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ON APPLIED AND PURE SCIENCE

THE terms "pure science" and "applied science" are frequently used at the present time, and usually in a manner that logically either does not differentiate between the two terms, or differentiates on the basis of motives of the devotees. The terms "pure" and "applied" are not happy ones, but I shall point out that there is a logical basis upon which a differentiation may be founded. Applied science includes more than what is embraced in the conventional branches of engineering.

It is sometimes intimated that applied science has to do with the selling or salesmanship side of science, whereas pure science is not so commonplace. Sometimes applied science is the practical, pure science the impractical, that is, something more or less associated with the helpless professor who has specialized to an extent that he is very much akin to the suburban ticket agent whose knowledge of time tables, of stations and of railroads is wholly contained upon one card giving the times of departure and arrival of trains at and from his station to the city station.[1] Sometimes pure science is the free or unrestrained as opposed to the applied or restrained. Indeed, some have it that pure science is the more or less useless as compared with the applied, the immediately useful. Or the pure may be the exact in contrast with the applied. At other times the distinction is made on the basis of the motives of the investigator rather than upon the nature or application of the subject-matter. The one then is the altruistic, as opposed to the selfishly commercial. These differentiations on the basis of motives shade off into the strictly intellectual class distinctions, which may even aver that applied science is not a worthy subject for the mind to entertain. This type of attitude was very general in countries outside of Germany up to recent times. It is of interest to remark that it is almost identical with the attitude that prevailed prior to the sixteenth and seventeenth centuries in regard to the experimental sciences in general, as opposed to other activities of the intellect such as the literary, the philosophic or speculative. So far as motives of the investigator are concerned one can find examples in both pure and applied that will illustrate almost any motive that can be entertained by the human mind. An attempt at differentiation on such grounds is futile. We can

[1] Specialization implies a dynamic and not a passive state. It may well be questioned whether either of these cases represents what is meant by specialization.

find in the humblest mechanic's shop that things are very frequently done for their own sake. Some investigators may pride themselves in that they carry on research for its own sake. This is probably true, but it may be equally true for the lawyer, the physician, the blacksmith, the carpenter, the farmer and indeed may be true for all kinds of activities and for all classes of human beings. The feeling of delight in activity of an intellectual kind is a very close kin to the feeling of delight in activity of a purely physical kind. Of course in the former case the attendant circumstances may be far more complex, having more intimate association with ideals, and perhaps at times involved with a more or less artificial standard of sacrifice. If the difference between the pure and the applied science is only one of motive on the part of the investigator, it means that in most cases we shall not be able to tell whether any particular product of research is pure or applied science. For, as the history of science is recorded at the present time, little attention is paid to any personal traits. In fact, it is a matter of common knowledge that the results of science are respected from whatever quarters of the world they come because they are not personal.

Men guard the products of their experimentation and thinking with about the same zealousness as they guard their purses. One may find any mental state activating in the adding to and the use of the purse. So also one may find almost any mental state activating in the adding to or in the use of the intellectual products for monetary returns or for social recognition and power. At the present time scientific research is a professional matter and to classify the products on the grounds of the motive or motives that may have been the governing factor impelling the particular individual to enter any particular profession will lead nowhere. Scientific research, like any other profession or occupation, may be entered into for destructive and even murderous purposes; witness modern wars and preparation for wars;[2] or it may be entered into by an abnormally zealous mind with the idea of sacrifice for the emancipation of mankind. Usually the impulse lies somewhere between these two, and is intimately coupled with the necessity of making a livelihood in a manner most appealing and commendable to the particular individual.

One may expect that if there is a sufficient contrast between the pure and applied for practical differentiation, there must be also a clear basis, other than personal, upon which a practical judgment may be made; or, at least something associated with the personal motive that may be easily discerned by some one not intimate with the investigator himself. There are immediately evident two possibilities; *viz.*, a differentiation upon the nature of the subject-matter itself and the manner of treating it, or upon the uses to which the subject-matter may be or is put. Classes based upon uses of subject-matter may be numerous and are equally trivial. The subject-matter of one branch of science may be said to be applied when used in another branch, whether in the theory or for practical purposes. Again, the uses of the subject-matter in theory may be set in contrast with the uses in practice, as pure and applied. Experimental work might on this basis be called pure or applied science according as it was undertaken for the sake of the theory or for its possibility of usefulness in commerce and industry (*i.e.*, for the sake of its commoditivity). The viewpoint here becomes coincident with that given in detail below based upon a division of the subject-matter rather than upon the uses of the subject-matter.

If the differentiation is on the grounds of the useful and the non-useful, it remains exceedingly difficult to define what may be meant by the word useful. If this word be taken in a very general sense of having the property or capacity of facilitating activity, physical or mental, in any department of human endeavor, then there remains little if any ground upon which to differentiate not only the products of science but those of art and religion as well. If, however, by useful is meant "that which may be immediately applied to net monetary returns," then it might seem to the business man at least that we have a working definition of pure and applied science. But there is no logic in this definition. Some applied science can never net under ordinary circumstances any monetary returns that a bookkeeper may know it. The best that one may hope for is that the aggregate activities over appreciable intervals of time of a laboratory devoted to applied science shall not have been carried at a monetary loss. The interval of time that one may care to consider in this discussion is an important element. If the interval is too short not even applied science can be useful. From the ordinary business viewpoint the interval may be the ordinary business cycle. For larger and more permanent and extensive industrial establishments the interval becomes longer and even indefinite perhaps. No department of science would welcome it, to be stigmatized as useless. There is probably nothing felt more convincingly than that all the present activities that may be classified as scientific will in due time be useful to mankind at large, and will amply redound in actual material wealth and well-being. The aim of science (perhaps in conjunction with other activities ultimately, too) is the conquest of the universe. This has been the theme of the dreams of master minds

[2] This is instanced because it has professional and social recognition. I am not referring to ignoble and unsocial purposes of social outcasts.

down through the centuries for which history has been clearly written. To entertain that such conquest is futile is to indict the whole of mankind throughout the ages.

The greatest workers in physics have pointed out and in many cases actually carried through certain applications of science: witness the ophthalmoscope of Helmholtz, the miner's lamp of Davy, and many others. Kelvin said: ". . . in physical science many of the greatest advances that have been made from the beginning of the world to the present time have been in the earnest desire to turn the knowledge of the properties of matter to some purpose useful to mankind."

In considering the uses of sciences and the worthwhileness of science one is prone to recall the late wars and to ask semi-philosophic and semi-moral questions. Such uses do not concern us here and may be dismissed with a statement or two. The aims of science in peace time are to construct and to give the maximum of good to the world. The aims of science in wars are to construct as necessity demands only for the one party and to destroy most effectively the best of and to take the most from the other party. There is here not a question of science *versus* wars and destruction, but a peaceful *versus* a warlike state of mind. A state of rationality against a state of irrationality, more or less—a healthy mind against a pathological mind. These states of mind are entertained alike by all levels of society, as is amply recorded during the present and late wars, from those who apparently in peace time pursue scientific research with loftiest ideals, down to those who exist on the verge of mental anarchy. The group impulse overwhelms the individual. All social entities are builders in this world and rise to different scaffolding levels with the ages. As the workers on the ground have only mud and pickaxes with which to build, so they have also only these with which to menace. So, too, every age has its tools, whether for social good or for social menace.

Sometimes a differentiation is made on the grounds of being exact and applied. Such demarcation is more applicable to mathematics as such in contrast to all other sciences. Mathematics strives for the accuracy that only logic can attain. Nothing is too small or too large to be reckoned with. In fact, relative magnitude in general does not set relative importance of quantities, as it does in all other sciences. In physics, for instance, one strives to take account of as small quantities of things as it may be practical or possible in any given experiment to do so. Enormous efforts are made in the perfection of methods and of apparatus in order to take account of smaller and smaller relative amounts of a thing or of the effect. So, in any application of mathematics to physics, summations, for example, are carried out only to such extent as is consistent with the attainments of experiments. In applied science (in general, the engineering sciences) relative magnitudes become even more important. Small relative quantities of any thing or effect are ignored as soon as it is shown that they are of no practical importance; and enormously large quantities are avoided. Accuracy without limit is a characteristic of mathematical logic; accuracy as great as may be attained is the aim in physics; accuracy as good as need be is the practice in engineering.

One sees no practical and logical basis of differentiation between any two phases of science by motives alone, nor by the uses of the subject-matter. We must return, then, to the nature of the subject-matter itself and the manner of treating it, or its interrelations. As has already been hinted at, what is ordinarily clearly classed as applied science is in some way connected with some commodity of commerce. We find also that what is clearly pure science is far removed from any commodity, although sometimes it appears to be intimately associated with a commodity. However, this idea does present a basis for a logical differentiation between pure and applied science. For logic all sciences look to mathematics. Mathematics has also two viewpoints of the pure and the applied mathematics. We may expect, then, that mathematics may be clear on definitions of parts of itself, and perhaps may suggest a basis of definition that is useful in all cases. This is found to be the case.[3] We then may proceed to differentiate between pure and applied science on the basis of subject-matter chiefly and on the manner in which any particular portion of subject-matter is related to the general subject-matter. First, however, a few statements will be introduced to bring out what is meant by certain useful terms, proposition, propositional function, verifiers, falsifiers, that are not commonly found in the physical sciences.

All of the physical sciences have the objective viewpoint. That is, they deal with objects of the external world that exist independently of and outside of ourselves. These objects have various properties, some of which enable the object to stimulate sense organs in what is termed an adequate manner, so as to make us aware of its existence. In general, it is never an isolated body nor a single property of the object that is the stimulating factor. There is always a complex of stimuli to which our sense organs are exposed. Likewise, such complexes of stimuli give rise to complexes of sensations. We analyze the complexes of sensations when we learn about the ob-

[3] In this connection reference may be made to Keyser, "Mathematical Philosophy," Dutton and Co., 1922.

jects of the universe. Abstractions are formed into concepts of things and of relations between things. New things and new relations may be discovered. Many things are found to be related in many ways. These relations, more or less general, are usually referred to as laws. The primary aim of a great portion of science is to discover these laws. The properties of matter and of organisms are studied and compiled in order that new and more general relations may be discerned. Such general relations may be termed propositions, irrespective of whether they have been dignified as laws. Propositions are bound together with other propositions into more general relations and more far-reaching, which in turn may be called propositional functions. Now, pure science is in search of propositions and of propositional functions. Pure science is interested in the special properties of matter only in so far as they are "verifiers" or "falsifiers" of propositions and propositional functions. It must in most cases proceed from the facts of individual species of matter and move on inductively. However, having once established or arrived at a proposition or propositional function, it may proceed deductively. The singular fact is that a proposition or a propositional function may guide into paths not dreamed of during its formulation. So, in fact, we might cite as an illustration of a proposition, that when thinking is logical, the conclusions arrived at are very frequently found to fit experience in far-removed and new fields. Somehow, the guiding that makes us feel that a process of thinking is logical is also connected with the restraining or guiding in the processes of nature. Herein lies the power of mathematical logic when applied to physics or to any other branch of science. A very good illustration of a propositional function in physics is the theory of relativity, with its deduced proposition that electromagnetic wave radiation is subject to gravitation. A particular verifier is the influence of the sun upon a beam of light passing near it.

Pure science, then, deals with the propositions and propositional functions and with properties of materials in so far as they furnish verifiers or falsifiers of the propositions and propositional functions, or in so far as they may be made the basis for new propositions. Applied science, on the other hand, as has already been intimated, is associated with some commodity of commerce or with some substance or thing which is destined to become such. That is, it is concerned with particular verifiers and falsifiers that are directly associated with a commodity. It is interested in all properties which the commodity has and even in those of other commodities and materials that have a bearing upon the commodity in question. It is interested in materials entirely different from the commodity in so far as it may be possible and necessary to have substitutes, either for the purpose of bettering the commodity or the service it renders, or for the purpose of controlling the market more efficiently. Here is noted an element of restraint in applied science that apparently did not enter into pure science. This is not, however, a clear difference between the two. Much of applied science is as individualistic as most of pure is. But the products of applied science have a social judgment placed upon them much sooner in general than those of pure science. After such social judgment has been made and especially if favorable or encouraging, a portion of the science thereafter connected with the product always remains more social, for then it means that the product is destined to be a commodity or closely associated with a commodity in some more or less direct manner. This portion (*i.e.*, the more social) will be under restraint, for a commodity is essentially a social thing and modern industry requires the concentrated efforts of talent, capital and labor. These restraints are not inherent in the subject-matter in general of applied science, nor in the mind of the investigator, but lie in the organization or institution responsible for the commodity. Or, they may lie in the mutual agreement between two or more organizations or institutions, or in the ethical coercion that may have grown up in any realm of thought or activity. The individual who does the technical or research work is selected so that his activities resulting in important developments—from whatsoever motive so far as he himself is concerned—may fit into the restrained order of things. It is obvious that this is not a restraining that exists in or is peculiar to industrial laboratories only where most of the scientific work done is applied science; and that such restraints exist in other institutions as well. In scientific institutions that are endowed for a particular purpose the same restraining influences manifest, and in other educational institutions as well. Some kind of restraint is inevitable in any social undertaking.

There are various attributes that are frequently assigned to either pure or applied science which now are obviously only part descriptions in the light of these definitions. For instance, consider the matter of patentability. Letters patent, copyrights and franchises of any kind are essentially applicable to commodities or to processes related directly to commodities. Propositions and propositional functions are not subjects patentable. We might expect, then, that applied science and not pure science should concern itself about them. The attributes of timeliness and of being individualistic are possessed the more or less by applied science according as the commodity with which the applied science is associated possesses them. Again, because a portion of applied science requires greater social co-operation than most of pure

science generally does, the matter of proper units and standards wherewith to gauge the performance and composition of the commodity in a manner that will have unity of meaning and universal acceptance, is very early of serious concern to applied science.

If, then, we must use the terms pure and applied science, a differentiation based on the grounds of subject-matter and relationships found in the subject-matter is the more preferable. Applied science deals with the properties of commodities, or with properties of materials more or less directly connected with the production, distribution or utilization of commodities. It is interested in pure science in so far as the latter may give the general formulas by which particular behavior may be foretold, or the behavior of one kind of material may be compared with that of another kind which is involved in a given commodity or may become a substitute for the commodity. In addition, applied science is interested in pure science in so far as any particular verifiers or falsifiers may suggest new kinds of commodities, or new ways of effecting the production, distribution and utilization of commodities. Pure science is concerned with the propositions and propositional functions of science. It is interested in applied science in so far as the latter may furnish particular verifiers and falsifiers of propositions and of propositional functions. In addition, it is interested in applied science in so far as the data may suggest new avenues to new propositions.

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THE LOS ANGELES MEETING

THE preliminary announcement of the seventy-seventh meeting of the American Association for the Advancement of Science to be held with the seventh annual meeting of the Pacific Division and the fourth annual meeting of the Southwestern Division at Los Angeles, from September 17 to 30, will shortly be mailed to the members. It is an attractive folder reflecting credit upon the Los Angeles committee on arrangements which assumed the entire expense of printing this announcement as well as the final program which will be distributed at the meeting in September. The well-known enterprise and hospitality of the Los Angeles people, together with its unique advantages as a convention city, gives assurance that the sojourner will be well taken care of and every provision made for the success of the meeting.

The total eclipse of September 10, which centers in the vicinity of Los Angeles, will occasion the presence of many distinguished astronomers from all parts of the world. A diagram of the path of the eclipse is presented in the folder with a table showing the duration of totality for various places. Quoting from the announcement the eclipse "will be of especial interest to astronomers and other scientists because of the unusual opportunity it will afford for undertaking observations with exceptionally powerful and complete equipment. This is due to the accessibility of much of the area within which the eclipse is total. The path of totality passes close to Los Angeles and over San Diego and many other towns which have excellent transportation facilities. Furthermore, the eclipse occurs at a season of the year and at a time of day when the prospect of clear skies is very good, as is shown by records extending over many years."

Naturally, astronomy will be featured rather strongly at the Los Angeles meeting. Detailed reports of observations of the eclipse are of course not to be expected. The astronomers in attendance will however meet under the auspices of the association, holding joint sessions of Section D with the thirtieth meeting of the American Astronomical Society, and the summer meeting of the Astronomical Society of the Pacific. These sessions will be held at the University of Southern California, the Laboratory of the Mount Wilson Observatory and the California Institute of Technology.

A symposium on "Eclipses and Relativity," with Dr. W. W. Campbell, president of the University of California; Dr. Charles E. St. John, of Mount Wilson Observatory, and Dr. S. A. Mitchell, of the University of Virginia, as speakers, will be a feature of the general sessions at the University of Southern California.

A Research Conference will be held Monday at noon, September 17, during the luncheon period. The encouragement and coordination of research work on the Pacific Coast will be discussed and delegates will be heard from the various universities and research institutions in this field.

The Los Angeles meeting will be formally opened Monday evening, September 17, in the Bovard Auditorium, University of Southern California, with an address by President E. P. Lewis, of the Pacific Division of the American Association for the Advancement of Science, following which the usual public reception will be held.

On Monday afternoon, September 17, the symposium on "Eclipses and Relativity" will be held. It is represented that this discussion will be judiciously bereft of some of its inherent technicalities and suited to the comprehension of the average layman. It will prove a most attractive feature of the general sessions.

A banquet will be arranged for Tuesday evening, September 18, at 6:30 for all members of the asso-