

SOCIOLOGY-BIOLOGY

The Menace of Radiation

A most important question for the future of human beings on earth is asked by a great biologist: Is radiation a menace to posterity?

By DR. H. J. MULLER

The effect of the increasing use of radioactivity upon our human germ plasm and heredity was discussed in a recent Science Service radio talk by the discoverer of radiation-induced mutations. Dr. Muller, who is a Nobelist, and professor of zoology at Indiana University, expands in this article this important contribution.

► NO MAN, worthy of being a man, lives for himself alone, or for today only. We are aware, as never before, that we are the heirs of hundreds of millions of years of biological evolution, that our culture is built of thousands of years of accumulated civilization, and that we ourselves are but fleeting guardians of all this precious heritage. We know that important changes are still taking place in it, even as it lies in our own custody, and in fact are accelerating. And so we want to know what kind of world we are making for the future.

Use of the Atom

In our age the greatest advance in our physical powers has been that derived from understanding and control over the inner constitution of the atom, and over the radiations which it gives forth. What are likely to be the consequences of our use of these techniques? We know that, if they are employed for our benefit, they will immeasurably enrich human life, and open up vast new domains. Let us also recognize that a war in our generation, if conducted by both sides of the conflict with atomic weapons, could, depending on its magnitude, throw back civilization for generations. Conceivably, by the widespread scattering of radioactive material, it might even wipe out mankind in one sweep. But let others deal with these questions. Let us ask here about the genetic effects, that is, the effects on that most invaluable of all materials that have been entrusted to our care: the biological basis of our heredity, the living substance which we will hand down, if we survive at all, to all generations following us, out of which they will have to make their lives.

A number of persons who are not professional geneticists have expressed themselves about this matter. One school has claimed that there is likely to be a great increase in the number of freaks of all kinds and that many living horrors, but possibly also supermen, will be produced. Perhaps, they say, if mankind is not destroyed in our

generation, the accumulated damage to his heredity caused by an atomic war may result in his dying out at some future time, or perhaps it may cause his speedier biological evolution. Another school, in denying all this, has claimed that there will be no significant hereditary damage, either from atomic warfare or from other applications of radiation. They say that hereditary changes, the mutations, if produced at all, will be negligible, and that we need not concern ourselves about them.

Both schools are wrong, and fail to understand the known principles concerning mutations. They imagine that most mutations give rise to visible monstrosities, and that these would be evident within a few generations following the change in the hereditary material. Moreover, both sides misunderstand how mutations of natural origin, which would occur anyway, work themselves in so as to obscure the picture of what the radiation has done.

As I have insisted on numerous occasions, as far back as 1940, the exposure of people's reproductive organs in any one generation to the largest doses of radiation which would allow reproduction at all would probably give rise to no important increase in the number of human monsters appearing in any succeeding generation. This would be true even if the whole population had been exposed in this way. And there would be little if any measurable decline of any human attributes. For the effects would be spread too thin, over thousands of years, to constitute anything readily appreciated at any one time. They could not, in themselves alone, be any source of danger to civilization.

On the other hand, this is very far from saying that the ultimate hereditary damage would be negligible, if we are Western enough to consider that individual men are important. The effects of radiation on heredity are more insidious, elusive and delayed than any other biological effects known. Their total magnitude would undoubtedly be very considerable. They would be comparable, in their summation, with the damage to the original generation that was directly exposed.

To believe that the particles of heredity, the "genes", as we call them, have as their main function the control of such visible traits as hair form, eye color and other conspicuous features is to grossly underestimate their role. The gene determine our entire bodily constitution, including our marvelously intricate system of chemical substances and physiological activities.

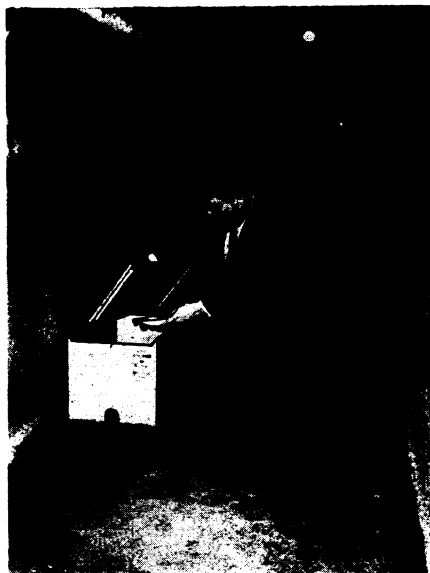
Mutations are permanent changes in these genes. They result, mainly, in inner physiological alterations, which we can seldom directly see the effects of. Being blind changes, happening at random, they are harmful in the vast majority of cases. Some of them cause death, even before birth. But the effects of the majority are not so drastic, and are often very difficult to recognize, even though they may secretly handicap us. Usually the effect is exceedingly slight if we have received a harmful gene from only one parent. For the corresponding normal gene from our other parent largely protects us. Yet even the slight effects of a harmful gene from one parent are seldom negligible, in the long run.

Hereditary Weaknesses

Nearly all of us, if a detailed study were to be made, would be found to suffer from the effects of a number of mutated genes, whether from one or both parents. These mutations arose in past generations as accidents of nature. At least one germ cell in twenty, if we may judge by fruit fly studies, carries a newly arisen natural mutation, besides many derived from earlier generations. So, even under relatively good conditions, most individuals bear the brunt of one or more of these hereditary weaknesses, that usually become more expressed as we grow older. For instance, one person may require more vitamin B₁ to keep fit, another may be unduly subject to hayfever, rheumatism or cancer, this one is near-sighted, and that one is by his natural idiosyncrasy unusually nervous, or tends to be anemic or to have high blood pressure. To say that these deviations are negligible and that doubling their frequency in the population would do no harm is simply irresponsible.

In natural populations, these ailments do not multiply beyond a certain frequency, even though new ones are always arising by fresh natural mutations. The only reason they do not accumulate more and more, and so drag us down to the lowest depths of biological degradation, is because the most afflicted individuals tend to die out, or not to reproduce. Such an event is what we call a "genetic death". In the long run, as many mutations derived from the past must die out in each generation as there are new mutations arising. This figure, as we have said, is likely to be about one in twenty. On the average, each harmful mutant gene, no matter how slight its usual effect, must cause the genetic death of some descendant in the end. Yet a given ailment may handicap a long succession of individuals, usually scattered sparsely through hundreds or even many thousands of years, before it does make its kill. These

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POISON WITH SAFETY—U. S. government rat-killers advocate putting poisons, especially the deadly 1080, inside feeding boxes like this one where rats can reach them but pets and children cannot.

caution observed in its use, effective against rats though it is.

One safeguard has been added this year. The same chemical firm that reluctantly accepted the unwelcome monopoly of making 1080 now provides operators with a black dye to discolor the water baits in which this poison, itself colorless and odorless, is set out for thirsty rats. Use of this dye is not legally required but it is strongly recommended, and most pest control operators have begun using it.

One procedure that is recommended to householder and professional alike is the use of bait-boxes. These are tightly lidded boxes, with entrances and exits through which rats can move freely, and within which the baits are placed. Thus rats can reach them, and pets and children cannot. If there are small children about, it might be a good idea to equip each box with a

hasp and inexpensive padlock, just to make sure.

Pre-baiting is also recommended practice. This means placing unpoisoned baits or little paper cups of water where the rats can find them, for several nights. Then, when the beasts have got used to expecting you to play Uncle Sucker for them, you switch roles and play Aunty Borgia instead. Usually, one or two nights of poisoned baits after one of these pre-baiting campaigns will clean up the premises.

Of the several types of rat traps that have been used at one time and another, probably the favorite nowadays is the snap-trap, that whacks down on the animal's neck or back, breaking the spine and killing almost instantly. Like all traps strong enough to be effective, it must be treated with considerable caution, for it is easily able to break the bones in a child's hand, or inflict painful injury on even an adult finger incautiously poked into it. So a trap of this kind should be set with care, and placed where a rat, and a rat only, is likely to spring it.

As commonly manufactured, this type of trap has a trigger much too small for best effect. It almost requires suicidal in-

tent on the part of the rat to get caught. The value of the trap can be greatly increased by simply tacking or gluing a piece of stiff cardboard to the top of the trigger. It should be a size that will just permit the trap to clear it when it snaps.

You can be surer of getting your rat if you will place the trap, not directly in front of a rat hole, but a little to one side, close to the wall, and lean a short piece of board so as to form a kind of tunnel with the rat hole at one end and the trap at the other. A rat likes a sheltered run of this kind, and will readily scurry into it after preliminary cautious look-around before coming out of its hole. It is a good idea to use the pre-baiting approach too, setting up the improvised runway a couple of nights before you place your trap.

In general, whether you attack with poison or traps or both, study your rats as you would study any enemy in combat. Look for signs of their presence and movements, try them with various baits placed in different spots. Every piece of information you can get will prove of value in the defense of your household against its stealthiest and most dangerous enemy.

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are the most delayed-action biological time-bombs known.

There is no way to reduce substantially, below the natural level, the number of mutations, and of genetic deaths caused by them. But their number is considerably increased by artificial application of energetic radiation, such as alpha, beta, gamma or X rays. All forms of life are affected in this way, but the higher forms on the whole are affected more. There is no practicable means of reducing this mutational effect, if the radiation is allowed to reach the germ cells. Nor can a mutation, once arisen, be undone by our design. It is also well established, despite some objections by non-geneticists, that the frequency of the mutations induced in the genes is exactly proportional to the total dose of radiation, no matter in how concentrated or dilute a form the dose was received. Thus there is no dose without at least some slight risk, commensurate with its size.

The exact risk of mutation for a given dose is by no means known for a man, however, nor even for any backboneed animal, important though this matter is. It cannot be discovered by observations on people at Hiroshima, nor on goats from Bikini. We may anticipate with high probability no detectable effects in their descendants, even though, as before explained, these effects, spread thinly over thousands of years, will probably be considerable in

their totality. Only most meticulous grand-scale experiments, conducted painstakingly over many years with laboratory animals like mice, bred in precisely controlled ways, can give a good indication of just what quantities of mutations of different types have been produced. Meanwhile, we must rest our case on the very definite results from lower forms, such as flies, moths, molds, and bacteria. To be sure, these results are already supplemented by some fragmentary data from mammals—mice—which do prove that higher types are no exception so far as the principle is concerned, and that the general magnitude of the effect in them is similar.

In flies, a dose of about 150 roentgen units results in a frequency of induced mutations about equal to the frequency of those that

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arise naturally per generation, that is, about one among twenty germ cells, but occurring in addition to the natural ones. This means that one in twenty offspring of the exposed parents, while seldom appreciably affected themselves, would hand down a hidden change that had been induced. Somewhere in the succession of future generations this would cause a genetic death, and usually, before doing so, it would handicap several individuals. Thus, among all the descendants of 20,000 parents so exposed, about 1,000 eventually would in the end be killed genetically, and along the way several thousand, though not killed, would have been more or less handicapped. Mostly, the mutations would express themselves as indefinite debilities which, mixed with the similar debilities naturally occurring in the population, could not be singled out individually as due to the radiation. And, unless special breeding methods were used, they would be scattered over too many generations to affect the population of any one generation measurably in a statistical way. And yet, if these individuals had been human beings, could we say that the killing and hampering of these several thousand people had been negligible?

Average Radiation Dose

Now, it can be estimated that this dose of 150 roentgens is the average dose to which not 20,000 but several hundred thousand people would probably be exposed if one bomb like that at Hiroshima were dropped on a metropolitan area. You yourselves can calculate from this the probable future effect. Moreover, this dose is only about half of that which some physicians have made a practice of applying to the ovary, to facilitate release of the egg in those desiring pregnancy, and thousands of babies in this country have been started on life with this treatment. It is about a third to a quarter the dose sometimes given purposely by physicians to the reproductive organs of people who wish to be made temporarily—but only temporarily—infertile. It is about twice the dose which is commonly received by the *skin* in the course of one five-minute fluoroscopic examination of internal organs, although of course much less than this amount usually reaches the reproductive organs on one such occasion. It is just the dose which would be received in five years by people getting, day after day, the dose of one tenth of a roentgen per day which has till recently been accepted as the so-called "tolerance dose", and it is what they would get in ten years with the new "permissible dose". It is probable that many X-ray operators, patients, industrial workers, shoe salesmen and their customers, and even scientists dealing with radiation in their laboratories, accumulate in the course of years a considerably bigger dose than this although, in the governmental atomic installations themselves, great care is used to keep exposure much lower than this.

If persistent neglect of the consequences

should lead to the general population's receiving a dose comparable to the above, generation after generation, indefinitely, as a combined result of military, medical, industrial and commercial uses, the results would in time be very noticeable. For in that case not only the frequency of genetic deaths but that of all hereditary weaknesses would finally rise appreciably. Though the effects from one generation's exposure are spread so far, in a layer so thin, they would in time become piled up in so many superposed layers, as at last to cause a doubling in the number of effects expressed per generation, to correspond with the doubled number of mutations constantly arising.

Our incautiousness in this matter makes it a good thing that doses of more than 600 roentgens usually result in sterility, and that, while means are being developed of mitigating radiation sickness, nevertheless the associated sterility can probably not be counteracted. For we are thereby provided with a fortunate defense which tends to protect the hereditary material of later generations from extreme contamination.

Now it has recently been discovered that, beyond the radiation sickness, there are much more delayed after-effects on the individual himself. These are elusive debilities that will cause him, on the average, to have a little shorter life span, perhaps six months less after 150 roentgens. It can be reckoned that the years thus lost either after atomic bombing or other widespread radiation exposure would be considerable—amounting in all to something like seventy million years if a population of the size of the United States was subjected uniformly to some 150 roentgens. This would be equivalent to some two million people having been killed outright. Nevertheless, it is easy to reckon that this number is probably smaller than the total number who would be killed in *subsequent* generations by the same dose, and considerably smaller than the number handicapped in subsequent generations. However, we are likely to take the danger to our own generation more seriously than that which is spread out over the future, and this too may help to protect our descendants.

We see then that the genetic effects produced by the exposure of only one or a few generations are, in themselves, far from being a threat to the existence of mankind or his civilization. Neither can they be of military value, being so remote. We certainly need not be afraid that our own children will, in the physical sense, be monsters. The induced mutations are only long-term debts which we would pass on lightly to posterity, who would rarely be able to single them out, and could never determine their source in any individual case in which they were singled out. No, it is "only" a question of some millions of lost and frustrated human lives, mostly scattered through the far future, and in our grandiose modern way we might consider this penalty cheap enough—for our-

elves. But let us not merely close our eyes to the price, or deny it. We cannot, ethically, evade responsibility for the consequences of our actions merely by getting a long distance away from them, either in space or time. "Out of sight, out of mind" is hardly an excuse that our descendants will readily grant to us. Certainly the less fortunate among them will realize acutely that, for some of these misfortunes even though they cannot know which, we were the responsible agents. And they will blame us the more if their distant injuries had been produced rather in the cold blood of peace than in the heat of war. This stricture holds not only for those dealing with atomic energy and radioactive materials but for all other users of penetrating radiation, such as X-rays, whatever the immediate benefits of their practice may be, so long as they continue to allow this radiation to reach the reproductive organs in any considerable amount.

Radioactive Materials

Now, our foregoing estimates concerning the genetic effects of atomic warfare were based on the very unlikely premise that this was carried out mainly by means of bombing like that practiced at Hiroshima. There the chief effects were from the blast, and from the one intense but localized flash of radiation, but the radioactive materials themselves were mostly dissipated in the upper air. Vastly more menacing to human existence are the Bikini under water type of explosion, and any of the various other possible techniques whereby the deadly radioactive materials are methodically deposited over great areas. By such means a much higher average dose of radiation is caused to reach the general population, and not only far greater human damage to this generation must result, but many more mutations.

To be sure, even in this case, the hereditary damage, though so much greater, would as it were be quarantined, by the directly sterilizing and killing effects on those receiving doses above about 600 roentgens. This is a level which, for the production of mutations, is still relatively low. Thus far more people would be killed and far more of the survivors sterilized than by bombing of the Hiroshima type. Yet, if there were any people left to reproduce, these could in time repopulate the world with practically normal inhabitants, provided not too much long-lived radioactive material had been left about to keep corroding them.

It is likely that, in the technically less advanced regions of the world at least, there would be people left to reproduce. Let us hope that, on reaching their atomic age, they would not acquire the point of view that a few million dead and injured were negligible if they could not see them.