agencies as the National Institutes of Health and the National Science Foundation, need further consideration—carefully and promptly. For this purpose, it has been suggested by others that the National Academy of Sciences be invited to arbitrate in the present controversy. What could be more appropriate in this case?

Specifically, there is need (i) to reduce the present limitations upon modifications of research objectives; (ii) to abolish the keeping of records by research workers of "time and effort"; (iii) to liberalize the interpretation of "full-time" and to permit scientists entirely paid from research grants to participate to a modest degree in teaching; and (iv) to remove restrictions upon the transfer of funds between the different categories of a budget set up to permit an initially desirable research objective to be attained.

It is unthinkable that the errors of a very small proportion of the grantees of the Public Health Service and of other federal agencies should be so exaggerated that, in purging them, serious and lasting harm be done to the progress of science. The people of the world probably have received more permanent benefit from unimpeded scientific research and development than from almost any other application of American intelligence, ingenuity, enterprise, and public money (*1*).

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Note

1. The substance of this letter, by the chairman of the Department of Pharmacology, Yale University School of Medicine, has received the approval, as well as the constructive criticism, of the other chairmen of the departments and the dean of the School of Medicine, and the provost of Yale University.

Intelligence and Genetic Trends

From time to time students of evolution have urged that adverse changes are probably taking place in the collective pool of human genes and that practical measures may be needed to counter the trend. For geneticists such assertions raise questions, to which there are no simple answers, about their individual and collective responsibilities for the genetic future of man. Some of the more perplexing of these questions do not appear to have been discussed in print.

In his recent book, *Animal Species*

and Evolution (*1*), Ernst Mayr devotes a chapter to the evolution of man in which he supports the view of Julian Huxley that the frequency of superior combinations of alleles in the collective pool of human genes has diminished and is probably continuing to do so. The assertion applies especially to human intelligence and is based on (i) fossil evidence of long-term changes in cranial capacity, indicative of an early period of rapid evolution of mental ability which apparently came to an abrupt halt, and (ii) the much discussed negative correlation between I.Q.'s of school children and family size. As a remedy for this supposed trend, Mayr proposes the introduction of financial changes, involving the manner of taxation and the payment of educational fees, to encourage (rather than to deter as they now do) procreation by, and the education of, gifted people.

Even if the evidence for a decline in the genetic basis of intelligence were generally accepted as adequate (which Mayr recognizes is not the case), many geneticists would still be inclined to wonder just what they personally should do about a problem which can seem at one and the same time terribly important and yet, perhaps, not very urgent.

Probably only a minority, even among geneticists, feel reasonably sure that there is such a downward trend. Experts called upon to advise the British Royal Commission on Population (*2*) have pointed out a number of deficiencies in the evidence, and recent limited data have done little to support the view that a decline is, in fact, in progress (*3*, *4*).

Interpretation of the seemingly unfavorable fertility differential is far from simple. (i) Childless members of the parental generation, who are not ascertained in studies of the I.Q.'s of school children, may be predominantly of lower-than-average intelligence (*4*). (ii) Children with many brothers and sisters may develop more slowly than other children so that they underrepresent their parents' intelligence. (iii) A similar negative correlation has been observed in the Scottish Mental Survey (*5*) between sibship size and height (and also weight) which, by the reasoning applied to intelligence, would seem to indicate a decline in the frequency of superior gene combinations for stature—an interpretation which is difficult to reconcile with the dramatic increase observed in stature. Nevertheless, a continuing attitude of concern

for man's genetic future must be regarded as essentially healthier than one of smugness based on present ignorance.

To hope that the biological aspects of man's evolution will be "duly taken into consideration by those entrusted with the task of planning the future of mankind" (*1*, p. 662)—if by this is meant the elected representatives of the people or the civil servants whom they control—seems either unrealistic or else positively dangerous as long as geneticists themselves are not in some sort of general agreement.

Let us suppose, however, that the reasoning and the inference are correct, although still unproved, and that all that is required in order to achieve unanimity of opinion on the urgency of the matter is adequate evidence. How much effort would be justifiable, under these circumstances, in an attempt to obtain such evidence in spite of known substantial difficulties? A major defect in most studies so far, which will have to be remedied in future undertakings, is that the negative correlation of I.Q. test scores with family size has been investigated in only a single generation of tested individuals—a procedure that must be regarded as inherently unsuitable for distinguishing between a genetic and an environmental component in intelligence. More elaborate studies will, of course, be much more demanding in their requirements.

While it is generally recognized that the first step in detecting the supposed genetic trend would have to be the devising of methods by which mental capacity or performance can be partitioned into a heritable and a non-heritable fraction, the unlikelihood that a strictly psychological test will ever do this has not been especially emphasized. Certainly no physical test is envisioned which would partition stature into a heritable and a non-heritable fraction, and intelligence may well be much the same. The only sound method in either case would seem to be a breeding test. For intelligence, this would have to take into account not only the I.Q.'s (or other measures of performance) of the parents, but also various assessments of the degrees of social adversity against which these I.Q.'s were achieved. To identify a transmissible component, it would then be necessary to observe the I.Q.'s of the children as developed under known degrees of social adversity.

Even this does not represent the ultimate in refinement and must be regarded as just one more step in the quest for discrimination. True, it will distinguish a transmissible component from one conditioned by an environmental factor which has been newly injected into the family history. The further distinction, however, between transmission by genes and that which takes place as a result of family traditions and habits is more difficult, although it must not be regarded as wholly impossible. Curiously, neither the suggested obvious improvements in design, nor possible further refinements, have been explored in any detail, even in discussion. Haldane suggested to the Royal Commission on Population that a two-generation approach was needed, but neither he nor any of the other advisers mentioned details. It would almost seem as if the organizational and financial difficulties in a two-generation study of appropriate design and size have caused the geneticists to renounce their own special kind of test (that is, the breeding test) in favor of something they have hoped the psychologists might devise, but which will probably never materialize. One could probably defend even the extreme opposite view that a very bad test of performance, when used in a suitable two-generation study, is superior to the most refined test of performance when used in any single generation study.

Two generations of I.Q. scores, specific for families, are in fact available from the investigation being carried out at the Dight Institute (*4*) but measures of social adversity are lacking. This project is small in comparison with what would be required to detect correlations of fertility with the heritable component of intelligence, as assessed by a two-generation approach incorporating refinements of the kinds mentioned earlier, although it is considered large by most standards since it includes records of over 80,000 people. Size can be critical where precision is required, and especially where a number of variables are to be considered.

A more appropriate scale might even approach that of the Scottish Mental Survey (in which about 80,000 children, 11 years of age, were tested in a single year), but the test would be repeated annually to build up family histories, including social particulars, spanning two generations. This would be exceedingly laborious unless use were made of the large amounts of data on intelligence that are already being gathered routinely by most schools (as was done to a limited ex-

tent in the Dight Institute study) and of such information on family size and social characteristics as is collected by the vital statistics system.

An undertaking of this kind would become possible only through rapid handling and compact storage of the large quantities of data, and through use of an appropriate technology for linking up successive records relating to the same individuals or families (*6*). Under such conditions, however, it would become less laborious to follow all the families in a geographic region by using the routine records, than to follow a 1-percent sample by personal interview and correspondence. A study involving 50,000 to 100,000 records per year might correctly be regarded as large, but it seems less so when it is pointed out that a central office of the Canadian Pacific Railway receives a similar number of records of freight car movements each night and uses them to update a master file of freight-car histories for accounting purposes.

For any large two-generation study of family histories full-time effort on the part of one or more senior research scientists would be needed, in designing and testing procedures, arranging for use of existing records of I.Q. test scores and family relationships, and ensuring continuity and flexibility in the running of the project over a period of 30 years or more. Other costs might equal the salaries, or be even greater. Nevertheless, I.Q.'s of children are measured by most schools routinely, and family relationships are unambiguously recorded in the vital statistics registration system together with some social data. Thus, we have hardly begun to use the vast amounts of relevant information we already possess and much of it (relating chiefly to the I.Q. scores) is sytematically destroyed after a limited period so that if not used currently it may be irretrievably lost.

Mayr's reasoning, like that of Huxley and others, is largely divorced from questions of detailed design and costs of relevant scientific studies. Perhaps, after all, the effort required would be too great in view of present uncertainties about the extent of the refinement that might be achieved even with the best of planning, difficulties in interpretation that might still remain, and the nature of other important competing demands for funds and scientists. But what, then, is the degree of importance associated with the problem raised by Mayr? He has suggested reapportionment of taxation and educa-

tional costs involving many billions of dollars even in a single lifetime. If the matter is really that important, who should be doing the detailed thinking about the next step towards an ultimate demonstration of the presumed deleterious trend?

Perhaps consideration should also be given to the possible genetic effects of legislative changes of the kinds recommended by Mayr, irrespective of whether the frequencies of "superior" gene combinations are decreasing. Would such measures lead to any substantial increase in their frequencies, and is this desirable? These questions could, presumably, be studied by following appropriate sub-groups within a population, but how much thought and effort are such studies worth?

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That 1953 Fallout

E. J. Sternglass refers to the fallout in 1953 in the Troy-Albany area in his report "Cancer: Relation of Prenatal Radiation to Development of the Disease in Childhood" [*Science* **140**, 1102 (7 June 1963)]. He assumes that there would have been a significant dose to the bone marrow of the human embryo because of radioisotopes ingested by the mother with fresh milk and vegetables.

As I pointed out in a previous comment, upon a report by Ralph Lapp [*Science* **138**, 732 (9 Nov. 1962)], the 1953 fallout in this area occurred on 26 April 1953 and the average date of first pasturing in the area was 12 May, 17 days later. There was a total of 5.36 inches (13.6 cm) of rain during the period between the deposition of the