PHILOSOPHY OF SCIENCE GROUP

Supplement Number 2

to the Bulletin of the

BRITISH SOCIETY FOR THE HISTORY OF SCIENCE

Vol. 1. APRIL, 1950. No. 3.

Heuristics and the Inductive Method

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ABSTRACT of Paper read on 25th April, 1949.

The aim of this paper was to illustrate the following contention : " The most instructive examples of inductive method can be found in mathematical research ". The term " induction " is taken here in the meaning as used in the natural sciences (non-mathematical, incomplete induction). Such induction, of course, can never yield more than a plausible heuristic ground. It was shown by examples with some historical background (Descartes, Fermat, Goldbach, Lord Rayleigh) that, nevertheless, such non-mathematical induction plays an important rôle in mathematical research and various analogies with the use of the inductive method in the natural sciences were pointed out. The general ideas about the nature of inductive inference, to which these examples lead, were not explicitely discussed. It was just observed that the mere existence of such mathematical examples shows that the assumption of any specific link between causality and induction is without foundation.

The Inference of the Gene

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ABSTRACT of Paper read on 30th May, 1949

Many different units are recognised in genetics. The set of chromosomes is a unit in balanced action, the chromosome is a unit in movement, and the whole nucleus is a unit in the production of polyploids. The gene is the smallest, the ultimate, unit into which the genetic material can be divided : it is the unit further subdivision of which must lead to loss of the special properties which make us regard these materials as determinants of living processes.

Several criteria have been used in inferring and distinguishing genes. Mendel used the mechanical criterion of relation in hereditary transmissions. He recognised two relations between the determinants he was led to postulate : they could be strict alternatives in inheritance, allelomorphs of the same gene as we should now say ; or they could be quite independent of one another in their transmission, *i.e.* distinct genes. With the discovery of linkage this latter relation was perforce extended to take in all cases other than allelomorphism. Determinants belonged to different genes if they could be recombined, however rarely, in inheritance.

The second criterion used is that of homology of action. Most mutant genes are hypomorphic : they fail to bring about the same process as successfully as the non-mutant. If two determinants can be shown to be affecting different processes, or different stages of a process, they are regarded as belonging to distinct genes.

The third criterion is that of independence in mutation, *i.e.* change. If mutations can occur independently of one another, they must be changes in distinct genes.

The great success achieved in associating genetically inferable linkage groups with cytologically visible chromosomes has led to the attempt to relate genes within the group to chromomeres or bands visible within the chromosomes. This would give a fourth criterion—visible separation—for distinguishing genes ; but a number of observations have cast doubt on the validity of this method of inference.

Finally, we could define a gene, *a priori*, as a unit of self-reproduction ; but no means are available for using such a criterion in practice.

The criteria of transmission, action, and mutation lead to identical inferences in a great majority of cases. In a few they do not. Sometimes the special properties of polyploidy or crossing-over serve to explain the disparity, but a number of difficult cases still remain. The reason for this may well be that our inferences of the genotype are limited by the necessity for making all observations on the phenotype. We have no means of direct observation of the genotype : all inferences in genotype must be inferred from differences in action as expressed in the phenotype. Thus the unit of action is the fundamental one in that different changes within such a unit will have similar effects on the phenotype, and recombinations within the unit will not be detectable.

Now the action of any piece of genetic material must depend on the circumstances in which it is acting, and these circumstances are clearly changing during development. A determinant detectably acting at one stage may not be detectably acting at another, so that genes will appear to have their characteristic times of action. It is also conceivable that a gene may act as one unit in some circumstances, and as several units in others, so that whether we regarded it as one or several units would depend on whether we looked at the organism as a whole or whether we compared different organs or stages. Several cases which may well be examples of such a relation are now known.

If this interpretation is correct, we should be led to picture the chromosomes as having a constant physio-chemical structure, and indeed a constant genetical potential throughout development ; but at the same time as having an effective action which could vary with the changing circumstances of development, and by so varying, alter in its content of those genes which we could infer from comparative studies of the phenotype.

The Philosophical and Experimental Aspects of Psychology

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ABSTRACT of Paper read on 30th May, 1949

The kind of philosophy that is important to an experimental science is that which is a technique for the removal of muddles created by words. The lack of philosophical interests in experimental scientists is liable to create a situation in which the activity of theorising is far lower in quality than the activity of designing and carrying out experiments. This situation very largely exists in experimental psychology as a result of the history of the subject.