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THE GENETIC EFFECTS OF ATOMIC BOMB EXPLOSIONS

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I SHOULD perhaps begin by defending myself for writing on this topic. I am not a physicist, still less have I any special knowledge on the physics of the atomic nucleus. Nor have I experimented on the artificial production of mutations, and very little work on this topic has been done under my supervision. On the other hand, twenty years ago Penrose and I were the first to calculate human mutation rates. And as it is feared that atomic bombs have caused, or will cause, increase in these rates, I have at least some claim to knowledge on this matter.

In the first quarter of this century it was found that a great many characters were inherited in accordance with Mendel's laws, though as early as 1902 Correns had discovered some which were not. The inheritance of the Mendelian characters has turned out to be explicable in terms of genes, which are believed to be small sections of chromosome, each responsible for a particular metabolic process, and usually copied very exactly at each cell division. By 1915 it was already known that this copying, or replication, process sometimes went wrong, so that a new gene appeared, and was then copied in its turn. The appearance of a gene of a new type is called mutation.

For example, the human X chromosome, of which women have two in each nucleus, whilst a man has only one, inherited from his mother, includes a small section which is concerned in making a particular globulin in the blood plasma. When this section is altered the globulin is no longer made, and the blood will only coagulate after a day which may last several hours. Persons lacking this globulin are called hæmophilics, and most of them die before puberty.

As a result of natural selection the abnormal gene causing hæmophilia would disappear in a few centuries if it did not constantly arise afresh by mutation. Of the genes responsible for making the anti-hæmophilic globulin, about one in 40,000 mutates in each generation, and a new pedigree of hæmophilia arises..

In 1927, H. J. Muller found that X-rays greatly increase the frequency of mutation of some of the normal genes in the small fly Drosophila. This has since been found to be true in other animals (including mice), many plants, and bacteria. Alpha particles, neutrons, and gamma rays have similar effects. In 1942 Auerbach and Robson proved what had been suspected for some time, that some chemical substances were also mutagenic. In 1955 Fahmy and Fahmy proved that one such substance caused genes in Drosophila to mutate which had never been known to mutate spontaneously or under the influence of X-rays.

The question then arises: "If a large number of human beings are exposed to abnormal amounts of high frequency radiation, what effects may be expected in their descendants?" The first point to be made is that everyone is exposed to a certain amount of high frequency radiation, especially from cosmic rays, and from the radioactive isotope of potassium. The mean dose per generation is about 3 roentgens, but it may be as high as 5 or 6 in high countries like Tibet where cosmic radiation is more intense, and in igneous areas like some of Southern India where the soil contains appreciable amounts of radioactive elements.

In *Drosophila melanogaster* it is fairly easy to measure the frequency of lethal mutations, that is to say, mutations which cause so great a change as to kill the flies in the egg or larval stage. Most such mutations are recessive. That is to say the abnormal gene is harmless or nearly so, provided the animal has received a normal gene from one parent. Occasionally we understand why this should be so. Thus normal human beings can oxidise phenylalanine to tyrosine with a very specific enzyme found in their liver cells This enzyme is only formed if a normal gene is present in a cell nucleus. If neither parent contributes such a gene, the enzyme is not formed. The blood and cerebrospinal fluid contain large amounts of phenylalanine and oxidation products such as phenylpyruvic and phenyl-lactic acids, which are also excreted in the urine. The head is usually rather small, and a child unable to oxidise phenylalanine is always mentally backward and generally an idiot, dying fairly young. The abnormal gene, which does not produce phenylalanine oxidase, is handed down (by copying) for many generations in healthy people till two such people (heterozygotes for the gene) marry. Such marriages are particularly common between cousins, who may both have received the abnormal gene from a common ancestor.

Some recessive genes formed by mutation disappear by chance. Others spread by chance. But on an average, two such genes are only lost from the population as the result of a premature death, or a sterility.

Probably over 2% of all children born die before puberty as the result of such recessive genes, and many more die before birth. Now if we knew what fraction of human mutations is due to radiation we could calculate the effect of a given addition to the amount received. We do not know this. In *Drosophila melanogaster* most mutations are not due to radiation But a human generation is about 500 times as long as a Drosophila generation. And a human nucleus contains about 30 times as much desoxyribonucleic acid (of which genes are probably composed) as a Drosophila nucleus. So the number of mutations produced by radiation in a human generation may be expected to be about 15,000 times as great as in the same number of Drosophilæ. It is therefore quite possible that most human mutations are due to radiation.

The amount of radiation needed to produce a lethal mutation in a *Drosophila melanogaster* is about 10,000 roentgens. More accurately about 1% of eggs or spermatozoa of flies exposed to 100 r. will carry a lethal mutant. About 4 times this number will carry a sublethal mutant causing serious abnormality. If man is 30 times as sensitive, the 3 roentgens received per generation should produce a lethal gene in about 1% of spermatozoa or ova and a sublethal in about 4%. Between them they would account for something like half or a third of the lethal and sublethal genes in human populations.

If we take the lower figure of one-third, this would mean that if the human race were permanently exposed to 10 r. per generation, the deaths and illnesses due to genetic causes would be about doubled. If, as I suppose, some kinds of mutation are not mainly due to radiation. some kinds of illness would be increased more than others.

Sir John Cockroft, in a recent article in *Nature*,[1] estimated the average increase in high frequency radiation at ground level due to the explosion of atomic bombs. Bombs such as were exploded over Japan had a negligible effect on the radioactivity at ground level beyond a few kilometres from the site of the explosion. Thermonuclear or "hydrogen" bombs contaminate the whole planet.

Cockroft states that enough radioactive elements have fallen and will fall on the surface of England to give "completely unprotected persons" a mean extra dose of about 0·03 r. He adds that as most people spend a good deal of time indoors, and brick houses give considerable protection, this dose is probably reduced to about a tenth on an average. This is very reassuring to British readers. But he did not add that most of the people in India spend a great deal of time out of doors, and their houses have very thin walls which give no serious protection against gamma radiation from outside.

It follows that if radioactive substances are spread fairly evenly all over the world, most of the harmful genetic effects will occur in countries like India, Pakistan, Indonesia, Tropical Africa and Brazil, where conditions are similar. I am sure that Sir John regrets this, but some persons associated with him may not do so. Thus Sir Ernest Rock Carling, official representative of the British Government at the recent Geneva Conference at which Dr. Bhabha presided, said, "In a world contemplating a future in which the expansion of its population may outrange its food supply, it is conceivable that diminished fertility and shortening of the life-span might not altogether be deplored". He might deplore these consequences even less if they were largely concentrated in tropical countries.

It is very hard to estimate the probable killing effect on Indians. But if we assume that about 15 crores of future Indian parents have been erposed to ·03 r., this gives a total dose of $4{\cdot}5 \times 10^6$ r. which might cause 15,000 lethal mutations and 30,000 or 40,000 sublethal. Most of them are recessive, so that we should expect one death for every two mutations if the population remains about its present level, but more if it increases, perhaps 30,000 deaths in all. These extra deaths will be spread over many thousand years, though the maximum incidence will probably occur in the next century.

The British Government is probably going to explode a hydrogen bomb in the next year or so. The Americans are reported to be about to explode two. The Soviet Union will probably follow their example. Although its government wishes to prohibit atomic bombs, it would presumably not accept the arguments of this paper, which are based on "Mendel-Morganism". These explosions, if they occur, may produce about as much more radioactivity as Sir John Cockcroft allowed for. Sonnenblick[2] estimates a mean dose for the human race of 0·2 to 0·3 r. I have based my calculations on a much lower figure to avoid alarmism.

India is the most important state in a position to protest against all such projects, and, as I have shown, it has special reasons for doing so. The Indian Government might also initiate experiments designed to estimate the probable effects. The figures which I have given are conjectural. They may be too high by a factor of ten or even more. They may also be too low. The experiments on mice whose results have been so far published in the U.S.A. were not so designed as to estimate the risk. They showed that some genes in mice were much more easily caused to mutate than genes in Drosophila, but they gave no estimate of the number of genes at risk. And one cannot safely argue from mice to men. But the risk to mice could be determined experimentally, and the effects of X-rays or gamma rays on human and mouse tissue cultures compared. The research could be done in India. I have worked out a scheme for the research on mice, but wish to discuss it with colleagues before publication.

I am quite aware that it is frequently stated that so many people die already from the effects of mutation that an increase by an extra few per cent. does not matter. Such an opinion does not coincide with my own ethical views. I venture to hope that these views are shared in India.

1. *Nature*, 1955, **175**, 873.
2. *Genetics*, 1955, **40**, 597.

CONFLICT *VS.* CO-OPERATION AS FACTORS IN EVOLUTION*

A SEGMENT of Acharya J. C. Bose's own philosophy of the "Unity of Life" forms the subject-matter of this Memorial Lecture. According to Bose, it is a misunderstanding of the Laws of Nature to regard conflict as the only factor in evolution; far more potent than competition is mutual aid and co-operation in the scheme of life. He had also pointed out that there must be unity of all human efforts and that in the realm of the mind there can be no boundaries and no separations. For, the evolutionary process has been active not only in morphological differentiation, that is, in the development of new forms, but also in physiological differentiation, that is, in the development of special mechanisms for performance of various vital functions. Thus every organ of a living being is an instrument subserving a particular function for the advantage of the organism.

The above views expressed by Bose as early as 1927 are not only very significant and important but prophetic when judged by the present-day urge for peace among the nations of the world through the adoption of the principles of *Panch Shila*. Modern development in the biological sciences would also tend to refute the Darwinian principles of evolution through random variations, competition, struggle for existence, natural selection and survival of the fittest, and lend support to evolution through the adjustment of organisms to the physical and biological factors in their respective environments. Thus the principle of coexistence, in spite of varied conditions of life, is biologically sound for all living organisms, including the human race. Biological principles would only appear to lend support to the philosophy of Acharya Bose that "far more potent than competition is mutual aid and co-operation in the scheme of life".

* Abstract of the Seventeenth Acharya Jagadish Chandra Bose Memorial Lecture by Sunder Lal Hora.

INDIAN SCIENCE CONGRESS, FORTY-THIRD SESSION, AGRA

THE Forty-Third Session of the Indian Science Congress Association will be held at Agra during the week 2-8, January 1956, under the presidentship of Dr. M. S. Krishnan. The session will be inaugurated by the Prime Minister, Shri Jawaharlal Nehru.

Besides scientists from all parts of India, the following distinguished visitors from abroad are expected to attend the Congress: Prof. Martin Eichler and Prof. C. L. Siegel (W. Germany), Prof. B. A. Houssay (Argentina), Prof. M. H. Stone, Dr. D. W. Bronk and Dr. Robert Oppenheimer (U.S.A.) and Dr. J. H. Burn (U.K.).

A number of symposia have been arranged and an exhibition of instruments, apparatus and equipment will also be organised during the session.