living reagents may differ in their physiological responses has often led to conflicting results of different investigators, as well as of a single investigator, when working with the same species.

When results are easily evaluated, over-refinement in an experiment may be a waste of time, but it is well to recognize the sources of error before making short cuts in methods. It will probably be safer in starting an elaborate experiment to use pure chemicals and comparable biological material.

In plants, genetically comparable material may be secured by using cuttings of a single individual, or relatively pure races may be obtained by selfing for a few generations. With animals having biparental reproduction, purification of races is difficult. By continued brother to sister matings, however, strains can be isolated incomparably better adapted to experimental purposes than the ordinary run of laboratory animals. Such inbreeding of mice, for example, has led to the isolation of races differing markedly in susceptibility to inoculated and to spontaneous tumors. Medical investigators as a class seem only just beginning to realize the value of the genetic view-point. Perhaps of more value to the medical profession than another endowment for cancer research would be an international institute for the breeding of purified races of rats, mice, guinea-pigs and other biological test material. Investigators in different parts of the world might then have available a source of comparable living reagents.

In man, our worst experimental animal, such purification is impractical. Identical twins we have suggested as the only source of really comparable material in the human race, but their use for experiments is limited. In human experiments, in which controls are most needed, it is most difficult to get comparable material. In human problems, therefore, dependence is unavoidedly placed upon the dangerous methods of random sampling and statistical treatment and conclusions are often drawn from data which, with forms better adapted to experimentation, would be considered inadequate. It should not be forgotten, however, that the mathematical reliability of conclusions bears no relation to the difficulty in securing adequate data.

We have given an all too inadequate presentation of the need of the genetic view-point in the street and in the biological laboratory, and have pointed out how common has been its lack even in high places. We have reached the point in our discussion at which to inquire what we are going to do about it.

In research, a blending of view-points in cooperative investigations suggests itself as a remedy. The geneticist may find he receives more than he contributes in such cooperation.

For the oncoming generation we can strive to strengthen the genetic education. It seems difficult for one to come to think in terms of the genetic view-point without actually following the shuffling of genes in breeding experiments. We may not succeed in convincing our educational administrators that laboratory work is as much needed in genetics as in chemistry. We can at any rate encourage the growing of Drosophila and to this end might bring political pressure to bear to lower the duty on bananas.

In stressing the shortcomings in other fields of labor, my voice may sound like the voice of a preacher. I have tried, however, to follow the lines of least resistance and at the same time of greatest efficiency. We know more about the faults of others than of ourselves. If we were able to view ourselves from a distance and there were unlimited time, we might relate some of our own sins and give advice to geneticists. The pleasure of giving advice to geneticists, however, can more profitably be left to a later speaker who is not a geneticist. Advice, you know, is a commodity which it is more blessed to give than to receive.

In conclusion, we feel justified in believing the genetic view-point, with all that it implies, is the most important biological contribution of the nineteenth and twentieth centuries. It is still broadening its scope and influence, but even now it has within it the power to change profoundly our philosophy of everyday life. In any program for the salvation of the future of the human race, it will be necessary to have the genetic view-point somewhere in the formula.

# AN OPTIMISTIC VIEW OF THE EVOLUTION OF THE SCIENCES[1]

By Dr. VIRGIL F. PAYNE
PROFESSOR OF CHEMISTRY, TRANSYLVANIA COLLEGE

THE American Association for the Advancement of Science has fifteen sections devoted to the activities of specific science or related groups. Science has been defined as accumulated and accepted knowledge which has been systematized and formulated with reference to the discovery of general truths or the operation of general laws. In this sense a specific science is any

[1] Address of the president of the Kentucky Academy of Science read on April 3 at a joint meeting of the Ohio, Indiana and Kentucky Academies.

branch or department of systematized knowledge considered as a distinct field of investigation or object of study. If we accept this definition the fifteen sections are in reality science sections. In fact, standard dictionaries define all the fields of knowledge represented as sciences except history, and the association itself has designated section "L," historical and philological sciences. This broad view of science and the sciences is the one accepted for the present purpose.

While many fields of knowledge are accepted as sciences, only physics, chemistry, biology, psychology, sociology and economics will be taken as illustrations. For our purpose physics is defined as that branch of science dealing with those phenomena of inanimate matter involving no change in chemical composition. From the view-point of the complexity of original subject-matter physics may be considered the simplest of the sciences mentioned. No doubt, due to this simplicity and the availability of its materials, physics was one of the first bodies of knowledge to be accepted as a science.

Chemistry is defined as the science that treats of the composition of substances, and the transformations which they undergo. Since chemistry involves transformations in the inanimate matter of physics, it is to that extent a more involved science. It was as a consequence accepted later as a field of knowledge worthy of the efforts of scholars and as a suitable subject for students. In the sense that art relates to something to be done in contrast to science as something to be known, the art period of alchemy made its contribution to modern chemistry. Likewise the periods of iatrochemistry and of phlogiston made contributions. However, we trace our modern chemistry back more definitely to the work of Lavoisier.

Biology is the science of life; the branch of knowledge which treats of organisms. As such, biology involves more intricate and elusive subject-matter than do physics and chemistry. On account of the difficulties involved in establishing controls and in accumulating tested knowledge the workers in the simpler sciences are prone at times to deny the biologist unqualified admission to the science fraternity. The value of biology and the perseverance and caution of its workers have, however, long since resulted in the establishment of a science of biology with its various branches.

Psychology is the science of mind; systematic knowledge and investigation of the genesis, powers and functions of mind. Just as biology is considered more involved than physics or chemistry so in turn psychology in its pursuit of knowledge of the consciousness of life has had more difficulty in finding its place as a science. The techniques involved in the study of psychology differ so markedly from those associated with the measuring instruments of physics, the balance in chemistry, and the microscope in biology that we should not be surprised. The fact that the psychologists are so divided by their theories has been a factor in their tardy acceptance. In spite of the reluctance of the older sciences, psychology has now been generally accepted.

Sociology is defined as the science of the constitution, phenomena and development of society. Sociology involves the complexities of life and consciousness with all the added difficulties in adjustment attending the interplay of conscious life in groups of various sizes. Many thinkers maintain that sociology can never be a science but since the time of Comte the claim for this right has made progress. The greatest difficulty individual scientists have is in the recognition of the worth of techniques of scientists in other fields. The statistical method of sociology with its use of the expression, probability, is almost too much for the older sciences.

Economics is the science that investigates the conditions and laws affecting the production, distribution, and consumption of wealth. This science is included not so much because of a logical place in the order of complexity of the other sciences named but more on account of its timely interest. We may judge from the present condition of the world that there is no true science of economics or that the best economists are not trusted and such scientific knowledge as exists is not practiced. This conclusion is obvious in spite of the slowly accumulated and tested knowledge since the writings of Adam Smith in 1776.

It is difficult to divide the sciences into sub-groups. We may call physics and chemistry physical sciences, and the others considered biological and social sciences. For the present purpose the older and more commonly accepted sciences of physics, chemistry and biology will be referred to as exact or material sciences, and, the newer and more reluctantly accepted, psychology, sociology and economics will be referred to as social sciences.

A mixture of extravagant praise and equally bitter condemnation has been heaped upon these and other material sciences. These sciences have been commended as making possible the material advantages of our present civilization. They have been blamed for contributing to an increasing disregard for the accepted social values. This machine age has had to face the anomalous charge of bringing hunger to many because of an over-production of food and of depriving many people of the very benefits of the age because too many of these benefits had been produced. It seems only fair to assume that the material sciences have been working effectively and have the power to do much more. They have indeed made possible our material civilization and, in fact, also

they make possible the very best social civilization. By them all the necessities and the luxuries are produced with an average individual expenditure of time that allows leisure for transforming the social studies into real sciences.

Our hope then seems to lie not in decreased interest in the material sciences but in using the leisure afforded by them in perfecting the social sciences. We now have much more tested knowledge in psychology, sociology and economics than we are using. We may reasonably hope that intensive, continued research in these fields, equivalent to that given in the past to the material sciences, may produce comparable results. Confidence in the work of the social scientists should result in the establishment of a social order respected and observed by an improved race of people. The economist and sociologist may expect to assume the burden of so organizing society that it would be impossible for over-production and want to exist simultaneously on the earth. Under such an economic and social system everyone may be profitably engaged as producer, investigator or subject of investigation. In our present system a severe migraine headache has qualified one man for profitable employment as a research subject. The social scientists are ready to assume their responsibilities and the next step is to train a generation that will turn as readily to them for guidance in these fields as the present generation depends on the physicist, the chemist and the biologist. Because of the sobering influence of such a responsibility we need have little fear of extravagance of promise or action.

The accepted sciences may do well to drop their double standard of viewing one group of sciences as exact and another as inexact. They should lead in the unqualified acceptance and encouragement of the social sciences. The physicist and chemist deal with 25,000,000,000,000,000,000 molecules per cubic centimeter of gas or 33,667,000,000,000,000,000,000 molecules of water per cubic centimeter. They do not face all the hazards the sociologist encounters in individual differences of human beings in a small community. The physicist and chemist, in particular, should be very tolerant of the efforts of the sociologist to determine the statistical significance of the different phenomena observed in small populations.

If our social order is to come under the dominant influence of science it seems worth while to consider what will happen to some of the arts that have concerned themselves with society. The oldest and most highly respected of these arts is religion. We have in this art to deal with elements of belief, faith and prejudice which seem diametrically opposed to the principles of caution, control and tests in science. However, in 1873 F. Max Muller had written an "Introduction to the Science of Religion." We may hope that religion may eventually be saved for a scientific age by the acceptance of the method of science.

What attitude are we to take concerning the conflicts of theories in the social sciences? We must follow the plan we have always used in the older sciences. The conflicts must serve as a stimulus to more intense and exhaustive research. The conflicting doctrines in science have almost invariably resulted in bitterness—also a great amount of experimental study. It is not possible to condemn too heartily the attitude of the chemist who would get the camel through the eye of the needle by dissolving him in nitric acid and then using a squirt gun.

Finally, a word of caution seems appropriate. Should we displace entirely an old established art such as religion because it involves some unscientific principles and practices? No more should we discard this art than that of pottery-making while we are developing a science of ceramics. The vessel of the pottery craftsman may be crude. It may contain unnecessary ingredients; some very valuable ingredients may have been omitted, but if it makes a satisfactory container it has served a useful purpose. Certainly if perishable and necessary goods are being produced the industry should not be closed over a long period for repairs and remodelling. It has long been held that religion is such an enterprise. Furthermore it is worth while to be reminded again that our oldest sciences such as chemistry and astronomy were preceded by the arts, alchemy and astrology. When we feel most certain that we have found the final solution we may well recall Oliver Cromwell's exhortation, "My brethren, by the bowels of Christ I beseech you, bethink you that you may be mistaken."

# OBITUARY

## RAOUL GAUTIER

PROFESSOR RAOUL GAUTIER died at his home in Geneva, Switzerland, on April 19, 1931. He was vice-president of the International Geodetic Association of the International Geodetic and Geophysical Union. At the end of 1927, when he retired from the position which he had so long filled as director of the Astronomical Observatory of Geneva, Switzerland, the Conseil d'Etat of the Canton of Geneva conferred on him the titles of honorary professor of the University of Geneva and of honorary director of the Observatory. Previous to his retirement he