put costs, and the relative effectiveness of the various systems in the performance of subject searches. The question of input costs of tailor-made systems versus conventional library systems has been fairly well settled. But the remaining elements of the overall question still remain unanswered.

As part of the study which is being performed under National Science Foundation auspices, an attempt is being made to find answers to these remaining elements of the question. Carefully designed experiments have been set up to test each of the comparative aspects of the new system against those of existing systems. These experiments have been designed to minimize biases resulting from differences in the mental and physical dexterity and doggedness of the persons using the systems as well as biases resulting from differences in the complexity and intellectual level of the literature that the systems are designed to organize. The tests will also take into account the effect of reference questions of varying levels of difficulty being put to the systems.

For the purposes of the present tests, a comparison will be made between the classification system which is being constructed for atomic energy literature and the indexing system now in use in most Atomic Energy Commission libraries.

Another question that still requires an answer is the comparative usefulness of tailor-made classifications as a basis for codes in mechanical searching systems. Although there is good theoretical evidence that tailor-made systems, their notations, and the mutual exclusiveness of their classes lend themselves to machine-encoding, this evidence has never been tested on a comparative basis in actual machines and real-life situations.

In order to furnish a basis for such tests, we have under construction a small, computerlike device which is capable of sorting and correlating literature references and various types of data. This machine will be amenable to codes based both on indexes and on classification systems. Thus, it will be useful for controlled, unbiased comparisons between tailor-made classifications and most other systems as coding media for mechanical searching devices.

It is very probable that there will develop, in the wake of the answers to the foregoing questions, many new questions that require answers. But, as new questions and new answers arise, they are bound to result in more and more effective means for making information available to the scientist and to other members of the scholarly community.

Science, Imagination, and Art

Norman Robert Campbell

Two criteria [may be used] to determine why a scientific proposition has value and what degree of value it has. . . . First, a proposition is valuable if truly universal assent can be obtained for it; second, it is valuable if its contemplation causes intellectual satisfaction to students of science. These two principles are to some extent contrary, and, if the test provided by each of them is applied to the same proposition, one might sometimes determine that the proposition is valuable and the other that it is not. For a student of science is a student of science in virtue of some difference between his intellectual constitution and that of the rest of mankind; if he finds intellectual satisfaction in a proposition it is almost certain that persons with different training and different interests can be found to whom it will give none; and on the other hand the mere fact that a proposition is approved by everyone, however different their modes of thought, will deprive it for him, not of course of all its value, but of that very special value which is the basis of the second principle. It is necessary therefore to examine the two principles rather more nearly and to determine exactly what part each of them plays in the establishment of scientific propositions. . . .

Everybody recognizes today that what I have called truth is an essential element of a scientific proposition and few, if any, will deny explicitly that what I have called meaning is also important. But it does not seem to me that facts which are universally admitted openly, or their implications, are always remembered when the most general and fundamental questions concerning science are raised. In such discussions attention is apt to be concentrated on the truth and the meaning is apt to be left out of sight.

The tendency is natural. The great advance or, more accurately, the first beginnings of scientific knowledge which took place in the 16th and 17th centuries were a consequence of the recognition of the possibility of scientific truth. To say that science must be based on experiment and observation is simply to say that it must satisfy the first principle of value, for it is only concerning the results of such experiment and observation that universal agreement of the kind which is characteristic of science can be obtained. It is the neglect of truth, the failure to test evidence according to the canons of modern science, the acceptance of well-attested fact, vague rumor, and the product of riotous imagination as equally valuable—it is the attitude of mind to which such things were possible which raises an insurmountable barrier between ourselves and the most enlightened of the ancients. That science should have meaning, they would have agreed readily; it was the doctrine that it should have truth which was strange to them. The ghost of Greek learning still stalks ruins not yet abandoned; it still disturbs timid minds and has still to be exorcised; the weapon of Galileo cannot be allowed to rust in its sheath, and while it has still to be used other dangers may be neglected.

However there is a more cogent reason why truth rather than meaning receives emphasis whenever any question is raised of the value of science or of its relation to other studies. Truth, it has been said, is a quality of which we may hope to convince others; it is a valuable quality because it is appreciated by everyone. And there is actually no doubt that scientific propositions have the kind of truth that is here attributed to them and that this truth has some value. Nobody disputes that truth, if they once agree to use that word in our sense; what they may dispute is whether or not it is misleading to call this quality truth and what is its value in comparison with that

Dr. Campbell is a noted British scientist who has made significant contributions to the philosophy of science. This article is reprinted from his *Physics: the Elements* (Cambridge University Press, London, 1920), chap. 8. By arrangement with Cambridge University Press, Dover Publications, New York, will issue a reprint of this book in May.

of other qualities. When therefore there has been any discussion of the value of science as a whole, its supporters have tended naturally, but, as I think, mistakenly, to insist on that element of science which everyone agrees is valuable and to attempt almost to conceal other elements concerning the value of which a difference of opinion is possible. They have tried to maintain that science is nothing but truth and indeed that it differs from other systems of thought in consisting of nothing but truth. Such were the motives which led, for instance, to Huxley's famous definition of science as "organized common sense," a phrase admirably suited for polemics and the obscuring of clear thinking. The word *organized* begs the question completely. It is not disputed that science, like all other forms of knowledge (*1*), has its basis in common sense, the agreed judgments of mankind, among which are those (relating to the external world) which have the truth characteristic of science. But the problem is how and by whom this common sense is to be organized, and whether the organization adopted by science introduces anything which does not share the truth of the things organized. . . .

Science and Imagination

But the fundamental reason why the meaning of science has been unduly neglected lies in the unwillingness of men of science themselves to recognize it. Their training in the methods necessary to attain truth has impressed on them so firmly that, in this part of their work, everything that can possibly be a matter of personal opinion must be excluded, that they are afraid to admit that anything can properly form part of their study which involves deliberate, though often unconscious, choice. In the early days both of the individual and of the study such caution is both desirable and necessary; there is an undoubted temptation to relax the criterion which must be applied before truth can be firmly established. But when the individual and the study have come to full maturity the danger has passed away; there is now no need to insist at every turn that science must have a firm experimental basis. The time has come to face the facts boldly. The search for truth alone never has and never will lead to any science of value. The spirit which must be so carefully curbed in the search for truth must be given free rein when truth is attained. Our passionate desire that truth will be found in one form rather than in another must never be allowed to influence our decision in what form it actually appears; but once that matter is settled, we not only may but must choose in accordance with our desire in which of the innumerable alternative forms that truth must be expressed; the more freely we choose, the more likely it is that a renewed search for truth will confirm our choice.

The attempt to conceal from ourselves that choice is necessary may stifle the imagination on which the choice depends; and therefore I make no apology for insisting, even at the risk of irrelevance, on the necessity of proclaiming openly the imaginative element in science. Our view of the meaning of science must influence our methods of teaching and training ourselves and our pupils; 19th-century philosophy, with its anxiety to conceal the essential part played by imagination in scientific discovery, is largely responsible for the ineptitude of modern scientific education. The very man who laughs to scorn the doctrine that a love of literature or an imaginative appreciation of its value is to be obtained by the grinding out of Latin hexameters will proceed gravely to assert that science is to be taught only by the determination of the nodal points of lens systems. Of course for the student who means to take science seriously and hopes in his turn to take his share in its advancement, a thorough training in the experimental art is as essential as is a complete understanding of the intricacies of meter and construction to the classical scholar. But neither the scholar nor the man of science will have a living grasp of his study if he buries himself in these pedantries. The scientific imagination can be developed by tedious laboratory practice no more than the artistic imagination by the laborious study of Greek particles, by the day-long practice of a musical instrument, or by unceasing copying in the galleries. It must come from direct and intimate contact over the widest possible range with the great original works which represent its noblest expression. It is doubtless difficult to introduce a student to the latest modern theories of solid structure, of atomic constitution, or of relative motion, before he has an entire understanding of what are commonly regarded as the elements of physics; but it is no more difficult than to teach a boy to read the *Odyssey* before he can parse and interpret any word; and the failure to overcome the difficulty is equally disastrous.

Doubtless "there is nothing like leather," but I cannot refrain from suggesting that it would have been better if chemistry had not come to be regarded as the standard and natural "elementary" science. For chemistry, so rich in laws (though not often explicitly named as such) and so powerful in the ordering of facts, is poor in theory. And since it is in theory that the highest meaning of science is expressed, chemists are more apt than the students of other sciences to overlook its vital importance. The absurdities of the "heuristic" school, fortunately short-lived, could hardly have taken root at all in any other soil; no physicist could imagine that there was any similarity between the "discovery" of a law by the elementary pupil under the eye of his teacher and the true discovery of that law when it was unknown. Chemistry has but one noteworthy theory and but one set of hypothetical ideas, the theory of the combination of atoms into molecules with is fundamental idea of valency. It is a most beautiful theory, surpassed by none other in the intellectual satisfaction it affords, but unfortunately it is not easily or certainly applicable to the compounds on which the attention of the elementary student is concentrated; we know far less about the constitution of water than about that of some organic compound with a name a yard long—long simply because the theory is so strictly applicable to it. If chemistry is to be the vehicle of elementary instruction in science, we should begin with stereoisomers and proceed (if we have time) to the simple compounds of oxygen, hydrogen, and nitrogen.

Nor should we think only of the effect of our repression on those who are serious students of science. The opinion of our fellows, even if they are not our colleagues, cannot fail to react, directly or indirectly, on our own studies. If scienific education today is unsuited for those who are to make science their life work, it is even less suited for those to whom it is merely to be part of a general education. Men of science complain of the lack of a wide appreciation of scientific knowledge; what else can they expect if they offer to the world only the dry bones of knowledge from which the breath has departed? Nothing could be better adapted than the ordinary school course, with its tedious insistence on bare and uninspiring facts, to kill any rising enthusiasm. It is important certainly to impress the student with the nature of scientific truth and with the possibility of definite positive knowledge concerning the material world. No doubt it is the failure to realize that there is such knowledge, the mistaken notion that everything is a matter of opinion on which two sides should be heard, that produces, so ludicrous if it were not so lamentable, the familiar chaos in the administration of the affairs of state and industry by the half-educated persons who pride themselves on their ignorance of science. But to insist on the truth of science and to neglect its meaning is to aggravate the evil which we seek to cure; those who are endowed with any measure of creative imagination can never hold in anything but contempt a study from which such imagination appears to be wholly banished.

Such attempts as are made to exhibit the imaginative element in science are almost more disastrous than the attempts to conceal it. The "romance of science" is usually associated with childish books and popular lectures on speculative geology and "spherical" astronomy (*2*). Now both geology and astronomy are magnificent sciences, offering superb examples of the highest meaning of science; but they also contain elements, of no importance to their earnest students, which possess a specious and flashy interest which makes a passing appeal to shallow minds. An audience of children of all ages gapes amazedly while the lecturer discourses glibly of times reckoned in millions of years and distances in thousands of millions of miles. But science has something better to offer than sensational journalism; nothing could be less characteristic of its spirit. The mere fact that the interest of the uninitiated can thus be easily stimulated with[out] serious training suggests doubts of the value of the stimulus; nothing worth having in this world is to be had without effort.

Science and Art

When we so often hide what is best in science and display only its less admirable features, it is not surprising that in the outside world there is suspicion of its ultimate intellectual value. There has been in recent years a great improvement in the general appreciation of the meaning of science; but open antagonism has been in part replaced by an armed neutrality which indicates no better understanding, but merely greater caution. Many will still be found to deny that science can satisfy our imaginative needs to the same extent as art and literature, and the denial does not arise only from conservatism and ignorance. Science, it is said, is impersonal; the highest good must be intimately connected with personality. It is overlooked that the impersonal truth of science is inseparable from its personal meaning. Science, it is said, is mechanical; the accusation at once displays the misunderstanding. A mechanism is certainly something which will produce desired results independent of the attention or volition of a skilled operator, but it is also something which is and must be the individual product of a human mind. A mechanism implies an inventor; it is a means by which one exceptionally endowed man makes his endowments available for the common good; it is something characteristic, not of dead matter, but of the highest spirit of man; it is something that theologians and savages do not understand. If the term is rightly understood science is truly mechanical; for science, like mechanism, is the expression of genius in a form which the dullest can appreciate.

It is curious how even today the laity seem unaware of the part played by the genius of great men in the development of science. They recognize perhaps that the often quoted examples of the greatest achievements of science, the discovery of Neptune or of Hertzian waves, represent something not easily attained by the common mass of mankind; they are willing to admit that Newton or Leverrier, Maxwell or Hertz, must have had some qualities to distinguish them from lesser folk. But they have no knowledge of what these qualities are; they have no idea that their work was an expression of their personality just as surely as the work of Giotto, of Shakespeare, or of Bach. They still tend to contrast the cold-blooded rationalism of the man of science with the passionate dreamings of the artist. But science too has its dreamers, and their dreams come true; they dream, and messages flash across the empty ocean; they dream again, and a new world springs into being and starts upon the course that they have ordained. Nor does the quest of knowledge inspire less passion than the quest of beauty. It is not sickly sentimentality but honest emotion that makes us cry (*3*):

"Car c'est chose divine
D'aimer, lorsqu'on devine,
Rêve, invente, imagine
  À peine. . . ,
Le seul rêve intéresse;
Vivre sans rêve, qu'est-ce?
Et moi, j'aime la princesse
  Lointaine."

Nothing could be more absurd than the attempt to distinguish between science and art. Science is the noblest of the arts and men of science the most artistic of all artists. For science, like art, seeks to attain esthetic satisfaction through the perceptions of the senses; and science, like art, is limited by the impositions of the material world on which it works. The lesser art accepts those limitations; it is content to imitate or to describe Nature and to follow where she leads. The greater refuses to be bound; it imposes itself upon Nature and forces her to submit to its power. The apostle of Art in a previous generation can make no higher claim for the greatest art than this (*4*):

"CYRIL. But you don't mean to say that you seriously believe that Life imitates art, that Life in fact is the mirror, and Art the reality?

"VIVIAN. Certainly I do. Paradox though it may seem—and paradoxes are always dangerous things—it is nonetheless true that Life imitates art, far more than Art imitates life. We have all seen in our own day in England how a certain curious and fascinating type of beauty, invented and emphasised by two imaginative painters, has so influenced Life, that, whenever one goes to a private view or to an artistic salon one sees, here the mystic eyes of Rossetti's dream . . . there the sweet maidenhood of the 'Golden Stair' the blossom-like mouth and weary loveliness of the 'Laus Amoris'. . . . And it has always been so. A great artist invents a type, and Life tries to copy it, to reproduce it in a popular form, like an enterprising publisher. . . . Literature always anticipates life. It does not copy it, but moulds it to its purpose. The nineteenth century, as we know it, is largely an invention of Balzac."

But if to lead the way and to bid life follow is the distinctive character of the greatest art, what art can be so great as science? A Newton, a Faraday, or a Maxwell conceives a theory and Life adapts itself for all time to the laws which it predicts; by the force of his imagination he creates no passing fashion, but the permanent structure of the world. He is no puny creature closely bound by the laws of time and sense; he is the creator who lays down those laws; verily the winds and the waves obey him.

Of course such powers are not given to all who pursue science. There are degrees of scientific as of artistic imagination. But the least of us can share in some small measure these achievements. A man need not abandon all pretensions to the proud title of artist because he could not design the Parthenon or write the *Fifth Symphony*. Most of us who have attempted to advance science have had our all too brief and passing moments of inspiration; we have added a single brick to the mighty structure or finished some corner which the master in his impetuosity has overlooked. And though our tiny efforts rightly pass almost unnoticed by the rest of mankind, they have a value for ourselves beyond what we can tell; one instant we have stood with the great ones of the earth and shared their glory. Even if nothing as yet has stirred in us the creator's joy, we can yet appreciate the success of others. Nobody who has any portion of the scientific spirit can fail to remember times when he has thrilled to a new discovery as if it were his own. He has greeted a new theory with the passionate exclamation: It must be true! He has felt that its eternal value is beyond all reasoning, that it is to be defended, if need be, not by the cold-blooded methods of the laboratory or the soulless processes of formal logic, but, like the honor of a friend, by simple affirmation and eloquent appeal. The mood will and should pass; the impersonal inquiry must be made before the new ideas can be admitted to our complete confidence. But in that one moment we have known the real meaning of science, we have experienced its highest value; unless such knowledge and such experience were possible, science would be without meaning and therefore without truth.

References and Notes

1. Perhaps this statement is not quite true. The system of thought against which Huxley was especially concerned to defend science was theology, and some theological systems rest, not on common sense, but on immediate and fundamental judgments or revelations which are definitely stated to be confined to the elect. Such systems have not the truth characteristic of science. The value of their propositions is determined wholly by principles analogous to the second and not at all by those analogous to the first.
2. I have heard this term used wickedly to denote the form of science which, at the end of the 19th century, was closely associated with the name of Sir Robert *Ball*.
3. E. Rostand, *La Princesse Lointaine*.
4. O. Wilde, *The Decay of Lying*.

Natural and Cultural Aspects of Floods

Paul B. Sears

Nature makes floods, but man makes flood hazards. Although there is no known way to prevent floods, much can be done to minimize flood damage. Protection, not prevention, therefore, is the real problem. Effective protection can come about only from improved land use and management, based on a better understanding, by the general public, of the relation between water, land, and ground cover.

Ordinarily water which has been evaporated from the ocean and moved inland by air falls on land and returns to the sea through stream channels cut by the flow of water. When the amount is too great for the channel to carry, the water rises and spreads out over the land. This we call a flood.

Stream channels swing back and forth as time goes on, producing level plains on each side. These are called floodplains, for the very good reason that they are flooded when the channel cannot handle all the water that is present.

Modern Flood Settings

Like many others of my vintage, I have been observing floods off and on for more than a half-century and have read about many that I have not seen. As far as I can recall, these floods, whether in Arkansas, California, Florida, Mexico, New England, Ohio, Oklahoma, or Utah, had one feature in common. They took place where earth-forms and vegetation gave clear warning that man should be on guard.

Not all floods take place, however, in what can technically be considered flood plains within stream valleys. Thus at Bellevue, Ohio, the citizens long considered themselves unusually fortunate in that they could dispose of their sewage by simply poking a hole in the underlying limestone. Waste, poured into this hole, vanished. That is, it vanished until March 1913—a month of rapidly melting snow and excessive rainfall. Then the good people of Bellevue suddenly found themselves immersed and mysteriously so. They had been taking advantage of an underground river which flowed beneath them through tunnels cut in the limerock. This stream, suddenly overloaded, relieved the pressure by surging upward through the vents they had made in order to get rid of municipal waste.

Another type of destructive flood that does not involve a valley, properly speaking, occurred near Arcadia, Florida, during the rainy season of 1918. Here the Army had established a flying center, known as Dorr Field, in a rather extensive, treeless area. This seemed logical enough at the time. Much of the space was grassy prairie, the rest low-growing scrub palmetto, which could be scraped away by gangs of workmen. There were no troublesome pine trees to be reckoned with, and the whole area was quite flat.

All went well until the rains came. Then, suddenly, the whole post was transformed into a shallow lake, and much valuable property was submerged.

Had the engineers bothered to consult any local naturalist, all of the trouble might have been avoided, for prairie growth is the characteristic vegetation in areas that are regularly flooded during rainy season. Surrounding these prairies, and separating them from the pine flatwoods on slightly higher ground that is never flooded, is a zone of scrub palmetto, covered occasionally by high water. Thus, Dorr Field was bound to be submerged at times.

Today, nearly 40 years later, the growing economy of Florida is pressing upon these same treeless stretches that form the low backbone of the peninsula, not many feet above sea level. This pressure extends to the lower lying marshes and swamps known as Everglades, naturally filled with water the year round. The demand for more pasture and horticultural space is being met by vigorous efforts to drain away both seasonal and permanent water into the surrounding seas. This means, at times, an abnormal load of water moving through almost level land and across the densely populated and highly developed seaside margin of the state. The problem thus created is obvious, and the cultural element in it, equally so.

Lower mountain slopes in California, Utah, and Colorado provide a somewhat different example. Mountains wear away through the ages, of course, and lowlands are built up by virtue of this process. But the process becomes catastrophic when the mountainside vegetation that normally restrains the violence of moving water is destroyed by fire, excessive grazing, or the plow. When this occurs, not only does water pour down in abnormal volume, but rocks of incredible size are converted into rolling missiles, that wipe out homes and schools, orchards and roads.

An excellent example of this phenomenon can be observed in the Wasatch Mountains north of Salt Lake City. Here are two steep watersheds, side by side. One has been protected from the time of settlement, since it provides a municipal water supply. Its vegetation is intact, and neither rain nor melting snow has caused flood or brought down sediment in excess of the geologic norm. Next to it is Parrish Canyon, whose sides have been cleared and heavily pastured. Here, in 1928 and subsequently, surprisingly small amounts of rainfall on the upper slopes have gathered headway, bringing down

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