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The Newest History: Science and Technology

It is joining the history of kings and generals, of society and ideas, as part of the study of the past.

Melvin Kranzberg

History deals with change, and history itself is a changing thing. At least the emphases in interpretations of historical events are constantly changing. Exactly 50 years ago James Harvey Robinson signalized a major shift in historical approach with his publication of *The New History*, which sought to overcome the "old" history's preoccupation with the state. Just as the "new" history triumphed over the "old" but never succeeded in dislodging it completely, so today the "new" history is itself being supplemented by the "newest" history. Called the history of science and technology, it deals with the development of science and technology and their impact on man and his society.

The "old" history of the 19th century was rooted in the Romantic movement, which stimulated intellectuals to be historical-minded and to seek in the past for the sources of national culture and greatness. Its subject matter was the state, or politics, as in E. A. Freeman's celebrated definition: "History is past politics, and politics is present history."

But the very forces which had helped to bring about concentration upon national political history were also working to broaden that history. Historians would continue to be engrossed with the growth of nations, the achievements of men of action, the rise and fall of political parties, and the changing friendships and enmities among nations, but wider interests were beginning to assert themselves. The rise of the nation state had also brought the masses to prominence, and the growing democratization of the European states meant that even political history must thenceforth be interpreted not in terms of the aristocratic classes but in terms of the new rulers: the people. The focus was to be on society as well as on the state, on the group as well as on the individual leader.

At the same time, as man strove to understand society, new sciences were coming into being: the social sciences. Economics (at first called political economy), archeology, anthropology, sociology, psychology—all stimulated investigations into aspects of the past which broadened the entire field of historical study and interpretation.

Out of this material amassed by the social sciences, James Harvey Robinson fashioned his "new" history. He did not throw away the concept of history as "past politics"; instead, he claimed that it was no longer adequate, and he expanded the concept to include the reconstruction of a civilization in its entirety. As he expressed it, history includes "all that we know about everything that man has ever done, or thought or hoped."

Defining history as the study of man in the past, Robinson said that historians know much about the past but little about man. He therefore urged historians to learn something about man by acquiring knowledge of the newer sciences of man. With such knowledge the historian could tell us something more worth while about man in the past than "whether Charles the Fat was at Ingelheim or Lustnau on July 1, 887."

No sooner had Robinson provided Clio with a "new look" than some cynics observed that, far from being a new dress, it was simply an older model, taken from the attic of history. As far back as the 18th century Voltaire had declaimed against concentration on political history, writing: "It seems that, for fourteen hundred years, there has been none but kings, ministers, and generals among the Gauls." Indeed, Voltaire himself had written histories endeavoring to depict the life and spirit of peoples, their art, science, and politics. But Voltaire was not the only 18th-century predecessor of the "new" history. Montesquieu's *Spirit of the Laws* was largely historical in content and dealt with laws as related to manners, climate, religion, and commerce. In the 19th century Buckle and Green in England, Lamprecht in Germany, and McMaster in the United States also helped to broaden the historical perspective.

Despite these progenitors there was still much in Robinson's "new" history that *was* new and different. Besides its emphasis upon a broader subject matter and upon the application of the social sciences to the art of history, what excited many of the teachers—and nearly all of the students—who came into contact with it was its attempt to apply history to current problems, to "turn on the past and exploit it in the interest of advance." To Robinson and his cohorts it was not enough for the student of history merely to understand the present in the light of the past; it was necessary that he act on this knowledge to improve society.

Despite the enthusiasm shown for this "new" history among Robinson's students and colleagues at Columbia

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University, most historians continued to write history in the old-fashioned way. Political history, particularly that focused upon the diplomatic events which led to World War I, retained its hold upon historians. Reporting in *Historical Scholarship in America: Needs and Opportunities*, the American Historical Association's Committee on the Planning of Research revealed in 1932 how little impact the "new" history had made upon the profession: "Even a cursory examination shows that in the field of modern European history there has been, in the last decade, a very decided emphasis upon the study of diplomatic history and international relations. There are indications of interest in intellectual history, but very little is being done in other fields, notably in the field of social history." To some degree a similar lack was noted in the field of American history.

But the situation was soon to change. Just as World War I had concentrated the attention of scholars on diplomatic history, so the Depression and the New Deal made American scholars more conscious of social and economic developments. By 1937, Crane Brinton was moved to remark: "Even among professional historians, the 'new' history has already so far triumphed that almost everyone is working on social, economic, or intellectual history."

But—and here we come upon a strange paradox—despite its emphasis upon social, cultural, economic, and intellectual change, the "new" history, as presented, omitted one great aspect of human experience: science and technology. This may seem strange, for after all, the new history was supposed to be devoted to the totality of human development, and certainly science and technology form part of the totality. It is even stranger when we consider that the "new" history intended to focus upon the present world and to trace the elements which had brought contemporary society into being. How could it ignore science and technology, the most potent and in many ways the most dramatic elements of all?

As Herbert Butterfield has pointed out, it is the Scientific Revolution of the 17th century, rather than the Renaissance or the Age of Reason, which brought something to our civilization that had been unknown to Greece or Rome or India or China. Science and technology are the hallmarks of our society, differentiating it from all that has gone before in human history and from all that has taken place in other parts of the globe. The Scientific Revolution and the later Industrial Revolution mark the distinctive contributions of our Western civilization to the world. The conclusion is unavoidable: history, if it is to be the interpretation of the changes and transformations of a whole culture, must take into account technology and science as essential components of our culture, affected by and affecting every other aspect of society.

Why Has Interest Lagged?

If the truisms hold that we live in a scientific and technological age and that each age rewrites history in accordance with its own interests, why, then, has there been such a lag in studying the history of science and technology?

This is not to say that there were not histories of science and technology before the mid-20th century. Several scientists in the 18th century wrote histories surveying the state of existing knowledge in their specialized fields, but these histories were written by scientists for other scientists and did not enter into the mainstream of historical thought.

During the 19th century, Auguste Comte, in his efforts to secure the unification of knowledge and to make knowledge completely scientific, advocated study of the evolution of the different sciences in order to understand the development of the human mind. Toward the end of the century another French scholar, Paul Tannery, emphasized the necessity of investigating all branches of science and their interrelations. But only a few scholars heeded the teachings of Comte and Tannery. Foremost among these was George Sarton. As early as 1912 he founded *Isis*, later to become the official journal of the History of Science Society, for the publication of scholarly articles in the history of science. One of the great scholars of our times, Sarton wrote many articles, monographs, and books which serve as an indispensable introduction to the history of science.

A few other pioneers pursued the same path during the first three decades of this century: Henry E. Sigerist and Charles Singer, both of whom started out in the history of medicine. But these were the exceptions; the historical profession as a whole appeared indifferent to the claims of science upon its attention, and Sarton plaintively lamented: "When so many institutions, libraries, lectureships, have been dedicated to the history of everything, how is it that the history of science has been so much neglected?"

Part of the answer may be that historians have been more closely in touch with the classical literary tradition which ignored natural science. Furthermore, many historians did not dare enter the field; they were afraid of it, feeling that they did not possess sufficient training and background in the sciences. This left the history of science largely to the scientists themselves—and most of them felt that it was useless to study the scientific past. What counted was the latest discovery; nothing useful could be gained from a study of science which had already been superseded.

Nevertheless, it became increasingly impossible for historians to ignore the ever-growing importance of science in the development of society. How could they describe the 18th-century Enlightenment without some knowledge of Newton's description of the laws of the physical universe? How could they deal with 19th-century concepts without an investigation of biological doctrines of evolution?

Despite the growing interest of intellectual and cultural historians, the history of science as a recognized scholarly discipline languished. Sarton established himself at Harvard during the 1920's, and during the 1930's trained a small but excellent group of disciples, men such as I. Bernard Cohen and Henry Guerlac. Yet few universities taught the history of science, and despite Sarton's vigorous missionary work in its behalf, as late as 1951 only three American universities (Harvard, Cornell, and Wisconsin) had full-scale graduate programs leading to a doctorate in the history of science.

But if the history of science was slow in achieving recognition, its allied field, the history of technology, has lagged even further behind. It was not until 1960 that the first issue of a scholarly journal devoted to the history of technology, *Technology and Culture*, appeared in America, and it was not until the fall of 1961, at Case Institute of Technology in Cleveland, Ohio, that the first graduate students entered a program in the history of technology.

As in the case of the history of science, one can point to earlier isolated examples of scholarship in the history of technology. Archeologists and anthropologists working in the field of

prehistory were forced to reconstruct ancient and primitive societies on the basis of artifacts. They could classify the early stages of mankind only in technological terms of the basic materials employed and the types of tools utilized. The anthropologists were even forced to define the human species on the basis of tool-using and tool-making. Modern physiology, psychology, evolutionary biology, and anthropology combined to make the scholarly world aware that *Homo sapiens* could not be distinguished from *Homo faber* (man the maker). Indeed, it was gradually realized that man could not have been a thinker had he not at the same time been a maker. Yet historians refused to take up the story and to deal with that one characteristic of man which distinguishes him from other animals. The history of technology was thus almost completely confined to prehistory; technological developments in historical times, while dealt with by social theorists such as Marx and Veblen, went virtually untouched by professional historians.

A few European scholars, such as Frémont in France and Feldhaus in Germany, began to work in this field during the first two decades of this century, but it was not until the late 1920's and the 1930's that Abbott Payson Usher and Lewis Mumford published works in this country which called attention to the history of technology. We might well ask why Americans lagged behind European scholars, particularly since the 20th-century United States is one of the most technologically minded of all nations in history. For the answer, we must look far into the past, as far back as Plato, with his distinction between brain and hand—the notion that thinking is man's highest activity, whereas manual labor lacks dignity and is confined to individuals of lower class and inferior capacity. This Platonic notion corresponded to the social system of antiquity, when work was left largely to the slaves, and it persisted throughout the Middle Ages, when manual labor was regarded as servile, except in the monasteries.

As modern industrial society came into existence, the Platonic aristocratic dualism began to wane. This revolution in social attitude went farthest in America, where the development of social democracy—caused by the influence of the frontier, the disciples of Frederick Jackson Turner would say—elevated the role of the worker. Indeed, the American myth—from log cabin to the White House—fostered the feeling that manual labor was not a thing to be despised but a prerequisite for realization of the great American dream of success. Furthermore, the magnificent achievements of the Industrial Revolution in supplying man's material wants and creature comforts served to develop an awareness of the role of technology in civilization.

Nevertheless, the academic world lagged behind popular opinion in its appreciation of the importance of technology. Even among engineers there was little concern with the history of their fields. Why bother with the past? Why investigate what has already been superseded? The study of political or intellectual history admitted no such questions; past politics, past philosophy, past literature—all were believed to teach valuable lessons, as well as to have intrinsic value. No such claims were made for the history of technology; not only was technology itself viewed as an inferior subject, but the study of its past was considered irrelevant. Thus, the history of technology, like the history of science, suffered from the fact that scientists and the general public alike were too much concerned with the "latest" scientific and technological discoveries to devote any time to the past. And historians shied away from the field because of a feeling that they lacked the requisite technical knowledge to treat it properly.

Once the intellectual snobbery had been overcome, there still remained difficulties which discouraged investigation into the history of technology. Throughout most of history the technical innovators have been unknown figures or collective entities, and "anonymous" history is more difficult to study and less exciting to describe than conventional history. Besides, the evidence of technological history tends to disappear: inventors try to hide their secrets; machines wear out or become obsolete and wind up on the junk heap, leaving no record except for archeologists of centuries yet to come.

Another factor which perhaps militated against the study of the history of science and technology was the too-narrow view of those historians who regarded the history of science merely as the account of the scientific ideas and experiments themselves, and the history of technology solely as the story of machinery and tools. Regarded in that fashion, it is not surprising that these subjects failed to stimulate enthusiasm. For a time the economic or business historians were the only ones to mention technology, but their interest centered in the relations between technology and economic processes. But technology is more than a function of economic adaptation, and it is about more than tools, processes, and products. It is about human work; and as the Lynds demonstrated in *Middletown*, the "long arm of the job" extends to every domain of human activity, influencing the beliefs, habits, and assumptions upon which men base their lives.

Similarly science is more than a collection of dehumanized and dull formulas, laws, procedures, techniques. It is the product of the creative human imagination. George Sarton was fond of pointing out that the history of science was the "new humanities"—the humanistic study of science through its history, its cultural context, its humane aspects, transforming the subject from a lifeless enumeration of names, hypotheses, and discoveries into a living inquiry into human culture.

Why Is Interest Now Arising?

Having examined at length the reasons for the lag in the professional historical study of history of science and technology, we may wonder why there has been such a great spurt of interest in the history of science and technology during the past three or four years.

Two developments account for it. The first is the heightened interest in science and technology arising largely from the challenge of Soviet Russia to American scientific and technological supremacy. We can even give an exact date for the onset of this phenomenon: 4 October 1957, when Sputnik I, the first man-made earth satellite, was launched by the U.S.S.R. Until that time America had been supremely smug and confident of scientific and technological superiority. Once people realized that America might be behind, they turned to the history of science and technology, demanding to know more about the wellsprings of contemporary science and technology. Here, then, was a powerful incentive for the study of the "newest" history.

The second factor is the growing interest that arose from an examination of the defects within modern Western culture. That scientific and technological advance had proceeded too quickly

for society to absorb it and to cope with it had long been a favorite theme of humanists and moralists. This platitudinous—and fallacious—concept had been so completely worked over that it was almost worked out, until C. P. Snow gave his Rede Lecture, in which he used the expression "the two cultures." By dramatizing in one phrase the existence of two worlds of the modern mind, Sir Charles made the point that the whole intellectual life of Western society is increasingly being split into two cultures, one scientific and one literary, and that these have almost ceased to communicate with each other.

What did this have to do with the history of science and technology? The latter was history which had for subject matter the thoughts and deeds of the scientist and engineer. It might, if properly studied, help to relate scientific and technological advances with the traditional liberal arts. Here perhaps lay the means to bridge the gap between Snow's "two cultures."

For the history of science is no more an antiquarian narrative of names, dates, and scientific discoveries than the study of literature is a listing of authors and titles. Indeed, the search for truth and order and beauty in science is comparable to the same striving in literature, art, poetry.

Poetry, you say? What is poetic about science? Well, what could be more poetic than Euclid's definition of a point as "that which hath no parts"? Where can we see the human imagination at a higher peak of creativity than in Newton's *Opticks* or in Einstein's theory of relativity? Science is a great human adventure, whether the object is the exploration of space or the exploration of the atom, the digging up of the past or the pursuit of disease germs.

True, a single scientific fact, such as that the temperature of the sun's corona is 1 million degrees Kelvin, may seem uninteresting and of little value except to an astrophysicist. But as we look at that fact from the standpoint of the historian, asking ourselves how on earth they discovered the temperature of the sun's corona, then we find ourselves caught up in some fascinating historical problems. I meant that question literally —how *on earth* did they discover that the temperature on the sun is 1 million degrees? Think for a moment of the problems involved here. First of all there was the problem of devising a telescope before the sun's corona could be discerned, and we must go back to Lippershey and Galileo in the 17th century for that. A method of analyzing the sun's light is also necessary, and we can trace this from Newton's theoretical formulations on the nature of light to the highly refined spectroscopic techniques developed by Bunsen, Kirchhoff, and Fraunhofer during the 19th century. Once the techniques are available to analyze the sun's light, to tell what the sun and stars are made of and what their degree of hotness may be—and all of these are fascinating historical stories in themselves, involving questions of the relations of techniques to the intellectual climate, the cumulative nature of scientific investigation, and the role of the human imagination in arriving at scientific discoveries—then we may ask where the heat of the sun comes from. This brings us to relatively modern history, to the smashing of the atom and the investigation of the microcosm in order to unravel the secrets of the macrocosm.

Now the story of how these scientists came to make their discoveries—what they did, and why and how they did it —is part of the great drama of man fighting against the unknown; this is the continuation of the struggle of Prometheus to bring light and understanding to man.

But can the same be said about the history of technology? What is human about a monkey wrench, a lathe, a computer? Indeed, what repels the unthinking individual about technology is the very inhumanity of its products, particularly the monster automatons which it has created which threaten to make man expendable.

To the degree that technology is concerned only with the making of physical objects, it lies in the realm of the physical sciences. Yet the significance of technology lies in what it does. Take, for example, the telephone. Regarded only as a collection of wires through which current passes from a transmitter to a receiver, the telephone would interest only those antiquarians who wished to enter the debate on who first conceived the idea and put it into practice. But the human meaning of the telephone lies in its transmission of sound for long distances between persons. It is the communications function of the telephone that gives it importance, for the significance of technology is in its use by human beings.

Whether he likes it or not, the technologist is up to his neck in human problems. When our Peace Corps builds a road in tropical Africa, this road is more than an exercise in civil engineering. It is, in fact, a major experiment in social anthropology, for it affects the primitive villages up-country and acts as a communication link which will stimulate these peoples to adopt elements of modern Western culture. Science and technology are thus of humanistic interest not simply because they are products of the human mind but because they have increasingly widespread social consequences.

Some scholars have claimed that the history of science and technology is important to a scientist or an engineer in his professional capacity. George Sarton, for example, believed that a study of the "sequence of old discoveries suggests similar concatenations to the scientist, and so enables him to make new discoveries." The history of technology, he tells us, shows how a return to ancient knowledge may be useful to the technologist.

But the history of science and technology has more to offer than substantive knowledge of immediate use to the scientist and the engineer. It can deepen the scientist's understanding of science itself by enabling him to make a more detailed examination of certain key concepts and problems. Through a thorough knowledge of the past, the scientist or engineer may become more conscious of the forces that affect his work, more alive to the limitations of his methods, more aware of the tentative nature of his findings. Furthermore, while the research scientist as investigator may have no need of history beyond a knowledge of the immediate background of the research field in which he is heavily engaged, no scientist or engineer works in a vacuum. As James Bryant Conant has said regarding the significance of the history of science to the scientist: "The importance lies in the effect it will have on developing him as a person who views the whole world, including the activity of scientists, with a broad and informed vision."

Indispensable to the Historian

If the history of science and technology is valuable to the practicing scientist and technologist, it is indispensable to the historian. No historians, even those who restrict themselves to narrow fields within political, economic, or cultural history, can afford to ignore

the scientific and technological aspects of their subjects. This does not mean that the history of science and technology supersedes all other approaches to history, although ever since the time of Condorcet there have always been a few scholars who correlated human progress with advances in natural science and technology. Even George Sarton at times became so carried away by his own missionary zeal and rhetoric that he equated the history of science with the history of all of civilization. And James Kip Finch, in his *Engineering in Western Civilization*, gives what can only be called an "engineering interpretation of history," claiming that man's material welfare, advanced by engineers, forms the basis upon which the rest of society and culture is erected.

The "newest" historians make no such wide-sweeping claims for their specialty. Science and technology form an important part, hitherto neglected, of the human record, but they are by no means all of the human record, nor do they, by themselves, account for all history. All we ask is that the general historian remind himself that no adequate presentation of historic events can be made without reference to scientific ideas and technological facilities. Thus, for example, our view of the so-called Dark Ages of European history has had to be revised to take cognizance of the discovery, by historians of technology, that that period witnessed important technological developments, including the lowly but by no means insignificant horse-collar.

The history of science and technology also offers benefits to the social scientist. For there are certain questions which the social scientist asks upon which the history of science and technology can shed some light. For example, what conditions—social, political, economic, cultural—stimulate or inhibit scientific and technological advance? Can invention and scientific discovery be guided? Can they be predicted? In brief, what is the nature of the creative process as applied to science and technology?

How are advances in basic science transformed into technological progress? And how do advances in technology affect investigations in the basic sciences?

What is the impact of industrialization on society? What effect did the Industrial Revolution have on Western civilization in the past, what is the impact of industrialization in the African and Asian countries today, and what effect will industrial use of nuclear energy have in the future? How, to cite another example, will Western man utilize the new leisure given him by technological advance?

How will developments in space science and technology affect man's future on earth—and elsewhere?

How do technological changes affect industry—economic growth, competition, investment, capital formation, unemployment, the size of companies, advertising, obsolescence, the business cycle?

How have science and technology affected man's esthetic senses and values? Can technology enrich man's spiritual and esthetic life as well as minister to his material wants and creature comforts? How can scientific and technological advance contribute to man's security and happiness? Has technological change proceeded more rapidly than the ability of society to adjust to it, or of man to control it?

These are basic questions; the answers to them will affect the lives of all of us. By itself the history of science and technology cannot give the answers, but, together with other studies, it can make a start in answering some of these perplexing questions.

That is perhaps the primary reason why the history of science and technology is important to every educated citizen in a 20th-century democracy. Ours has been called a scientific and technological age, not because all men are scientists or engineers and certainly not because all men understand science, but because science and technology have become major disruptive as well as creative forces in our times. As citizens we are increasingly called upon to make decisions involving the utilization and application of our scientific and technological resources; thus, we must have some insight into the nature, problems, achievements, and limitations of science and technology. The history of science and technology, for example, demonstrates to us that no single ethnic group, no single nation, has a monopoly on scientific knowledge or technical achievement. Our experience with the Russians—for example, during the International Geophysical Year—indicates that science and technology can show the way to a type of fruitful international cooperation which the diplomats seem unable to achieve. It is important for us to recognize that personal contacts on the scientific and technological level can be made with profit to both sides and that not all our dealings with the Russians are fraught with frustration and, as is all too frequently the case, with humiliation.

There is still another reason why the history of science and technology is of interest to the educated man, no matter what his field of special interest might be. It is fun! There is the sheer joy, the intellectual excitement of following man's struggle to understand the operations of the physical universe and of observing man's progress in mastering his environment. This is a never-ending battle, begun by earliest man and still going on today.

And this brings me to my final point about the value of study of the "newest" history. When Robinson first devised his "new" history, shortly before World War I, there was radiant optimism about human progress. Today, after two world wars and the relapses into barbarism which preceded and followed these catastrophes, it is difficult to believe that there has been any progress in human affairs. Instead, we seem to be entering upon a period of continual strife and constant tension—a time when man seeks again to bury himself in caves with the prospect of emerging only when the rest of mankind has been virtually exterminated, a time of having to start from scratch to erect a new and, hopefully, better civilization out of the shattered remnants of the past.

In this contemporary atmosphere of gloom and pessimism there is still another reason for turning to the history of science and technology. There men can find intellectual solace. There men can see the potentialities of the human spirit. There, with some exceptions, they can chart the growth in man's knowledge and achievement. For progress in science and technology is cumulative; we know more about the functioning of the physical universe than our forebears knew, and we can control our environment to a greater degree than our ancestors could control theirs, even though we may be no happier and no more secure than they were.

A study of the history of science and technology does not prove that the progress of mankind is necessarily guaranteed, but it does show us that the possibility of progress is always present in human affairs. In the darkness which surrounds us, some ray of hope for the future is necessary. Grant-

ed that science and technology have now made it possible to obliterate mankind, and that these can be used for evil and destructive ends as well as for good and constructive purposes, the fact remains that while nearly all indices of the level of culture and civilization seem to have advanced not one whit in our century—and some of them seem to have retrogressed—in one field we can point indisputably to progress: in science and technology. If the history of science and technology can provide us with some hope for the future, if it can show us how man can transcend petty national rivalries and how the human mind can employ its reason for the solution of complex and disturbing problems which have long defied the human intellect and imagination—that is reason enough for turning to its study. This is not escapism from the realities of the present. Rather, by realistic appraisal of the road which man has trod in developing science and technology to their present eminence, we may gather faith and hope that the other problems which beset us may be conquered by the use of human reason, ingenuity, and imagination. And nowhere do these human traits show more clearly than in the study of the "newest" history: science and technology.

Experience and Experiment in Biology

Does blind probing threaten to displace experience in biological experimentation?

Paul Weiss

"Experiment versus Experience": if I had had to give this talk in French, I could not even have phrased the title as I did. For "expérience" in French stands for both experience and experiment. And yet there is a fundamental difference between the two. Experience means familiarity with happenings in the world. It is our cumulative record or store of judgments and suppositions, which we have formed by conscious or subconscious evaluation, from countless observations, impressions, and comparisons. It is personal and subjective. Experiments, by contrast, are objective tests of whether our suppositions are factually valid, not just intuitionally plausible or logically cogent. Experience makes us assume and expect relations between things in nature, but it remains for the experiment to verify the assumptions and expectations. Experience prompts and guides experiments, and the experiments in turn confirm or amplify or modify the content of experience. In short, experience, experiment, and logic play back and forth upon each other in mutual enhancement; it takes this triple interplay to promote knowledge.

However, in biology, the experiment has long been but a junior member in this partnership. It is fitting, therefore, to pay tribute to the period of Vallisneri, which we commemorate, for having raised experimentation to senior rank and status. It seems that during that epoch the number of converts from speculation to the discipline of the experimental method reached, in the terms of physics, the "critical mass" necessary to generate a carrier wave of telling force and sweep, whose mounting swell, washing away old rocks of idle supposition and contention, has brought on the stupendous growth of our understanding of living systems. So we may date from that period the systematic ascent of biological experimentation to its present culmination as the powerful tool for sorting fact from belief, for testing the pertinence of logical premises and conclusions, for settling ambiguous issues, for removing inconsistencies among conflicting data, and in general, for aiding the human mind in getting to understand living nature by manipulating natural events and tricking them into revealing crucial information.

The point is that experiments have been done, and ought to be done, for a purpose—a purpose other than just to do another experiment. Experimentation used to be deliberate, not improvised; planned to reduce confusion, not just to add profusion; it was meant to be relevant and incisive, not just trifling and redundant. Or, to put it succinctly, in the tradition of those past centuries, designing an experiment has been like training a gun at a target, rather than like spattering buckshot all around at random in the hope that somewhere something might be hit. The targets, in turn, were products of experience, including those extrapolations from experience by logic and imagination which generate hypotheses and theories. Throughout, deliberate orientation of experiments toward visible or envisioned goals has been the practice and tacitly accepted work rule.

Yet work rules have a way of changing imperceptibly as time goes on and as conditions change. Much as in evolution, such trends of change may be for the better or the worse, ending, respectively, in progress or disaster. But unlike evolution, intelligence ought to be able to recognize turns into disastrous courses in advance and thus prevent potentially monstrous products. For instance, let us take a complex system—an organism or a community or any social enterprise—whose proper functioning requires that all its vital parts maintain harmonious proportions; let one set of parts defy this harmony

The author is a member and professor at the Rockefeller Institute, New York. This article is the text of an address delivered at a symposium, "The Experimental Method in Biology from the Time of Antonio Vallisneri to the Present," that was held 29–30 September 1961 at the University and Academy of Padua, Padua, Italy, in commemoration of the 300th anniversary of Vallisneri's birth.