really talk of "parts") will be found to arrange themselves so as to serve the purpose of the whole. This, for instance, is the assumption that underlies the biologist's attempt to study and to understand organs and cells. It is this "arrangement in contemplation of the purpose of the whole" that we mean today when we speak of "order."

This universe of ours is again a universe ruled by purpose, as was the one that the Cartesian world view displaced three hundred years ago. But our idea of "purpose" is a very different one from that of the Middle Ages or Renaissance. Theirs lay outside of the material, social, and psychological universe, if not entirely outside of anything Man himself could be, could do, or could see. Our "purpose," by sharp contrast, is in the configurations themselves; it is not metaphysical but physical; it is not the purpose *of* the universe, but the purpose *in* the universe.

I read the other day a piece by a leading physicist in which he talked about the "characteristics of sub-atomic particles." A slip of the pen, to be sure; but a revealing one. Only a generation ago it would not have been possible for a physicist, no matter how slipshod, to write of anything but the "properties" of matter. For atomic particles to have "characteristics," the atom—if not matter and energy themselves—must have a "character"; and that means that matter must have a purposeful order within itself.

THE new world view, in addition, involves the idea of *process*. Each of the new concepts involves growth, development, dynamism—and these are irreversible, whereas events in the Cartesian universe were as reversible as the symbols on either side of an equation. Never, except in fairy tales, does the grown man become a boy again, nor does lead change back to uranium, nor does a business enterprise return to family partnership. All these changes are irreversible because the process changes its own character; it is, in other words, self-generated change.

Only seventy-five years ago the last remnant of pre-Cartesian thinking, the idea of "spontaneous generation" of living beings, was finally laid to rest by Louis Pasteur. Now it comes back to us in the researches of biologists who look for clues to the origin of life in the laboratory "creation" of amino-acids. Now respectable mathematical physicists seriously talk about something even more grossly shocking to the Cartesian view: a theory of constant and spontaneous self-generation of matter in the form of new stars and new galaxies. And a leading biochemist, Sir Macfarlane Burnet, the Australian pioneer of virus research, recently defined a virus, as "not an individual organism in the ordinary sense of the term but something that could almost be called a stream of biological pattern."

In this new emphasis on "process" may well lie the greatest of all the departures of the new world view. For the Cartesian world was not only a mechanical one, in which all events were finitely determined; it was essentially a static one. Inertia, in the strict meaning of classical mechanics, was the assumed norm. It had been an accepted doctrine since Aristotle that the Unchangeable and Unchanging alone was real and alone was perfect. On this one point Descartes, otherwise so daring an innovator, was the strictest of traditionalists.

In fact it was the great achievement of the Cartesian view to make this traditional axiom usable. Motion so obviously exists; yet on the basis of inertia it cannot be explained and measured—as was first pointed out two thousand years ago in the famous "paradoxes" of Zeno, such as that of Achilles and the tortoise. Only "calculus"—together with Descartes' Analytical Geometry—could find a way out of the impasse between the idea of inertia and the experience of motion. This it did by a most ingenious trick: by explaining and measuring motion as though it consisted of an infinite number of infinitely small but perfectly static "stills."

It is far from true that this "solved" Zeno's paradox, as the textbooks assert. But it could do what no one before had been able to do—assert the axiom of inertia and yet handle motion with growing assurance—and it could point to its success in actually analyzing, predicting, and controlling physical motion. Today, however, we are becoming all-too-painfully aware that the "solution" is inapplicable to true motion—that is, to growth and development, whether biological or economic, which cannot be explained away as a kind of optical illusion. We assume—and are increasingly aware that we assume—that growth, change, and development are the normal and the real, and that their absence is the abnormal—the imperfect, the decaying, and the dead.

TOWARD A NEW PHILOSOPHY

WITHIN the past twenty or thirty years these new concepts have become the reality of our work and world. They are "obvious" to us. Yet, though we take them increasingly for granted, we do not fully understand them. Though we talk glibly of "configuration," "purpose," and "process," we do not yet know what these terms express. We have abandoned the Cartesian world view; but we have not developed, so far, a new tool box of methods or a new axiom of meaning and inquiry. We have certainly not yet produced a new Descartes. As a result we are in an intellectual and artistic crisis.

True, there is a rapidly growing literature of the "new" philosophy. Though anticipations of it can be found in numerous thinkers—for example, in Whitehead, Bergson, Goethe, Leonardo, or Aristotle—the earliest to expound the new vision in our time was probably that astounding South African, Jan Christiaan Smuts, with his philosophy of "holism" twenty-five or thirty years ago. There are pronounced reflections of it in the work of two physicists, Lancelot Law Whyte, with *The Next Development in Man,* and Erwin Schroedinger, with his *What is Life?,* and one of its latest and most persuasive expressions is provided by the distinguished economist, Kenneth Boulding, in a small book called *The Image.* It is hardly an accident, moreover, that one of the contemporary philosophers who sells best in paper-back editions is the late Ernst Cassirer; his books—though anything but "popularly" written; in fact, a veritable thicket of Teutonic abstractions—deal with patterns, configurations, and symbols of order as essential elements in Man's experience.

But the people working in a specific discipline are still in difficult straits. They see the new ideas everywhere around them; indeed, they often see little else. But whenever they want to do rigorous work, all they have to work with are methods based on the old world view, methods which are quite inappropriate to the new.

In the social sciences this shows itself in the glaring discrepancy between our talk of "culture," "personality," or "behavior" and our inability to produce much more than vast collections of empirical data about particular—and therefore largely meaningless—manifestions. In a discipline that is much closer to my own daily interest, the study of management, the situation is equally frustrating. The discipline only exists because we have a new conception of the business enterprise. All of us know and stress continually that the really important things are process-characteristics, such as the "climate" of an organization, the development of people in it, or the planning of its features and purposes. But whenever we try to be "scientific," we are thrown back on mechanistic and static methods, such as work measurement of individual operations or, at best, organization rules and definitions. Or take the physicists: the more they discover about

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What About Indoor Plumbing?

A KU KLUX KLAN rally was held Saturday night off Highway 25-W and Klan speakers attacked polio vaccination programs, fluoridation of water, Gov. Frank Clement, the Supreme Court and President Eisenhower.

—Clinton (Tennessee) *Courier-News,* May 16, 1957.

the various sub-atomic particles of matter, the more confused, complicated, and inconsistent become their general theories of the nature of matter, energy, and time.

As a result, the very disciplines that are advancing the fastest, in which therefore there is the most to learn, are rapidly becoming unteachable. There is no doubt that medicine, for instance, has made giant strides in this generation. But virtually every experienced teacher of medicine I know wonders whether the young medical-school graduate of today—the very one who gets "the best medical education the world has to offer"—is as well taught and as well prepared as his much more ignorant predecessor of thirty years ago. The reason is simple. Medical schools are still organized around the idea of disciplines as static bundles of knowledge. But, where a hundred years ago there were at best six or seven such "bundles," there are perhaps fifty today. Each has become in its own right a full-blown "science" which takes a lifetime to master—even to acquire a "smattering of ignorance" in any one of them takes more than the five years of medical training.

In addition we suffer the affliction, perhaps inevitable in a time of philosophical transition, of a maddening confusion of tongues among the various disciplines, and the consequent cheapening and erosion of language and style. Each discipline has its own language, its own terms, its own increasingly esoteric symbols. And whenever we try to re-establish unity all we can do is fall back on the outworn language of the Cartesian world which originally brought disunity upon us.

All of this, it should be firmly said, is not merely the "natural" result of advancing knowledge, as some academicians assert. The "natural" result should be, as it has always been, greater simplicity—greater ease of learning and teaching. If our knowledge becomes constantly more specialized, more complicated, rather than more general, then something essential is lacking—namely, a philosophical synthesis appropriate to the world we actually inhabit.

A BIG ORDER

YET we now can—as we could not a decade or two ago—foresee what shape the new integration will take, when and if it comes. We can see, first of all, what it will not be. The way out is not to repudiate the Cartesian world view but to overcome and encompass it. Modern physics may have given us cause to rediscover Aristotle on a new level of understanding, but it has not made us more appreciative of astrology. Modern biology and operations research have made us more conscious of the need to measure quality, value, and judgment; they have not made us repudiate strict proof, or abandon the quest for objective measurement.

Another negative prediction: in the coming synthesis, the Cartesian dualism between the universe of matter and the universe of mind will not be retained. This was certainly the most potent, as it was the most central, element in Descartes' own system; and for three hundred years it has paralyzed philosophy—if not all our thinking—by widening the split between "idealist" and "materialist," so that each has built ever-higher fences around his own little plot of reality. If there ever was a useful distinction here, it ceased to be meaningful the day the first experimenter discovered that by the very act of observing phenomena he affected them. Today our task is to understand patterns of biological, social, or physical order in which mind and matter become meaningful precisely because they are reflections of a greater unity.

We can also say something affirmative. We need a discipline rather than a vision, a strict discipline of qualitative and irrevocable changes such as development, growth, or decay, and methods for anticipating such changes. We need a discipline, in other words, that explains events and phenomena in terms of their direction and future state rather than in terms of cause—a "calculus of potential," you might say, rather than one of "probability." We need a philosophy of purpose; a logic of quality, and ways of measuring qualitative change; and a methodology of potential and opportunity, of "turning points" and "critical factors," of risk and uncertainty, of constants and variations, "jump" and continuity. We need a dialectic of polarity, one in which unity and diversity are defined as simultaneous and necessary poles of the same essence.

This may sound like a big order, and one we are as yet far from able to fill. Yet we may have the new synthesis more nearly within our grasp than we think. In philosophy and science—perhaps even more in art—a "problem" begins to be solved the moment it can be defined, the moment the right questions are being asked, the moment the specifications are known which the answers must satisfy, the moment we know what we are looking for.

And that, in one after another of the areas of modern knowledge, we already know.