GENERAL SCIENCE

Langmuir's Address

Effect doesn't follow cause, says retiring A.A.A.S. president in radio address; while divergent phenomena give opportunity for individual action.

➤ BECAUSE science now finds that effect does not necessarily follow cause, Dr. Irving Langmuir, speaking as retiring president of the American Association for the Advancement of Science, called for the use of common sense, judgment, experience and intuition, in solving human problems, including the winning of the war.

"A sense of morality and decency, although not scientific, may be a major factor in winning the war," Dr. Langmuir said, in speaking from Albany on Dec. 26 over the Columbia Broadcasting System under the auspices of Science Service to thousands of scientists throughout the nation who forewent their traditional Christmas meetings to ease the transportation difficulties.

Two types of natural phenomena must be recognized, Dr. Langmuir said. One of these is the basis of classical physics. In "convergent phenomena" what happens can be determined and predicted from the average behavior of the parts that make up a system. The older ideas of cause and effect come in this realm.

The new idea of nature, that upsets conventional logic, is that a single discontinuous event, even a single minute quantum charge of electricity, becomes magnified in its effect so that the behavior of the whole actually depends upon something that started very small indeed. Dr. Langmuir calls this class of happenings "divergent phenomena" and these can best be understood on the basis of the quantum theory of modern physics.

Applying these observations to everyday living, Dr. Langmuir declared, "I can see no justification whatever for teaching that science proves that general causes (convergent phenomena) dominate in human affairs over the results of individual action (divergent phenomena).

"The mistaken overemphasis on convergent phenomena in human affairs, and the reliance on so-called scientific methods, has been responsible in large degree for much of the cynicism of the past few decades."

Dr. Langmuir, Nobelist in chemistry and associate director of the General Electric Research Laboratory, was introduced by Dr. Arthur H. Compton, Nobelist of the University of Chicago, president of the American Association for the Advancement of Science. Dr. Compton spoke from Chicago.

"It is not always recognized," said Dr. Compton, "that the total effect of science is to bring about conditions which favor world cooperation and thus tend to eliminate war. The growth of science and technology needs specialists. These specialists make an effective society only as long as their work is coordinated. Thus science demands a highly coordinated, cooperative society. Where men do not work together in cordial relations, the tools of science cannot be used effectively. It is thus that science emphasizes the strength of a society in which men work together with mutual good-will."

Science News Letter, January 2, 1943

Science, Common Sense And Decency

By DR. IRVING LANGMUIR

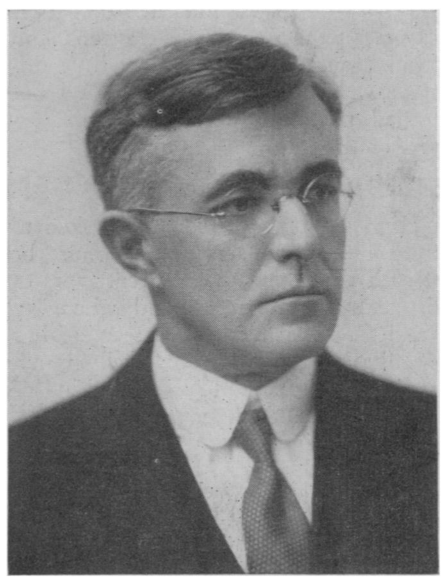
➤ UP TO the beginning of the present century one of the main goals of science was to discover natural laws. This was usually accomplished by making experiments under carefully controlled conditions and observing the results. Most experiments when repeated under identical conditions gave the same results.

The scientist, through his own experiments, or from previous knowledge based on the work of others, usually developed some theory or explanation of the results of his experiments. In the beginning this might be a mere guess or hypothesis which he would proceed to test by new types of experiments. If a satisfactory theory is obtained which seems in accord with all the data and with other known facts, the solution or goal of the investigation was considered to have been reached.

A satisfactory theory should make possible the prediction of new relationships or the forecasting of the results of new experiments under different conditions. The usefulness of the theory lies just in its ability to predict the results of future experiments. The extraordinary accomplishments of the great mathematical physicists in applying Newton's laws to the motions of the heavenly bodies gave scientists of more than a century ago the conviction that all natural phenomena were determined by accurate relations between cause and effect. If the positions, the velocities and the masses of the heavenly bodies were given it was possible to predict with nearly unlimited accuracy the position of the bodies at any future time. The idea of causation, or a necessary relation of cause and effect, has long been embedded in the minds of men. The recognized responsibility of the criminal for his acts, the belief of the value of education, and thousands of words in our language all show how implicitly we believe in cause and effect. The teachings of classical science, that is, the science up to 1900, all seem to reinforce this idea of causation for all phenomena.

Philosophers, considering many fields other than science, were divided in their opinions. Many went so far as to believe that everything was absolutely fixed by the initial conditions of the universe and that free will or choice was impossible. Others thought that cause and effect relations were mere illusions.

From the viewpoint of the early classical scientist, the proper field for science was unlimited. Given sufficient knowledge, all natural phenomena, even hu-



DR. IRVING LANGMUIR

man affairs, could be predicted with certainty. Ampere, for example, stated that if he were given the positions and velocities of all the atoms in the universe it should be possible theoretically to determine the whole future history of the universe. Practically, of course, such predictions would be impossible because we could never hope to get the necessary knowledge nor the time to carry out such elaborate calculations.

A little later scientists developed the kinetic theory of gases according to which the molecules of a gas are moving with high velocity and are continually colliding with one another. They found that the behavior of gases could be understood only by considering the average motions of the individual molecules. The particular motion of a single molecule was of practically no importance. They were thus taught the value of statistical methods, like those which insurance companies now use to calculate the probable number of its policy holders that will die within a year.

The theories or explanations which were developed in connection with the natural laws usually involved a description in terms of some kind of a model. In general, instead of thinking of the whole complex world we select only a few elements which we think to be important and concentrate our minds on these. Thus, the chemist developed the atomic theory according to which matter was made up of atoms of as many different kinds as there are chemical elements. These were thought of as small spheres, but no thought was given as to the material of which they were made. When later theories indicated that these atoms were built up of electrons and positive nuclei this made very little difference to the chemist, for he had not needed previously to consider that aspect of the model.

Material Unimportant

High school boys today are asked to build model airplanes. These must be of such shape that the different types of airplanes can be recognized when the profiles of the models are seen against a white background. It naturally is not particularly important just what kind of material is used in constructing them. Airplane designers build model airplanes to be studied in wind tunnels but these do not need to be provided with motors.

Most of the models which the scientist uses are purely mental models. Thus, when Maxwell developed the electromagnetic theory by which he explained the properties of light he thought of a medium through which these waves travelled. This was called the ether. It was supposed to have properties like those of elastic solid bodies. The reason for this choice of a model was that at that time the average scientist had been taught in great detail the theory of elasticity of solid bodies. Thus the magnetic and electric fields could be understood in terms of the familiar elastic properties. At the present time relatively few students are well trained in the theories of elasticity. The situation is thus reversed and today we explain the properties of elastic solids in terms of the electrical forces acting between their atoms.

Every student of geometry constructs a mental model when he thinks of a triangle. The mathematical lines that bound the triangle are supposed to have no thickness. In other words, they are stripped of any properties except those that we wish particularly to consider.

Equation Is a Model

Most of the laws of physics are stated in mathematical terms, but a mathematical equation itself is a kind of model. We establish or assume some correspondence between things that we measure and the symbols that are used in an equation, and then, after solving the equation so as to obtain a new relation, we see if we can establish a similar correspondence between the new relation and the data obtained from an experiment. If we succeed in this we have demonstrated the power of the mathematical equation to predict events.

The essential characteristic of a model is that it shall resemble in certain desired features the situation that we are considering. On this basis we should recognize that practically any theory has many arbitrary features and has limitations and restrictions imposed by the simplifications that we have made in the development of the theory, or the construction of our model.

Beginning with Einstein's relativity theory and Planck's quantum theory, a revolution in physical thought has swept through science. Perhaps the most important aspect of this is that the scientist has ceased to believe that words or concepts can have any absolute meaning. He is not often concerned with questions of existence, he does not know what is the meaning of the question, "does an atom really exist?". The definition of atom is only partly given in the dictionary. Its real meaning lies in the sum total of knowledge on this subject among scientists who have specialized in this field. No one has been authorized to make an exact definition. Furthermore, we cannot be sure just what we mean even by the word exist. Such questions are largely metaphysical and in general do not interest the modern scientist. Bridgman has pointed out that all concepts in science have value only insofar as they can be described in terms of operations or specifications. Thus, it doesn't mean much to talk about length or time unless we agree upon the methods by which we are to measure length and time.

For many years, up to about 1930, the new physics based on the quantum theory seemed to be fundamentally irreconcilable with the classical physics of the previous century. Through the more recent development of the uncertainty principle, developed by Bohr and Heisenberg, this conflict has now disappeared. According to this principle it is fundamentally impossible to measure accurately both the velocity and the position of any single elementary particle. It would be possible to measure one or the other accurately but not both simultaneously. Thus it becomes impossible to predict with certainty the movement of a single particle. Therefore, Ampere's estimate of the scope of science has lost its basis.

Probability Fundamental Factor

According to the uncertainty principle which is now thoroughly well established, the most that can be said about the future motion of any single atom or electron is that it has a definite probability of acting in any given way. Probability thus becomes a fundamental factor in every elementary process. By changing the conditions of the environment of a given atom, as for example, by changing the force acting on it, we can change these probabilities. In many cases the probability can be made so great that a given result will be almost certain. But in many important cases the uncertainty becomes the dominating feature just as it is in the tossing of a coin.

The net result of the modern principles of physics has been to wipe out almost completely the dogma of causation.

How is it then that classical physics has led to such definite, clean-cut laws? The simplest answer is that the classical physicist naturally chose as the subjects for his studies those fields which prom-

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ised greatest success. The aim of the scientist in general was to discover natural laws. He therefore carried on his experiments in such a way as to find the natural laws, for that is what he was looking for. He was best able to accomplish this by working with phenomena which depended upon the behavior of enormous numbers of atoms rather than upon individual atoms. In this way the effects produced by individual atoms averaged out and became imperceptible. We have many familiar examples of this effect of averaging: the deaths of individual human beings can not usually be predicted, but the average death rate in any age group is found to come close to expectation.

Atom Is Unpredictable

Since the discovery of the electron and the quantum and methods of detecting or even counting individual atoms, it has been possible for scientists to undertake investigations of the behavior of single atoms. Here they have found unmistakable experimental evidence that these phenomena depend upon the laws of probability and that they are just as unpredictable in detail as the next throw of a coin. If, however, we were dealing with large numbers of such atoms the behavior of the whole group would be definitely determined by the probability of the individual occurrence and therefore would appear to be governed by laws of cause and effect.

Just as there are two types of physics, classical physics and quantum physics which have for nearly 25 years seemed irreconcilable, just so must we recognize two types of natural phenomena. First, those in which the behavior of the system can be determined from the average behavior of its component parts and second, those in which a single discontinuous event (which may depend upon a single quantum charge) becomes magnified in its effect so that the behavior of the whole aggregate does depend upon something that started from a small beginning. The first class of phenomena I want to call convergent phenomena, because all the fluctuating details of the individual atoms average out giving a result that converges to a definite state. The second class we may call divergent phenomena, where from a small beginning increasingly large effects are produced. In general then we may say that classical physics applies satisfactorily to convergent phenomena and that they conform well to the older ideas of cause and effect. The divergent phenomena, on the other hand, can best be understood on the basis of quantum theory of modern physics.

Let me give some illustrations of divergent phenomena. The wonderful cloud chamber experiments of C. T. R. Wilson show that a single high speed electron, or an alpha particle from an atom of radium, in passing through a gas leaves a trail of ions. By having moisture in the gas and by causing the gas to expand just after these ions are produced, drops of water are made to condense on the ions. By a strong illumination it thus becomes possible to see or photograph this track of ions as a white line on a dark background. The time at which an alpha particle will be emitted from a radium atom is inherently unpredictable. It would be totally contrary to the teachings of modern physics to suppose that our inability to predict such an event is merely due to our ignorance of the conditions surrounding the particular atom. The uncertainty principle requires that even if these conditions were absolutely fixed the time of emission and the direction of emission of the alpha particle are subject to the laws of chance and thus for a single particle are unpredictable.

May Alter History

The occurrences in the Wilson cloud chamber following the disintegration of a single radium atom are typical divergent phenomena. The single quantum event led to the production of countless thousands of water droplets and these made the track of the alpha particle visible and led to its reproduction in a photograph. This track may show some unusual feature of particular interest to the scientist. For example, it may have a kink which indicates that the alpha particle collided with the nucleus in one of the molecules of gas. The photograph may therefore be published—may start discussions among scientists that involve thousands of man hours—may delay one of them so that he misses a train on which he might otherwise have suffered a fatal accident. Examples of this kind, any number of which could be given, show that it is possible for single unpredictable quantum events to alter the course of human history.

The formation of crystals on cooling a liquid involves the formation of nuclei or crystallization centers that must originate from discrete, atomic phenomena. The spontaneous formation of these nuclei often depend upon chance.

At a camp at Lake George, in winter, I have often found that a pail of water is unfrozen in the morning after being in a room far below freezing but it suddenly turns to slush upon being lifted from the floor.

Glycerine is commonly known as a viscous liquid, even at low temperatures. Yet if crystals are once formed they melt only at 64 degrees F. If a minute crystal of this kind is introduced into pure glycerine at temperatures below 64 degrees the entire liquid gradually solidifies.

During a whole winter in Schenectady I left several small bottles of glycerine outdoors and I kept the lower ends of test tubes containing glycerine in liquid air for days but in no case did crystals form.

My brother, A. C. Langmuir, visited a glycerine refinery in Canada which had operated for many years without ever having any experience with crystalline glycerine. But suddenly one winter, without exceptionally low temperatures, the pipes carrying the glycerine from one piece of apparatus to another froze up. The whole plant and even the dust on the ground became contaminated with nuclei and although any part of the plant could be temporarily freed from crystals by heating above 64 degrees it was found that whenever the temperature anywhere fell below 64 degrees crystals would begin forming. The whole plant had to be shut down for months until outdoor temperatures rose above 64 degrees.

Here we have an example of an inherently unpredictable divergent phenomenon that profoundly affected human lives.

Every thunderstorm or tornado must start from a small beginning and at least the details of the irregular courses of such storms across the country would be modified by single quantum phenomena that acted during the initial stages. Yet small details such as the place where lightning strikes or damage occurs from a tornado may be important to a human being.

Heredity and Evolution

Still more obvious examples of divergent phenomena which affect human life are those involved in the mechanism of heredity and the origin of species. Whether the genes are inherited from the mother or from the father seems to be fundamentally a matter of chance, undoubtedly involving changes in single atoms. It is known definitely that changes in genes or mutations can be produced by X-rays and it has even been proved that a single quantum is sufficient to bring about such an alteration. The growth of any animal from a single cell is a typical illustration of a divergent phenomenon. The origins of species and all evolutionary processes involving as they do natural selection acting upon mutations, must depend at almost every stage upon phenomena which originate in single atoms.

An idea that develops in a human brain seems to have all the characteristics of divergent phenomena. All through our lives we are confronted with situations where we must make a choice and this choice may sometimes alter the whole future course of our lives.

Will Affect Thought

As the implications of the uncertainty principle, especially as applied to divergent phenomena, are more generally recognized the limitation of the idea of causality should have profound effects on our habits of thought. The science of logic itself is involved in these changes. Two of the fundamental postulates of logic are known as the law of uniformity of nature, and the law of the excluded middle. The first of these laws is equivalent to the postulate of causality in nature. The second law is simply the familiar postulate that a given proposition must be either true or false. In the past these so-called laws have formed the basis of much of our reasoning. It seems to me, however, that they play no important part in the progress of modern science. The cause and effect postulate is only applicable to convergent phenomena. The second postulate in assuming that any proposition must be true or false implies that we attach absolute meanings to words or concepts. If concepts have meanings only in terms of the operations used to define them we can see that they are necessarily fuzzy. Take for example this statement, "atoms are indestructible." Is this true or false? The answer depends upon what aspect of atoms is considered. To the chemist the statement is as true as it ever was. But a physicist, studying radioactive changes, recognizes that some atoms undergo spontaneous disintegration or destruction. The fact is that the chemist and the physicist have no exact definitions of the word atom and they also do not know in any absolute sense what they mean by indestructible.

Fortunately such questions no longer occupy much of the time of scientists, who are usually concerned with more concrete problems which they are endeavoring to treat in common sense ways.

It is often thought by the layman, and many of those who are working in so-called social sciences, that the field of science should be unlimited. That reason should take the place of intuition, that realism should replace emotions and that morality is of value only so far as it can be justified by analytical reasoning.

Human affairs are characterized by a complexity of a far higher order than that encountered ordinarily in the field of science.

To avoid alternating periods of depression and prosperity economists propose to change our laws. They reason that such a change would eliminate the cause of the depressions. They endeavor to develop a science of economics by which sound solutions to such problems can be reached.

I believe the field of application of science in such problems is extremely limited. A scientist has to define his problem and usually has to bring about simplified conditions for his experiments which exclude undesired factors. So the economist has to invent an "economic man" who always does the thing expected of him. No two economists would agree exactly upon the characteristics of this hypothetical man and any conclusions drawn as to his behavior are of doubtful application to actual cases involving human beings. There is no logical scientific method for determining just how one can formulate such a problem or what factors one must exclude. It really comes down to a matter of common sense or good judgment. All too often wishful thinking determines the formulation of the problem. Thus, even if scientifically logical processes are applied to the problem the results may have no greater validity than that of the good or bad judgment involved in the original assumptions.

May Have Vital Importance

When we consider the nature of human affairs it is to me obvious that divergent phenomena frequently play a role of vital importance. It is true that some of our historians cynically taught most of our college students from 1925 to 1938 that wars, the rise and fall of nations, etc. were determined by nearly cosmic causes. They tried to show that economic pressure, and power politics on the part of England or France, etc. would have brought the same result whether or not Kaiser Wilhelm or Hitler or any other individual or group of individuals had or had not acted the way they did. Germany, facing the world in a realistic way, was proved, almost scientifically to be justified in using ruthless methods—because of the energy and other characteristics of the German people they would necessarily acquire and should acquire a place in the sun greater than that of England, which was already inevitably on the downward path.

I can see no justification whatever for such teaching that science proves that general causes (convergent phenomena) dominate in human affairs over the results of individual action (divergent phenomena). It is true that it is not possible to prove one way or the other that human affairs are determined primarily by convergent phenomena. The very existence of divergent phenomena almost precludes the possibility of such proof.

The mistaken overemphasis on convergent phenomena in human affairs, and the reliance on so-called scientific methods, has been responsible in large degree for much of the cynicism of the last few decades.

The philosophy which seems to have made the German people such willing aggressors is allegedly based upon scientific realism. Almost any system of morality or immorality could receive support from the writings of Nietzsche, so inconsistent are they with one another. But his teachings, which purport to be based on the laws of natural selection, have led in Germany to a glorification of brute strength, with elimination of sympathy, love, toleration and all existing altruistic emotions.

Darwin, himself, however, recognized that the higher social, moral and spiritual developments of mankind were factors which aided in survival. Natural selection is often referred to loosely as the law of the survival of the fittest. The concept of fitness seems, however, inherently rather fuzzy. Apparently these individuals are fittest which possess characteristics that increase the probability that they shall survive.

Realists' Arguments

We often hear realists deplore the effects of charity which tend to keep the unfit alive. We are even told that the whole course of evolution may be revised in this way. Similar arguments could be used against the surgeon who removes an appendix or a doctor who uses a sulfa drug to cure pneumonia.

But what is the need of developing a race immune to appendicitis or pneumonia if we possess means for preventing their ill effects. The characteristics that determine fitness merely change from those of immunity to those which determine whether a race is able to provide good medical treatment.

The coming victory of the United Nations will prove that survival of the nation may be prevented by an aggressive spirit, by a desire to conquer or enslave the world, or by intolerance, ruthlessness and cruelty. In fact there is no scientific reason why decency and morality may not prove to be vastly more important factors in survival than brutal strength.

Must Plan for Future

In spite of the fact that we can no longer justify a belief in absolute causation and must recognize the great importance of divergent phenomena in human life we still have to deal with causes and effects. After all we must plan for the future. We can do this, however, by estimating probabilities even where we do not believe that definite results will inevitably follow. When our Army lands in North Africa its probable success depends on the carefulness of the preparations and the quality of the strategy. But no amount of foresight can render success absolutely certain.

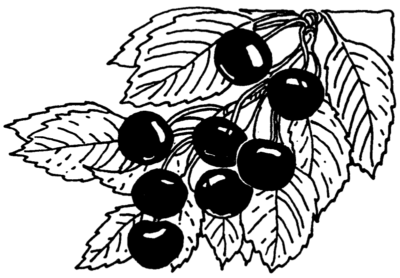
It does not seem to me that we need be discouraged if science is not capable of solving all problems even in the distant future. I see no objection to recognizing that the field of science is limited.

In the complicated situations of life we have to solve numerous problems and make many decisions. It is absurd to think that reason should be our guide in all cases. Reason is too slow and too difficult. We often do not have the necessary data. Or we cannot simplify our problem sufficiently to apply the methods of reasoning. (*turn to next page*)

AGRICULTURE

NATURE RAMBLINGS

by Frank Thone



Oils From Kernels

➤ REMEMBER how you saved prune pits during the first World War? If you were in the Army, you had to, Buddy; the corporal at the end of the mess table saw to that!

It looks now as if fruit pits and stones are going to be put to use again, though in a different way and for another purpose. What they wanted, back in 1917-18, was the shells, for gas mask charcoal. They have plenty of that now.

What's wanted in this new World War are the kernels within the pits, for the oil they contain. Such special oils as sweet almond oil, formerly imported, are on the list of war shortages now, and the oils from apricot, peach and cherry kernels resemble this rather closely. Prune-kernel oil would do nicely, too, but not many prunes are pitted at the processing plants.

It is not likely that housekeepers, restaurant owners and mess officers will be asked to save fruit pits this time. It is easier and far less expensive to go to the concentrated, quantity sources, the canneries and fruit-drying plants, where fruit pits have long been a useless waste, fit only for burning under the boilers. In normal times, the expense of cracking the pits and extracting and refining the oils has been too great, but with the price of oils much higher it seems worth while to install the necessary machinery.

Another source of vegetable oil that is recommended for industrial attention is the avocado. This fatty fruit has been steadily gaining in favor during recent decades, but as yet there is no really good, paying outlet for the disposal of culls and damaged fruits. Avocado oil is very much like olive oil in quality and flavor. Incidentally, despite the large quantities of olives raised in the West, domestic olive oil has never supplied more than 5% of the American market.

So-called rice bran oil has also received comparatively little attention. If ways can be found to prevent it from turning rancid, it has possibilities, Department of Agriculture chemists say, as a substitute for the now scarce vitamin-rich sardine oil in animal feeds.

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What then must we do? Why not do what the human race always has done—use the abilities we have—use common sense, judgment and experience. We often underrate the importance of intuition.

In almost every scientific problem which I have succeeded in solving, even those that have involved days or months of work, the final solution has come to my mind in a fraction of a second by a process which is not consciously one of reasoning. Such intuitive ideas are often wrong. The good must be weeded out from the bad—sometimes by reasoning. The power of the human mind is far more remarkable than one ordinarily thinks. We can often size up a situation, or judge the character of a man by the expression of his face or by his acts in a way that would be quite impossible to describe in words.

People differ greatly in their ability to reach correct conclusions by such methods. Our superstitions and the present popularity of astrology prove how often our minds make blunders. Since we have to live with our minds, however, we should train them, develop them, censor them—but let us not restrict them by trying to regulate our lives solely by science or by reason.

Our morality is a kind of summation of the wisdom and experience of our race. It comes to us largely through tradition or religion. Some people justify evil things on the basis of morality—but by and large a recognition of right and wrong, even if these concepts are sometimes fuzzy, has proved to be of incalculable value to mankind. The philosophical, metaphysical or even scientific analysis of the principles of ethics has not proved particularly fruitful. A sense of morality and decency, although not scientific, may be a major factor in winning the war.

Science News Letter, January 2, 1943