ETC.: A REVIEW OF GENERAL SEMANTICS

SCIENCE TEACHING AND THE HUMANITIES

[Foreword by A. Rapoport: The closeness of Dr. Frank's position, as it appears in the present article, to the point of view of general semantics is too evident to require elaborate comment. Stated in general semantics terminology, Dr. Frank's critique of our education and learning centers on its elementalistic character reflected in the rigid divisions between the 'special fields' of science and in the even more unfortunate chasm between the sciences and the humanities. A forest of ivory towers has arisen, and philosophy, shirking its modern social duty of providing means of communication between the towers of the 'special fields' and a bridge with the humanities, has instead gone into business for itself—that is, set up another tower.

Dr. Frank realizes the need for a new orientation. This orientation is to come through a close and critical scrutiny of the history of thought and of the methods of science. It is to come through considering science itself as a peculiar type of orientation, namely, one which enables us to predict and control some phenomena of nature. It is through this approach to his special science as a chapter in the book of Man that the science student can become 'humanized.' Philosophy really need not build the bridge between the sciences and the humanities. This bridge already exists in the view of man as a time-binder. Philosophy need only point to it.

In showing how a philosophy of science may summarize scientific method, Dr. Frank describes among other things 'operational definitions.' Operational definitions are, of course, intimately connected with the 'extensionalization' and the 'criterion of predictability' of general semantics terminology. He introduces the connection between the symbolic postulation of Ohm's Law and reality by describing the relationship between the abstract terms of the physicist such as 'current,' 'resistance,' 'electromotive force,' and the 'everyday English' terms such as 'wire,' 'position of the needle,' etc. In general semantics terminology this translation is described as a descending order of abstraction, hence as extensionalization. The criterion of predictability likewise plays an important part in these operational definitions. When the poles are connected, the needle will deflect so much. Then we say that an ampere of current is
passing.' Or, 'when heat is applied, the gas will expand so much. Then we say that the temperature has been raised one degree.' It is this constant reduction of scientific language to 'if thus, then so' propositions that makes science a unifying factor in human affairs, where metaphysics has so long been a dividing factor.

Perhaps the most important of Dr. Frank's emphases is on the fact that there is no such thing as 'not having a philosophy.' The hard-boiled writers of 'practical' textbooks who maintain that they stick strictly to the facts, often exhibit a surprisingly soft-boiled, not to say addled, 'philosophy,' a metaphysics of tacit assumptions which they somehow somewhere have picked up. This is another way of recognizing that no matter what we say or how we say it, we do not speak 'facts' but rather describe our evaluations of facts, which are necessarily refracted in any metaphysics which happens to be lying around.

In the words of Poincaré, 'It is often said that experiments must be made without a preconceived idea. That is impossible. Not only would it make all experiment barren, but that would be attempted which could not be done. Every one carries in his mind his own conception of the world, of which he can not so easily rid himself. We must, for instance use language; and our language is made up only of preconceived ideas and cannot be otherwise. Only these are unconscious preconceived ideas, a thousand times more dangerous than the others.'

Finally, Dr. Frank shows how the symbolism of the various 'integrative systems' are exploited by social, religious, and political groups to induce orientations in people which make them receptive to various patterns of propaganda. These observations are in our opinion of far-reaching significance. Their importance has not been generally recognized (probably because of insufficient interest in politics among philosophers) and certainly not sufficiently stressed. Just as Hitler exploited the frustrations under capitalist democracy in his bid for return to authoritative feudalism, so the reactionary religious and political groups are trying to exploit the dramatic failure of the mechanist-materialist world view (Newtonian) in a bid for return to aristotelian orientation. Dr. Frank pointedly connects the high incidence of conversions to fascism among engineers with their very poor contact with the humanistic aspects of science.

It is indeed difficult to find a more brilliant illustration of the contrast between the static and the dynamic orientation, between the reactionary and the forward-looking, the aristotelian and the non-aristotelian point of view than in the respective attitudes toward an exploding 'system.' The reactionary says, 'What did I tell you? It was wrong all the time. Now we can go back to good old -ism.' The progressive or the general semanticist, having carefully dated his 'truths,' says of the dying system, 'Requiescat in pace. It has served as it could. May the next one be short-lived.'

Dr. Frank, lecturer on physics and mathematics at Harvard University, is author of Das Kausalgesetz und seine Grenzen (1932), La Fin de la Physique Mecaniste (1936), Rozvrat Mechanisticke Fysiky (1938), Interpretations and Misinterpretations of Modern Physics (1938), Between Physics and Philosophy (1941), Foundations of Physics (1946), and associate editor of Philosophy of Science. His book, Einstein, His Life and Times, is scheduled for 1947. The present paper was given at the Seventh Conference on Science, Philosophy and Religion, University of Chicago, September 9-11.]
THERE IS a widespread belief that the rising contempt for tolerance and peace is somehow related to the rising influence of scientific thought and the declining influence of ethics, religion and art as a guidance of human actions. This contention is, of course, debatable. There is hardly a doubt that the causes of war can be traced back quite frequently to religious or quasi-religious creeds and very rarely to the doctrines of science. The humanities, including religion and ethics, have been for centuries the basis of education and the result has been, conservatively speaking, no decline in the ferocity of men. The scientists have never had a chance to shape the mind of several generations. Therefore, it would be more just to attribute the failure of our institutions to educate a peace-loving generation to the failure of ethical and religious leaders than to construe a responsibility of the scientists.

I do not think, however, that it makes much sense to discuss the share of responsibility. For I agree fullheartedly with the critics of science in the belief that the training of generations of scientists in mere science without making them familiar with the world of human behavior, would be harmful to the cause of civilization. Whether we like it or not, scientists will participate more and more in the leadership of society in the future. Also there is hardly a doubt by now that the contributions of the scientists to our political life has been more on the side of peace and tolerance than the contributions of the students of law or government, or, for that matter, of philosophy proper.

In order to make this attitude of our leading scientists a habit among the rank and file, it is important to imbue the future worker in science with an interest in human problems during his training period. Since for this purpose it is futile to argue for the supremacy of humanistic education over science education, the debate 'science versus humanities' or vice versa is, of course, without point here. But it is also of little avail to compel the student of science to 'take' some courses in the departments of 'humanities.' According to the record of all people I know, the mentality of the average science student is such that he will not sufficiently appreciate these courses, and therefore not assimilate them well. What we actually need is to bridge the gap between science and humanities which has arisen and widened more and more during the nineteenth and twentieth centuries. According to my opinion, this can be done only by starting from the human values which are intrinsic in science itself. The instruction in science has to emphasize these values and convince the science students that interest in humanities is the natural result of a thorough interest in science.

In this way the science teacher will be giving his support to the whole cause of general education as well as to his specialized teaching of science.

Special Fields

Everyone who has ever tried to raise his voice for the cause of general education among the faculty members of a university has been running almost regularly against one very definite objection: whatever of their time the students have to spend in classes on general education they have to subtract from the time they devote to specialized work in their own scientific field. As this field is, in any case, so vast that it cannot be covered during their stay in college, it would be almost a crime to curtail this short and valuable time. This attitude is particularly strong among the teachers of science proper.

I am going to discuss the issue 'special field versus general education' mainly
from the viewpoint of science students. However, I am sure that the general picture will be about the same in any other field of study, in languages, in history, etc.

Besides this negative attitude of a great many scientists who warn us not to replace 'honest work by idle philosophical talk,' opposition to general education arises also from a group which one would hardly suspect of playing this role. The instruction in the 'special sciences' is, on the college level, regularly complemented by a 'department of philosophy' which has been supposed to emphasize human knowledge as a whole in contrast to the special types of knowledge furnished by the science departments. However, the departments of philosophy have not attended much to this great historic task. They have rather added a new specialty, technically called 'philosophy.' In this specialty the emphasis has been put not so much on the integration of the special sciences as on the creation of a technical language which is just as difficult to understand for, say, a student of biology, as the language of a special field of mathematical analysis. To an increasing degree the departments of philosophy have kept to a policy of 'isolationism.' Instead of working towards a synthesis of human knowledge they have proposed a kind of 'truce' between science and philosophy. In my opinion, this gap is greatly responsible for the rift in our general education, or, exactly speaking, the gap between science and philosophy is the most conspicuous part of the gap between science and the humanities—thus the gap between science and the realm of human behavior in general.

This gap is perhaps nowhere as clear cut and conspicuous as in the domain of physical science. Therefore, the battle for the renewal of liberal education will not be won without a willing and intensive cooperation of workers in the physical sciences. On the other hand, if we want the students of the humanities to go in gladly for general education which requires them to take in quite a few helpings of science, one has to convince them that by learning science they will also advance toward a better understanding of human behavior.

I am going, first, to describe what harm the rift between science and philosophy has done to both of these fields and to the cause of liberal education in general. Secondly, I am going to make some suggestions as to how this rift can be repaired by removing the causes through which philosophy and science have been estranged.

**Physics and Philosophy**

There is no doubt that the public interest in the physical sciences is primarily due to their technical applications: television, radar, the atomic bomb, etc. However, when Copernicus suggested description of the motion of the celestial bodies with respect to the sun rather than with respect to the earth, this suggestion was quite irrelevant for any technical purpose. But the public interest and the heat of the debates were certainly greater in this than in the case of any new technical device. But we need not go back several centuries for examples, since we ourselves have been witnesses of the 'relativity boom' which arose when Einstein advanced his new theory of motion and light. Although this theory seemed at that time very far from any technical application, the public interest was in some cases rather hysterical, and there are examples of people who were almost killed in an attempt to get into an overcrowded lecture room where Einstein in person tried to put over Relativity to his audience. There
is also no doubt that the philosophical and even religious implications of such general physical doctrines account for the fact that quite a few clergymen have been eager to make use of Relativity in their sermons. In order to appreciate this situation correctly, we must not forget that Newton, during and after his lifetime, was a popular topic of parlor conversation and that many books popularizing Newton were published, some of them especially designed for 'the use of the ladies.'

Nowadays we find, not infrequently, books and magazine articles written by clergymen, philosophers, or, for that matter, by scientists, in which the theories of modern physics (relativity and quantum theory) are recommended for their philosophical or religious benefits. We learn from these papers that twentieth-century physics has 'restored' the place of 'mind' in the universe, that it has reconciled science with religion, and that the tide of materialism characteristic of eighteenth- and nineteenth-century science has definitely been broken in the twentieth century. As 'materialism' has always been connected with some political and social systems, these authors conclude that the new physics means also a defeat of all political systems based on materialism, by which they mean according to their personal bias, communism or, occasionally, nazism (racism).

There is no doubt that the correlation between physics and philosophy has been largely responsible for the great interest in twentieth-century physics in wide sections of the general public. The intelligent reader who follows the trend of contemporary thought in books and magazines, who listens to popular lectures of scientists, preachers, philosophers and global politicians, would often have a greater interest in the general ideas of twentieth-century physics than an average student of physics who specializes, say, in 'radar.' Even after graduation, a student of physics usually knows very little about the relation between physics and philosophy, let alone between physics and human behavior. He is generally less trained than the educated layman in well-balanced judgment about such problems as are daily discussed in magazines and lectures about the influence of modern physics on human affairs. If a student in high school or, for that matter, in most colleges, asks his physics teacher for information about problems of this kind, he will hardly get a satisfactory answer. The information, if any, will mostly be perfunctory and evasive. Therefore, the graduates in physics will rarely be able to advise the general public on questions which this public regards as relevant for their general outlook on man and the universe.

This failure of the learned physicist will not stifle the public interest. The thirst for knowledge which is not quenched by the scientists will be allayed by people who are ignorant in science but know how to give answers which flatter the wishes of the majority of people. Thus the longing for knowledge of large sections of the public will become grist for the mills of some organized propaganda groups.

The reason why the average teacher of physics is not able to give any adequate answer to these questions is obvious. The traditional teaching of physics fails to pay enough attention to the precise relation between the observed facts and the most general laws of nature. While the language of these general laws contains words like 'entropy,' 'relativity,' etc., the language by which observed facts are described is exactly the language of our everyday life. It contains expressions like
'red spot,' 'hard stone,' 'increasing heat,' etc. The failure to explain adequately the relation between these two types of expressions accounts for a great many shortcomings in our general education. For, to understand precisely the meaning of the general laws of science is the natural starting point for an understanding of the laws of human behavior. As these laws are much more complex, the analysis of science can serve fittingly as the first step towards the understanding of social relations—as long as this purpose is not frustrated by oversimplification and complacency which are so current in the traditional teaching of the fundamentals of science. In order to convince ourselves of the latter fact, we need only look at random into some elementary textbooks of, say, physics, and examine how they present a simple and familiar law, as for example, the law of inertia.

One author may call it 'describing a familiar fact of our daily experience proved by a book lying quietly on the table,' while the next textbook says that this law cannot be checked by any experience. The approach to general laws in advanced textbooks is equally perfunctory except that the lack of precision is hidden under a heavy load of mathematical formulae. In most textbooks the law of inertia is formulated by a proposition which is void of any physical meaning. We read 'if no force is acting on a body, it is moving along a straight line,' without the slightest hint to which system of reference the expression 'moving along a straight line' refers. The confusion inherent in this traditional formulation becomes conspicuous when the text tries to comment on the 'centrifugal force.'

These textbooks mostly claim to 'stick to the facts' and to exclude 'idle philosophical talk.' But actually, they formulate the laws of nature in such a way that no physical facts whatsoever can be logically derived from these laws. This means that they actually formulate not physical but purely metaphysical laws.

Thus, the physical sciences provide very good examples from which the students can learn that the expression 'sticking to the facts only' is frequently used as a pretext for 'avoiding all logical analysis,' and therefore 'favoring all kinds of obsolete prejudices.' What one should reasonably mean by 'sticking to the facts only,' is to make only statements which can be checked by experience, i.e., by observable facts. This habit is certainly of great use in debunking empty slogans and bigotry in politics or religion.

This issue can, for example, be brought home to the students very effectively by presenting to them in an adequate way the conflict between the Copernican world system and the older Ptolemaic system. They would learn, then, that the adherents of the old geocentric system that had the backing of the Church regarded their system as a description of sense-observation, as a 'sticking to the fact only,' in contrast to the Copernican heliocentric system which was, according to them, 'an artificial construct and contradictory to the testimony of our senses and even to common sense.'

The same failure to grasp the real relation between sense observation and mathematical construction has led frequently to a misunderstanding of such important developments in science as non-euclidean geometry. The great majority of the graduates in mathematics, even in good colleges, have never given even a thought to the question what the observable world would look like if non-euclidean geometry were correct and even what it means precisely to say that non-euclidean geometry is valid or is not in our physical world. The bulk of the students have never even
heard of such a question, as the traditional
teaching of mathematics ignores the exact
relation between physical facts and mathe-
matical conclusion.

As ‘sticking to the facts’ is the slogan
of traditional physics teaching, ‘ignoring
the facts’ is a slogan cultivated in the tra-
tional teaching of mathematics. Both
these slogans are logically legitimate
within a restricted domain of thought. How-
ever, on occasion, the students have
to learn the limitations of these slogans;
otherwise, the meaning of the most im-
portant laws of nature cannot be made
clear to them, and the very goal of gen-
eral education on the basis of s.
ience would be frustrated.

If no bridge is built between the tra-
ditional teaching of physics and mathe-
matics, students never get an understand-
ing of such an important subject as non-
euclidean geometry, let alone the theory
of relativity. The physics of the twentieth
century will remain to them a domain full
of fog and mystery with only some dis-
persed islands of clear visibility.

**Chance Philosophies**

Without understanding the tie up be-
tween mathematics and physics, the stu-
dent misses the best opportunity of gras-
ing the most important trait of human
knowledge: the relation between sense
observation and logical thinking. If this
bridge between the fields is not built by
a thorough analysis of the empirical and
logical procedure in science, that is, by a
systematic philosophy of science, the
necessity for this bridge is so overwhelm-
ing that it will be built anyway. This will
be done mainly by some obsolete but pop-
ular philosophy which will replace the
thoroughly logical analysis of science. It
is noteworthy that, in practice, crude em-
piricism in science, without critical analy-
sis, has often made possible the flourish-
ing of crude metaphysical systems.

Quite a few great thinkers who be-
longed to very divergent schools of
thought have been unanimous on one
point: if a scientist believes that he has
no philosophy and keeps tightly to his
‘special field’ he will really join some
‘chance philosophy,’ as A. N. Whitehead
puts it. This great contemporary meta-
physician with a solid scientific back-
ground assures us that for a scientist de-
liberately to neglect philosophy ‘is to as-
sume the correctness of the chance philo-
sophic prejudices imbibed from a nurse
or a schoolmaster or current modes of ex-
pression.’

We find complete agreement with this
opinion in a statement of Ernst Mach, a
philosopher and eminent scientist who
was the most radical enemy of all kinds
of metaphysics. He says, about obsolete
doctrines of philosophers, that they ‘have
survived, occasionally, much longer within
science where they did not meet such an
attentive criticism. As a species of animals
which has been badly adjusted to the
struggle of life has survived sometimes
on a remote island where there have been
no enemies, obsolete philosophy has sur-
vived within the borders of science.’

As a third and again very different type
of thinker we may quote Friedrich Engels,
(the life-long collaborator of Karl Marx),
who was particularly interested in the con-
sequences of obsolete philosophy in so-
cial and political life. He says: ‘How-
ever the scientists may try to avoid it,
they will be always directed by the philos-
ophers. The question is only whether they
prefer to be directed by some poor philos-
ophy which is just fashionable or by the
diversity of theoretical thoughts which
they would learn by acquaintance with the
history of thought and its achievement’
(‘Dialectics of Nature’).

One thing seems to be certain: if we
try to eliminate from, say, physics, teaching all philosophy of science, the result will not be a crop of 'scientifically minded' physicists, but a flock of believers in some fashionable or obsolete chance philosophy.

This fact becomes evident if we cast a casual glance into any textbook of college physics. If one reads the 'introduction' one notices in quite a few cases that some kind of 'philosophy' is taken for granted. Frequently one meets statements like this: 'Science has "involved" that there are only two "entities" in nature—matter and energy—but some scientists think that there is still a third entity—electricity.' Words like 'entity' have a status neither in our every day language nor in the language of physics but are reminiscences from mediaeval philosophy. If they turn up without the context of that system they are completely meaningless and have only a confusing effect on the reader.

Usually the student and, for that matter, the teacher of physics, pays little, if any, attention to this 'philosophical introduction.' If one ventures criticism the most frequent apology would be that nobody reads it anyway, let alone takes it seriously. But this seems to be a rather poor justification of a doctrine presented in a textbook of science. These perfunctory introductions do, certainly, no serious harm to the physicist in his business of handling the usual devices and predicting the outcome of the well-known experiments under normal circumstances. But if a non-physicist reads a physics textbook with the intention of profiting his own general education, he would usually believe that every word in this textbook is a result of physical science. In this way, some doctrines of ancient philosophy (like the existence of a finite number of entities in the world) which have been dropped for a long time from scientific philosophy, get the blessing of modern physical science. Then such a statement boomerangs back to the physicist as a statement of contemporary philosophy and bars the worker in physics from any contact with living philosophy. In turn, the chance philosophy which the authors of physics textbooks have absorbed from some obscure source, boomerangs back to the students of philosophy as the last word in contemporary science.

Among the science students the students of engineering are those who get traditionally the worst training in philosophical analysis. They often absorb science stripped of its logical structure as a mere collection of useful recipes. Is it a mere coincidence that the students of engineering have on the whole been more impressed by empty political slogans (like Fascism) than the students of 'pure' science? There is no doubt that general slogans play in politics a role similar to that general principles play in science. If someone is trained to understand to what degree general principles like 'conservation of energy' or 'relativity' are based on confirmable facts and how far on arbitrariness and imagination, he is more immune against the political slogans of demagogues than a student who has been trained only in recording his immediate experience and to regard the general laws as gifts dropped from heaven for helping him to bring some order into his record sheet.

The traditional method of physics teaching of 'sticking to the facts' and 'avoiding philosophical talking,' breaks down conspicuously in the attempts to teach Relativity Theory and Quantum Theory according to these slogans. The failure to discuss these theories from the philosophical angle is responsible for the awkward situation that even at present most of the graduates in physics regard the theory of relativity as a doctrine which
is somehow obscure if we compare it with the proverbial lucidity of, say, Newton's Mechanics or Maxwell's Theory of the Electro-magnetic Field. Quantum Theory is even at present mostly taught as a recipe for some formulae. Quite a few instructors attempt to hurry as quickly as possible through the foundations of Quantum Theory in order to protect the minds of the students from conceptual difficulties and obscurities. They want to reach as soon as possible the safe ground of familiar computation and experimentation on special problems where 'honest work' can be done. By this presentation it happens quite frequently that the student gets only a vague knowledge of important ideas such as Heisenberg's Principle of Uncertainty and Bohr's Principle of Complementarity. In this way the student misses just the points which are of the greatest interest for people who are not professional physicists. The purging of physics from philosophical discourse has become, in quite a few cases, a pet slogan in physics teaching. However, this discrimination between physics and philosophy has been quite unknown to men like Galileo and Newton or, for that matter, to Aristotle. In the famed conflict between Copernicus and the doctrine of the Church, philosophers and scientists disagreed often, but they never challenged their mutual competence to discuss this issue, as a common issue of science and philosophy. The discussion on Einstein's Theory of Relativity has been, from the logical point of view, largely a repetition of the discussion on Copernicus. But there is little doubt that the philosophical part of this discussion of the twentieth century has been much more confused than the above mentioned discussion in the sixteenth and seventeenth centuries. For nowadays, there is no longer any common ground which is accepted by both parties, scientists and philosophers. This separation has been growing more and more during the nineteenth century, particularly due to the influence of German idealism with its sharp distinction between empirical and transcendental knowledge or between 'pure' and 'practical' reason.

Practically, the separation between science and philosophy can be kept up strictly only during a period in which no essential changes in the principles of science take place. In a period of revolutionary changes the walls of separation break down. In Whitehead's statement quoted above, he makes particularly the point that the lack of a philosophy of physics among the physicists may be harmless in a time of stability, but during a period of reformation of ideas this lack will lead unavoidable to the chance philosophy of which we spoke. Our own age with the rise of Relativity Theory and Quantum Theory is an obvious example. These new fields have actually become, not only for the layman but also for the physicist of average training, a kind of mystery. We find this feeling well described in the autobiography of H. G. Wells, who has been particularly prominent in the field of science fiction. He tells us about his impression as a physics student in the Imperial College in London: 'All went well in the customary space-time frame work. Then things became difficult . . . . Beyond what were the empirical practical truths of the conservation of energy, the indestructibility of matter and force, etc., hung an enigmatic fog. A material and experimental metaphysics was reached.'

There are different methods which have been used by physics teachers to dodge the issue of giving to the students a coherent picture of the laws of nature. The simplest thing to do is to stick as tightly as possible to the description of physical devices and to the presentation of mathematical com-
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putations. This way of teaching has given to the non-physicist the impression that the science of physics, which has been, historically, the spearhead of enlightenment, has become in some cases a source of obscurantism. Quite frequently physics was actually used to attack the belief in human reason and to bolster the belief in irrational sources of truth. This misuse had its basis certainly in the failure of many books and instructors to give a logically consistent interpretation of the physical meaning of the formulae which express the most general laws.

The Department of 'Philosophy'

Besides the departments of the 'special sciences' there is in most colleges a department of 'philosophy' which is to counteract the extreme specialization. It is devoted to the task of investigating the foundations that are common to all the special sciences. According to our previous argument, the average instruction in the 'special sciences' has not achieved the goal of giving to the student an understanding of what is the place of his science in the whole of human knowledge and human life. Let us now inquire how the average instruction in philosophy has done the job which has been ignored by the instruction in the 'special sciences.' As a matter of fact, philosophy (as taught in most departments of philosophy) has become a special science itself which is more separated from mathematics, physics, biology, etc., than these branches are separated among themselves. The width of the gap that has separated science from philosophy became noticeable when the rise of completely new theories like the theory of relativity produced a confused situation among the scientists. The contribution of the philosophers trained in their special field towards a clarification of the new concepts and their integration into the whole system of our knowledge has been all but negligible. The students of philosophy trained in the traditional way have mostly studied the theory of relativity and quantum theory from superficial popularizations which were written by 'physicists' who, in turn, had no training whatsoever in the logical analysis and philosophy of science. Therefore, their popular writing is imbued with their 'chance philosophy' which they have picked up somehow. Concepts like space, time, causality are used according to these 'chance philosophies.' In this way, again their own traditional and sometimes obsolete philosophy has been returned to the philosophers in the disguise of the gospel of 'science.'

To get an estimation of the width and the depth of the abyss we have mentioned again and again, we have only to make an attempt to locate a philosopher who has a 'clear and distinct idea,' say, of the real issue in the old conflict between Copernicus and the Roman Church, let alone of the conflict between the Newtonians and Einstein. We would find very few. But it seems obvious that nobody can grasp the philosophical meaning of an issue in the history of human thought if he does not understand the issue itself, and by 'understand,' I mean 'thoroughly understand.'

Among the philosophers the apology is current that it is just impossible for them to have an exact insight into a scientific issue because the sciences have become, in our time, so highly specialized that only the specialist can have a thorough understanding. But if this is so, how again can one have a philosophical judgment about an issue which one understands only superficially because the matter is too complicated? In this situation a great many philosophers have chosen to establish as their 'redoubt' a special field
of philosophy outside the field of science. To master this field one supposedly needs only an acquaintance with the pre-scientific knowledge which is familiar to the 'man in the street.' According to this program of action, the philosopher investigates the concepts and beliefs that are the logical basis from which the experience of our every-day life can be derived. On this level we make free use of words like 'time,' 'space,' 'existence of external objects,' etc., in the sense in which the 'man in the street' uses these expressions. The 'special sciences' like mathematics, physics, biology, etc., as isolated branches of knowledge, are taken for granted and the policy of non-intervention is upheld. These 'recognized special sciences' have been born somehow. They thrive happily without bothering about philosophical analysis. The philosopher wants them to be happy in their innocence and not to intrude into his 'living space' which is located 'between' and 'above' and 'below' the domain of these isolated special sciences.

Actually, these autonomous sciences exist only in the oversimplified scheme set up by a large group of philosophers. The domain between mathematics, physics, biology, history, etc., is exactly of the same stuff and has exactly the same logical structure as the domain within physics or within mathematics. The borderlines between the special sciences are drawn only for the sake of the division of labor and not for any profound philosophical reasons. The special fields of physics and chemistry were regarded throughout centuries as being of an essentially different nature since physics has to do only with quantitative changes while chemistry inquires qualitative or even substantial changes. Today we have between physics and chemistry two new 'special fields,' physical chemistry and chemical physics which replace the 'mysterious something' which was supposed to be the 'philosophical link' between physics and chemistry.

The schools of thought which have advocated the separation of philosophy from science have certainly tended to cooperate in the integration of the sciences, but they perform this job by using as binding material some pre-scientific stuff, while we learn from our last example that the binding material between the 'special sciences' is itself a full-fledged science. But another school of thought, which claims to be very up-to-date takes an attitude which we may call an attitude of defeatism. They leave the 'special sciences' untouched and autonomous. But according to this school, philosophy does not even attempt to fill the gaps between these special sciences but plans to build up a completely separated stratum of knowledge 'beyond science.' This 'knowledge' is claimed to be completely independent of any advance of science proper, for it is based only on the pre-scientific experience of mankind. We may distinguish two groups within this school.

Both insist that when the scientist has done his job as thoroughly as he can, the philosopher's job begins. When, e.g., the physical laws of motion are established by the scientist, the philosopher, says the first group, steps in and puts his particular questions. The scientist has formulated by his law how motion takes place, what it is like, etc. But the philosopher wants to know what motion is, with the emphasis on the 'is.' While the scientist explores the observable attribute of motion, the philosopher wants to find out the 'being,' the 'essence' of motion. This essence of motion can be discovered on the basis of our pre-scientific knowledge about motion and cannot be affected by any further advance in our science of mechanics. To this group belongs present-day Neo-Thomism.
The second group starts also from the 'special sciences' as having accomplished their job. But instead of looking for the 'being' of things this group claims that these 'special sciences' take some 'presuppositions' for granted without investigation, e.g., the existence of material bodies, the law of causality, the law of induction, etc. Then they say the philosopher has to step in and investigate whether these presuppositions are correct or not. When I hear this claim, I have sometimes the feeling that the shoe may be on the other foot. For quite frequently scientists investigate the presuppositions which philosophers have taken for granted without investigation. The founders of non-euclidean geometry, Gauss, Lobatchevski and Bolyai, doubted the axioms of euclidean geometry. Einstein doubted the axioms of newtonian mechanics, while a great many philosophers believed in these axioms as eternal truths. Moreover, it is quite debatable whether 'presuppositions' like the existence of material bodies, really play any role in science and whether presuppositions which play a substantial role can be investigated by any method which is not scientific itself. Whatever may be our final judgment about this 'investigation of presuppositions,' the practical effect of this philosophical school is again the establishment of philosophy as a special science besides mathematics, physics, economics, etc.—and the perpetuation of a wide gap between science and the humanities in our educational system.

The role of philosophy as an integration of human knowledge is ignored, or, at least, neglected and, as a result of it, the educational values intrinsic in mathematics, physics, etc., are not exploited. These special sciences are reduced to the state of useful knowledge without truth value while, on the other hand, 'philosophy' becomes a type of discourse without contact with the advance of science and, therefore, without contact with the evolution of human intellect.

From these considerations, it seems obvious that the traditional teaching of philosophy may have contributed considerably toward sharpening the thinking of students and toward giving them a certain touch of sophistication, but has certainly made little contribution toward the synthesis of human knowledge which should be the chief goal of liberal education.

**Philosophy of Science**

If we look for a constructive plan for bridging the gap between science and philosophy and, as a result, between science and the humanities, we have to remove the chief obstacles blocking the way toward this goal. As we have learned, the two principal obstacles are, first, the exaggerated belief of scientists in specialization which sometimes leads even to a prejudice against general ideas and, secondly, the recent tendency of the schools of philosophy to establish 'philosophy' as a new 'special science' instead of working on the synthesis of knowledge.

The negative attitude of many scientists is based on their conviction that every trespassing beyond the limits of one's own field would lead to unavoidable superficiality. Therefore, the genuine scientist has to mind his own business and keep within the fences of his own department. There is, of course, a grain of truth in this argument of avoiding superficiality. However, it does give only one side of the picture, for the advance of science has not only revealed more and more complexities in science; but also more and more cross-connections between the 'isolated' special branches. By this fact it has become much easier than formerly for one
man to grasp the findings of several special fields. We have only to consider the example of physics and chemistry.

If we want to get a sound judgment of how, despite the abundance of factual material, to acquire a thorough knowledge across departmental lines, we have to ask, for example, how some people have managed to become experts in a field like biophysics. They did it, certainly, not by a thorough study of the whole of physics plus the whole of biology. For this cannot be achieved in one lifetime. Those men acquired a balanced survey knowledge in both fields, physics and biology, and tried to acquire a really thorough knowledge in those parts of physics and biology which are relevant for the interaction of the phenomena of life with physical phenomena. As a matter of fact, the behavior of the scientists who have worked within a traditional field like physics has not been different. An average physicist will acquire a survey in general physics and a detailed acquaintance with his special field within physics. If he wants to become a biophysicist his survey information has to be broader, but his field of special interest need not be larger than the special field of an ordinary physicist. Sincerely speaking, the average physicist learns some part of physics outside his special field only through popular generalizations. This is true frequently for the Theory of Relativity. The individual physicist is, of course, not to blame for this situation, for without using popularizations, he would not be able to get any information about important fields of his science.

From these remarks it becomes obvious what has to be the training of the 'philosopher of science' if he goes in for a synthesis of human knowledge as his goal. He has to acquire a survey knowledge of several sciences and a thorough and precise knowledge of those parts of each special field which are relevant for the relations across the borderlines and for the relation between sciences and human behavior.

Some people may object that a survey knowledge would not be sufficient, for one cannot know what part of science will be relevant for the purpose of philosophy before the integration has been actually achieved. There may be some truth in this argument, but it proves too much. For according to this argument, every physicist would have had to have a thorough knowledge of the whole of physics. For otherwise he cannot know what knowledge may be relevant for his special field of physics. Nothing can be done about it and he has just to take the risk in his training as a physicist. He will learn by and by to smell what is relevant and what is not. No greater effort is, in principle, required from the philosopher who wants to acquire a training in the philosophy of science. There is no doubt, however, that even a survey knowledge in the sciences will take him so much of his time that he will not be able to get the training which a philosopher has to get if he goes into 'philosophy as a special science.'

But it may be sufficient for a student who specializes in the philosophy of science and wants to take his Ph.D. in philosophy to get along with a survey knowledge in the history of philosophy, without learning the details of all opinions which have been uttered through two or three thousand years. Every philosopher of science should, of course, be familiar with the ideas of the great thinkers like Plato, Aristotle, Thomas Aquinas, Leibnitz, Descartes, Kant, Nietzsche, etc. But it is perhaps sufficient if this special candidate becomes familiar with the language of these men and knows how to locate their ideas within the great stream of the evolution of scientific thought. This
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would leave him time and, more important, the leisure to acquire a good survey in the physical and biological sciences. He would concentrate his effort on those parts of these sciences which are the most relevant for judging the borderline problems arising between the special sciences and between science and traditional philosophy. He would concentrate, for instance, in mathematics on problems like the 'truth of non-euclidean geometry,' in mechanics on the role of 'absolute motion,' and, in particular, on the ties between mathematics and physics, e.g., the distinction between mathematical and physical truth of geometrical axioms. He would, of course, try to acquire a thorough understanding of Einstein’s theory of relativity, of Heisenberg’s principles of uncertainty, of Bohr’s complementary concept of nature, etc. In traditional philosophy he would try to understand the approaches of different schools to the question of what is the precise borderline between physics and philosophy. He would try to learn the answer of the great philosophers to questions like: what is the logical status of the general laws of nature? Are they a result of experience or of reason or of what? What is the role of chance and of causality in the general laws of nature and in their application to observed phenomena?

Teachers of philosophy with a similar type of training could give to the students reliable information about the problems of the 'philosophy of science' and of the 'integration of sciences.'

But then we are confronted by a further task: If we know even the problems, do we know also the solutions? What should we present to the student as the result of the integration of science? One should give him reliable guidance without providing him with a 'chance philosophy' which may be either the result of an old and now obsolete tradition or just the fashion of a year and a certain social group.

**Neo-Thomism and Dialectical Materialism**

There is a suggestion which has been widely discussed during the past years: the ideas of Robert M. Hutchins, Chancellor of University of Chicago. The essential point of his thesis is that we have to base the integration of knowledge taught in our colleges on the last available synthesis in the history of thought, on a kind of 'standard-tradition.' According to this group, the spokesman of which has been the philosopher Mortimer J. Adler, the last system in history which has really achieved a synthesis of science, ethics, politics and religion is the philosophy of St. Thomas Aquinas. His *Summa Theologicae* and his *Summa Catholicae Fidei contra Gentiles* present a coherent system in which, from the same set of principles, not only astronomy, psychology, ethics and politics are derived logically, but also the behavior of the angels, e.g., the speed of their flight.

It seems, of course, debatable whether actually Thomism is the last coherent system which has attempted or achieved such a sweeping synthesis. Some people would, certainly, claim that the philosophy of Dialectical Materialism which is the official basis of education in the Soviet Union is just as well a set of principles from which not only physical science is derived, but also the laws of history and sociology. Just as well as Thomism this more recent system claims to give guidance not only in scientific research, but also in the question of what is a 'good life.'

The basic contention of Hutchins and his group is that a synthesis which may not be perfect is preferable to no coherent synthesis at all. There is no doubt that it
is the chief asset of Thomism that such distant subjects as astronomy and theology can be regarded as conclusions from one and the same set of principles. But if we disregarded, for example, theology, there would be hardly anyone who would claim that Thomism is a good system from which to derive an answer to the question whether the newtonian or einsteinian mechanics is preferable.

In the same way, the chief asset of Dialectical Materialism is the fact that the laws of physics are derived from the same principles as the laws of human societies. We learn from the textbooks of Dialectical Materialism that, for instance, the law of the transition of a capitalistic society into a communist one follows from the same principle as the transition of water into steam. Both are conclusions drawn from the dialectical principle that quantitative changes eventually become qualitative changes. But if we are not interested in the synthesis of physics and sociology into one set of principles, hardly anyone would claim that Dialectical Materialism is the best foundation of physical science, for example, the most helpful interpretation of the evaporation of liquids.

Dialectical Materialism has, as a matter of fact, nowhere been chosen as a basis of education except in countries where the government has been committed to Marxist economic and political principles. In this case, there is clear advantage in having these principles linked up with the laws of physical science by a common set of principles. With the same right we can assume that Thomism is not commendable as a basis of education except where the government is committed to the political and religious doctrine of the Catholic Church. For it will enlist science by regarding science, politics and religion as derived from common principles.

There is, on the other hand, no doubt that in an education which emphasizes the integration of human knowledge, much more attention than usual should be given to the systems which historically have performed such an integration, however we may judge the actual political and religious way of life which is coherent with this system. The student should get a good and unbiased presentation of Thomism as well as of Dialectical Materialism in their function as a synthesis of human knowledge. But to make either of these systems the main or exclusive basis of education in the philosophy of science can be justified only if a particular political and religious indoctrination is intended.

Logico-Empirical Analysis

Despite all these considerations there is some sound nucleus in the plan to use a historic philosophical system as a system of reference. There is no doubt that the integration of knowledge on the college level can be promoted among the students only by the use of philosophical and historical argument. However, the starting point has to be living science itself. Philosophical and historical discourse must emanate from this source. There are quite a few good reasons for this, but it may be sufficient to consider the practical reason that in no other way can philosophy and history be made palatable to the student of science, and he will fail to appreciate this unusual food if he has no appetite for philosophical and historical ideas. It would be, of course, a poor teaching method just to add to the traditional presentation of science some philosophical spice or sauce. We have rather to give to the presentation of science itself a philosophical touch.

The teacher of the special sciences will perhaps be afraid lest time would be wasted by such a treatment. The student
would pay for this 'philosophical and historical touch' by a deficiency of information in science proper. But it seems to me that this new approach will rather save time. For by this method a great many laws of physics, e.g., could be much more attractively presented to the students than by traditional methods. However, I do not mean that the approach should be made by one of the numerous metaphysical systems which have been invented during the ages for the purpose of an integration of human knowledge. Every attempt of this kind would introduce very questionable doctrines into the teaching of science and would lead to disaster. We have to make use of the philosophical argument which has grown up on the soil of science and has been fed with the blood of science. We must never forget that metaphysics divides people and science unites them.

If we try to build the bridge between science and philosophy, our first step will be to present to the students their own 'special science' as a chapter in the book of human knowledge. Every scientist is confronted with the amazing fact that it is possible to derive from a few simple principles by means of logical argument a wide range of facts which can be checked by actual observations. The existence of these principles allows us to put the phenomena of nature into our service, for they enable us to construct methods by which the outcomes of physical processes can be predicted from the start.

Philosophy of science is concerned with the nature of this method or device which man has invented in order to bring about the prediction of physical phenomena. To have a certain understanding of this device is a basic requirement for everyone who wants to understand the history and the behavior of mankind in the past centuries including our own. Everyone who has given but a little thought to this question will agree that the science student who has received the average training has but a very vague understanding about the function of this 'device.' This failure accounts for the devastating misinterpretations which twentieth-century science has met among scientists themselves as well as among 'educated' laymen. It has certainly been, conservatively speaking, puzzling for the truth-seeking student of science to learn from reputable science books, for instance, that Einstein has been able to explain some physical phenomena through profound insight into the nature of space and time or that he proved some physical law by a purely mathematical demonstration. For neither a reasonable scientist, nor, for that matter, a non-scientist will ever understand how the 'nature of space and time,' an obscure combination of words, can be the cause of observable facts. He will grasp still less how by a mathematical demonstration a physical fact can be proved. We can read quite frequently in books of good standing as standards in these questions go, that atomic physics gives us a new insight into the 'freedom of will,' although this expression has no meaning in terms of physics at all.

Briefly, the field between physics and philosophy is and has been a no man's land where mysterious beings are at large. Scientists who are very conscientious and consistent in their special field are prone to the wildest utterances when speaking about a problem which belongs to the domain of philosophy of science.

It has been an age-old dilemma whether the general laws of science are a result of reasoning or of experience. If they are a result of pure reasoning how can they predict observable facts in the external physical world? But if they are a result of experience only, how can they
allow a prediction of the future, since experience gives only a recording of past events? In our twentieth century, the belief that pure reason can prove physical principles has been exposed, as well as the belief that pure experience can set up general laws, like Newton’s Law of Gravitation or the Law of Inertia. Both beliefs have given way more and more to an approach which is known as the ‘logico-empirical analysis of science,’ which is recognized in practice by all theoretically-minded physicists and by a great many biologists, psychologists and sociologists, as the correct analysis of modern science. Logico-empirical analysis was the method by which the revolutionary theories of modern physics were set up (Theory of Relativity and Quantum Theory.) This type of analysis has been characteristic for the science of our twentieth century.

There have been approaches from different angles which have worked out in the same way. Several rivers came from different sources to open into the sea of logico-empirical analysis. This analysis has very different shades according to the background and the national and professional heritage and the author. For instance, we may consider on the one hand P. W. Bridgman’s Logic of Modern Physics, with his emphasis on the ‘operational meaning of propositions.’ His system of reference was the hard facts of the laboratory. On the other hand, we have a man like the French philosopher G. Bachelard with a good background of physics, who called the new orientation ‘non-cartesian epistemology.’ His system of reference was the historic presentations of science by the great European thinkers.

Through the work of all these men a common attitude has developed, or as P. W. Bridgman would like to say, a common program of action. It certainly would not be recognized by everybody as leading to the ‘ultimate truth,’ but by all scientists and most philosophers as being the first step to truth about science.

To give a perfunctory outline of what logico-empirical analysis stands for, it may be the best thing to remember old David Hume’s assertion that there are only two types of legitimate statements in science. Either a statement is a description of facts in terms of observational sentences or it is a mathematical or logical conclusion. ‘Science’ is a free creation of the human mind which is designed to predict and to master the observable phenomena. More specifically speaking, the device called ‘science’ consists of three kinds of propositions. We have first, the general principles of science. They are formulated, e.g., in physics, in abstract terms like ‘mass,’ ‘force,’ ‘electric charge,’ etc., in geometry in words like ‘straight line,’ ‘point,’ ‘intersect,’ etc. Secondly, we have the rules of logic and mathematics which tell us what conclusions you can draw from the principles without knowing their meaning. If we consider a ‘principle,’ e.g., ‘intensity of a current is equal electromotive force divided by resistance’ (I = E/R), we can conclude from the mathematical and logical rules that E = RI without knowing what the words ‘electric current,’ etc., and the symbols I, E, R, actually mean.

Neither the physical laws nor the mathematical rules have any connection with observable phenomena. To make them statements about observable facts we have to introduce a third group of sentences into our system of science. The sentences have to describe, e.g., what experimental operations we have to perform in order to make sure whether a certain ‘intensity of current I’ exists in a certain wire. These sentences contain the abstract words of the physical prin-
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principles like 'current' or symbols like 'I,' but also the words of the everyday English language. Obviously, they contain words like 'wire' and other words which describe the apparatus and the operations performed with the apparatus by which the intensity of a current is actually measured.

Such a sentence or group of sentences is called by P. W. Bridgman the operational definition of the word 'current.' Or, he says that the word current gets an 'operational meaning' by these sentences. By other authors these sentences are called 'semantical rules.' The art to find and to handle such rules in any discourse is called by these authors 'semantics.'

By means of these 'operational definitions' we can translate the terms and symbols of the physical laws (electric current, I E R, etc.) into expressions of ordinary English. If we substitute these expressions in the principles they are no longer relations between symbols without any bearing on the observable world, but they become statements which contain only words of the language of our daily life and, at that, words describing observable facts. In this way the principles themselves become statements about observable phenomena. We can say that these principles become now 'physical hypotheses' which can be checked by actual physical experiments. The statement $E = RI$, e.g., is by itself a relation between symbols, but if we add the operational definitions of $E$, $I$ and $R$, we know by what physical operations we can measure the intensity, the electromotive force and the resistance in a wire. Then the relation $E = RI$ becomes a relation between the result of actual measurements, and we can check whether this relation is in agreement with our observations or not.

We see now that a physical theory consists of principles expressed in terms of symbols plus mathematical rules plus operational definitions. Only all these parts together define a physical hypothesis and can be checked by experiments.

Perhaps the most important philosophical contribution of the logico-empirical analysis has been to make clear that a set of principles by itself is no theory since it cannot be checked by experiments. Only principles plus operational definitions constitute a theory. This means that no principle or system of principles can be confirmed or refuted by actual observation or that no system of principles can be called 'true' or 'false' by itself. It can only be called 'true in connection with a specific set of operational definitions of the symbols.'

By this analysis of a theory, a great many empty questions are eliminated. We find, e.g., in many books, even written by scientists, statements like this: 'This table is only apparently a solid piece of wood, but in reality, it consists of billions of small electrons and protons.' As no operational definition of the terms 'reality' and 'apparently' is given, this statement is void of meaning. If, however, such a definition is given, the statement becomes trivial and may just mean that from the description of the atomic constitution of a table you can draw more conclusions than from the simple statement that it is a solid piece of wood.

By this type of analysis many pseudo-questions disappear which have confused scientists and laymen alike. Into this category belong questions like this: Does 'electricity' ultimately consist of electric charges or of an electric field? If we discuss mechanics, does the reality consist

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1 See also the discussion of Operational Definitions in A. Rapoport, 'Semantic Aspects of Language and Mathematics,' ETC., II, 106-115 (Winter 1946).
only of the motion of material bodies or do, in addition to it, immaterial 'forces' exist which are located in the bodies and in the vacuum? Is the contraction of bodies, stated by the theory of relativity, a real or only an apparent contraction? Are the 'matter waves' introduced by De Broglie 'real waves,' or only 'apparent waves,' etc., etc.?

**Toward Mutual Understanding**

By learning about the logical structure of science, as described by the logico-empirical analysis, we learn a great deal about the analysis of statements in every field of knowledge. We learn, above all, the distinction between statements which can be confirmed or refuted by experiments and statements which can be confirmed by purely logical reasoning. The first type has always to contain the operational definition of the symbols. The second type can be checked without knowing the meaning of the symbols, if we know only the mathematical rules. To the last group belongs, e.g., as we learned, the statement: If \( E = IR \) is true, then \( I = E/R \) is true.

We learn, moreover, that if a system does not contain operational definitions, the logical conclusions that can be drawn contain only symbols. But no conclusion follows which can be checked by observation. The question whether such a statement is 'true' in our physical world, or more generally in the world of our experience, is an empty question, or as one sometimes says, a pseudo-question.

This insight is a large step toward the understanding of the meaning of statements in any domain outside science proper and a great step toward judging truth of any kind. In fields like ethics, politics or religion, we have also to distinguish clearly between the factual content of a certain doctrine and the symbolic language in which this statement is couched. The example of physical science is a guide in a more difficult world and will help us to disentangle statements of religious or political principles with respect to whether they are really statements about observable phenomena or only a bid to use a certain type of symbol.

In physics this analysis is comparatively simple and not so loaded with emotional and egotistic elements. If someone asks people in the strongest language to 'follow the voice of their conscience' or 'to follow the will of God' this bid will be empty if he is not able to state the operational meaning of the voice of our conscience or how actually to find out the will of God. The student of science who has been trained in logico-empirical analysis will immediately turn his attention not so much to the strength of the language, but to the question of who is authorized to interpret the will of God.

The training of students in logico-empirical analysis is also the first step towards an integration of human knowledge. For when this analysis has been applied, all human knowledge forms a homogeneous system. The concept of 'meaning,' of 'confirmation,' of 'truth,' becomes identical or at least similar in all fields. Our knowledge is reduced to statements about observable phenomena meaning not only sense observations but also emotions, as far as they can be described in a language which is understood by everybody with whom we want to communicate.

By logico-empirical analysis the student will learn that the statements of science are neither 'proved by reason' nor 'inferred by induction from sense observation.' The principles of science are a structure of symbols accompanied by operational definition. This structure is a product of the creative ability of the hu-
man mind and consists of symbols which are a product of our imagination. But this structure can be checked for its truth by observations which can be described in every-day language. By logico-empirical analysis the creativity of the human mind emerges as the primary factor in science. Thus the student will learn that the role of this creativity in science is by no means inferior to its role in the humanities and even in art or religion. And we now can understand that the emphasis on science teaching will no longer interfere with interest in the humanities but will rather support it.

However, the role ascribed to the human mind by logico-empirical analysis does not exhaust the contribution of science teaching to the understanding of the human aspect in our picture of the world. For by logico-empirical analysis the role of the human mind is only hinted at in a rather abstract way. But our imagination and inventiveness are much too limited to enumerate and discuss all possible principles which the creative ability of the scientists may set up in order to derive the widely ranged phenomena of our experience. For this we have to study the principles which have been actually set up in history. We have to complement our logico-empirical analysis where 'empirical' means individual experiences, by 'historical analysis,' which is empirical not for the individual, but for the human race. The history of science is the workshop of the philosophy of science. We have to teach the student all the relevant principles which have been set up in the course of history. And we mean by 'history' the extension in time as well as in space, the development of structures of science through the ages and over the surface of our globe.

In this way the logico-empirical analysis gains life and color and becomes a living link between science and the evolution of the human race. The average textbook of physics tells us very little about the evolution of the principles of this science, except some dates of anniversaries. Very often these books speak about ancient and medieval science in a derogatory way; they claim not to understand why for ages people were not able to discover such a simple law as the law of inertia which today every schoolboy knows is an obvious result of our everyday experience or is even self-evident. But despite these smug remarks the same textbooks are not able to formulate this law of inertia in a satisfactory way. They even block the understanding of this and similar principles. For it is clear that a principle which intelligent men have not found through centuries cannot be as obvious as the statement presented by these books as the law of inertia. This complacent attitude imperils even the understanding of the evolution of thought and helps to spread the spirit of intolerance and bigotry among the students, while an attitude of adequate 'logico-historical' analysis would contribute towards good will between people of different background and different creeds.

In order to understand the steps in the evolution of human thought the best way is to present to the student in an elaborate way the chief turning points in the evolution of science with the emphasis not so much on the discovery of new facts but on the evolution of new principles of changes in the symbolic structure. It would be, for example, of the greatest importance to discuss thoroughly the conflict between Copernicus and the Roman Church (or, for that matter, with the Lutheran Church). I think that every student of science and the humanities should have a clear understanding of this issue, which was one of the greatest and
most interesting in history. If this subject were discussed thoroughly and in a competent way, the student could get a good understanding of the eternal conflict between established patterns of presenting the facts and attempts radically to alter the symbolic structure of science. The student would learn that the tendency to preserve the old pattern of presentation is often disguised under the name of 'common sense.' He would learn from this example how the appeal to 'common sense' has been used in the history of mankind to disguise the interest of established governments and churches. For, as he would learn in particular, the role which the interaction between science, philosophy and religion has played in the justification of political aims is very great.

Equally, students of science and philosophy should learn exactly what was the issue between Descartes and Newton and again between Newton and Liebnitz. From these disputes has arisen what we now call the 'classical physics' of the nineteenth century, which until today has been the basis of the training in science which our students get in engineering or liberal arts colleges. To grasp these issues would help them to understand our present science as a dynamic living being. This would not happen if they were confronted only with the desiccated and artificially stuffed skin of science which is presented in most of the current textbooks.

If the students get an understanding of the earlier turning points in science, it would be much easier for them to grasp exactly the meaning of the turning point around 1900, when our twentieth-century science was born.

This last turn has been dramatized by the slogans 'crisis of classical physics' or 'decline of mechanistic physics' or 'refutation of materialism,' etc. If one has been trained to analyze the nature of a 'turning point in the history of science,' one will be less inclined to believe that the 'crisis of classical physics' is a 'crisis of rational thinking' or even a justification of an irrational approach to science.

As we already mentioned, it is not sufficient to approach these turning points of human thought by logico-empirical analysis only, for the human mind is not strong enough to carry out an exact analysis of such a complex structure. One has to study classical physics as an extinct organism which had grown up against immense obstacles, which eventually defeated its opponents until it turned out no longer to be fit for survival. With this training one would have a clear understanding, say, of the broad analogy between the fight of medieval philosophy against Copernicus with the fight of modern newtonian philosophy against Einstein.

Students who have this kind of logical and historical training will easily 'debunk' the attempts to exploit the 'breakdown of newtonian physics' and the 'defeat of materialism' in order to justify a return to ancient 'organismic science.' They will be, moreover, on their guard against the attempts to exploit this 'crisis of thought' in a fight against liberalism and democracy, or, for that matter, against all progressive trends which have been historically labelled 'materialistic' or 'atomistic' or 'mechanistic.'

What Is Behind Rival Ideologies

By this approach the student of science would be led in a natural way to an understanding of the struggle among rival ideologies. It will be a great attraction for him to approach these problems starting from the role which has been played by his own special field. The student of science will get the habit of looking at social
and religious problems from the interior of his own field and entering the domain of the humanities by a wide open door and not by the rear door of some isolated humanity course which he may take for 'distribution.' He will need neither a 'spoonfeeding' of trivial information nor a stuffing with technical material which is no real profit for his general education.

When the student has an understanding of the historical struggle of scientific thought, he will become aware of the fact that there will be always such a struggle when science pushes its frontier ahead. For then the traditional symbols used in the formulation of scientific principles will no longer be fit to cover the increasing range of newly discovered facts.

The symbols used to formulate the principles of science (terms like matter, force, energy, entropy, etc.) are taken from the language of everyday life and always keep some of their original connotation. Very frequently, they are traditionally connected with meanings that, in turn, have a certain status in a political or religious ideology. Terms like 'matter and form,' 'order of nature,' etc., are used in Thomistic philosophy and are by this fact connected with the political and spiritual goals of the Roman Catholic Church. Words like 'materialistic interpretation of the phenomena of nature and society' are used in the philosophy of Dialectical Materialism and are connected with the goals of Marxism in politics and economics. There can be no doubt that such creeds have played a decisive role in the actual appreciation of scientific theories in human history.

There is no better way to understand the philosophical basis of political and religious creeds than by their connection with science. The student who understands the relation of his science to these creeds has an access from an inside track. He will easily and confidently cross the bridge between science and the humanities.

The attentive student of science will notice soon that the traditional symbols of science have a life of their own. They persist in a changing world where the scope of science is continually growing. This point becomes particularly clear by focussing the attention of the students at the turning points in the evolution of scientific thought.

The student will learn, for example, in what sense materialism has been encouraged by the physics of the nineteenth century and how this in turn was anticipated to a certain degree by the Epicurean School in old Greece. He will learn how the transition from medieval physics (which was based, in its turn, on the aristotelian school of Greece) to the Galileo-Newtonian physics, found its continuation in the school of Laplace at the end of the eighteenth century at the time of the great French Revolution. He will appreciate, then, how the fight of newtonian (mechanistic) physics vs. aristotelian (organismic) physics became connected with the fight of liberalism and tolerance against feudalism and bigotry.

He would thus understand that what scientific and corresponding political (ideological) issues have in common is the use of the same symbols with their wide range of connotations. In this way the student of science would learn to appreciate the great value of symbols in the history of human thought and for that matter in the history of human behavior.

Whoever has understood these historic issues correctly will attain a sound judgment regarding the last great transition, around 1900, when mechanistic physics had to give way to a more general approach. The transition from the nineteenth-century to the twentieth-century
physics culminated in the Relativity and Quantum theories which, in turn, have led to new philosophical slogans describing this transition as 'overthrow of the conception of absolute time and space' and 'overthrow of physical determinism.' The student who has been through the training in logico-empirical and historical analysis will assess the attempts which have been made to exploit the new physical theories for the benefit of particular religious and political ideologies. He will look through the argument by which the 'overthrow of eighteenth and nineteenth-century deterministic physics' has been used in the fight against liberalism and tolerance, since these creeds had grown up in a period of mechanistic and deterministic science. He will understand that the breakdown of mechanistic physics did not actually imply a return to organismic physics, which was, historically, connected with the political and religious doctrines of the middle ages. He will understand why twentieth-century Fascism has gladly interpreted the 'crisis of physics' as a return to organismic physics which could provide a 'scientific support' for return to some political ideas of feudalism.

But, above all, the well-trained student will understand the paramount fact that, actually, mechanistic physics was not replaced by any organismic physics, but by an entirely new approach to science by logico-empirical analysis which has been in the twentieth-century the starting point of all the new physical theories.

If science is taught in this way, the emphasis on science and technology will no longer be an obstacle to a liberal education of the student. The deplorable gap between science and the humanities will not arise, let alone widen. On the other hand, the intensive study of science as a living being will give to its student a profound understanding of the role of the human mind in human action, which is the very goal of instruction in the humanities.

By emphasizing the historical evolution of scientific thought the student will learn, moreover, that the human mind has not always been satisfied with the logico-empirical analysis of science, since this presentation of science is only satisfactory for the 'purely scientific' purpose of predicting and mastering the observable phenomena of nature. But the phenomena are derived from principles which are couched in symbols and, as we hinted already, these symbols have their own life, which is to a certain degree independent of the evolution of science proper. These symbols which are created by the scientists may even become occasionally a 'Frankenstein.' However, as these symbols are not unambiguously determined by the scientifically observed facts, they are strongly influenced by extra-scientific factors. The choice of symbols is, as a matter of fact, very dependent on the impact of current social and religious movements. These influences are largely responsible for the decision whether one prefers rigid pieces of matter as fundamental symbols (materialism) or whether one builds up all concepts from mental elements (idealism), whether one picks as the ultimate building stone a nondescript reality (realism), or whether one starts from elements which cooperate to a certain goal (organicism). Every satisfactory instruction in the philosophy of science has to discuss these choices of symbols on the basis of logical and historical analysis. The influence of political and religious trends on the choice of these symbols should by no means be minimized as is often done in the presentation of the philosophy of science. On the other hand, if 'metaphysi-
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cal integrations of science' are discussed, particular attention should be given to those integrations which have played a role as bases of ideologies. For this reason, doctrines like Thomism or Dialectical Materialism should be carefully and correctly presented to the student and should have more time devoted to them than is devoted to some sophisticated systems which played but little role in human life and human actions.

If the foregoing plan is followed, we shall have no graduates of science who have no clear idea of the teaching of men like Aristotle, St. Thomas, and William of Occam, or, for that matter, of Hegel, Marx, and Lenin. The type of science graduates who are without humanistic training will disappear just like those who have not even a clear picture of what the contribution of Copernicus was to our world.

The educational value of this type of instruction for science students seems to me beyond doubt. However, there is still the question of where to find a place for this in the curriculum. The most natural plan probably would be to teach the science courses of broader scope according to this method. This would hold, e.g., for the elementary courses in college physics, chemistry and biology. Such a start, would certainly be very stimulating and helpful for the beginner. However, since they have not the background for subtle problems, these 'survey courses for beginners' should be complemented by 'survey courses for advanced students.' These would be appropriately given just before graduation. They should answer the questions which were prompted by the elementary courses and treat them on a higher level. These new courses should not be 'superficial survey' as this word is often understood, but a birdseye view of the results of science, with a special eye to unsolved problems. These courses could be given according to the suggestions of this paper.

If there are not a sufficient number of science teachers in a college who are interested and trained in this plan of instruction, one or two 'special' courses outside the usual science curriculum should be established to be given by the few available teachers who have the necessary training and inspiration for this task. One may give these courses under the title of 'philosophy of science' or 'foundations of science' or 'science and the humanities.'

The present trend toward 'general education' has, in some colleges, led to the establishment of science courses for non-science students. The program of these courses emphasizes the bridge between science and philosophy or science and the humanities in some ways along the lines I discussed in this paper. In these plans, however, only the non-science student will be presented with the educational value of science while the 'concentrator' in science will be the one who will neither be able to give any information about the role of science in human society to his future pupils nor to his community in general. The questions regarding science which are most interesting to the general public should be answered by a competent and responsible man; and this obviously can be only the science teacher in the high school or college.