The Current Transition in the Conception of Science

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THIS PAPER IS CONCERNED with the radical changing of things, with the tearing down and rebuilding of large parts of the understrutting of the world of science in which we work.

By definition, scientists are coldly objective, sternly devoted to the pursuit of their studies, wherever that pursuit may run. Led by Darwin, they set about breaking up other men's pictures of the world. They splintered the proud panorama of Man, the special creation, with all the lesser species spreading out from his feet as lower and lower forms of life. They have joined hands with the great psychopathologists of this century to set in premonitory trembling that image which men have held of themselves as beings guided by intelligence and sustained by a moral order not of their own devising. They have left that Garden, from which all things had seemed to have their origin, nothing more than a warmly smiling fantasy on the face of the enormous reaches of time and space which have been opened up behind us.

Now science itself must face its own bitter catalysis. For in very fact the world of thought is one world; and science, which has wrought such deep changes, must change with them. In this, our discipline, together with the social sciences to which we are so closely related, is a prime mover.

The arbiters of science in the 19th Century were physics and chemistry, mathematics and astronomy. Their language was the language of the universe itself. Their criteria of proof were the absolute in validity; they were the pure in science. In this arid climate the biological disciplines, and more lately the social sciences, have had a hard and bitter struggle to acquire status and, indeed, to win the simple right to the use of the word "science." To this very hour, controversy has not ceased as to whether psychology and psychiatry are true sciences, despite the fact that their discoveries have been among the most profound and moving of our age.

The theory of relativity has fertilized our thought to the liveliest growth. Under its stimulus we have outgrown and destroyed the old concepts of time and space; energy and mass and movement have become interchangeable, and we live in a universe expanding with cosmic speed, or as rapidly contracting, dependent upon the current phase of astrophysical speculation.

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Yet when we sit in dispassionate reverie upon our times, we may wonder whether some kindred spirit, far in the future, in like reminiscence upon these days, may not accord primacy in power to the discoveries of our social sciences. I do not refer to those discoveries-to-be with which the midcentury seems clearly to be pregnant, but to those already brought to birth and now in full and busy life.

The insights which psychology and psychiatry have given us have destroyed the absolute monarchy of reason; they are dissolving the ancient concepts of intellect and emotion; the will has almost disappeared.

Before the social sciences grew in power, the world of custom in which we live was a scattering of settlements in a forest of beliefs and folkways which had their roots in the medieval past. To the inhabitants of each little clearing, those outside were the strangers, whose ways of sharing goods, of bringing up children, of living with women, of administering justice, were ways of the foreigner and the savage. Governed by precedent, supported by supernatural beliefs, their aggressions curbed by taboos which they did not understand, they slowly won their battle with the material universe.

Worldwide communication and transportation finally set the field for comparative anthropology. The assertion of each rigid little moralistic system that deviation from its code must bring disaster could be shown to be false, and now the whole moralistic evaluation of human behavior is under question.

But the purpose of this discourse is not to compare the contributions of the physical and social disciplines working within a similar framework of science, but rather to consider how the framework itself is shifting and changing and evolving.

It is shifting—but why? Why should our system of science be changing? The last 100 years have seen incomparable gains in knowledge; those scientific concepts which have been worked out by the four brilliant leaders—physics and chemistry, astronomy and mathematics—have been applied to one field after another with success which has astounded the friends of science and shocked and dismayed its adversaries. The vitalists who declared that organic substances could not be produced without the intervention of vital force were driven from the scene when Wöhler applied potassium cyanate to ammonium sulfate and formed urea, the first of the great series of organic components which chemistry can now produce at will.

The principle of the reduction of the phenomenon to its elements brought us molecular physics. Then, like a view dissolving and changing as we sweep forward, came the atomic world, and now, the electron and the proton.

Finally, the right of these successful leaders to determine the form and manner of science appeared to be completely vindicated by the results obtained by certain of the new biological disciplines—most particularly, bacteriology. For here the principles of the isolation of the problem from its setting, the controlled manipulation of variables, the use of the deterministic dictum that similar causes are followed by similar effects, led to remarkable successes to which endless numbers of us owe our lives.

And yet its very successes have led to the changing of our conception of science.

At this point in time when the leadership of the basic sciences seemed to have reached the pinnacle of triumphant power, those same forces, the working of which had enabled science to appear, gathered up their strength for a fresh drive forward. What these powers are, we can grasp only in crude and faulty fashion. As we look back over great reaches of time, they appear to be related to, and perhaps derived from, our growing control over our world.

Very early in our history, when we had the lever, the spear, fire, but perhaps not yet the bow and wheel, when we had a few medicinal herbs, but no domesticated animals or agricultural arts, one can see that men attributed human characteristics to all of nature. The river and the hill, the deer and the trees, the wind and the sun, all had traits which man found in himself. Nature could be angered, be propitiated, protect, or exact vengeance.

Immense periods of time passed; man's control over nature grew wider, surer, and step by step his primitive animism gave place to the little gods of life and death—those who presided over the seasons, the gods and goddesses of fertility, of love, of fortune—in a word, those who controlled the happenings which man himself could not yet master.

With still further progress, these little projections of himself gave place to the great one-god systems, which in the last several centuries have been less and less concerned with the direct control of nature. Man was managing this pretty well himself, though whenever there occurred a particularly shattering earthquake, terrifying storm, or destructive drought, there was a return to the belief in the value of propitiation.

The last field which has been left to these systems is our own: that of human behavior—hence, the sharpness of the current struggle between these systems and the social sciences for authority and control over guilt and anxiety, over prohibition and convention, the struggle for direction of the growth of the personality and the ordering of the cultural pattern.

For a vast and rapidly growing number of people our universe now stretches out in endless vistas, neither friendly nor unfriendly to humankind. It awaits our use as we gain knowledge; it can be made to serve our needs without measure and enrich our living in an undetermined degree. If, failing to master our own nature, we turn these waiting powers against ourselves, we shall be destroyed.

These changes in our world image, in the picture which we have of our relations with the environment of men and things, are essential to a successful attack on the problems of human behavior. While men who held anthropomorphic concepts of their world have made great contributions to physics and astronomy, no man can with full effectiveness prosecute scientific studies of human behavior and at the same time maintain beliefs that behavior is subject to unpredictable transcendental control.

I wish now to discuss more specifically the changes which are appearing in our conception of science. They are related in varying degree to this growing confidence with which we deal with our world. The first change is the appearance of new ideas of causality —new concepts of the way in which event may be related to event.

Under the pressure of these vast slow shifts in the relationship between man and his world, changes have been taking place in the very cement which held the old world of science together. The doctrine of determinism had been a tight, hard binding; event was clamped to preceding and succeeding event with rigid unalterability. You had to have it that way. The battle for the lawfulness of the universe had been intense, bitter. Mystic and transcendental interpretations of events have an immensely ancient history. In the old ways of men's thinking, supernatural powers could break in at any point in a sequence of happenings. But if this was to be, there could exist no general scientific laws, there could be no possibility of prediction, and man was back on his knees again, a suppliant and no aspiring master of his world. For the early scientist, event was deterministically handcuffed to event, so that none could escape and nothing unpredictable could break into those long chains.

The scientific worker has now less and less reason to fear that, into his work, into his own thinking, there will once more erupt the ancient magical, the old transcendental, ways. They are all but gone, and what remains is dying.

Once the lockstep had been broken, new patterns of causality began to appear. The biologists freed from this domination were able to see and report that even the simplest of living organisms did not react identically to repeated exposure to what appeared to be identical conditions. They realized that the very fact of response altered subsequent responsiveness, and that living organisms at least must be thought of as continually evolving systems, the future reactivity of which could be predicted only in general outline.

The term organicism was coined to describe this new kind of relationship between the events. Allied to this is the concept of emergent evolution.

The postulates of Gestalt have taken us still further away from the older ideas of straight-line causality relationships and represent, moreover, a revolt against the fragmentation to which the physical sciences subjected their phenomena.

More recently, still other patterns of relationship between events have been discovered. Among them is the concept of the autonomous reaction, a reaction which, once initiated, tends to become self-perpetuating. It has also been described as a circular system, or, less clearly, as a feed-back mechanism, and, as I think quite erroneously and confusingly, as a teleological system. These concepts have been applied with profit to the problem of the perpetuation of chronic anxiety states, to the fluctuation of the population of algae in ponds, and to nonbiological phenomena such as the functioning of thermostats and other servomechanisms.

Before we had discovered these new ways in which event might relate itself to succeeding event, certain problems in behavior were quite insoluble. Before we had come upon the existence of the autonomous, self-perpetuating types of relationship, it was exceedingly difficult to understand the imperviousness of certain of the chronic anxiety states to the usual forms of therapy.

It seems reasonable to anticipate that further exploration of this exceedingly new and provocative field of the various ways in which events may be connected to each other will result in extension of our knowledge concerning such puzzles as the operation of the mechanisms which secure psychobiological homeostasis, often in the face of most considerable stress.

A second consequence of our vast, slow gain in confidence in dealing with our world is our diminishing need for absolutes. This is bringing in its train some highly important changes in our conception of science.

Scientists have long been aware that their facts are in a state of continual revision, and, indeed, in the earlier days when the scientific method was being attacked with more optimism by its opponents, one of the accusations against which scientists had to fortify themselves was that they did not know their own minds until they had read the latest technical journal and found whether yesterday's fact still stood unchallenged. This was usually countered by the declaration that science was concerned with ultimate truth and that its facts represented progressively more reliable approximations to that final truth.

But as we grow bolder, more and more of us are beginning to raise the question of whether the idea of a final truth is not simply a lingering remnant of our urge to anthropomorphize our universe—to provide our anxious-minded selves with some final fixed point. Certainly, nothing in our experience justifies our thinking that there is any such thing as an ultimate.

Hence, a number of workers are now beginning to discard a whole network of 19th-century scientific concepts—the ultimate truth, the scientific fact, the so-called laws of nature. In their stead, they are beginning to think of the fact as the working hypothesis of the day, which has not a validity but a utility. That utility consists in its effectiveness in expanding our control over events, and it lasts only until a better working hypothesis can be found.

The laws of nature are now considered simply to represent our ways of conceptualizing data, and the absolute is seen as our need for security.

A number of men are now feeling confident enough to work in an open rather than in a closed system. By an open system, I mean one in which there are no final facts, no unchanging truths, where everything is relative and conditional and, above all, fluid and plastic.

This group of changes in the conception of science is likely to bring with it consequences of considerable vitality, for if we can free ourselves of our beliefs in the ultimate and the final in the scientific field, we can anticipate that through the usual processes of the migration of concepts there will be a crumbling of similar beliefs in the inevitable and absolute in other fields.

It is everywhere recognized that we are approaching a crisis of the first magnitude in our affairs. We have been unable to produce the social adaptations and inventions necessary to meet the changes forced upon us by our industrial and material progress. What is not so clearly recognized is that we have not found adequate means or, indeed, sufficiently potent social sanctions to enable us to break up and remove ancient, outmoded beliefs and social institutions. Hence, the penetration of these new concepts, concerning the unreality of the absolute, from the scientific field into everyday thinking would be a most outstanding gain.

Perhaps most people, when asked to say what they consider to be the chief value of science, would answer that it was to discover the causes of things. But it does not seem likely that we will continue to believe this. Indeed, the whole idea of causes is now a much less clear-cut affair than it was two generations ago. The early bacteriologists, the pioneer endocrinologists, and those who worked in the new field of the vitamins were very sure that their great contributions were the working out of causes. Occam's razor—you may not multiply explanations unnecessarily—and the then-existing concepts of causal relationships partnered to produce the idea of the single cause.

Hence, in our field there was a long delay in recognizing that behavior could be conceptualized as an interaction between the total individual and his total environment. For decades, workers continued to seek to define specific reactions and specific causes. Modification came from a series of compromises, the more important being the Meyerian ideas of multicausal etiology and of action tendencies, rather than specific reactions—or diseases.

Now we are approaching a period when the whole concept of the cause may be abandoned in favor of a hypothesis of chains of event sequences continually interacting with, and modifying, each other. Causes, then, are seen to be no more than our recognition of places in these sequences at which we can most successfully interfere, either now or when we have gained more skill.

It is certainly true that in actual practice, even when we continue to think of causes and designate one of these as primary, we rarely attempt to control the situation by trying to modify the primary cause. The explanation of this is simple: such modification is impossible, since the primary cause is no longer operative.

Let us turn now to a procedure which scientists have used very widely in getting their projects ready for investigation. This procedure is that of abstraction.

The behavior of the 19th-century scientists at work on a problem is reminiscent of a dog with a bone. He dragged it off from wherever he found it to some secluded place of his own choosing. In the laboratory, the world, with all its contaminations, its uncontrollable variables, its uncertainties which simply would not submit themselves and be quantified, was shut out. It is amazing that, under such circumstances, what man worked out from his highly abstracted version of the original problem did have any validity at all when transferred back to the setting from which the problem originally had been lifted. Of course, often enough it did not, and the path between the laboratory and the industrial plant is just as liberally paved with good scientific intentions as was said to be that Hell of our guilt-ridden ancestors. A substantial measure of this difficulty of retranslating from the scientific abstraction to the actualities of scientific production is the existence of the pilot plant as the place of adaptation between the test tube and the production line.

This device of abstraction is difficult enough to apply to problems of chemistry, electricity, or magnetism. It becomes more difficult when we apply it to the living organism, and almost impossible when we try to use it in studies upon the behavior of groups of living things. It is customary to explain this difficulty by saying that it stems from the fact that such problems involve the control of far more variables. This is only a small part of the answer. Anyone even vaguely familiar with the complexity of matter, as now understood, can have no doubts of the great range of variables to be controlled in chemical and physical problems. The difficulty seems rather to lie in the fact that the living organism is essentially adaptive. Hence, the problems which we wish to study are compounded of the organism and its setting. If one lifts the organism out of its setting to transport it to the laboratory, the problem is ruptured.

At this point we return to what has already been said, namely, that the Gestalt approach, with its emphasis upon wholes, is the answer of the social disciplines to the elementarism of the basic disciplines.

An answer which is still lacking is how we are to rewrite the criteria of proof. The experimental method as elaborated by the physicists and chemists, and later by the bacteriologists and the animal physiologists, was a tool magnificently effective in meeting the needs of validation. We are learning how to apply it, how to modify it, for our purposes in the social sciences. We have long since redirected our attention from the immense regularities and averages to the study of individual differences. We have the beginnings of a statistics of small samples. But no one can feel satisfied with the validation of many of the concepts which have been advanced in our field during the last several years. Their only present justification is empiric. Progress has been made, however, and it can no longer be asserted that abstraction and isolation of the problem is an essential part of the scientific method.

Thus far we have discussed changes in particular aspects of the conception of science—changes in our ideas concerning causality, concerning the usefulness of the idea of cause, concerning absolutes, the replacement of a closed system by one that is open, and we have talked about profound modifications in the theory of the experiment. All these marshal great power and will bring about the most extensive reordering of our conception of science and, from this, of our image of the universe. But they are parts and systems within the whole, and change now impends not only for these components but for the over-all conception of science with which we passed out of the 19th Century. This was brought into existence during a period when it was urgently necessary that this new way of dealing with things should be separated as sharply as possible from the previous subjectivism, from the all but overpowering effects of traditional beliefs upon men's thinking.

Every effort was made to assert that science was a system which had a reality apart from the men who built and operated it. Hence, we have this curious inversion, the laws of nature which men sought to discover. It was a little like hunting a thimble which you yourself had hidden, because very certainly the laws of nature have no existence in themselves; they are simply the ways in which we find it convenient to conceptualize phenomena.

One of the earliest pieces of evidence that science was not a system, but a form of behavior, was a small discovery made, as it were, in a corner of that ordered world of science which had been fathered by the physical disciplines. This evidence was the "probable error," or, as Bessel, that sensitively perceptive astronomer of Koenigsberg, preferred to call it, the personal equation. Small though this discovery may seem, it was of great significance not only as a forerunner but in its own right. One may feel that to record the fact that a number of observers, watching the transit of a star under identical conditions, will report divergent readings, is a matter of importance only to those interested in the refinement of measurement. But of far greater meaning is the fact that it heralds the recognition of the human factor in science. It means that science can no longer be considered a machine which may be set in motion without any regard for the man who operates it.

Starting from the probable error, and passing through the minds and work of a great series of animal experimentalists, biologists, and social scientists, we are now emerging with an entirely new conception of science, namely, that it is a form of human behavior comparable to sexual behavior, economic, family, or industrial group behavior.

This at once opens up considerations which carry with them very far-reaching consequences. First, we must question to what extent our own innate organization determines the nature of our scientific behavior. Most assuredly it does. But how, and to what degree? Almost all of this new ground is highly speculative, and I shall discuss it as such. We are greatly plagued, both in lay thinking and in our scientific work, by the tendency to use dichotomies—good and bad, introvert and extrovert, conscious and unconscious, higher and lower functions. How far is this dependent upon the fact that we exhibit in ourselves the phenomena of sidedness? You will recall a number of schizophrenic patients who convert sidedness into just such terms as I have used. They refer to the right side as good, and to the left as the side on which they have fallen down—the bad side.

To what characteristics of the organization of our natures is due the fact that we have so much more difficulty in dealing with the abstract than the concrete? On this we have no data, and speculation has barely begun. Those very characteristics of our nature which have been responsible for our astounding progress as a species have carried with them hidden detriments. It is true that our adaptability is immensely greater than that of any other living creature. We are the animals which have taken a chance; we left the shelter of the trees and then the protection of the caves; we played with fire; we crossed the perilous seas; we have dared to leave the earth. Other animals have chosen to adapt themselves to circumstances and have produced protective coloring, speed for escape, armor for defense, and prolific fertility for survival. We have never made that choice. We have come to our problems without ready-made solutions, relying on our ability to work out answers on the spot.

While this has given us great gains, it has been at the cost of great anxiety and insecurity. It has been necessary to build up worldwide reassurance illusions, which in turn have slowed the progress of science. We can see this at a glance in our fairy tales, in the folk stories of powerful figures, in our father-image myths, beliefs, and creeds. Many of the effects of this species insecurity are less immediately obvious. To illustrate this, we may turn to the field of remembering, where the progress of our knowledge has been delayed by such lay beliefs as that the past is with us, that we can relive it, that by far the greater part (indeed, some of our psychopathologists believe, all) of what we experience is stored away as memories. In actuality, by far the greater part of what we experience is lost forever, and that within a few minutes. But we have an overpowering need to preserve our sense of identity, of fixity, in this rapidly changing world—hence, this illusion.

Of at least equal importance is another consequence of our new conception of science as a form of human behavior. We are beginning to appreciate the extent to which our cultural endowments influence both the range and acuity of our conceptional abilities. Everywhere anthropologists are showing that the people of a given culture may be able to develop certain concepts but not others, and that this has nothing to do with their innate ability but a great deal to do with the way in which their upbringing within the culture affects their capacity to conceptualize things.

The Mayas were able to create architectural and agricultural arts of a high degree of excellence. They developed a calendar more accurate than ours, and they devised a highly original system of mathematics. But amazingly enough, though they carried on this most successful agricultural society, they were quite incapable of inventing the plough.

We may well question why the Romans, who were such capable administrators, military experts, road and bridge builders, should have been unable to produce a power-industry civilization. We may go further and say that the basic concept was actually in existence, but that it simply could not be expanded and applied; for, in 130 B.C., Hero of Alexandria described in his "Pneumatica" at least two methods of harnessing power to steam.

We have been inclined to obscure this puzzle as to why scientific and industrial development came so late by considering that these earlier periods were somehow representative of the youth of our species—and, as everyone knows, the boy really does become smarter when he grows up. This might be a simple way out if we still believed that we originated in 4004 B.C. But now that we know that the first traces of man go back for at least half a million years, we have to think of the Romans almost as contemporaries. This concept of cultural indoctrination as affecting scientific behavior as well as all other forms of behavior has, of course, immediate signi ance. We shall want to know to what extent curre indoctrinations—political, nationalistic, religious—li it our ability to conceptualize our world and, the by, hinder the progress of our control of our univers through science.

I have tried to show th ugh what vistas we have the scene of the extremely teresting and provocative things which are happening to our conception of science. It is the inmost germinal place of our future.

I reiterate my belief that psychiatrists, with their unique position between the medical and social sciences, have a special responsibility to act as leaders and guides in entering and opening up this new territory. We have the responsibility not only to create the new tools and the new concepts but we also have a most serious duty to assist in finding means to destroy the old and the obstructionist. It is one of the graver lessons of our times that the new, the more liberal, the more effective, does not immediately succeed without our active assistance in driving out the old, the harmful, and the entrenched.

Obituary

Burton Edward Livingston
1875-1948

Burton Edward Livingston began his career as a botanist at a very early age in the fields and woods, along the ponds and streams in the vicinity of his home in Grand Rapids, Michigan. Early experiences with trees, flowers, and the general flora of his native region undoubtedly exerted a strong determinative influence upon his life. His parents and older brothers and sisters were unusually interested in plants, their habitats and behaviors. This home environment must have been a powerful stimulus to his development.

In addition to contacts with the flora of central Michigan, he had an opportunity to become familiar with all kinds of tools and machinery, for his father was a contractor in the street-paving and sewer-construction business in Grand Rapids.

A third factor which helped to shape his background development was the home library, which was quite out of the ordinary at that time. Burton acquired the habit of reading rather widely and became omnivorous in his literary tastes. He also had the privilege of playing with simple microscopes and of becoming familiar with their use before he ever attended school. All of these factors had a definite bearing upon the course of his life and helped to create that interest in the plant sciences which made him later on a great leader in the fields of plant physiology and forest ecology.

Grand Rapids was the scene of his grade and high school training. In the high school he had the good fortune to learn the fundamentals of many sciences, as well as a number of languages which would be useful to him as a leader of research in his chosen field. He began making an herbarium in high school and afterwards continued to collect plants as a scientific project. Having gone far beyond the requirements for school work, he acquired a wide acquaintance and knowledge of the plant kingdom and, upon entering the University of Michigan, was rewarded by being given 10 hours of advanced credit in botany for his herbarium activity.

When he was old enough to engage in gainful employment, he obtained a job at the Pitcher and Manda United States Nurseries at Short Hills, New Jersey. The year he spent at Short Hills gave him the oppor-