LETTERS TO THE EDITOR

GENERAL

Statistical Methods in Scientific Inference

It is regrettable that Edwards's interesting article[1], supporting the likelihood and prior likelihood concepts, did not point out the specific criticisms of likelihood (and Bayesian) concepts that seem to dissuade most theoretical and applied statisticians from adopting them. As one whom Edwards particularly credits with having "analysed in depth . . . some attractive properties" of the likelihood concept, I must point out that I am not now among the "modern exponents" of the likelihood concept. Further, after suggesting that the notion of prior likelihood was plausible as an extension or analogue of the usual likelihood concept (ref. 2, p. 200), I have pursued the matter through further consideration and rejection of both the likelihood concept and various proposed formalizations of prior information and opinion (including prior likelihood). I regret not having expressed my developing views in any formal publication between 1962 and late 1969 (just after ref. 1 appeared). My present views have now, however, been published in an expository but critical article (ref. 3, see also ref. 4), and so my comments here will be restricted to several specific points that Edwards raised.

If there has been "one rock in a shifting scene" or general statistical thinking and practice in recent decades, it has not been the likelihood concept, as Edwards suggests, but rather the concept by which confidence limits and hypothesis tests are usually interpreted, which we may call the confidence concept of statistical evidence. This concept is not part of the Neyman–Pearson theory of tests and confidence region estimation, which denies any role to concepts of statistical evidence, as Neyman consistently insists. The confidence concept takes from the Neyman–Pearson approach techniques for systematically appraising and bounding the probabilities (under respective hypotheses) of seriously misleading interpretations of data. (The absence of a comparable property in the likelihood and Bayesian approaches is widely regarded as a decisive inadequacy.) The confidence concept also incorporates important but limited aspects of the likelihood concept: the sufficiency concept, expressed in the general refusal to use randomized tests and confidence limits when they are recommended by the Neyman–Pearson approach; and some applications of the conditionality concept. It is remarkable that this concept, an incompletely formalized synthesis of ingredients borrowed from mutually incompatible theoretical approaches, is evidently useful continuously in much critically informed statistical thinking and practice.

While inferences of many sorts are evident everywhere in scientific work, the existence of precise, general and accurate schemas of scientific inference remains a problem. Mendelian examples like those of Edwards and my 1969 paper seem particularly appropriate as case-study material for clarifying issues and facilitating effective communication among interested statisticians, scientific workers and philosophers and historians of science.

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[1] Edwards, A. W. F., *Nature*, **222**, 1233 (1969).
[2] Birnbaum, A., *J. Amer. Stat. Assoc.*, **57**, 269 (1962).
[3] Birnbaum, A., in *Philosophy, Science and Method: Essays in Honor of Ernest Nagel* (edited by Morgenbesser, S., Suppes, P., and White, M.) (St Martin's Press, NY, 1969).
[4] *Likelihood* in *International Encyclopaedia of the Social Sciences* (Crowell-Collier, NY, 1968).

PHYSICAL SCIENCES

Redshifts of Companion Galaxies

Since 1966 (ref. 1) there has been observational evidence[2-4] that quasi-stellar radio sources (QSRs) and compact radio galaxies are ejected from galaxies. Whatever distance scale one uses, one of the characteristics of QSRs and compact radio galaxies is that a great deal of energy is compressed into very small dimensions. Unless very special conditions prevail, such concentrated sources would be expected to expand with time. Indeed, the short lifetimes which are inferred from their rapid rate of energy expenditure, the associated jets of material and the prevalence of ejected radio pairs across the sources all attest to expansion and eruption.

We would therefore expect that when a compact object which is initially not optically resolvable (that is, a QSR or a QSO) expands sufficiently it eventually must become resolvable (a compact galaxy). As it continues to expand we would expect the surface brightness to diminish and eventually the object should look only slightly more compact than a galaxy of normal surface brightness. I have recently reported results[5] which lead to the conclusion that compact galaxies and companion galaxies in general have also been ejected from large, central galaxies. The observations also indicate that the ejections are initially very compact and rapidly expand. The model which suggests itself is one where matter is ejected in a compact, QSR-like form, which evolves into a compact radio galaxy and finally into a less and less compact companion galaxy. (This is, of course, an evolutionary interpretation. As far as the observational evidence goes, one may simply wish to consider that smaller bodies, with a continuity of properties that reaches to the extremes of QSRs, are associated with large, normal galaxies.)

It is usually assumed in astronomy that galaxy redshifts are only due to Doppler, velocity shifts. Objects which differ greatly in redshift are always presumed to be at different distances so as not to violate the (expansion) velocity–distance relation. The only way such an assumption could be shown to be incorrect would be to demonstrate that objects of greatly different redshifts cluster together on the sky. The observational evidence on the QSRs and radio compact galaxies referred to simply argues that they do in fact cluster on the sky around lower redshift galaxies and tend to be aligned and paired across these galaxies.

The proposed continuity of characteristics of the ejected compact bodies, however, suggests another kind of test on the nature of their redshifts. We can investigate smaller companions around galaxies, companions which astronomers have long accepted as belonging to the central galaxy and being at essentially the same distance as the larger galaxy. If the intrinsic redshift evolves from high to low as ejected objects evolve toward brighter and less compact companions, then we would expect even the