Hiroshima and Nagasaki: The Survivors

Between 21 July and 3 August the Geneva-based International Peace Bureau assembled a team of 44 scientists from 14 countries to investigate the effects of the atomic bombs. The team, which included 25 Japanese specialists, visited research institutes and hospitals in Hiroshima and Nagasaki, examined evidence, and interviewed scientists, doctors, social workers and atom-bomb survivors. These two articles are from participants at the meeting

The reckoning

Three decades of research have revealed the following general picture of the overall effects of the two atomic bombs—but there remain some disturbing gaps in our knowledge

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Considerably less than one-half of the people now living remember the atomic bombing of Hiroshima and Nagasaki, 32 years ago. The two bombs, euphemistically called "Little Boy" and "Fat Man", dropped on the Japanese cities were all that then existed. But in the meantime the nuclear arsenals have been stocked with tens of thousands of nuclear weapons, most of them much more powerful than those that obliterated Hiroshima and Nagasaki. And the probability that all, or a major fraction, of them will be used in a nuclear world war is steadily increasing. Prudence demands that we do not forget the awesome damage done and the terrible suffering caused by those early nuclear weapons.

A great deal of information on the physical, biological, medical, genetic, social and psychological effects of the atomic bombs was made specially available by Japanese scientists to the international team which gathered in Japan late last month. It included the results of comprehensive surveys of the personal and social disabilities of the survivors.

Perhaps surprisingly after three decades, the investigation turned up new information. It also discovered serious and disturbing gaps in existing knowledge and research. But perhaps the most important conclusion of the investigation is that our knowledge of the long-term consequences of the atomic bombs will remain shockingly incomplete unless there is a massive injection of financial and scientific resources. In particular, the effort so far made to discover the social and psychological effects is pitiful. But very much remains to be done in the biological, genetic and medical areas. Given the urgent need for better data on the biological effects of ionising radiation on man, the paucity of the current research effort, the complacency of some of the relevant local authorities, and the lack of interest of international bodies is inexcusable.

In the words of the natural science experts: "While viewing with abhorrence the events that produced this type of experimental material, consideration of the well-being of present and future generations requires that full use be made of it. In a world still faced with the spectre of a nuclear war—in which radiation is now given the role of the main weapon of destruction—on the one hand, and with the possibility of large-scale utilisation of nuclear energy on the other, it is imperative that the maximum information be obtained from the fate of the victims of the A-bombs."

The international experts worked mainly in two groups —a natural science group and a social science group. The documents they produced give a fairly comprehensive description of the events following the bombings.

The atomic bomb dropped on Hiroshima on 6 August, 1945, is thought to have had an explosive yield equivalent to that of 12·5±1 kilotons of chemical explosive. The yield of the Nagasaki bomb, dropped on 9 August, 1945, is thought to have been 22±2 kilotons.

The Hiroshima bomb exploded 580±20 metres above the centre of the city, which lies on a flat delta with mountains to the north and west, and sea to the south. The entire city was damaged concentrically. The Nagasaki bomb exploded 500±20 metres above ground to the north of the city. Because the terrain is mountainous the damage in Nagasaki varied considerably according to direction.

Effects of fire, blast and radiation

About 35 per cent of the total energy generated by the bombs was given off as thermal radiation, about 50 per cent as blast, and about 15 per cent as ionising radiation. The fireballs produced by the explosions reached maximum temperatures of several million degrees Centigrade at the instant of detonation and grew to their maximum diameters of about 280 metres in about one second. At this time the surface temperature of the fireballs was about 5000°C. Two seconds later it was 1700°C; thereafter it fell more gradually.

The infrared radiation emitted during the first three seconds after the explosion was a particularly powerful cause of burns on unclothed parts of the human body. Even at a distance of 4 kilometres from the hypocentre (the point on the ground directly below the centre of the explosion) of the Hiroshima bomb, the thermal radiation emitted in the first three seconds amounted to about 1·3 calories/sq. cm, about 20 times more than that from the Sun. At a distance of 500 metres from the hypocentre nearly 60 calories/sq. cm of thermal radiation were emitted in the first three seconds. The thermal radiation from the Nagasaki bomb was about twice as intense as that at Hiroshima.

The thermal radiation was intense enough to burn exposed human skin at distances as far as 3·5 kilometres from the hypocentre in Hiroshima and 4 kilometres in Nagasaki. At these distances, fabrics and wood were charred. People caught in the open air within about 1·2 kilometres from the hypocentres were often burnt to death.

A widespread fire storm raged in Hiroshima for six hours, completely burning every combustible object within a radius of 2 kilometres from the hypocentre. The fire-storm in Nagasaki, even though less general than that in Hiroshima, was severe in specific areas.

Moisture condensed around rising ash particles, produced by the intense fires, as they came into contact with the cold air above. Consequently, much rain fell on the two cities. But it was not clear rain. The highly radioactive and oily liquid that came down is known to this day as "black rain".

The atomic explosions produced exceedingly high pres-


Keystone

Hiroshima after the bomb. Note wrecked fire-engine

sures of several hundred million millibars at the detonation points. The explosive expansion of the surrounding air produced a great blast. The front of the blast moved as a shock wave—a wall of air at high pressure, transmitted like a sound wave and spreading outward at a speed equal to, or greater than, the speed of sound. The shock wave travelled nearly 4 kilometres in the first 10 seconds after the explosion. In 30 seconds it had travelled about 11 kilometres and still retained some destructive power. It was followed by an exceedingly strong wind. But as the shock wave spread outward, the pressure within fell below atmospheric pressure and eventually the air flowed in the inward direction. Thus, at a given point from the hypocentre, a supersonic shock wave was followed by a very powerful wind and then, after an instant of stillness, a strong wind blew in the opposite direction.

At Hiroshima the maximum blast pressure at a distance of 2 kilometres from the hypocentre was about 3 tons/sq. in and the maximum blast velocity was about 70 m/s. All buildings within this distance were damaged beyond repair. Casualties due to blast, caused mainly by collapsing buildings and flying debris, were particularly severe within about 1·3 kilometres of the hypocentre. At this distance the blast pressure reached 7 tons/sq. m and its velocity 120 m/s.

Because of the destruction of an extensive area by a single powerful blow, fire-fighting facilities were all but completely destroyed. In any case, water stopped running in both cities. And the damage was so extensive that fire-fighting was impossible. In Hiroshima, about 76 000 buildings stood before the bomb dropped. Of these, 63 per cent were totally destroyed and 11 per cent seriously damaged. Destroyed by blast and 24 per cent were very seriously damaged. About 25 per cent of Nagasaki's 51 000 buildings were totally destroyed and 11 per cent seriously damaged.

Physical damage similar to that done to Hiroshima and Nagasaki by the atomic bombs could, of course, have been produced by high-explosive and incendiary bombs. Estimates show that, for Hiroshima, this would have taken about 290 tons of high-explosive bombs and 900 tons of incendiaries. But an atomic bomb delivers its enormous destructive power in an instant. And it inevitably produces ionising radiation and radioactivity. People exposed to this radiation may die of diseases which appear many years after exposure. And their offspring may be malformed because of genetic damage. The horrors of Hiroshima and Nagasaki are qualitatively worse than the horrors produced by the bombing of Tokyo, Coventry, Hamburg or Dresden.

About a third of the ionising radiation produced by the atomic bombs was emitted within one minute of the explosion. This is called initial radiation. The remainder, called residual radiation, was emitted by fission products deposited on the ground and by radioactive isotopes produced by neutrons in the soil and elsewhere.

The main components of initial radiation are gamma rays and neutrons. The initial radiation dose (air dose) 500 metres from the hypocentre at Hiroshima is thought to have been about 6000 rads, 2800 from gamma rays and 3200 from neutrons. At Nagasaki the dose at this distance was probably about 7700 rads, 7000 from gamma rays and 700 from neutrons. The neutron components of the initial radiation differ because each bomb had a different fissile material: uranium for Hiroshima, plutonium for Nagasaki.

It is generally reckoned that one-half of those receiving a whole-body radiation dose of 400 rads (air dose) will die, and that all those exposed to whole-body radiation of 700 rads or more will die in a short time. Exposed people within about 1 kilometre of the Hiroshima bomb, and 1·2 kilometres of the Nagasaki bomb, are thought to have received doses of about 400 rads.

Anyone coming within about a kilometre of the hypocentres in the first 100 hours after the explosions could have received substantial amounts of residual radiation, and could have ingested or inhaled radioactive materials. Only rough estimates of the doses of residual radiation received are available. The maximum possible dose is thought to be about 130 rads in Hiroshima and 50 rads in Nagasaki. But people in the "black rain" area of Nagasaki could have been exposed to doses of up to 150 rads.

Number killed

About 90 per cent of all those within 1 kilometre of the hypocentres when the atomic bombs exploded died by the end of 1945. About 60 per cent of those within 2 kilometres died: about three-quarters in the first 24 hours, and nearly 90 per cent within 10 days.

The number of people in Hiroshima at the time the bomb exploded is very uncertain, mainly because the number of troops there is unknown. But estimates indicate that about 350 000 people were directly exposed to the bomb. Considerable differences exist between the various estimates of the total number killed or injured. The international experts concluded that the most likely figure for the number of deaths up to the end of 1945 is 140 000, about 20 000 of whom were military servicemen. If anything, that may be an underestimate, as a large number of people are still unaccounted for in the 1950 national census. Many of those who survived the initial onslaught must have died within the next few years. And very little information is available about the fate of the 37 000 or so people who entered Hiroshima within the first week.

The number of persons directly exposed to the Nagasaki bomb is thought to be about 280 000, of whom approximately 74 000 died by the end of 1945. Again, the number who perished after 1945 is not known.

Large numbers of Korean forced labourers were in both cities during the bombings, and the fate of the majority of them is unclear. About 23 American prisoners-of-war are known to have died in Hiroshima. In Nagasaki about 450 Dutch, American and British prisoners were exposed but the number who died is not known.

All in all, the total number of people killed by the two atomic bombs is probably well over a quarter of a million, a death rate of about 40 per cent.

People killed instantly were mainly either crushed or burnt to death. The seriously burnt and injured suffered fever, intolerable thirst and vomiting. They went into a state of shock. Almost all of them died within a week. Such was the lack of doctors, nurses, medicines and even bandages that most died virtually without treatment.

Many of those exposed to large doses of radiation rapidly developed symptoms of radiation sickness. They became incapacitated, with nausea and vomiting. A few days later they typically vomited blood, developed a high fever, had severe diarrhoea and much bleeding from the bowels. They usually died within 10 days.

Those exposed to smaller doses of radiation suffered a wide variety of symptoms including nausea, vomiting, diarrhoea, bleeding from the bowels, gums, nose and genitals, and menstrual abnormalities. There was often a total loss of hair, fever and a feeling of great weakness. Resistance to infection was markedly decreased. And septicaemia was a frequent cause of death.

Delayed effects

The really unique, and perhaps the most terrifying, consequences of the atomic bombs are the delayed effects. Because of these, survivors, their children, and their grandchildren will live in fear for years to come.

Most of the survivors still alive at the end of 1945 appeared superficially to be in good health. But later a variety of medical effects—including diseases of the eye and blood, malignant tumours and psychoneurological disturbances—began to appear.

The incidence and mortality rate of leukaemia among survivors increased fast for about a decade and then reached a level about 30 times higher than that of non-exposed Japanese. Afterwards it started to decrease slowly but has still not reached the national average. An enhanced incidence of leukaemia occurred in those who received relatively low radiation doses, of well below 100 rads.

The incidence of other malignant tumours—thyroid, breast, lung, salivary gland, bone, prostate, and so on—has been, and still is, significantly enhanced among those exposed to radiation at Hiroshima and Nagasaki.

Tragically, children born to women-survivors who were pregnant when the bombs exploded show an increase in some congential malformation, particularly microcephaly (abnormally small size of the head) resulting in mental retardation. But no increase has been reported in the incidence of leukaemia among children exposed *in utero*. (This surprising finding, and also the apparent absence of genetic effects in children conceived by survivors exposed to radiation, are discussed in the following article by Professor Rotblat).

Among explanations advanced for this absence are: that the number of survivors available for investigation, and the radiation dose received by them, are such that too few children show genetic effects—even though these may be present—to be statistically significant; the research methods used to search for effects are insufficiently sensitive; the mutations induced are predominantly recessive ones and so they will only show up in second, third or even later generations; many of the affected persons may have died from acute radiation effects; and there may have been a large number of undetected spontaneous abortions.

The absence of demonstrable genetic effects among the offspring of the survivors of the Hiroshima and Nagasaki

An eyewitness remembers

Futaba Kitayama, then a 33-year-old housewife, was 1·7 kilometres from the hypocentre when the atomic bomb exploded over Hiroshima at 8.15 am on 6 August, 1945. In her words, first published in a Japanese journal:

"Someone shouted, 'A parachute is coming down!' I responded by turning in the direction she pointed. Just at that moment, the sky I was facing flashed. I do not know how to describe that light. I wondered if a fire had been set in my eyes.

"I don't remember which came first—the flash of light or the sound of an explosion that roared down to my belly. Anyhow, the next moment I was knocked down flat on the ground. Immediately, things started falling down around my head and shoulders. I couldn't see anything; it seemed pitch dark. I managed to crawl out of the debris.

"Soon I noticed that the air smelled terrible. Then I was shocked by the feeling that the skin of my face had come off. Then, the hands and arms, too. Starting from the elbow to the fingertips, all the skin of my right hand came off and hung down grotesquely. The skin of my left hand, all five fingers, also came off.

"What happened to the sky that had been such a clear blue one only a moment ago? It was now dark, like dusk. I ran like mad toward the bridge, jumping over the piles of debris.

"What I saw under the bridge was shocking: Hundreds of people were squirming in the stream. I couldn't tell if they were men or women. They looked all alike. Their faces were swollen and gray, their hair was standing up. Holding their hands high, groaning, people were rushing to the river. I felt the same urge because the pain was all over the body which had been exposed to a heat ray strong enough to burn my pants to

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A severely burned victim of the Hiroshima attack sits in a makeshift hospital

pieces. I was about to jump into the river only to remember that I could not swim.

"I went back up to the bridge. There, school girls, like sleepwalkers, were wandering about in confusion. Upon crossing it, I looked back and found that the Takeyachō-Hatchōbori area suddenly had burst into flame. I had thought that the bomb hit only the area where I was.

"When crossing the bridge, which I did not then recognise, I found all its parapets of solid ferro-concrete had gone. The bridge looked terribly unsafe. Under the bridge were floating, like dead dogs or cats, many corpses, barely covered by tattered clothes. In the shallow water near the bank, a woman was lying face upward, her breasts torn away and blood spurting. A horrifying scene. How in the world could such a cruel thing happen? I wondered if the Hell that my grandmother had told me so much about in my childhood had fallen upon the Earth.

"I found myself squatting on the centre of the parade ground. It must not have taken me more than two hours to get to the parade ground. The darkness of the sky lessened somewhat. Still, the Sun, as if covered with a heavy cloud, was dim and gloomy.

"My burns started paining me. It was a kind of pain different from an ordinary burn which might be unbearable. Mine was a dull pain that was coming from somewhere far apart from my body. A yellow secretion oozed from my hands. I imagined that my face also must be in this dreadful shape. By my side, many junior high school students were squirming in agony.

"They were crying, insanely, 'Mother! Mother!' They were so severely burned and blood-stained that one could scarcely dare to look at them. I could do nothing for them but watch them die one by one, seeking their mothers in vain.

"As far as I could see with my declining eyesight was all in flames.

"Steadily, my face became stiffer. I put my hands carefully on my cheeks and felt my face. It seemed to have swollen to twice its size. Now I could see less and less. Soon I would not be able to see at all. I kept walking. I saw on the street many victims being carried away by stretcher. Carts and trucks, heavily loaded with corpses and wounded who looked like beasts, came and passed me. On both sides of the street, many people were wandering about like sleepwalkers." □

bombs does not, of course, mean that there is no genetic effect of radiation. On the contrary. The use of large numbers of modern nuclear weapons could, over a number of generations, decimate human life.

The social and psychological effects of the atomic bombings were extremely severe. In some ways they overshadow the other effects. The damage was so great that the communities totally disintegrated. So many firemen, doctors, nurses, policemen, teachers, and so on died or were injured that social services collapsed. Of those people that initially survived, many went mad or committed suicide. Thousands of children became orphans. Hiroshima and Nagasaki became ghost towns.

Thirty two years later, the effects of the bombs are still apparent. So many young people died that there is a disproportionate number of aged among the survivors. This imbalance is being increased by the widespread use of contraceptives among survivors who fear that their children would be malformed. Acute diseases and chronic after-effects do not allow the survivors to live normally. Fear of genetic damage often prevents marriage, and susceptibility to disease and fatigue often prevents employment.

The ratio of sick and injured among the survivors is about 40 per cent—almost twice the national average. The ratio of physically handicapped is over three times the national average. The vicious circle of disease and poverty among the survivors is continuously aggravated by ageing and failing health.

Academic discussions of nuclear strategies have lost sight of the human suffering caused by atomic bombs. Hiroshima and Nagasaki leave no doubt about the immorality of strategies based on nuclear weapons. □

The puzzle of absent effects

Although the survivors of the two atomic bomb attacks have become the model for all studies of long-term radiation effects, there are some curious anomalies which suggest that the nuclear holocaust itself may have produced a selected population

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Over 350 000 of the 1945 inhabitants of Hiroshima and Nagasaki survived the immediate effects of the atom bombs dropped on these cities. Most of them were exposed to the radiations, neutrons and γ-rays, and some received doses of over 200 rads. The survivors thus constitute the largest human experiment for the study of long-term radiation effects. Such studies were carried out on a large scale, first by the Atomic Bomb Casualty Commission, and more recently by the Radiation Effects Research Foundation which took over from the ABCC. The researchers made a very great effort to calculate the radiation doses, separately for neutrons and γ-rays, which the survivors received under their conditions of exposure. They set up a "master sample" of some 110 000 persons for whom the location at the instant of the explosion and shielding conditions were sufficiently well established to estimate the doses with a reasonable degree of accuracy. They have monitored this population very carefully in a series of investigations, including a life-span study, incidence of malignancies, and genetic effects. Current estimates of radiation risks relating to carcinogenesis, particularly leukaemogenesis, are largely derived from these studies. But the question now arises whether it is justified to base estimates of risks of populations exposed to radiation under normal, peace-time activities, on the results obtained from the A-bomb survivors.

The bulk of our knowledge of radiation effects comes from experiments with animals. Most of these effects have also been observed in man. Thus, among the hibakusha the Japanese term for A-bomb victims) there is a definite dose-related increase in the incidence of leukaemia; there is also an increase in the incidence of thyroid cancer, breast cancer and lung cancer, and probably of a number of other malignancies.

However, other radiation effects are conspicuously absent. Thus, no genetic effects in children conceived by hibakusha after the explosion have been found so far, despite a vigorous search. For some end-points the statistical material was sufficiently large for effects to be observed. This negative finding is being used in some quarters as evidence that there are no radiation-induced genetic effects in man.

Another absent effect is any increase in malignancies after exposure *in utero*. It is generally accepted, following the findings of Alice Stewart, that children born to mothers who received diagnostic X-ray doses in pregnancy, are more prone to leukaemia and other malignancies. No such effect was found among the children born to women who were pregnant at the time of the bombing.

Equally puzzling is the absence of an increase in overall mortality. Animal experiments show that whole-body exposure to a single dose of external radiation results in a life-shortening proportional to the dose, due to an increase in age-specific mortality rates. Among the hibakusha, not only was there no evidence of an increased mortality rate, but there was in fact a *reduced* mortality from causes other than malignancies.

Table 1 taken from the 1977 Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, gives the mortality figures for Hiroshima and Nagasaki over the period 1950-72 for survivors exposed to doses over 9 rads in the master sample. The expected mortality is based on Japanese National Statistics. While there was an increase in deaths from leukaemia and other malignancies, there was a decrease for non-malignant causes of death. This decrease was so large that the total mortality among the hibakusha is significantly lower than in the rest of the Japanese population.

A reduction in overall mortality in selected groups, as compared with a total population, is often observed and easily interpreted. A paper published in 1974 by Schofield and Dolphin shows that the mortality of workers in the Windscale plant is significantly lower than for the UK population as a whole. While not saying explicitly that "a small dose of radiation is good for you" some members of the nuclear industry used this finding as evidence that work in a nuclear plant is a healthy occupation. This highly

Table 1 Mortality in Hiroshima and Nagasaki

Causes of Death	Observed	Expected	Excess
Leukaemia	84	14	70
Other malignancies	1075	919	156
All diseases except malignancies	3970	4592	-622
Total	5129	5525	-396

misleading information is even now fed to the public in the "Jubilee Atom" pamphlet issued by the UK Atomic Energy Authority. It is misleading because it compares two populations of different structure. The Windscale workers are a selected population, they are all healthy people under good medical care. Ill people, who contribute most to the general mortality, are not as a rule accepted for jobs at Windscale or other such establishments. No wonder that the mortality rate at Windscale is comparatively low.

Why should the A-bomb survivors be such a selected population? One suggested reason is that—after the first few years—more care was taken of them and that they are being looked after medically. However, many hibakusha maintain that their standard of living is in fact lower than for the average of the population. But there may be another, or an additional, reason for the lower mortality.

A product of natural selection?

The hibakusha are unique in that they were exposed to radiation at the same time as being subject to injuries from the blast, and burns from the heat flash. Those who did not perish immediately also faced the psychological trauma of bereavements and the collapse of the fabric of society. Under these conditions only the fittest managed to get over the physical and psychological insults. The weaker of the population, with less will to live, did not recover from the injuries—or succumbed to other illness—and have died during the following weeks or months. One might, therefore, say that the hibakusha are the product of a natural selection; as such they may be expected to show a lower mortality.

If ability to survive is due to one's genetic make-up, then the hibakusha may also be a selected population genetically. Therefore it would be much more difficult to observe any radiation-induced genetic effects, when compared with a normal heterogeneous population. Similarly, it is likely that the weaker of the pregnant women have either died before giving birth, or produced weaker children who died of other causes before developing malignancies.

If this hypothesis of selection is correct, it raises the question whether it might also have affected the magnitude of the carcinogenic effects of radiation in the hibakusha in the sense of exhibiting a lower sensitivity to these effects.

In a recent paper George Kneale and Alice Stewart have shown that in children there may exist a precancerous condition which manifests itself in a greater susceptibility to infectious or other diseases well before the cancer symptoms show up. They also suggest that this may apply to cancers in general, and that in particular it may have resulted in a low cancer mortality among the A-bomb survivors. Indeed, where data are available for comparison, the incidence of cancers among the hibakusha is markedly lower than for other groups exposed to radiation. This applies to the incidence of cancer of the thyroid, breast and lung. Various interpretations, none really convincing, have been put forward to explain this discrepancy.

No suitable data are available for a comparison of leukaemia incidence, although this is the earliest and most studied of the late effects of radiation. However, there appears to be a way of putting the selection hypothesis to the test in the case of leukaemia. A large number of people entered the cities after the bombing in search of bodies of relatives, or for rescue work. These people were exposed to the residual radiation, ie γ-rays partly from fission products but mainly from radioactivity induced by neutrons in the soil and the walls of buildings. Many cases of leukaemia occurred among these entrants. Table 2 is taken from a paper by F. Hirose published in 1968 in a Japanese journal. It refers to the incidence of leukaemia, in the 18-year period 1950-67, among the entrants to Hiroshima. This table is interesting in that it contains a sort of built-in control. Most of the radioactivity was short-lived, with an effective half-life of about 12 hours. Therefore, those who entered after the third day received much smaller doses than those who entered earlier. The table shows that the leukaemia incidence was indeed much higher among the early entrants.

Table 2 Incidence of leukaemia among entrants to Hiroshima

	Entered 6–9 August	Entered 10–13 August	Entered 14–20 August
Population	25 798	11 001	7327
Number of leukaemias	45	8	1
Incidence per 100 000 per year	9.7	4.0	0.8

Researchers appear to have made no attempt to estimate the doses received by individual entrants after the explosion, but they have carried out calculations on average cumulative doses for entrance at different times, and location at different distances from the hypocentre. These calculations indicate that the doses during the first three days were likely to be in the range 10 to 50 rads. If one now takes from the master sample the leukaemia incidence among those exposed to the primary radiation who received doses in the same range (17 cases in Hiroshima and two in Nagasaki), the rates come out to be 7·4 and 2·5 per 100 000 persons per year, for Hiroshima and Nagasaki, respectively. The leukaemia incidence among the early entrants thus appears to be higher even in relation to the Hiroshima victims, but the more relevant comparison is with Nagasaki. The reason is that the primary radiation from the Hiroshima bomb had a greater neutron component than the Nagasaki bomb; the much higher relative biological effectiveness (RBE) of neutrons has served to explain the greater number of radiation induced leukaemias in Hiroshima than in Nagasaki for the same dose in rads. But there were no neutrons in the radiation to which the entrants were exposed, and which was of similar quality to the primary radiation in Nagasaki. Thus, the radiation-induced leukaemia incidence is much higher among the entrants than in those directly exposed for the same dose range.

In Nagasaki, too, many cases of leukaemia were observed among the early entrants, but no data are available about the size of the population involved. There is one interesting observation, however. The heaviest fall-out came down in the Nishiyama Valley, which is separated by a mountain from the area where the bomb was exploded; the inhabitants were thus shielded from the heat and blast effects and there were no immediate casualties. But among the 200 inhabitants two cases of leukaemia were reported. Leukaemia is such a rare disease that even two cases in such a small population suggests a very high incidence rate.

All these estimates of leukaemia incidence in those exposed to the residual radiation are of course extremely rough. Much more information about age and time distributions is needed before they can be made into a quantitative assessment, but they are strongly suggestive of a difference in response to radiation, as far as leukaemia is concerned, between persons exposed to radiation alone, and those who were also subject to mechanical injuries and heat burns. Together with the absence of other expected effects of radiation, and the lower cancer incidence, this indicates that the hibakusha population cannot be assumed *a priori* to behave in response to radiation in the same way as those exposed to radiation alone, without accompanying physical, psychological and social traumata. Estimates of radiation risk based on observations on the A-bomb survivors may thus turn out to be too low, by a considerable margin. □