3. This investigation was supported in part by funds from the Rockefeller Foundation and the Office of Naval Research. We should like also to express our appreciation to the Institute for Advanced Study, Princeton, where this paper was written.
4. G. Wald, *J. Opt. Soc. Amer.* **35**, 187 (1945).
5. ———, *Science* **101**, 653 (1945) ; *Documenta Ophthal.* **3**, 94 (1949).
6. Stiles refers to a second "blue mechanism" which, in addition to the peak at about 435 mμ, is relatively sensitive throughout the remainder of the spectrum. This may represent the composite effect of the violet receptor and other types of cone discharging through the same optic nerve fiber.
7. A. König and C. Dieterici, *Z. Psych. und Physiol. Sinnesorgane* **4**, 241 (1892) ; reprinted in A. König, *Physiologischen Optik* (Barth, Leipzig, 1903), p. 214.
8. G. F. Göthlin, *J. Opt. Soc. Amer.* **34**, 147 (1944).
9. A. König, *Sitzber. deut. Akad. Wiss. Berlin* (1894), p. 577 ; reprinted in A. König, *Physiologischen Optik,* chap. 24 ; E. N. Willmer, *Nature* **153**, 774 (1944) ; E. N. Willmer and W. D. Wright, *ibid.* **156**, 119 (1945).

Social Implications of the Genetics of Man*

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MAN is one of the most unsatisfactory of all organisms for genetic study. The time interval between successive generations is long, at best individual families are too small to establish ratios within them, and the test-matings that a geneticist might want cannot be made. Obviously no geneticist would study such a refractory object, were it not for the importance that a knowledge of the subject has in other fields.

One consequence of the difficulty of the material is that the exact mode of inheritance is known for very few of the differences among individuals. It is important that suspected cases be recorded, in order that other workers may check them; but there is an unfortunate tendency to accept such records as demonstrations rather than as suggestions. After examining some of the available published evidence, I am convinced that, even for some of the standard textbook examples, the evidence for the accepted mode of inheritance is far from conclusive—and that it would be recognized as at best suggestive, if any organism other than man were concerned.

There are enough unambiguous examples known to make it clear that the same principles are at work in man as in all other higher animals and plants—and even without such evidence, enough is known about the cytology of human tissues to give us confidence that no peculiar kind of inheritance is to be expected in man. In fact, much of the argument concerning the practical aspects of the genetics of man is best based on experimental evidence from other organisms rather than on what is known directly from study of human populations.

The position is especially unsatisfactory with respect to the heritability of the most important of all human differences—namely, mental ones. It would be possible to quote recent authorities for rather extreme positions on each side of this question. To some there appears to be no clear evidence for genetic differences in mental capacities among most individuals or among races, the observed mental diversity being attributed to environmental effects; to others the position is reversed—the environment accounts for little, genetic differences for nearly all the observed diversity. In these circumstances it is necessary to examine what direct evidence we have.

At the sensory level there is good evidence for inherited differences. There can be no question that such things as color-blindness, night-blindness, or sensitivity to the bitter taste of phenylthiourea are simply inherited; and one may confidently suppose that other such inherited sensory differences remain to be discovered. As has been pointed out by Blakeslee, we all live in different worlds by virtue of inherited differences in our sensory reactions to external stimuli. It should further be pointed out that these differences have effects at the highest mental levels. About 8 percent of white males are at least partially red-green blind; and when such a man looks at a painting he does not see what the artist put there or what other people see. It is clear that this simple and rather frequent genetic property has inevitable effects on the esthetic life of the individual.

These remain rather trivial sorts of differences; but there is another large class of inherited mental differences that is far from trivial. Certain types of severe mental derangement, such as Huntington's chorea or phenylketonuria, clearly have at least a large inherited element in their causation, although for most of them the exact method of inheritance may be regarded as somewhat uncertain.

However, what we are really most interested in is the vast array of differences lying between these extremes; and it is just here that the difficulty of the human material becomes most serious. When one is dealing with complex characters that vary more or less continuously in diverse respects, a genetic analysis is difficult in any material; in the case of man, a direct attack on the problem looks even more difficult.

One thing we want to know is: What portion of

* Presidential address at the Pacific Division of AAAS, Pullman, Wash., 22 June 1954.

existing mental diversities is of genetic origin and what portion is of environmental origin? Under these conditions the usual scientific procedure is to try to hold one variable constant, and then study the effects of variations in the other one. This can in fact be approximated in the problem of human mental differences, through the study of twins. Ordinary fraternal twins arise from the separate fertilization of two eggs and are no more alike genetically than are brothers and sisters that are not twins; but the environment to which they are subjected is likely to be more nearly the same. Identical twins arise from a single fertilized egg and are genetically identical. If one studies members of such pairs that were separated in infancy, any observed differences must be nongenetic.

The difficulty here is in the measurement of the properties we are interested in. Such studies of separated identical twins were begun by Muller and have been greatly expanded by Newman, Freeman, and Holzinger. I must confess to a feeling, however, that these studies tell us more about what the psychological tests used are really measuring than they do about the relative effects of heredity and environment.

There are then inherited differences in the sensory components of human mentality and also in components leading to severe derangements. In the area between these extremes the technical difficulties of getting clear-cut evidence are still unsurmounted. But it seems safe to conclude, from what we know of the genetics of complex characteristics in other organisms, that any property as complex and as variable as this must have a large amount of underlying genetic diversity.

This conclusion applies to individual differences. Analogy with other organisms leads likewise to the conclusion that there must also be at least statistical differences between racial groups. This is a rule that has held consistently wherever it has been tested—in many different kinds of animals and plants.

On general grounds, then, as well as from some direct evidence, one must conclude that there are inherited differences in mental properties among individuals and, at least statistically, among racial groups. But it is necessary to insist that one must not go beyond this point. Specifically, one must not conclude that a particular observed difference is genetically determined. It is, of course, a platitude to say that no one ever does anything for which he does not have the necessary genes; but one must never forget that there is also a necessary environment. It scarcely needs argument that human behavior is strongly influenced by economic status, tradition, and training. After all, most of the members of this society are in the business of teaching or, at least, have spent a good deal of time and energy pursuing academic work; we are therefore all of us witnesses to the obvious fact that men are teachable—that their behavior can be strongly modified by environmental stimuli.

This caution about attributing observed differences to genetic causes, rather than to environmental ones, applies with special force to comparisons among racial groups, for here the effects of tradition and of public opinion are especially strong.

Another thing that must be avoided is the view that one race (usually that to which one himself belongs) is "better" than another. All that can properly be concluded is that they are inherently different. It follows that society would do well to insure that as many people as possible, of as diverse racial origins as possible, get an opportunity to show what they can do to advance civilization. It may confidently be expected that individuals of various races will have the necessary genetic equipment to make unique contributions.

I wish to devote the rest of this paper to the effects of high-energy radiation on the genetic properties of man. This is a matter that has been of significance chiefly because of the use of x-rays for diagnostic and therapeutic purposes; but with the development of A-bombs and H-bombs it has become of far more general importance, for it is already true that all of us have been subjected to irradiation from these sources.

There are two possible types of radiation damage to be considered—damage to the exposed individual, and damage to the genes in his germ cells. The first will be more or less immediate in its manifestation, whereas the latter will have detectable effects only in future generations. This, however, is not the most basic distinction. Irradiation has a gross effect on tissues, resulting in the burns and other symptoms recognized as direct effects of heavy dosages; there is also an effect on the genes, leading to mutations.

The former, tissue effect, appears to be substantially absent at low doses, recovery from moderate effects is possible, and doses spaced well apart in time have little or no cumulative effects. It is on the basis of these effects that the "permissible" dose, to which it is supposedly safe to expose individuals, is calculated. But there is reason to suppose that gene mutations, induced in an exposed individual, also constitute a hazard to that individual—especially in an increase in the probability of the development of malignant growths, perhaps years after the exposure. There is, in fact, no clearly safe dosage—all high-energy radiation, even of low intensity and brief duration, must be considered as potentially dangerous to the exposed individual.

Let us now turn to the effects of irradiation on the genes in the germ lines of exposed individuals. Here again we are handicapped by the special difficulties of dealing with the genetics of man, for the quantitative determination of the genetic effects of irradiation requires much more refined techniques than are possible with man—a point that becomes obvious when one tries to evaluate the data available concerning the survivors of the Hiroshima bomb. There is sufficient evidence that quantitative results obtained with one organism cannot safely be applied to a wholly different kind of organism. However, there are certain general qualitative results that have now been so widely confirmed that we may confidently assert that they apply to all higher organisms, including man. These results are

1) High-energy irradiation produces mutations.
2) The frequency of induced mutations is directly proportional to the dosage of irradiation. There is almost certainly no threshold value below which irradiation is ineffective.
3) The effects of successive exposures are cumulative.
4) The effects are permanent in the descendants of the affected genes. There is no recovery.
5) The overwhelming majority of these mutations is deleterious—that is, they seriously affect the efficiency of individuals in later generations in which they come to expression. These deleterious genetic effects may lead to early death or to any of a wide variety of defects, often gross ones.

There is a store of such undesirable genes already present in any population. What irradiation does is to add to this store.

It follows from these facts that any large-scale increase in the amount of irradiation to which human populations are subjected is a serious matter. Even though we cannot say that a given amount of irradiation will have a quantitatively specified effect, we can say that it will have some effect. The probability of an effect on the germ cells of any one individual may be very low; but when many millions of people are being exposed, it becomes certain that some of them will be affected. There is no possible escape from the conclusion that the bombs already exploded will ultimately result in the production of numerous defective individuals—if the human species itself survives for many generations. And every new bomb exploded, since its radioactive products are widely dispersed over the earth, will result in an increase in this ultimate harvest of defective individuals. Some such defectives would be present if the bombs had never been invented; the point is that the number due to the bombs will be added to this irreducible minimum.

Under these circumstances, I have been disturbed that Chairman Strauss of the Atomic Energy Commission should state, in an official press release from the White House, on 31 March 1954

> . . . it should be noted that after every test we have had, and the Russian tests as well, there is a small increase in natural "background" radiation in some localities within the continental United States. But currently it is less than that observed after some of the previous continental and overseas tests, and far below the levels which could be harmful in any way to human beings. . . . [*Bull. Atomic Scientists* **10**, 164 (May 1954)].

Presumably this statement is intended to refer only to immediate effects on exposed individuals; but, as I have pointed out, there are important other effects, less immediately apparent. Every geneticist familiar with the facts knows that any level whatever is certain to be at least genetically harmful to human beings when it is applied to most or all the inhabitants of the earth.

I do not wish to be understood as arguing that the benefits ultimately to be derived from atomic explosions are outweighed by the biological damage they do. It may be that the possible gains are worth the calculated risk. But it must be remembered that the risk is one to which the entire human race, present and future, is being subjected. I regret that an official in a position of such responsibility should have stated that there is no biological hazard from low doses of high-energy irradiation.

Byron Cummings, Archeologist and Explorer

BYRON CUMMINGS, twice acting president of the University of Arizona and director emeritus of the Arizona State Museum, died at his home near Tucson on 21 May 1954. A teacher for more than 50 years and the organizer of two university museums, he retired from the classroom in 1938 at the age of 78 and from museum administration 7 years later. In his 94th year, he was actively engaged with the day's work until a few months previous to his death.

Byron Cummings was born at Westville, New York, 20 September 1860, youngest of the seven children of Moses and Roxana (Hoadley) Cummings. The father, a Union soldier, was killed during the Civil War. Byron was graduated from Oswego Normal School in 1885 and received his A.B. from Rutgers College in 1889. Rutgers awarded him an A.M. degree in 1892 and an honorary doctor of science in 1924. He pursued graduate studies at the University of Chicago in 1896 and at the University of Berlin, 1910–11. His devoted service at the University of Arizona was recognized with an LL.D. in 1921.

A teacher of magnetic personality, Professor Cummings began his professional career at Syracuse High School in 1887 and as an instructor in Greek and mathematics at Rutgers Preparatory School, 1889–93. In the fall of 1893 he moved to the University of Utah as instructor in Greek and Latin. Two years later he was designated full professor and head of the department, a chair he held for the next 20 years. At Utah he served also as dean of men, 1905–15, and as dean, School of Arts and Sciences, 1906–15. In the latter year, with 16 other faculty members he resigned in protest against administrative policies. While resident in Salt Lake City Professor Cummings was an active participant in church and civic affairs. He was a member of the Utah State Park Commission, 1909–15 and as a member of the managing board, School