Comments and Communications

The Study of Disordered Systems

The communication of A. G. Huntsman with regard to "Scientific Research vs. the Theory of Probabilities" (*Science*, 1949, **110**, 566) is interesting indeed, though the subject discussed there is in need of a more complete exposition than he has provided. It is certainly true, in a sense, that mathematicians have gained a great deal of prestige, often even in the eyes of the biological scientists that Dr. Huntsman represents, but it is greatly to be questioned that this is entirely the result of their being able to command something like mystified awe from their admirers rather than that they have been able many times to light a way through problems that would have remained inscrutable without their help.

There is certainly no need to justify the construction of a concept of perfect disorder for the purpose of dealing with some of the problems of modern physics and chemistry, or to justify the development of probability theory as a branch of pure mathematics. The results speak for themselves. To compare the states of physics before and after Maxwell, or of the theory of errors before and after such mathematicians as Khintchine and Kolmogoroff, is to be convinced that indeterminability, i.e., ignorance, can be dealt with in precise terms, and the process made to yield intelligible and useful results. However, in the science of biology, which does not yet share either the philosophical attitudes of the other natural sciences (see, for example, the confused atmosphere of du Noüy's *Human Destiny*) or their ability to manipulate their problems symbolically and thus to maintain a nice balance between the experimental and theoretical parts of investigation, it is still an acceptable habitus to be frightened by the strange world of mathematical operations, seeing in them only complexity where there is really preciseness and simplicity.

It may be epigrammatic to say that the theory of probability permits the exact systematization of ignorance, but it is also quite misleading. By means of a particular calculus, the theory of probability, or the theory of random processes, disordered systems can be specified with the same degree of precision as ordered systems; it is simply obscuring the intent of this viewpoint to erect the dichotomy "ordered systems vs. disordered systems equals knowledge vs. ignorance." The conclusion that actuarial tables are useless because they are unable to predict the day on which a particular person will die is based upon a failure to recognize the restrictions that the theory of probability has freely and necessarily placed upon itself. It is sufficient to observe here that the insurance companies continue to earn money in spite of these difficulties. In yielding generalities of steadily increasing inclusiveness, consistent with the results of experimentation, as it has so eminently done, the study of disordered systems has written its own *raison d'être*.

It is the belief of the writer that the mistrust of a statistical viewpoint (and to some extent the mistrust of mathematics as a tool in biology) arises not so much from the difficulties involved in replacing an older notion of a one-to-one correspondence between cause and effect, or even of causality itself, with one of chance determination of events, as rather from the difficulty of erasing entirely the older notion of causality and not attempting to replace it with any equivalent idea, counting ourselves lucky to have removed a barrier to intellectual and scientific progress. In fact, it might almost be said that the concept of causality itself is a sort of philosophic dodge, a symbol without a referent, a semantic chimaera that has seated itself so firmly in our intellectual tradition that it can now be dislodged only with great difficulty.

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The inadequate logic of A. G. Huntsman's argument embodied in his letter "Scientific Research vs. the Theory of Probabilities" (*Science*, 1949, **110**, 566) will be obvious to all those who have had even an elementary training in the applications of probability in scientific research, but for the benefit of beginners it may be advisable to point these out. The principle of his criticism seems to be that statistical laws with reference to populations are of no scientific value because they do not accurately predict what will happen to any particular individual. This amazing statement is supported by two examples—Dr. Huntsman was himself refused life insurance over twenty years ago, and a friend of his was accepted for life insurance in the morning and died going upstairs in the afternoon. Anyone in his right senses who wishes to know how long he can expect to live, will consult his doctor rather than a life insurance table. The life insurance company is not concerned with the individual as such, but only with what will happen to the population as a whole. Is the conclusion respecting the population, which is of acknowledged accuracy, any less scientific because it does not concern itself with the future of a particular individual?

Dr. Huntsman expresses a basic objection to the use of probability methods. To quote from his letter:

> The biologist's greatest gift from mathematics might well be, not a theory that may delude him into belief that he is wise when he is ignorant, but rather the ideal of clear definition and precise use of his terms and symbols, not excepting science and research.

It is clear, again, that a statistical law stating a characteristic of a population as a whole is regarded as ignorance merely because it fails to make an accurate statement with respect to a particular individual, and the poor biologist or physicist is deluded by the mathema-

tician into thinking he is wise when he is really ignorant. This statement sets one to wondering who is really ignorant. Can it be that there are leading biologists in Canada who are not aware of the tremendous progress made in recent years in the fields of physics, physical chemistry, and applied mathematics, wherein the laws discovered are essentially statistical in that they deal with the average behavior of units of matter and fail completely to describe or predict the behavior of an individual unit? To take a very familiar example, laws have been discovered dealing with the natural distintegration of radioactive materials. By means of these laws the half-life of a piece of radium can be accurately predicted, but no physicist can point to an individual atom and make any prediction as to when it will disintegrate. Possibly all knowledge of fundamental things must be expressed eventually in terms of probability. In this field scientists are coming closer and closer to a knowledge of the ultimate. As they approach this end they can be assured by Dr. Huntsman that they will be approaching the acme of total ignorance.

In biology the application of mathematical methods and in particular probability methods is indeed increasing. Biologists are delving into fields of research where variability exists, and in order to derive order out of chaos they must deal with population trends rather than the behavior of an individual toad, say, which may or may not be characteristic of the population to which it belongs. I take violent objection to Dr. Huntsman's statement that "there is an increasing tendency to force use of the theory of probabilities upon those engaged in scientific research." There are still a great many problems to be solved in those fields where results are often clear-cut and obvious, and there is no quarrel with those who wish to stay in this narrow field and content themselves with the solution of problems of this type, but the more advanced thinkers should not be retarded in their development by such superficial criticism of their mode of action. The entomologist wants to know what happens to a given population of insects when a predator moves in. Is it not rather childish to say that he is not being scientific unless he wants to know what will happen to a particular insect? The plant pathologist is concerned with the balance between populations of plants and disease organisms. All the preliminary and more elementary phases of the relation between the plant and the organism under given conditions have probably been worked out, but this still does not provide the answer to the question as to what will happen in nature.

Predictions of a statistical nature about populations as a whole may be of much greater importance than those concerned with individuals. Even in the human field it is clear that accurate predictions with respect to a given individual (actually impossible because of difficulty of predicting his future environment) are of far less value to the human race, than predictions dealing with the population as a whole. Whether or not such prediction methods are worthy subjects of scientific research, or merely an acknowledgment of ignorance, can very easily be left to the discretion of the average research worker.

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May I, at this late date, be allowed to comment on A. G. Huntsman's letter (*Science*, 1949, **110**, 566), which has only now come to my notice? It will be limited comment, confined to those parts I understand, because some parts, for instance the statement "The prestige of mathematics is so great that many persons forget that even in mathematical hands, *probability, chance,* and *random* mean ignorance," are on a semantic plane beyond my reach.

However, I take it that the nub of Dr. Huntsman's plaint is this: That the use of the theory of probability to handle aggregates blinds the researcher to his proper task of investigating the behavior of individuals. Perhaps the best rejoinder is simply that studies of aggregates and individuals are complementary. This notion is indeed an implicit *sine qua non* of the work of all good scientists—including those who, like Dr. Huntsman, outwardly assert that it involves an antilogy. Was Clerk Maxwell wrong to develop the kinetic theory of gases before a thorough investigation of molecular behavior had been carried out? Does the solvency of life insurance companies inhibit medical research in diagnosis and prognosis? Is the zoologist working on a rat contributing more to the corpus of scientific knowledge than the epidemiologist working on the correlation between rat population and typhus? These are the kinds of questions to be mulled over by Dr. Huntsman and anyone who shares his views.

Finally, it is to be remembered that the distinction between aggregates and individuals is in some respects a convenient fiction. If we abandon the study of disease statistics in favor of the study of single cases, so might we abandon the study of what the pathological organisms cause en masse in a particular case in favor of the study of individual organisms. Now, organisms contain aggregates of cells, cells of molecules, molecules of atoms. . . . I seem to recall a rhyme about big fleas and little fleas—composed, be it noted, by a mathematician.

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