TEXTS AND MOTIFS

For the philosopher, the problem of evidence divides into two. One great question is: what can be taken as the indisputable, or least disputable, data from which inference about matters of fact may safely start? This question belongs officially to epistemology or theory of knowledge, where at present the technical results on the point are so numerous that, for ordinary purposes, they amount to no results at all—except that contemporary writers are dissatisfied with the belief prevalent in the last two centuries that the ultimate data are phenomena of individual consciousness which are known directly and unmistakably.

The other main question is: assuming that we do have reliable data, what specific sorts of them will provide grounds for valid inference to what sorts of conclusions? Systematic answers to this will enable us both to choose the right conclusions on the basis of given evidence, and to look for the right evidence to decide among moot conclusions. Roughly, they are the province of inductive logic, which is still an extraordinarily amorphous discipline. No one has grasped its purpose better, or pursued it more single-mindedly, than William Stanley Jevons (1835-1882), philosopher, logician, and political economist at the Universities of Manchester and London. And probably no one else has combined so thorough a familiarity with pertinent philosophical tradition and the elements of the old textbook logic (his *Elementary Lessons in Logic* was the favorite primer of the subject down to the last decade or two), and so encyclopedic a knowledge of scientific materials, with so much competence in the special logic of the latter. He was a pioneer in deriving the rules of induction from the rules of probability and these from the principles of deductive logic, introducing the combinatorial method recently employed by Rudolf Carnap in *Logical Foundations of Probability* (1950), and he developed a symbolic calculus and constructed a "logical machine" rudely anticipatory of the binary operations of modern computers.

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Donald C. Williams

W. S. Jevons: "Principles of Science"

It may be truly asserted that the rapid progress of the physical sciences during the last three centuries has not been accompanied by a corresponding advance in the theory of reasoning. Physicists speak familiarly of Scientific Method, but they could not readily describe what they mean by that expression. Profoundly engaged in the study of particular classes of natural phenomena, they are usually too much engrossed in the immense and ever-accumulating details of their special sciences, to generalize upon the methods of reasoning which they unconsciously employ. Yet few will deny that these methods of reasoning ought to be studied, especially by those who endeavour to introduce scientific order into less successful and methodical branches of knowledge.

The application of Scientific Method cannot be restricted to the sphere of lifeless objects. We must sooner or later have strict sciences of those mental and social phenomena, which, if comparison be possible, are of more interest to us than purely material phenomena. But it is the proper course of reasoning to proceed from the known to the unknown—from the evident to the obscure—from the material and palpable to the subtle and refined. The physical sciences may therefore be properly made the practice-ground of the reasoning powers, because they furnish us with a great body of precise and successful investigations. In these sciences we meet with happy instances of unquestionable deductive reasoning, of extensive generalization, of happy prediction, of satisfactory verification, of nice calculation of probabilities. We can note how the slightest analogical clue has been followed up to a glorious discovery, how a rash generalization has at length been exposed, or a conclusive *experimentum crucis* has decided the long-continued strife between rival theories.

In following out my design of detecting the general methods of inductive investigation, I have found that the more elaborate and interesting processes of quantitative induction have their necessary foundation in the simpler science of Formal Logic. The earlier, and probably by far the least attractive part of this work, consists, therefore, in a statement of the so-called Fundamental Laws of Thought, and of the all-important Principle of Substitution, of which, as I think, all reasoning is a development. The whole procedure of inductive inquiry, in its most complex cases, is foreshadowed in the combinational view of Logic, which arises directly from these fundamental principles.[1]

ALL knowledge proceeds originally from experience. Using the name in a wide sense we may say that experience comprehends all that we *feel*, externally or internally—the aggregate of the impressions which we receive through the various apertures of perception—the aggregate consequently of what is in the mind, except so far as some portions of knowledge may be the reasoned equivalents of other portions. As the word experience implies, we *go through* much in life, and the impressions gathered intentionally or unintentionally afford the materials from which the active powers of the mind evolve science.

No small part of the experience actually employed in science is acquired without any distinct purpose. We cannot use the eyes without gathering some facts which may prove useful. Every great branch of science has generally taken its first rise from an accidental observation . . . ; but one accidental observation well used may lead us to make thousands of observations in an intentional and organized manner, and thus a science may be gradually worked out from the smallest opening.

It is usual to say that the two modes of experience are Observation and Experiment. When we merely note and record the phenomena which occur around us in the ordinary course of nature we are said *to observe*. When we change the course of nature by the intervention of our will and muscular powers, and thus produce unusual combinations and conditions of phenomena, we are said *to experiment*. Sir John Herschel has justly remarked that we might properly call these two models of experience *passive and active observation*.[2]

The fundamental action of our reasoning faculties consists in inferring or carrying to a new instance of a phenomenon whatever we have previously known of its like, analogue, equivalent, or equal. . . . The great difficulty of reasoning doubtless consists in ascertaining that there does exist a sufficient degree of likeness or sameness to warrant an intended inference; and it will be our main task to investigate the conditions under which the inference is valid. In this place I wish to point out that there is something common to all acts of inference however different their apparent forms.[3]

The processes of inference always depend on the one same method of substitution; but they may nevertheless be distinguished according as the results are inductive or deductive. As generally stated, deduction consists in passing from more general to less general truths; induction is the contrary process from less to more general truths. We may however describe the difference in another manner. In deduction we are engaged in developing the consequences of a law or identity. We learn the meaning, contents, results or inferences, which attach to any given proposition. Induction is the exactly inverse process. Given certain results or consequences, we are required to discover the general law from which they flow.

In a certain sense all knowledge is inductive. We can only learn the laws and relations of things in nature by observing those things. But the knowledge gained from the senses is knowledge only of particular facts, and we require some process of reasoning by which we may construct out of the facts the laws obeyed by them. Experience gives us the materials of knowledge: induction digests those materials, and yields us general knowledge. Only when we possess such knowledge, in the form of general propositions and natural laws, can we usefully apply the reverse process of deduction to ascertain the exact information required at any moment. In its ultimate origin or foundation, then, all knowledge is inductive—in the sense that it is derived by a certain inductive reasoning from the facts of experience.

But it is nevertheless true—and this is a point to which insufficient attention has been paid—that all reasoning is founded on the principles of deduction. . . . *Induction is really the inverse process of deduction.* There is no mode of ascertaining the laws which are obeyed in certain phenomena, except we previously have the power of determining what results would follow from a given law. Just as the process of division necessitates a prior knowledge of multiplication, or the integral calculus rests upon the observation and remembrance of the results of the differential calculus, so induction requires a prior knowledge of deduction.[4]

It must be allowed that in logic inductive investigations are of a far higher degree of difficulty, variety, and complexity than any questions of deduction; and it is this fact no doubt which has led some logicians to erroneous opinions concerning the exclusive importance of induction. . . . The truths to be ascertained are more general than the data from which they are drawn. The process by which they are reached is *analytical,* and consists in separating the complex combinations in which natural phenomena are presented to us, and determining the relations of separate qualities. Given events obeying certain unknown laws, we have to discover the laws obeyed. Instead of the comparatively easy task of finding what effects will follow from a given law, the effects are now given and the law is required. We have to interpret the will by which the conditions of creation were laid down.[5]

I HOLD that, in all cases of inductive inference, we must invent hypotheses, until we fall upon some hypothesis which yields deductive results in accordance with experience. Such accordance renders the chosen hypothesis more or less probable, and we may then deduce, with some degree of likelihood, the nature of our future experience, on the assumption that no arbitrary change takes place in the conditions of nature.[6]

As DEDUCTIVE reasoning when inversely applied constitutes the process of induction, so the calculation of probabilities may be inversely applied; from the known character of certain events we may argue backwards to the probability of a certain law or condition governing those events.[7]

THE inverse application of the rules of probability entirely depends upon a proposition which may be thus stated, nearly in the words of Laplace.[8] *If an event can be produced by any one of a certain number of different causes, the probabilities of the existence of these causes as inferred from the event, are proportional to the probabilities of the event as derived from these causes.* In other words, the most probable cause of an event which has happened is that which would most probably lead to the event supposing the cause to exist; but all other possible causes are also to be taken into account with probabilities proportional to the probability that the event would have happened if the cause existed. . . .

We may thus state the result in general language. If it is certain that one or other of the supposed causes exists, the probability that any one does exist is the probability that if it exists the event happens, divided by the sum of all the similar probabilities. There may seem to be an intricacy in this subject which may prove distasteful to some readers; but this intricacy is essential to the subject in hand. No one can possibly understand the principles of inductive reasoning, unless he will take the trouble to master the meaning of this rule, by which we recede from an event to the probability of each of its possible causes.

This rule or principle of the indirect method is that which common sense leads us to adopt almost instinctively, before we have any comprehension of the principle in its general form. It is easy to see, too, that it is the rule which will, out of a great multitude of cases, lead us most often to the truth. . . .

In many cases of scientific induction we may apply the principle of the inverse method in a simple manner. If only two, or at the most a few hypotheses, may be made as to the origin of certain phenomena, or the connection of one phenomenon with another, we may sometimes easily calculate the respective probabilities of these hypotheses. It was thus that Professors Bunsen and Kirchhoff established, with a probability little short of certainty, that iron exists in the sun. On comparing the spectra of sunlight and of the light proceeding from the incandescent vapour of iron, it became apparent that at least sixty bright lines in the spectrum of iron coincided with dark lines in the sun's spectrum. . . . Coincidence in the case of each of the sixty iron lines is a very unlikely event if it arises casually. . . . The odds, in short, are more than a million million millions to unity against such casual coincidence. But on the other hypothesis, that iron exists in the sun, it is highly probable that such coincidences would be observed. . . . Hence by our principle it is immensely probable that iron does exist in the sun. . . .

A good instance of this method is furnished by the agreement of numerical statements with the truth. Thus, in a manuscript of Diodorus Siculus, as Dr. Young states, the ceremony of an ancient Egyptian funeral is described as requiring the presence of forty-two persons sitting in judgment on the merits of the deceased, and in many ancient papyrus rolls the same number of persons are found delineated. The probability is but slight that Diodorus, if inventing his statements or writing without proper information, would have chosen such a number as forty-two, and though there are not the data for an exact calculation, Dr. Young considers that the probability in favour of the correctness of the manuscript and the veracity of the writer on this ground alone, is at least 100 to 1.[9]

As BUTLER truly said, "Probability is the very guide of life." Had the science of numbers been developed for no other purposes, it must have been developed for the calculation of probabilities. . . . In spite of its immense difficulties of application, and the aspersions which have been mistakenly cast upon it, the theory of probabilities, I repeat, is the noblest, as it will in course of time prove, perhaps the most fruitful branch of mathematical science. . . . The grand object of seeking to estimate the probability of future events from past experience, seems to have been entertained by James Bernouilli and De Moivre, at least such was the opinion of Condorcet; and Bernouilli may be said to have solved one case of the problem. The English writers Bayes and Price are, however, undoubtedly the first who put forward any distinct rules on the subject. Condorcet and several other eminent mathematicians advanced the mathematical theory of the subject; but it was reserved to the immortal Laplace to bring to the subject the full power of his genius, and carry the solution of the problem almost to perfection. It is instructive to observe that a theory which arose from the consideration of the most petty games of chance, the rules and the very names of which are in many cases forgotten, gradually advanced, until it embraced the most sublime problems of science, and finally undertook to measure the value and certainty of all our inductions.[10]

REFERENCES

1. W. S. Jevons, *Principles of Science* (New York: Macmillan and Company, Ltd., St. Martin's Press, 1874), pp. v-vi.
2. *Ibid.*, Vol. II, pp. 1-20.
3. *Op. cit.*, Vol. I, p. 11.
4. *Ibid.*, pp. 13-15.
5. *Ibid.*, pp. 139-140.
6. *Ibid.*, p. 262.
7. *Ibid.*, p. 276.
8. *Mémoires par divers Savans,* Tome VI; quoted by Todhunter in his *History of Theory of Probability*, p. 458.
9. Jevons, *op. cit.*, Vol. I, pp. 279-284.
10. *Ibid.*, pp. 224, 248, 302.