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Induction

INTRODUCTION

As the list of Additional Readings indicates, the theory of induction falls within the province of logic and is part of the logician's concern with the methods of inference or reasoning employed in the sciences. The great controversies about induction seem to be of relatively recent origin in the history of logic, beginning perhaps with the argument between William Whewell and J. S. Mill over the contributions of reason and experience to the inductive process. Later in the 19th century and in our own time, writers like W. E. Johnson and John Maynard Keynes, Bertrand Russell and Jean Nicod, who present different formulations of inductive inference, call attention to the unsolved problems with which any theory is left. They underline the assumptions that seem to be unavoidable in any statement of the formal conditions which validate the so-called "inductive leap"—the jump from observed particulars to general truths, truths having a wider generality than the particular evidences from which they are drawn or on which they are based.

The problem of induction, in anyone's version of it, is the problem of generalization. This may involve psychological questions about how the mind generalizes from experience. But however they are answered, the basic logical questions remain substantially unaltered. By what criteria is valid distinguished from fallacious induction? Can induction be secured from error by rules of inference? Is induction indispensable in the development of scientific knowledge, or is there, as Whewell, for example, suggests, a sharp distinction between the inductive and the deductive sciences?

What is the relation of induction to deduction? Is it the relation of a method of discovery to a method of demonstration or proof? Is it a relation between two modes of reasoning, both of which can be formulated as processes of proof? Is there both an inductive and a deductive type of syllogism, or is induction the very opposite of all forms of reasoning and proof?

It is with these last questions that the discussion of induction begins in the great books, especially in Aristotle's *Organon* and Francis Bacon's *Novum Organum*, but also in the writings of Descartes and Locke, and in observations on scientific method by Newton, Harvey, and Pascal. Though many of the controversies and problems which become central in the 19th century do not appear explicitly in the earlier tradition, they are anticipated by the fundamental distinctions and issues which can be found in the earlier writers.

Bacon's dissatisfaction with Aristotle, for example, leads him to formulate specific rules for induction. Going further in the same general direction, Mill later develops his elaborate theory of inductive inference. We move in the opposite direction if we are guided by Aristotle's distinction between scientific and dialectical induction and by his way of setting induction off as the very opposite of reasoning. The question then arises whether Bacon and Mill are treating induction in all or in only one of several quite distinct senses.

As the chapter on Logic indicates, the names of Aristotle and Bacon are sometimes used as the symbols of opposed tendencies in logic. The one is supposed to represent an almost exclusive emphasis on deduction, the other the primacy and importance of induction. An

opposition between Aristotle and Bacon is also implied in the current use of such phrases as "inductive logic" and "deductive logic." These phrases are sometimes used to suggest that the inductive or the deductive process can be favored to the exclusion, or at least the subordination, of the other. Such understanding of the matter usually includes the popular notion that induction is always reasoning from particulars to universals and deduction always reasoning from universals to particulars.

But none of these things seems to be true, or at least not without serious qualification. Neither Aristotle nor Bacon emphasizes deduction or induction to the exclusion of the other. On the contrary, both appear to insist on the absolute priority of induction, since, according to them, it provides deductive reasoning with its ultimate premises. Far from conflicting, induction and deduction complement each other. "The consilience of the results of both these processes," Mill writes, "each corroborating and verifying the other, is requisite to give to any general proposition the kind and degree of evidence which constitutes scientific proof."

Until principles are established, the deduction of their implications or consequences cannot begin. Unless principles, once they are obtained, are then used in the proof of other truths, or are otherwise rationally employed, the purpose of inductive generalization is not fully realized. In this understanding of the relationship between induction and reasoning, Aristotle and Bacon do not seem to disagree, nor does either of them conceive induction as a process of *reasoning* from particulars to universals.

There is no question that the direction of induction is from particulars; but in the precise sense in which induction precedes deduction—the sense in which both Bacon and Aristotle regard it as the source of axioms—they do not think it is a process of reasoning or a form of proof. As for deduction, it is questionable, at least for Aristotle, whether its direction can be described as from the universal to the particular.

Aristotle seldom uses the word "deduction" as the name for that phase of thought which is complementary to induction. He speaks rather of demonstration. Demonstration takes place through the various forms of reasoning which he calls "syllogisms." As the chapter on REASONING explains, these are collections of premises each of which yields a conclusion by valid inference. In the most perfect forms of reasoning, the conclusion is as universal as its premises, and though there are syllogisms in which a particular proposition can be demonstrated from a universal and a particular premise, it is seldom the case that from exclusively universal premises a particular conclusion can be validly drawn. The statement that deduction is reasoning from universals to particulars certainly does not seem to fit Aristotle's theory of the syllogism, and even less his conception of scientific demonstration, the aim of which is to prove universal, not particular, propositions.

"WE LEARN EITHER by induction or by demonstration," Aristotle writes in the *Prior Analytics*. "Demonstration develops from universals, induction from particulars." In the *Posterior Analytics* he says that the ultimate premises of demonstration must be primary or basic truths. A basic truth is an immediate proposition—what is sometimes called a "first principle" or an "axiom." Since in his view "an immediate proposition is one which has no other proposition prior to it," the basic premises cannot be demonstrated.

Whence come these primary premises which are indispensable to demonstration but which demonstration cannot establish? Aristotle's answer is that "we know the primary premises by induction." In another place he says, "it is by intuition that we obtain the primary premises."

The word "intuition" indicates an essential characteristic of the sort of induction which, because it is not itself a form of reasoning, can be prior to all reasoning and *must be*, in order to supply the premises from which reasoning proceeds. Reasoning is discursive. It is a process involving steps. One proposition is drawn from another by the mediation of a third. Intuition, in contrast, is immediate. Like an act of seeing, it apprehends its object at once and directly. When Aristotle speaks of induction as a kind of intuition, he implies, therefore,

that it consists in the immediate grasp of a universal truth. The proposition thus held he calls "immediate" precisely because it can be known intuitively and in no other way. Intuitive induction, as opposed to what may be called "inductive reasoning," consists in seeing the universal in the particular. When what is seen is expressed in the form of a proposition, the universal implicit in the known particulars is made explicit.

Induction and intuition are, however, not identical for Aristotle. In one passage in the *Prior Analytics* he considers syllogistic induction, which can hardly be called "intuitive." And in the *Nicomachean Ethics*, where he discusses intuitive reason, he distinguishes between two sorts of primary truth that can be known by intuition.

"Intuitive reason," he writes, "is concerned with the ultimates in both directions; for both the first terms and the last are objects of intuitive reason and not of argument, and the intuitive reason which is presupposed by demonstrations grasps the unchangeable and first terms, while the intuitive reason involved in practical reasoning grasps the last and variable fact, *i.e.*, the minor premise. For these variable facts are the starting-points for the apprehension of the end, since the universals are reached from the particulars; of these therefore we must have perception, and this perception is intuitive reason."

This applies to theoretical as well as practical knowledge. By intuitive reason, it seems, we grasp both the universal principles or axioms and the particular facts of sense perception. As perception is intuition on the part of the sensitive faculty, so induction is an intuitive use of the intellect (though Aristotle attributes both to "intuitive reason").

These two forms of intuition are functionally related. The induction of universal truths from particulars is impossible without sense perception, "for it is sense-perception alone which is able to grasp the particulars." But, according to Aristotle, a single isolated perception does not give rise to an intuitive induction. Repeated perceptions of things of a certain sort—particulars of a certain class—are formed by memory into what he calls "an experience." Because the experience refers, not to a single individual, but to a class of similar individuals, it provides the material for the mind's intuitive act of induction.

This theory of the role of experience in induction is more fully discussed in the chapter on EXPERIENCE. For our present purposes, the main point is that the universal, lying implicitly in the experience, is ready, as it were, to be extracted therefrom and made explicit. "Though the act of sense-perception is of the particular, its content is universal," Aristotle writes. With the help of memory and experience, induction makes the latent universal manifest.

BACON'S CRITICISM of the logic of Aristotle seems to rest on two counts: first, he complains of Aristotle's overemphasis on syllogisms, whether they are used dialectically or demonstratively; and second, he charges Aristotle with a superficial understanding of induction. One of the chief efforts of the *Novum Organum* is to correct the latter mistake.

"There are and can exist," says Bacon, "but two ways of investigating and discovering truth. The one hurries on rapidly from the senses and particulars to the most general axioms, and from them, as principles, and from their supposed indisputable truth, deduces the intermediate axioms. This is the way now in use. The other constructs its axioms from the senses and particulars, by ascending continually and gradually, until it finally arrives at the most general axioms, which is the true but unattempted way."

Where Aristotle proposes that only the primary truths or first principles be established by induction, while all the others (which Bacon calls "intermediate axioms") are to be derived from them by demonstration, Bacon urges a method of induction which shall mount gradually from the least general to the most universal propositions. We should not "suffer the understanding to jump and fly from particulars to remote and most general axioms." We should "proceed by a true scale and successive steps, without interruption or breach, from particulars to the lesser axioms, thence to the intermediate (rising one above the other), and lastly, to the most general."

According to this theory, induction can intuitively draw more general from less general truths, as well as the least general truths from the particulars of perception. It might seem at first as if there were no place for deduction in the development of science. But Bacon divides the study of nature into two phases: "the first regards the eliciting or creating of axioms from experiments, the second the deducing or deriving of new experiments from axioms." Here too there seems to be a crucial difference between Bacon and Aristotle. This difference is indicated by Bacon's emphasis upon *experiments* both as the source of inductive generalization and also as that which is ultimately derived by deduction from axioms.

The difference between *experience* (which Aristotle makes the source of induction) and *experiment* is more than verbal. "The axioms now in use," Bacon contends, "are derived from a scanty handful, as it were, of experience, and a few particulars of frequent occurrence." There has been too little attention given to negative instances, that is, of cases which seem to run counter to the generalization being formed. "In establishing any true axiom," Bacon insists, "the negative instance is the most powerful."

The chapter on EXPERIENCE dwells on the difference between ordinary experience and planned experiments. Where Aristotle seems to be satisfied with the ordinary experience which arises from the perceptions of men in the course of daily life, Bacon thinks it does not suffice. Because it is haphazard, it fails to collect the variety of instances, both positive and negative, upon which genuine and solid inductions can be founded. Unusual and special experiences must be sought out, and the effort must be made to invent experiences which do not arise spontaneously. For this, experiment—or the production of experiences—is necessary. Bacon thinks we must, "by every kind of experiment, elicit the discovery of causes and true axioms."

TWO CONSEQUENCES FOLLOW from the several differences we have noted between Aristotle's and Bacon's theories of induction.

In the first place, Aristotle does not seem to think that induction can be methodically prescribed by logical rules. It is a natural act of intelligence to draw universals from experience. Though men may differ in the readiness of their native wit, the induction of the primary truths, which are the axioms or first principles of science, does not require special genius nor can it be improved or rendered more certain by following rules. Precisely because it is intuitive rather than discursive, induction, unlike reasoning, cannot be regulated by rules of inference such as those which govern the syllogism.

Without disagreeing that it is intuitive rather than argumentative, Bacon seems to think that induction requires the practice of the most detailed and precise method. Not only must the various ascending stages of induction be regulated by observance of an order of generality, but the making of experiments and the collection and arrangement of particulars, "forming tables and coordinations of instances," must be governed by a complex set of rules. The twenty-seven tables of instances, set forth in the second book of the *Novum Organum,* constitute the heart of Bacon's method of induction. This new method "of discovering the sciences," he observes, "levels men's wits and leaves but little of their superiority, since it achieves everything by the most certain rules."

In the second place, since genuine induction depends for Bacon upon ample experiments, it belongs primarily to the method of the experimental sciences—the physical or natural sciences in which experimentation is possible. Though the first principles or axioms of arithmetic and geometry may be learned by induction, the method of gradual ascent from experiments through intermediate generalizations does not apply to mathematics. Here we may have the beginning of the notion that only the experimental sciences are primarily inductive, whereas other sciences, like mathematics, are primarily deductive.

But such a division of the sciences does not accord with Aristotle's theory of induction. He thinks mathematics and metaphysics require induction for their foundation no less than physics and in no different way; if anything, induction is of the greatest importance

for metaphysics, because all its principles are indemonstrable, whereas some of the principles needed in mathematics and physics can be demonstrated in metaphysics. Yet no science is peculiarly inductive, just as none stands in a special relation to experience. All depend equally upon experience for the induction of the primary truths on which their demonstrations rest.

Descartes seems to fall somewhere between Aristotle and Bacon. He regards arithmetic and geometry as more certain than the physical sciences, because mathematics is largely developed by deduction, whereas the study of nature depends upon induction from experiments. In this lies the superiority of mathematics. "While our inferences from experience are frequently fallacious," Descartes writes, "deduction, or the pure illation of one thing from another . . . cannot be erroneous when performed by an understanding that is in the least degree rational."

Nevertheless, Descartes does not exclude induction as the source of the axioms of mathematics or, for that matter, of metaphysics; he only excludes the kind of induction which depends upon experiments. Such axioms as *when equals are taken from equals the remainders are equal* or *the whole is greater than any of its parts* are products of induction, as may be seen, he points out, from the fact that a child can be taught these general truths only "by showing him examples in particular cases." Similarly, the metaphysical truth in the proposition *I think; therefore, I exist* cannot be learned by deduction or syllogistic reasoning. The axiom that *to think is to exist* has to be learned by induction "from the experience of the individual—that unless he exists he cannot think. For our mind is so constituted by nature that general propositions are formed out of the knowledge of particulars."

FROM THE FOREGOING we can gather that different theories of induction may be, in large part, theories about different kinds of induction. Common to induction of every sort is the motion of the mind from particulars, apprehended by sense, to general propositions or universal notions. But the character of the induction, or its conditions and method, may differ according to the precise character of its source: (1) whether it arises from ordinary sense-experience or from planned experiments; and (2) whether it is based upon a single experiment or upon an enumeration of instances. There remains the most radical distinction in type of induction: (3) whether it is intuitive or discursive—accomplished by an act of immediate insight or by a process of reasoning from premises to a conclusion.

These three divisions cross one another to some extent. Descartes, for example, seems to regard the complete enumeration of a series of connected facts as a way of drawing a general conclusion about their connection. That he has inductive reasoning rather than intuitive induction in mind, we learn from his statement that "by adequate enumeration or induction is meant that method by which we attain surer conclusions than by any other type of proof, with the exception of simple intuition."

Pascal seems to be making the same point when he says that "in all matters whose proof is by experiment and not by demonstration, no universal assertion can be made except by the general enumeration of all the parts and all the different cases." Bacon, on the other hand, always thinks of induction as intuitive generalization, and therefore maintains that "induction which proceeds by simple enumeration is puerile, leads to uncertain conclusions, and is exposed to danger from one contradictory instance."

The elaborate procedure which Bacon proposes for collating instances stresses, not completeness of enumeration, but an examination of their relation to one another and, in the light thereof, an interpretation of their significance. Mill's four or five methods of induction bear a close resemblance to Bacon's more numerous tables of instances; but Mill's methods are attempts to formulate the rules of inference for inductive reasoning, whereas Bacon's rules are rules, not of reasoning, but of tabulating the particulars from which intuitive generalizations can be formed.

On Mill's view of induction, it may be questioned whether induction from an exhaustive enumeration is induction at all, for it seems to

result in a *summary* of the facts enumerated rather than a *generalization* from particulars. Where there is no inductive leap, there is no induction. Where the inductive leap does occur, however, it seems easier to understand it as an intuitive act—a seeing of the universal in the particular—rather than as a process of reasoning. Each of Mill's methods requires a rule of inference which is itself a universal proposition. His critics have asked, Whence come these universal propositions about the relations of cause and effect or about the order and uniformity of nature? They point out that he cannot answer that these propositions are themselves conclusions of inductive reasoning without begging the question.

The uniformity of nature, according to Russell, is the controlling principle of induction from repeated instances of the same natural occurrence or natural association of cause and effect. "A sufficient number of cases of association will make the probability of a fresh association nearly a certainty." Russell goes on to say this principle is "not capable of being *disproved* by an appeal to experience," and he adds that it is "equally incapable of being *proved* by an appeal to experience."

In Whitehead's view, "induction presupposes metaphysics . . . it rests upon an antecedent rationalism. You cannot have a rational justification for your appeal to history till your metaphysics has assured you that there *is* a history to appeal to." Without this, "you have made nonsense of induction." Whitehead also tells us that he does "not hold Induction to be in its essence the derivation of general laws. It is the divination of some characteristics of a particular future from the known characteristics of a particular past."

SUCH CRITICISM of inductive reasoning does not seem to apply to Aristotle's conception of it, for with him it is not, as with Mill, distinct in form from the syllogism. It is simply a distinct type of syllogism, which consists in reasoning from effect to cause rather than from cause to effect. Nor does the observation that an inductive inference cannot be more than probable apply to what Aristotle means by an inductive syllogism. What Poincaré calls "mathematical induction" or "reasoning by recurrence" is not, strictly speaking, induction at all, but a form of demonstration.

The certainty or probability of non-syllogistic induction depends on the source of the inference—whether it derives from a single specially constructed experiment or from an enumeration of particular instances, with or without a statistical calculation based on their frequency. The conception of a perfect experiment implies that the operation of a universal law can be exhibited in a single case. It is almost as if the controlling aim of the experiment were to make the universal manifest in the particular.

Newton's experiments on reflection and refraction seem to be of this sort. From them certain laws of optics are directly induced, even as, according to Aristotle and Descartes, the axioms of mathematics or metaphysics can be directly induced from simple experiences, available to a child or familiar to all men. Yet Newton does not think that the inductive establishment of such laws is as certain as demonstration.

The analytic method, he writes, "consists in making experiments and observations and in drawing general conclusions from them by induction. And although the arguing from experiments and observations by induction be no demonstration of general conclusions; yet it is the best way of arguing which the nature of things admits of, and may be looked upon as so much stronger, by how much the induction is more general. If no exception occur from phenomena, the conclusion may be pronounced generally; but if at any time afterwards any exception shall occur from experiments, it may then begin to be pronounced with such exceptions as occur."

Because it must depend on inductive generalizations from experience which, in his view, can never be certain, Locke doubts that physics can ever become a science. "I deny not," he writes, "that a man, accustomed to rational and regular experiments, shall be able to see further into the nature of bodies and guess righter at their yet unknown properties, than one that is a stranger to them; but yet, as I have said, this is but judgment and opin-

ion, not knowledge and certainty. This way of *getting and improving our knowledge in substances only by experience and history,* which is all that the weakness of our faculties in this state of mediocrity . . . can attain to, makes me suspect," Locke concludes, "that *natural philosophy is not capable of being made a science.*"

Hume offers two reasons for the inconclusiveness and uncertainty which he thinks qualify all our generalizations or inductions from experience. The first calls attention to the fact that, unlike mathematical reasoning, inferences from experience in the realm of physical matters depend on the number of cases observed. "The conclusions which [reason] draws from considering one circle," he says, "are the same it would form upon surveying all the circles in the universe. But no man, having seen only one body move, after being impelled by another, could infer that every other body will move after a like impulse."

The principle "which determines him to form such a conclusion" is, according to Hume, "Custom or Habit"; and precisely because inductive generalization is an effect of custom rather than of reasoning in the strict sense, the strength of the induction—or the force of custom—varies with the number of cases from which it arises. "After the constant conjunction of two objects—heat and flame, for instance, weight and solidity—we are determined by custom alone to expect the one from the appearance of the other. This hypothesis," Hume maintains, "seems . . . the only one which explains the difficulty, why we draw, from a thousand instances, an inference which we are not able to draw from one instance, that is in no respect different from them. Reason is incapable of any such variation."

Since *all* the relevant cases can never be exhaustively observed, the inference from a customary conjunction must always remain uncertain, no matter how high a probability it derives from the multiplication of like instances. To this first point, concerning the dependence of the probability of generalizations from experience upon the frequency of the observed instances, Hume adds a second point about the similarity of the cases under observation. Analogy, he says, "leads us to expect from any cause the same events, which we have observed to result from similar causes. Where the causes are entirely similar, the analogy is perfect, and the inference drawn from it is regarded as certain and conclusive . . . But where the objects have not so exact a similarity, the analogy is less perfect, and the inference is less conclusive; though still it has some force, in proportion to the degree of similarity and resemblance." The absence of perfect similarity is Hume's second reason for the inconclusiveness or uncertainty of inductive generalizations.

The contrary supposition—that one case can be perfectly representative of an infinite number of similar cases—may explain why Aristotle seems to think that induction is able to produce the primary truths or principles of science with a certitude which gives certainty to all the demonstrations founded on these axioms. Another explanation of Aristotle's view may be found in his distinction between scientific and dialectical induction. He regards the former as based on the kind of common experience which, unlike even the best experiment, admits of no exceptions. In contrast, dialectical induction, or the still weaker form of induction which he calls "rhetorical," is based on an enumeration of cases (which may not be complete) or upon a single example (which provides no safeguard against possible exceptions).

In its dialectical form, the inductive argument proceeds from a number of particulars taken for granted. Aristotle offers this example of dialectical induction: "Supposing the skilled pilot is the most effective, and likewise the skilled charioteer, then, in general, the skilled man is the best at his particular task." In its rhetorical form, no more than a single example may be used, as when the orator generalizes that honesty is the best policy from the story of a particular individual who was finally rewarded for his virtue.

In both forms, the inductive generalization is at best probable; and it is more or less probable according to the soundness of the suppositions or the examples from which it originates—to be tested only by extending the

enumeration of particulars. But if an induction is merely probable in the first place, it can only be made more probable, it can never be made certain, by multiplying cases or by increasing their variety.

Aristotle's theory of dialectical induction thus seems to have a bearing on the probability of induction from limited experiments (or from a single experiment whose perfection is not assured) and of induction from the frequency or variety of observed instances. The other point to be noted is that Bacon's basic rule of gradual ascent from particular cases through less general to more general propositions seems to be relevant to dialectical induction, but not, on Aristotle's view, to that kind of induction which produces the axioms or principles of science.