IS RADIATION ALWAYS DANGEROUS?

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There is no doubt that cancers can be initiated by large doses of ionising radiation (X-rays, short wavelength ultra-violet light and the radiations from radioactive materials). Medical treatment of certain diseases with large doses of X-rays, and the radiation from the two nuclear bombs dropped on Japan, have both shown increases of the risk of death from cancer after large doses. A lot of radiation is needed to promote a large increase. In Britain today 25% of deaths each year are due to cancer. If we were all subjected to a quickly delivered radiation does large enough to kill half of us within a year or so by damage to the blood-forming organs or to the gut, the cancer death rate among the survivors would be raised from 25% to about 30%. Studies of the irradiated survivors in Japan have shown no evidence of an increase in death rates from causes other than cancer.

The whole world and even our own bodies are radioactive, and we are continuously bombarded by cosmic rays from outer space. It is assumed for the purpose of regulating exposures to workers in the nuclear industry or to the public that the cancer risk is proportional to the radiation dose. On this basis the natural sources of radiation, inside us and outside us, would be responsible for about 1/250th of our present 25% average cancer risk. The effects of the radioactive effluents from the nuclear industry are smaller still, even on the coast of the Irish Sea within a mile or two of Sellafield.

Most people are genuinely astonished by any suggesting that ionising radiation may be doing us some good. Not only are they astonished, but, even when shown evidence suggesting this, there is a large probability that they will first disbelieve

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Emeritus Professor J. H. Fremlin joined the Physics Department of Birmingham University in 1945, after having spent eight years in industrial research. In 1966 he become Professor of Applied Radioactivity. For ten years before retirement he was responsible for the post-graduate course in Radiobiology. Consultant to Cumbria County Council on radiation hazards for twelve years, his many authoritative publications include 'Be Fruitful and Multiply' and 'Power Production - What Are The Risks?'.

if and then forget it. For a generation we have been constantly bombarded by the media with the message: 'Radiation is dangerous. Radiation is dangerous. Radiation is DANGEROUS.' The idea that radiation may do good seems to contradict this. A child still gathering facts can easily believe two incompatible things by not thinking of them simultaneously. Later, our minds take trouble to decide which they think is right - or perhaps more widely believed by others - and dismiss the other as wrong and better not remembered.

LOW DOSES

A lucky accident made me remember and take seriously the possibility that radiation might be good for us. In Vienna in 1978 I was at a conference on radiation damage. A morning lecture by Dr. Spalding and reported the life-shortening effects on mice of different radiation doses delivered at low dose rates; and I noticed that the group receiving the lowest dose, of several rems, had actually lived on the average longer than the controls which had no dose at all. This seemed to me to be obviously nonsense, and I at once concluded that the control group had been less well treated than the irradiated groups.

If that had been all, I would undoubtedly have forgotten all about it. But the next lecture but one, investigating a different aspect of radiation effects on mice, showed the same unexpected feature. So I thought 'How funny that two independent and competent experimentalists should *both* have neglected their controls'. And again, even this might have been neglected or forgotten, but the coincidence niggled me; and it suddenly occurred to me that maybe mild continued irradiation of the immune system might lead to an improvement of its ability to resist disease, just as regular tiring exercise to our muscles can lead to greater strength and better ability to resist tiredness. Whereupon the two results would fit perfectly well between two parts of my existing pattern of knowledge, and were no longer incompatible with my previous belief that radiation was harmful, so long as I was willing to accept that it might sometimes do good *as well as* harm. And the final event that fixed my memory of the unexpected effect was a discussion at coffee time with Dr. Stanton Cohn, head of the medical physics unit at Brookhaven, USA. He didn't contribute any information about immune systems, but instead said; 'Do you know, John, I got exactly that result when I was a research student. I never dared to publish it.'

So I wondered how many others had not dared to publish it, and set out to look for further evidence. I found a good deal.

FOUR EXAMPLES OF THE EFFECT

I will give a few examples of this evidence. Most of the experiments have been done with small rodents. It would take a very long time and be very expensive to do experiments on the extension life span of elephants.

The first example that I found was given by a large-scale experiment by Dr. Robin Mole in 1958 on the life shortening effect of continuous gamma irRadiation of mice. An increase of about 7% in average survival time over the average survival time of unirradiated mice was shown by mice receiving a dose of 1 rem a week, more than 200 times the natural background. The effect of a dose of 1 rem is not large. Present legal limits of radiation dose are based on the assumption that 1 rem will add about 1 chance in 8,000 to our present one chance in four of dying from cancer. 7% is not very large, but was well above the expected random error.

The next example was shown by the results of a little-known mouse study by Lorenz as long ago as 1950, which showed an increase in median age at death from 23 months for zero irradiation to 27 months with a radiation dose of about 0.25 rem per day, spread over 8 hours each day for the entire lives of the animals.

The most strIking example was published by Carlson and Jackson in 1959. They irradiated a series of groups, each of 22 young adult rats, all of the same strain, for 16 hours a day for a year, the total daily dose to different groups varying from zero to 8 rems a day. Their results showed that, for each group of rats at below 8 rems a day, the life expectancy was greater than that of the controls, the maximum increase being around 30% for a daily dose of 2.5 rems - a total dose in the course of the year's irradiation of about 900 rems.

A gain from low doses of radiation is not confined to mammals. Pentreath, in 1980, reported an experiment in which batches of eggs and young fry of Canadian salmon (about 100,000 eggs per batch) were irradiated from a few hours after laying until they started feeding. Another batch from the same site were not. Now, salmon return after two to four years to the same spawning ground. It was found that a larger proportion of adults from the most lightly irradiated group (half a rem a day) returned than did from the unirradiated group. Furthermore, the ones that had been lightly irradiated produced a larger number of fertile eggs. Presumably in some way the irradiated batch had been protected from whatever diseases reduce the numbers of growing salmon, and left them in better health. Batches receiving large radiation doses did less well than the controls.

RESTORATION OF DAMAGED DNA

The fact that in each of the four experiments cited the large total doses were spread over long periods is important. Our entire evolution has taken place in a radioactive world in which everyone of our living cells will have been struck by an ionising particle several times a year. Inevitably these ionising particles will sometimes do serious damage to the DNA on which our genetic inheritance and the proper working of our cells depend. To cope with this, the cells of our very early ancestors, probably before they crawled out of the water on to the land, developed exceedingly efficient repair systems, capable of perfect restoration of the damaged DNA to its original state.

The repair takes at least a few minutes, which doesn't matter at all under natural conditions, when background radiation will rarely cause significant damage to the DNA of any particular cell more than about once a year. The cells or irradiated survivors of the nuclear bombs on Japan will have received almost their entire dose, causing up to several hundred separate injuries to the DNA of every cell in their bodies, in a tiny fraction of a second. It is likely that in such conditions the repair system may have been less effective, and that deductions made from the cancer rates observed among the heavily irradiated survivors may seriously overestimate the cancer rates to be expected from comparable doses received at low dose rates. In the course of a year Carlson and Jackson's most heavily irradiated rats received a total dose of nearly 3,000 rems, which would quite certainly have killed them outright if it had been received in a few seconds, but which in fact barely reduced their life-span to the zero-dose level.

Dr. T. D. Luckey in a review article quotes over 200 references to experiments, on a great variety of creatures, with similar results. But while collectively these carry some weight, if only because none of them show life-*shortening* at low dose-rates, most of them are individually less convincing than the four I have quoted.

The results of these experiments are consistent with the hypothesis suggested above to explain the increase in longevity: that irradiation, perhaps by producing a great variety of aberrant cells, some of them cancerous, was giving a general stimulus to the immune system, which left it more effective in dealing with the early stages both of cancers and of diseases caused by micro-organisms.

IMPROVEMENT OF THE IMMUNE SYSTEM

Support for this interpretation has been given by a different type of experiment, published by Hoffsten and Dixon in 1974. Here the effectiveness of antibody formation in the immune system of mice was determined by measuring the number of micrograms of a foreign hormone that were bound by antibodies in 1 millilitre of mouse blood plasma, after six weeks of irradiation of the mice at a series of dose rates. The standard errors were considerable, but there was a very clear maximum at around 170 rems a week, a dose which gave in each week a radiation dose 850 times the average natural background dose received in a year.

The possibility of an improvement of the human immune system by apparently irrelevant stimuli has recently been shown by Dr. Alice Stewart and her collaborators. She studied the relation of childhood cancer rates to earlier experience of inoculation against eight specific diseases - smallpox, measles, poliomyelitis, whooping cough, diphtheria, German measles, tetanus and tuberculosis. In each case, a smaller proportion of the children who had been inoculated died later of leukaemia or other cancer before the age of 16; and putting the whole lot together this result was statistically completely convincing. Dr. Stewart's proposed explanation is similar to mine for the increased longevity: that the specific experience given to the immune system improved its general capacity to distinguish and inhibit or destroy aberrant cells that might otherwise have multiplied into a cancer.

On purely logical grounds it is difficult to explain why a favourable effect of low levels of irradiation, now known as radiation hormesis, should not already have been expected by analogy with the biologically well-known phenomenon of hormesis: the stimulus given to an organism by non-poisonous concentrations of poisonous substances. Thus small amounts of arsenic improve the complexion, and in Austria and elsewhere are used by peasants to improve resistance to fatigue. Arsenic and strychnine are used in tonics. Compounds of copper, zinc and selenium, and of course vitamin D, are essential to our lives in small quantities but lethal if swallowed a gram at a time. An even closer analogy is given by ultra-violet light; at moderate intensities it can enable us to make all of the vitamin D that we need for ourselves; in excess it can cause dangerous burns and cancer.

DIFFERENT EFFECTS FOR DIFFERENT AGES

Much stress is laid by those who fear the radiation from radioactive materials on the fact that we can neither see it, smell it nor taste it. Exactly the same exaggerated fears for exactly the same reasons were expressed by those who opposed the introduction of electricity. Partly this is the common objection to the new, as when most of the medical profession refused for a generation to believe in the harmful effects of bacteria, and for two generations refused to believe in the existence of viruses, which couldn't be seen under a microscope. A large part is due to the connection with nuclear weapons.

Now, I have no direct proof that the irradiation of young humans would on balance be good for them, as it has been proved to be for a variety of other creatures. There is no doubt that radiation, however small the dose and dose rate, must initiate cancer in a correspondingly small number of living cells. Neither is there any question that an improvement in our immune system could improve the recognition of modified cells as aberrant and a larger proportion would therefore be destroyed. The comparative importance of good and bad effects, however, may well be different in different species of animal, and at different ages in a single species, so that the balance might be bad for us although it is good for many other creatures.

The evidence from Hiroshima and Nagasaki shows incontrovertibly that large doses can on the average cause up to 5 percent or more of a mixed population to die of cancer who would not have done so without the radiation dose. If we look specifically at the young however, whose immune systems are still developing, it is apparent that the results are consistent with a useful degree of radiation hormesis.

Table I (from a paper by Kato and Schull) shows the total number of leukaemia deaths and of all cancer deaths including leukaemia, between 1945 and 1978, among those who were children under 10 years old at the time of bombing, for a series of ranges of radiation doses recorded. It is strikingly clear that not only was there no increase in observed cancer death rates for the lower doses, but that below a dose of 100 rem the cancer death rate was actually less than the death rate of children who received no radiation at all. The numbers of deaths are so small that a pure lucky chance could have led the death rates following doses from 10-49 rems and from 50-99 rems to be less than the death rate for none. Above 100 rems the conventional prediction that about 1.25 extra cancers per 10,000 people per rem should be added to the no-dose figures is as close to the observed rates as could be expected from the small numbers involved. Below 100 rems the deficit is therefore consistent with a useful degree of radiation hormesis.

Figures for the cancer rates among people between 35 and 50 at the time of bombing, whose immune systems were likely to have already reached their peak, showed no sign whatever of radiation hormesis; the cancer death rate rose with dose all the way, with no anomalous change in rate above 100 rems.

Hormesis or no hormesis, it must be a relief to all of us that the long-term effects of the bomb radiation on children are unobservable even for quite large doses at the enormous dose-rate experienced at Hiroshima and Nagasaki.

It has been pointed out that the oldest children under 10 at the time of bombing will have been only in their forties by 1978, an age at which 'normal' cancer rates are beginning to increase rapidly; but there is no reason to suppose that the cancers initiated by the doses from the bombs will be delayed for longer than those initiated before the age of 10 by 'normal' causes. Such evidence as we have suggests that cancers due to larger doses appear *earlier* than those due to small doses.

A SERIOUS DEGREE OF EXAGGERATION

Until we know a lot more than we do now, it will be sensible to keep tight limits on the radiation doses to which the nuclear industry is permitted to expose their workers, all of whom are adults, and the lower limit to which they are permitted to expose the public. And I think we are a long way from the time when we might expect every home to have a gamma ray source in the children's bedroom to extend their later lives. (Even when we do know enough, the government may want to make it illegal, because it won't want to increase the number of 'senior citizens'.)

At the same time I think that the evidence shows conclusively that the estimation of risks at low dose-rates received at Hiroshima must lead to a serious degree of exaggeration, at least for young people; and that the true causes for such clusters of cases of leukaemia as at Seascale must be looked for elsewhere. (Although less publicised, clusters of child (and adult) leukaemias have occurred in many places far from any nuclear establishments, and strongly suggest infectious sources, probably of viruses.)

CHERNOBYL

Our understanding of the disaster at Chernobyl has not changed any estimates of risks in Western reactors. Since the Soviet catastrophe, operators everywhere will be less likely to disobey the rules, and the quite specific structures that made the Chernobyl explosion possible have no counterpart outside the USSR.

Being myself an experimentalist rather than a theorist, I note that among civil power reactors outside the USSR one accident, at Three Mile Island, led to an even chance that one person might die as a result of the escape of radioactive material, and that several accidents have occurred without any significant risk to anyone. If we have learned nothing from these it is likely that in the next three thousand reactor years we shall have another accident giving an even chance of killing one person, and several accidents causing no significant risk to anyone. Actually we have learned a great deal, and the prospects should be better.

Measurements of the radioactivity absorbed by people in the Ukraine suggest a resultant cancer excess over the next 50 years of under 1,000, if we forget about radiation hormesis. Radiation hormesis however may be particularly helpful in the unusually young Ukrainian population; among the 20 million who died in the Soviet Union during the war, few Ukrainians who would by now be in the dangerous age range for cancers between 55 and 75 survived.

The disruption of the lives of those evacuated is in many ways more serious than the tiny addition to the millions of cancer deaths that will occur from other causes.

To put the whole nuclear risk in Britain in perspective I have extended in Table II data given by Dr. Richard Peto from British mortality statistics and his own work on the causes of cancer.

FRIGHTENED BY GHOST STORIES

Finally, I very much want to know why the numerous agitators who oppose nuclear power, some of whom must have known about the animal experiments of the kind I have described, have concealed their knowledge from the public. The irresponsible hullabaloo they have raised, with the help of the media, about tiny doses received from the nuclear industry, and their complete neglect of the thousands dying each year as a result of diesel fumes and other fossil fuel discharge is inexcusable. I do not regret the decision of Nirex not to bury low level wastes as planned. I do not like people to be frightened, even if they have been intentionally frightened by ghost stories. And the ocean bottom, of which the top 10 cm or so has from natural sources some ten times the alpha activity of average land surface soils, has always seemed to me the best place for it. But the callous cruelty of the propagandists who have successfully terrified people in areas which might have been used for the safe storage of low level nuclear wastes has not been exceeded since the witch hunts of the seventeenth century.

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Table I

Death rates from leukaemia, and from all cancers, in Hiroshima and Nagasaki combined, among children under 10 at the time of bombing. 1945-1978.

Dose range (rems)	Number of children	Observed deaths. Leukaemia	All cancers	Death rate per 10,000. All cancers
0	5,800	7	22	38
1-9	4,420	3	18	41
10-49	2,970	4	8	27
50-99	700	1	2	29
100-199	380	4	7	180
200-299	190	4	12	350
300-399	80	1	1	130
400 up	260	9	11	420

Table II

Among 1,000,000 young adult males starting a lifelong addiction to cigarettes:

About 600 will be murdered -

About 6,000 will be killed on the roads -

Several thousand will die from chemical air pollution by fuel burning and vehicle exhausts -

About 250,000 will be killed by tobacco -

About 1 will be killed by the effluents of the British nuclear power industry -

About 1 will be killed by the fall-out from Chernobyl.