differentials required to detect hybrids. McKee, however, has observed[9] that infection rates by zoospores derived from mixtures were higher than expected, a result that is at least compatible with the occurrence of hybridity.

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GENERAL

Generation of Hypotheses and Theories

THE view that induction is an operation of valid inference of the same kind as deduction, expounded notably by John Stuart Mill, has been rightly rejected by modern scientists and philosophers. Instead, the growth of scientific understanding is looked on as a hypothetico-deductive activity. According to this view, hypotheses or theories are created, subsuming far more than the known facts they are intended to explain; they are tested for internal logical consistency and compatibility with the known facts; and implications are deduced from them for test by further observation or experiment. If such a test is adequately carried out and gives a negative result, the theory is scrapped or, alternatively, modified so as to be compatible with the new facts. Thus theories (if they have an adequate degree of generality) cannot be absolutely verified, though they can be absolutely falsified. Supporting evidence can corroborate them—strengthen our reasons for believing that they are true—but not verify them.

This much would be accepted, I think, by most working scientists. But protagonists of the hypothetico-deductive view of scientific method, in reacting against Mill's account of induction, have taken an extreme position which is untenable and also inhibits them from consideration and study of what is the central and most interesting aspect of induction, namely, the generation of the hypotheses and theories themselves. Popper[1], for example, writes "... there is no such thing as a logical method of having new ideas, or a logical reconstruction of this process. My view may be expressed by saying that every discovery contains an 'irrational element' ...". Hempel[2] writes: "There are, then, no generally applicable 'rules of induction', by which hypotheses or theories can be mechanically derived or inferred from empirical data. The transition from data to theory requires creative imagination." And Medawar[3] says "although one can put oneself in the right frame of mind for having ideas and can abet the process, the process itself is outside logic and cannot be made the subject of logical rules".

Even if it were true that no completely rational account could at present be given of any inductive operation, it would be both unjustified and conducive to the blocking of enquiry to assert as a matter of principle that there could be no such account. To do so is, indeed, to evade the key issue in the "logic of discovery". But in fact, not only in science but also in everyday thinking, rules are constantly employed in hypothesis formation. A child throws a stone and sees it sink in the pool—he makes the (deductively invalid) inference that all stones if dropped on water will sink. He has used a rule of abstraction and generalization which, formulated in the language of first-order predicate logic, reads: from $P(a)$ infer $(x)P(x)$; that is, from the fact "the object a has the property P" generate the hypothesis "all objects have the property P". Not only is this simple rule all-pervasive in science and thought, but its power can be judged from the fact[4] that, applied to relations instead of properties, and implemented as the sole inductive principle in a computer program, it has generated a remarkably close approximation to the axioms of group theory on the basis of only ten elementary facts about two simple mathematical groups.

This example is a clue to where one might fruitfully look for the discovery of rules of induction, for abstraction plus generalization is just the inverse of a standard rule (instantiation) of deductive inference, namely: from $(x)P(x)$ infer $P(a)$. And in fact, in spite of accepting Popper's dogmatism, Medawar seems to be dimly aware of this possibility, for he says[3] that "nowadays the tendency is to use 'experimentation' to stand for the acts used in testing a hypothesis, leaving 'induction' as a vague word to signify all the various ways of travelling upstream of the flow of deductive inference".

The process of abstraction, applied in the language of higher-order logic, is enormously powerful in the generation of new concepts. For example, suppose in some domain of phenomena involving a 2-place relation denoted by R, there is available the fact

$$R(a, b) \ \& \ R\ (b, c) \supset R\ (a, c),$$

where a, b, c denote particular objects in the domain. One might then apply two operational rules in succession: first, abstraction plus generalization as before, giving

$$(x)\ (y)\ (z)\ [R(x, y) \ \& \ R\ (y, z) \supset R\ (x, z)];$$

then, asserting the material equivalence of this to $T(R)$, where T is a gratuitously introduced new second-order one-place predicate letter, giving

$$T(R) \equiv (x)\ (y)\ (z)\ [R(x, y) \ \& \ R\ (y, z) \supset R\ (x, z)],$$

R being now a free predicate variable. One has thereby formally created and defined the abstract and most useful concept of transitivity, here denoted by T. This has been done in effect by two kinds of abstraction, first on the individual constants a, b, c, then on the relational constant R.

It is interesing that Pierce (see ref. 5) had long ago suggested that the instinctive structure of human intelligence imposed severe constraints on the admissible hypotheses human beings could make about their experience and that only because of this was the attainment of knowledge by them possible at all. If there are such negative rules, it would be surprising if there were not positive ones too.

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