Chapter 10: Science Distorted by Frightened Men

_Fear does not prevent death. It prevents life._
Naguib Mahfouz, 1988 Nobel Prize for Literature

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**Evolution after Darwin**

_Faster development and greater personal threat_

To develop productively and peacefully, civilised society needs both trust and knowledge. Marie Curie gave both when she introduced radiation and nuclear technology into medicine. So the public acceptance of ionising radiation
started well and she was active herself in organising the use of X-rays for the casualties of battle during WWI \[1\]. However, later in the twentieth century, when radiation and nuclear technology made an appearance in the form of nuclear weapons, knowledge was explicitly suppressed in the name of security and there was no figure like Marie Curie to instil public confidence. How did this go wrong? We need to go back in time.

In the nineteenth century Darwin introduced his revolutionary biological ideas of variation, selection and survival, as applied to living species. Over time most of human society came to understand and accept these, in spite of their revolutionary effect on our view of ourselves in the world. Perhaps this was because the changes that evolution described acted relatively slow, and an individual's perception of himself and his immediate family did not feel much affected. So, though knowledge was thinly spread, trust was not seriously impaired and variations in family ancestors, desirable or not, were safely removed to prehistory.

The principle of selective breeding of humans is a natural extension of the improvement of plants and animals, as practised from earliest times. But, independent of Darwin's ideas, the manipulation of human characteristics through planned breeding is widely seen as taboo and excites strong passions. Nevertheless, it was in fact Darwin's relation, Francis Galton, who in 1883, the year after Darwin's death, introduced eugenics, the name for this study.

Darwin developed his ideas to describe the development of populations of organisms – that is whole individuals. Later, the same ideas were applied to populations of cells including viruses and bacteria, where the timescales of change are much faster. With a cycle time of a few weeks cells can turn over hundreds of times in a human generation, and other constituents of microscopic life like bacteria and viruses evolve faster still. Evolution on this scale gave a picture of cellular life that might, even in the short term, be manipulated or artificially engineered for nefarious or political purposes. This picture alarmed the public in a way that Darwin, with his account of the characteristics of the finches observed on the Galapagos Islands, never did. However, what Darwin's theory did not describe was how the genetic record might be systematically changed, that is how mutations might be induced in the DNA. The power to manipulate would depend on controlling these mutations, but the structure of DNA would have to be found first.

It is not widely known that in the years before WWII X-rays were used with some success to control infection \[2\]. However, this work was cast aside in the enthusiasm for antibiotics when these became available to treat infections on the battlefield. If the current increase of antibiotic resistance continues, perhaps this use of X-rays should be considered again – but that is an aside.

After WWI there was increasing disquiet as the Soviet and Nazi authoritarian
regimes grew and industrialised military interests expanded with them. The Nazis engaged in experiments in eugenics in pursuit of their racial ideas although with limited success. However, a more significant development dates from the 1920s and even before, when it was shown that X-rays could create random mutations in fruit flies, as first studied by Hermann Muller. It was at this point that ionising radiation first entered the story that later became radiophobia.

**When evolution met radiation: Hermann J Muller**

Hermann Muller (1890-1967) was an American geneticist with outspoken political beliefs and an early interest in eugenics – he even named his son Eugene. In 1926 he published his experimental results on the production of mutations in fruit flies by X-ray radiation. Later, in 1946 he was awarded the Nobel Prize for this pioneering work. Significantly, in his lecture he claimed that any radiation dose produces genetic damage in direct proportion, all the way down to zero dose \([3, 4, 5]\). This was the birth of the LNT model, but in making this claim he says *these principles have been extended to total doses as low as 400 r*. In modern units that is 4,000 mGy – which is a very high dose indeed, high enough as an acute dose to have killed the firefighters at Chernobyl. So he did not establish the LNT model for low or moderate doses found in the environment. Since then, other work has shown that the LNT model does not fit low-dose data for fruit flies \([6]\). Nevertheless, he continued to claim that the response to such doses is linear all the way down to zero, as now enshrined in the LNT model.

Elsewhere in the middle of the twentieth century, biology became entangled with politics and made other wrong turns. In the Soviet Union, Trofim Lysenko, an agronomist, persuaded Stalin that Soviet agriculture should deny the principles of Mendelian genetics and develop crops based on the principle of the inheritance of acquired characteristics, as suggested by the Frenchman Lamarck (1744-1829). Unsurprisingly the programme failed and many inhabitants of the Soviet Union died of starvation as a result. The application of this fallacious pseudo-science was not finally halted until 1956.

Although both the LNT model and Lamarckism are mistaken, the former still has vocal supporters who are reluctant to look at the evidence. In the same way, even today, in parts of the USA, opposition to Darwin's ideas is seen as a belief – a political or religious question. Some people, it seems, live their lives knowing the answer as they see it, without ever looking at the evidence, but that is not an effective way to avoid danger.

However, the public perception of physical science was derailed in the middle of the twentieth century by a quite different mechanism, such that it was then seen as a closed book, shrouded in mystery and secrecy.
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**Nuclear weapons and the Cold War**

A year that made history and buried truth

The end of WWII and other events in 1945 coloured how the birth of nuclear weapons was received. In that year the public of every nation were steeped in daily accounts of horror and war that are not easily forgotten, even with the passage of time. On 15 April British troops entered the Bergen-Belsen concentration camp, and in the following few days the public were shown press pictures of piles of naked bodies, evidence of tens of thousands dying of starvation and disease [7]. So the media were already experienced in the transmission of genuinely shocking news when in August the official reports arrived of the two nuclear bombs dropped on Japan. Each nuclear explosion caused a blast wave and a heat wave that destroyed buildings and killed most people within a radius of about 1 mile, and generated a fire-storm over 4.4 square miles [8]. The death toll was said to be less than in the conventional fire-bombing of Tokyo six months earlier [9], but peculiar to the nuclear explosion was the intense flash of X-rays and the lesser flash of neutrons emitted from the detonation point at a height of 500-600 metres. Because the explosion was high above ground there was less radioactivity released than would have been the case for a detonation at ground level. As a result, the inhabitants received acute doses of radiation, with less chronic dose from fallout.

The historical narrative that one usually reads is what the victors wrote, but more significant for the subject of this book is what the vanquished thought of the nuclear bomb. They learned of its power when at their lowest psychological point, and their national consciousness has been branded by the thought of it ever since. It is no coincidence that the most visceral reactions to the accident at Fukushima have come from Japan and Germany. But with the passage of years those reactions should be tested against science. When writing the account of Fukushima for the sake of future generations, the world has a duty to ensure the story is honest and scientific, not emotional.

**Dissent over nuclear weapons**

But after WWII the victors were troubled too. Though a scientist may respect the science and its reliability, his fear of what his fellow human beings may do with the power it gives them is increased by his technical understanding. Fears of Nazi Germany and the Soviet Union were rife in the twentieth century, but there were also worries on the US home front about politicians, military leaders, fellow scientists and foreigners who held a variety of views on how science should be used. Nuclear energy, by its very power, intensified questions of trust, confidence and secrecy [10]. Significant tensions built up
between individual scientists, and also between other groups involved; and these were not eased when peace came. Worries about war-time allies, particularly the Soviet Union, grew too.

Unlike science, history often provides several coherent accounts of a maze of events from different perspectives. Thus the military and political perspectives of the history of nuclear radiation are not based in science. In the development of nuclear weapons in WWII, the raison d’être of the Manhattan Project, there were many major players who were not scientists, and misunderstandings between them and the physical scientists continued to be important into the Cold War era. It could be argued that the lack of confidence and mutual trust between these two groups was as instrumental in the rise of radiophobia as the ingrained fears of the defeated populations.

Many of the physical scientists involved were in some shock when they realised the energy of what they had developed, and had little confidence in the readiness of the military to forego the influence of this muscle at the end of hostilities with the Axis Powers. Their concern was well founded, for other nuclear scientists threw themselves, without a second thought, into building the most powerful weapons possible, in particular the fusion device known as the hydrogen bomb. A conventional fission bomb is limited in size and power by the speed at which it is possible to assemble a large super-critical mass of explosive. But a fusion bomb has no such limit, and the Soviets tested a 50-58 megaton device, about 2,000 times the energy of the Hiroshima and Nagasaki explosions.

Political and military concern, particularly in the United States, was focussed on fears that other powers might obtain the secrets of nuclear weapons. As a result the development of the hydrogen bomb was supported amid tight security. Exceptional scrutiny was applied to root out any potential Soviet sympathisers, and the sharing of information with other allies, even the UK, was curtailed. A reign of anti-communist hysteria, verging on paranoia, ensued: there were the Senate subcommittee McCarthy-Army hearings of 1954 about claims of communist infiltration; there were the investigations of the House Un-American Activities Committee with its witch hunt for communist sympathisers; there was the investigation of the patriotic loyalty of Oppenheimer before the US Atomic Energy Commission. Dr Robert Oppenheimer was the physicist war-time leader of the Manhattan Project whose security status was revoked in 1954, largely on the testimony of Edward Teller, the Hungarian-born theoretical physicist who pushed the development of the hydrogen bomb. The late 1940s and early 1950s were a dark period in the USA – many liberties that we normally take for granted were suppressed. The lives of many eminent people were seriously damaged and they went into hiding, or went abroad, like Paul Robeson, the legendary actor and singer, and Charlie Chaplin, the film director and comedian.
helpful to appreciate this turbulent background when judging the scientists and scientific opinion of the day – opinion that led to the establishment of the LNT model and the suppression of contrary views for over 60 years.

How scientists express their concern on matters beyond their own immediate field varies, but their natural discipline makes them cautious – in fact considerably more cautious than those unused to scientific argument. Since few physical scientists and engineers appreciate much about biology, and biological scientists know very little of nuclear physics, they are frequently rather over-awed by their shared interdisciplinary questions. That was the case in the Cold War era in the matter of nuclear radiation and its biological effects, particularly genetics. At a crucial time in the 1950s as the official view was forming, the voice of biology was missing. In the confrontations between the main parties, the military and the physical scientists, nobody could speak to the biology with the required authority. There was no biologist on the Manhattan Project with the necessary clout, and the mode of scientific thinking in biology is quite different from that in the physical sciences, as explained in Chapter 4. And into this gap came Hermann Muller, recently anointed Nobel Laureate (1946), with his outspoken support for the LNT model, his concern about radiation, and his antipathy to Soviet ideology and Lysenko-ism. There was no competition.

Illustration 36: A graph showing the number of US and Soviet nuclear warheads deployed at different dates.

The madness of the Arms Race

In the post-war period political backing in the USA for the growth of nuclear armaments was very strong. It was seen as the means to impress Pax Americana on the world, and other nations, friend and foe, were very much
aware of that. Those that were able to do so reacted by developing and deploying their own nuclear weapons. When the allies, Britain and France, did so, it was seen as politically undesirable and a loss of security, but no worse. However, when the Soviet Union exploded test devices, that was seen in the USA as an existential threat.

In the intervening decades remarkably few nations have bothered with nuclear weapons. Though they may wield influence at the conference table, they are very expensive in technical manpower and mostly useless in the field from a military perspective. In his work John Muller of Ohio State University has explored why nations consider nuclear weapons such an undesirable waste of resources [see Selected References on page 279, SR4]. Nevertheless, a few have flexed their muscles in practice (China, India, Pakistan) or in theory (Israel, Iran, South Africa), leaving North Korea as the only state likely to consider using a nuclear weapon in anger.

The US paranoia about nuclear weapons was exacerbated by Soviet behaviour in taking over Eastern Europe. So was started the Cold War, as recorded by Churchill in March 1946 [11]. As the US nuclear arsenal built up, it was no surprise that the Soviet Union, no stranger to national paranoia, felt threatened and joined the nuclear Arms Race (see Illustration 36). For many years the system for delivering nuclear warheads was manned bombers, patrolling around the clock and ready to respond to any attack. Later, these were replaced by missile delivery, at first of limited range. But with the launch of the first satellite, the Russian Sputnik, in 1957, came the realisation that inter-continental rockets would be able to deliver nuclear warheads to anywhere on Earth with minimal delay, and that the Soviet Union had the lead in this technology. Later developments included missiles carrying multiple warheads and missiles launched from submarines that can remain submerged and hidden for months at a time, ever ready to deliver a revenge counter attack should the other side mount a first strike. International politics at this time was dominated by the tension between the USA and the Soviet Union, said to be stabilised by the mutual fear of the consequences of nuclear war and the balance between their arsenals. The end of the Cold War came at a summit meeting in Iceland in 1986, coincidentally six months after the Chernobyl accident. Although technically quite unrelated, the Soviet political self-confidence in nuclear technology seems to have collapsed generally at this time, and by 1991 the Soviet empire, as such, appeared to be no more.

**Chronology of nuclear turning points**

- 16 July 1945: Trinity test of the plutonium bomb, 21 kiloton.
- 6 August 1945: Uranium bomb dropped on Hiroshima.
- 9 August 1945: Plutonium bomb dropped on Nagasaki.
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- 29 August 1949: First Soviet nuclear test.
- 3 October 1952: First British nuclear test.
- 1 March 1954: The voyage of the *Lucky Dragon* (more below).
- 9 July 1955: Russell-Einstein Manifesto (more below).
- 1956: Recommendation from the BEIR1 Committee that Radiological Safety should no longer be assessed against a threshold but using the LNT model (for reasons expanded upon later in this chapter).
- 4 October 1957: Soviet Union launch of Sputnik, the world's first Earth-orbiting artificial satellite.
- 1958: Petition to UN by Linus Pauling and others (more below).
- 17 January 1961: President Eisenhower's valedictory speech, in which he warned of the power of the Industrial Military Complex that had built up, distorting the free exercise and funding of much scientific academic work in universities, as discussed further in *Radiation and Reason*, Chapter 10.
- March 1962: Letter from Linus Pauling to President Kennedy (see page 248).
- October 1962: Cuban Missile Crisis (see page 250).
- 5 August 1963: Partial Test Ban Treaty (Soviet Union, USA, UK) banning atmospheric nuclear testing.
- 11 October 1986: Meeting in Iceland between Presidents Reagan and Gorbachev, often seen as marking the end of the Cold War.
- 1988: The report of the BEIR IV Committee attempted to close the door on evidence-based thinking, claiming as \[12]\)

\[...
\text{a matter of philosophy, it is now commonly assumed that the stochastic effects, cancer and genetic effects, are non-threshold phenomena and the so-called non-stochastic effects are threshold phenomena. Practical limitations imposed by statistical variation in the outcome of experiments make the threshold-nonthreshold issue for cancer essentially unresolvable by scientific study.}...\]
Because the proponents saw the question as untestable, they were not prepared to scrutinise it.

- 10 September 1996: UN Comprehensive Test Ban Treaty banning all nuclear explosions (still not ratified by the USA).
- 2004: Repudiation of the biology of the LNT model in a unanimous joint report by the French academies of science and medicine [26].
- 2007: ICRP Report 103. An excerpt from paragraph 36 indicates their non-scientific thinking [13]:

  At radiation doses below around 100 mSv in a year, the increase in the incidence of stochastic effects is assumed by the Commission to occur with a small probability and in proportion to the increase in radiation dose over the background dose. Use of this so-called linear-non-threshold (LNT) model is considered by the Commission to be the best practical approach to managing risk from radiation exposure and commensurate with the ‘precautionary principle’ (UNESCO, 2005). The Commission considers that the LNT model remains a prudent basis for radiological protection at low doses and low dose rates.

Far from being the best practical approach, as they suggest, the LNT model has been used to justify the most inhuman response to nuclear accidents.

**Public exposure to radioactivity from weapons**

**Nuclear testing in the atmosphere**

The radiation from weapons testing in the atmosphere was caused by the extreme heat of the detonation carrying radioactive material high into the stratosphere where it spread over the whole Earth and descended gradually, giving an exposure of radioactivity at the surface known as fallout. This was measured, and annual values in the UK are shown in Illustration 37. The decrease after 1963, the end of atmospheric testing by the USA, Soviet Union and UK, was due to natural depletion of atmospheric radioactivity by the action of the weather and radioactive decay. The small blip in 1986 is the effect of Chernobyl, evidently far smaller than the effect of weapons testing that lasted for many years. Nevertheless, all these exposures are small, as the scale shows: at its peak the exposure from fallout was 0.14 mGy per year. This may be compared to the average annual natural radiation dose of less than 2 mGy per year, and to 10 mGy from a modern diagnostic scan which is beneficial.
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Much more worrying to the world population in those years were the thousands of nuclear warheads that were stockpiled, principally by the Soviets and the United States (see Illustration 36). These could have been fired in semi-automatic response by a few people in error or in an ill-considered response to an international incident resulting in worldwide fallout on a scale a thousand times larger than testing – that is a few hundred mGy per year. The effect of this global radiation dose would have been in addition to that of the local blast and fire in the regions where the warheads exploded. The need to cease adding more missiles, to cease testing and to decommission these stockpiles was clear; it generated semi-permanent public protest around the world with many scientists taking part. Nevertheless, few people understood the numbers and that the dose from the testing alone was harmless. Although the LNT claim that every dose, however small, is harmful is not substantiated by reliable measured evidence, the belief that it would be harmful was important in the political decision to halt the Arms Race, as will become clear.

Antoni-nuclear demonstrations in free countries

Everyone alive at the time of the Cold War may prefer to forget what it was like, and it is seldom explained to later generations what a pall of dread hung over every man, woman and child on Earth who could read a newspaper or listen to the radio. The effect of a nuclear attack was seen as more than just a remote region devastated by blast and fire – in those days everyone could still recall the pictures and news from the total ruins that were Berlin, Hamburg and Tokyo after WWII. A nuclear war was visualised in the media as an escalating tit-for-tat leading to the destruction of thousands of cities, given that the arsenals of the two sides had several tens of thousands of missiles ready to fire (Illustration 36).
The result of such a nuclear exchange was seen as even worse, because of the reported effect of the radiation from the fallout, spread far and wide around the Earth, the combined effect of all the warheads – and lasting for centuries.

Anti-nuclear movements started at national level, first advocating nuclear disarmament then opposition to nuclear power. They mounted large public demonstrations, marches and occupations, in particular the famous annual 52-mile march from London to the Atomic Weapons Establishment at Aldermaston, which was held from 1958 to 1962 and attracted many tens of thousands of participants. The leading anti-nuclear peace movement organisations around the world at various times – the Campaign for Nuclear Disarmament, Greenpeace and Friends of the Earth – have attracted a large following, including many distinguished intellectuals, church leaders and public figures.

Mobilisation of public opinion on this scale influences political parties in a democracy, and politicians are obliged to take note. In many countries both nuclear energy and nuclear weapons have been made illegal. Nations that are currently opposed to nuclear power in principle include Australia, New Zealand and many EU countries.

**Fallout in fact – The Lucky Dragon**

The US test of a hydrogen bomb on the Bikini Atoll in the Pacific Ocean on 1 March 1954 was exceptional [14]. It was designed to use lithium deuteride (LiD) as a solid fuel in which the minor component, lithium-6, provides the tritium needed when bombarded by a neutron. It was not known before the test that the major component, lithium-7 (92.5%), would also react with a neutron, thereby increasing the energy released from 6 megatons to 15 megatons, the highest energy test ever detonated by the USA and nearly 1,000 times the energy of the Hiroshima or Nagasaki device. As a result, the area that had been kept clear of shipping to avoid high levels of fallout was far too small. Further, the fallout was particularly large because the device was detonated at ground level, thereby creating much additional radioactive material and propelling it into the upper atmosphere.

Most heavily contaminated by the fallout was the Daigo Fukuryu Maru, the Lucky Dragon No. 5, a 140-ton Japanese fishing boat with a crew of 23. The exact position of the boat at the time of the explosion is not known, but it is thought that it was about 80 miles away. The crew suffered severe beta burns on their skin and when they reached Japan they were treated for ARS although, unlike those contaminated at Goiania and Chernobyl, none died of it in the next few weeks. One crew member died after seven months of cirrhosis of the liver – radiation is unlikely to have been the prime cause. Like survivors of Hiroshima and Nagasaki, the crew were stigmatized because of the Japanese public’s fear of radiation exposure, believing it to be
contagious or inheritable. Another crew member reported that when the fallout came down he had licked it to test it – in 2013 he was reported to be alive at 79 years old. In 2014 another crew member was reported to be alive at the age of 87. Many details are missing, but, as in other nuclear accidents, the mortality that many had feared or expected at the time, has not been realised.\[15\].

The incident was a diplomatic disaster for the USA, and did nothing for the reputation of the radiation and its safety either. As often happens, an attempt was made to make amends by paying compensation, although litigation and compensation muddy the water for the scientific record by persuading voices to remain silent or change their story. But after more than 50 years we can say that the effect on human life may have been no more than several cases of intense beta burns, similar to sunburn in fact. However, absolutely nobody believed that at the time, and nobody has corrected the public perception since. No erratum ever makes a good news story.

**Fallout in fiction – On the Beach**

Fear of nuclear technology has stimulated 70 years of sensational entertainment that has gripped the world. One of the most famous novels, *On the Beach* by Nevile Shute published in 1957, is set in Australia where a surviving southern outpost of life watches as the radioactive fallout, liberated by an all-out nuclear war in the northern hemisphere, creeps gradually south, extinguishing all signs of life as it does so. The story is thrilling, and was made into a popular film, but the science is flawed, although that did not prevent it making many conversions to the anti-nuclear cause; notably Helen Caldicott who says that when she read the book as a 12-year old it scared the hell out of me. Since then she has pursued an emotional anti-nuclear campaign which has been heavily attacked for its fear mongering and lack of any scientific basis.\[16\].

No one who lived in the Cold War era could have failed to enjoy the talents of Tom Lehrer, the American singer-songwriter, satirist, pianist, and mathematician. Among his blacker nuclear songs was *We will all go together when we go*. It was a piece with a typically jolly tune and words about total nuclear death – the Cold War years encouraged such macabre humour. The words nuclear and radiation have entered the popular language as scare words, the adult equivalent of saying BOO! to a small child who then runs away and hides.\[17\].

There were many more expressions of nuclear gloom and horror in the arts, but why should we make note of these here? Because we are going to need to counter them with equal talent if we are to overcome the legacy of 70 years of nuclear phobia. The effects of carbon fuels on our environment and our civilisation may be the alternative. So we need to find the sons of Nevile
Shute, sons of Tom Lehrer, daughters of Jane Fonda, and of all those in the arts who performed in the anti-nuclear era. New artistic talents are urgently needed in the coming decades to reverse the message their parents and grandparents gave so brilliantly.

**Warnings from the intellectual elite**

**Russell-Einstein Manifesto**

By 1955 it was widely felt that mankind faced an existential threat from the nuclear powers, and with the prospect that many further nations might also acquire such weapons, the prospects looked dire. Joseph Rotblat, the only scientist to leave the Manhattan Project on moral grounds, remarked that he became worried about the whole future of mankind. In the following years he worked with Bertrand Russell, the eminent British philosopher, on efforts to curb nuclear testing and proliferation. It became apparent that only a joint declaration by a number of respected Nobel Laureates could hope to wield the moral authority needed to head off the danger – although, as will become apparent, even that was not sufficient.

The Russell-Einstein Manifesto was launched at a news conference in London on 9 July 1955. Albert Einstein had died shortly before, but after signing the manifesto. The other signatories were: Max Born, Percy Bridgman, Leopold Infeld, Frederic Joliot-Curie, Hideki Yukawa, Cecil Powell, Hermann Muller, Linus Pauling, Joseph Rotblat and Bertrand Russell. Of the eleven, ten had won, or would win, a Nobel Prize. This is a very distinguished list indeed, but, with the exception of Hermann Muller, not one of them was a biologist or medical scientist.

The manifesto started by calling for a scientific conference:

*In the tragic situation which confronts humanity, we feel that scientists should assemble in conference to appraise the perils that have arisen as a result of the development of weapons of mass destruction*

and went on:

*No doubt in an H-bomb war great cities would be obliterated. But this is one of the minor disasters that would have to be faced. If everybody in London, New York, and Moscow were exterminated, the world might, in the course of a few centuries, recover from the blow. But we now know, especially since the Bikini test, that nuclear bombs can gradually spread destruction over a very much wider area than had been supposed.*

*It is stated on very good authority that a bomb can now be*
manufactured which will be 2,500 times as powerful as that which destroyed Hiroshima. Such a bomb, if exploded near the ground or under water, sends radioactive particles into the upper air. They sink gradually and reach the surface of the earth in the form of a deadly dust or rain. It was this dust which infected the Japanese fishermen and their catch of fish. [reference to the Lucky Dragon]

No one knows how widely such lethal radioactive particles might be diffused, but the best authorities are unanimous in saying that a war with H-bombs might possibly put an end to the human race. It is feared that if many H-bombs are used there will be universal death, sudden only for a minority, but for the majority a slow torture of disease and disintegration.

Many warnings have been uttered by eminent men of science and by authorities in military strategy. None of them will say that the worst results are certain. What they do say is that these results are possible, and no one can be sure that they will not be realized. We have not yet found that the views of experts on this question depend in any degree upon their politics or prejudices. They depend only, so far as our researches have revealed, upon the extent of the particular expert's knowledge. We have found that the men who know most are the most gloomy.

The scientific conference that they called became known as the Pugwash Conference which still works today for world peace. With its co-founder, Sir Joseph Rotblat [10], the Conference was awarded the Nobel Peace Prize in 1995.

But scientists can make mistakes, particularly if they take their eye off the evidence. The signatories of the Russell-Einstein Manifesto did not know whether or not the crew of the Lucky Dragon would die from the radioactive fallout that covered them, but they assumed that they would. Today we know that was pessimistic, although records of the fate of the crew, distorted by litigation and compensation, are not fully available. We have more complete and optimistic evidence from Fukushima, and also from Goiania and Chernobyl. Except for a handful of cases, it seems that radiation is far less injurious to life than anyone expected, even the distinguished signatories to the Russell-Einstein Manifesto.

Linus Pauling to President Kennedy

The aim of the signatories to the manifesto was to stop the Arms Race; stop the testing, stop the stockpiling, then get rid of the stockpiles. What happened showed them that calling for a conference might be a good way to move scientists, but it did not have the desired effect at the political and military level, and so another way to tackle the problem had to be found.
After winning the Nobel Prize in Chemistry in 1953, Linus Pauling had become science's most prominent activist against nuclear weapons testing. He resolved to speak out with the backing of the wider public, and in 1958 with his wife he presented a petition to the UN with 11,000 signatures calling for an end to nuclear weapons. But still the testing and Arms Race continued.

The public initiatives of 1955 and 1958 had not been sufficient to create the magnitude of radiation scare required to stop the nuclear Arms Race. Therefore Linus Pauling and Hermann Muller, in particular, evidently felt that they needed to raise the rhetoric another notch. The only way they thought might be effective was to exaggerate the evidence for genetic harm to future generations caused by radiation. There was no scientific basis for what they claimed, and today we know that it is factually incorrect.

They realised that committees do not make radical decisions or changes of direction – only individuals are likely to do that. To ensure success, they needed to pin the responsibility personally on one person who could stop the testing – and that meant President John Kennedy. Linus Pauling's letter to Kennedy shows the strength of feeling and the lengths to which distinguished scientists were prepared to go. It read: [18]

March 1962 Night Letter Durham NC

President John F Kennedy

Are you going to give an order that will cause you to go down in history as one of the most immoral men of all time and one of the greatest enemies of the human race? In a letter to the New York Times I state that nuclear tests duplicating the Soviet 1961 test would seriously damage over 20 million unborn children, including those caused to have gross physical and mental defect and also the stillbirths and embryonic, neonatal and childhood deaths from the radioactive fission products and carbon-14. Are you going to be guilty of this monstrous immorality, matching that of the Soviet leaders, for the political purpose of increasing the still imposing lead of the United States over the Soviet Union in nuclear weapons technology? (sgd) Linus Pauling.

He could not substantiate the threatening prospect that he held out in this letter and today we can say that he was wrong in his claims. The concerns that he expressed were based on a political and human agenda, not science, but once such concerns are created, in this instance about the effects of small amounts of radiation, it is very difficult to switch attitudes back, even with the benefit of scientific evidence. Trust is fragile.

The dangerous road chosen by Linus Pauling led to two results: firstly the signing of the 1963 atmospheric test ban treaty; secondly the establishment of fallacies in the public mind, and in the mind of the authorities too, about the
effects of radiation on human life. The first was what he was trying to achieve, but the second created a mindset that distorted reactions by authorities, for instance at Fukushima. These fallacies were primarily the responsibility of Hermann Muller, for he was the biologist, not Linus Pauling.

**A game of nuclear chicken**

**Cuban Missile Crisis**

In a game of chicken each player prefers not to yield to the other, but the worst possible outcome for all concerned occurs when neither player yields.

For 13 days in October 1962 the USA and the Soviet Union came closer to full-scale nuclear war than at any time, before or since. New US missiles in Turkey had put Moscow in range for the first time and the Soviet Union had started constructing missile bases in Cuba, just 90 miles from the coast of the USA. A US *U-2* spy plane produced clear photographic evidence of the missile facilities being readied in Cuba, and so a naval blockade was established to prevent further missiles from entering Cuba. The US demanded that the weapons already in Cuba be dismantled and shipped back to the Soviet Union. After tense negotiations and days when the world felt it was living on a knife edge, agreement was reached between Kennedy and Khrushchev. The Soviet Union would dismantle its missiles in Cuba and the US would dismantle those in Turkey and Italy – although this was not known to the public.

It was a chilling time for everybody worldwide, and there can be no doubt that it played a significant part in pressing the case for controlling the Arms Race. The first result was the Partial Test Ban Treaty of 5 August 1963 that ended the testing of weapons in the atmosphere. How much the Pauling letter to Kennedy contributed to this development we do not know, but the consequences of repeatedly stoking popular fears of radiation, even though they lack a scientific base, are with us still.

**Radiological protection and the use of the LNT model**

**US National Academy of Sciences genetics panel report**

After the bombing of Hiroshima and Nagasaki the physical science view of the world was in the ascendency. The power of mathematics and physics had been demonstrated and in case of doubt its supremacy was usually accepted.
This obviously had a profound effect on the judgement of those with research ambitions in biology and in other sciences. Major opportunities opened for those able to work by importing methods and ideas from the disciplines of mathematics and physics into biology, even if they struggled to understand them.

The question of the effects of ionising radiation on life was an important one for biology after WWII, and US science naturally took the lead in establishing international standards, rather as the British had done for maritime and geographical standards in earlier centuries. And so it was that recommendations to the ICRP came from the Genetics Panel of the US National Academy of Sciences, actually its Biological Effects of Atomic (later, Ionising) Radiation Committee (BEAR 1) of which, significantly, Herman Muller was a member.

Edward Calabrese has researched the history of what happened and found copies of original correspondence that suggest the BEAR/BEIR committee saw radiobiology as an appropriate vehicle to build funding for their interest in genetics \[19, 20, 21, 22, 23]\]. In addition, and perhaps more altruistically, there was the Arms Race. By reporting a worst case conclusion on the negative effects of radiation, they might achieve both goals. So it was that in 1956 the panel recommended that the use of thresholds in radiological protection be discontinued and the LNT model be used instead. Its conclusions were then adopted internationally by ICRP.

Safety not fit for purpose

Because the LNT model makes the administration of risk particularly straightforward, other areas of safety regulation have copied it, without establishing any scientific demonstration that it is appropriate. For example, it is assumed that any toxic chemical poses a risk in proportion to its mass, however small the quantity and however much it is concentrated or dispersed. But toxicity does not work like that – small quantities may be good for health, even essential, while excess may endanger life. This was already well understood by the physician Paracelsus in the 16th Century (see page 188).

Since BEAR1 in 1956 there have been further BEAR/BEIR reports, but none has reversed the adherence to the LNT model, and thence to ALARA, in spite of the overwhelming weight of evidence against it and the serious consequences it has had around the world in human and financial terms. Indeed, in 1988 BEIR IV dug itself further into a non-scientific position, as quoted on page 242. A review in 2014 of the most recent BEIR report by Calabrese and O’Conor brings the discussion up to date \[24\].

Fortunately, many eminent scientists and physicians are not impressed by the wishful thinking embedded in these reports. Lauriston Taylor (1902-2004),
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who was a founder member of ICRP (1928) and first president of US NCRP, spoke out expressing his disquiet in an invited lecture as early as 1980 [25]. Some passages from his lecture are quoted on page 214.

In its 2007 report ICRP condemned the use of the Collective Dose to assess the number of deaths in a large population subjected to low doses. (The Collective dose is the sum of all individual doses added together and measured in man-sievert.) This was quite illogical as the ICRP committee failed to withdraw its support for the LNT model which, on its own, provides sufficient simple justification for the use of the Collective Dose in this way.

Internationally, there has also been support for fresh thinking, independent of NAS. In 2004 a unanimous joint report was published by the French Académie des Sciences (Paris) and the Académie Nationale de Médecine [26] that set out the biological case for a complete change in the regulation of radiation. It was highly critical of the use of LNT theory (see further discussion in Chapter 8).

In 2014 a new informal international group of professionals, Scientists for Accurate Radiation Information (SARI), was set up, dedicated to securing change both for radiological safety in general and also for a more enlightened use of radiation in health care. It posts important articles and correspondence [27] and its members make representations for change to major committees around the world, including UNSCEAR, NAS, NRC and the Health Physics Society (HPS). It has also been active in spreading a positive scientific message in Japan in collaboration with the Japanese Society for Radiation Information (SRI) [28].

There is great resistance from an entrenched clique to any change to the belief in LNT concepts that they have worked with all their lives. But like alchemy, ptolemaic epicycles, astrology, Lamarckism and other pseudosciences, LNT theory is not supported by the evidence. The necessary changes are:

- firstly, to acknowledge the crucial role of the reactive and adaptive cellular mechanisms in protecting life from attack by radiation which have been an essential feature of all life-forms for billions of years;
- secondly, to accept that the prime cause of cancer is immune failure rather than the generation of mutations that are present in any case and kept in check by the immune mechanisms;
- thirdly, to replace LNT-based safety regulations by ones based on scientific threshold dose rates and doses;
- fourthly, to foster a corresponding reform of public attitudes towards safety that teaches by explanatory education rather than ex cathedra instruction issued by authority.

These are not matters for piecemeal or incremental improvements. Policy
should change completely and be re-based on science as soon as possible.

**Notes on Chapter 10**

14) The background is described in this archival account which makes reference to the labs "rushing to develop", indicating internal competition in the Arms Race [http://nuclearweaponarchive.org/Usa/Tests/Castle.html](http://nuclearweaponarchive.org/Usa/Tests/Castle.html)
16) Helen Caldicott - "Th" Thorium documentary A video by G McDowell [https://www.youtube.com/watch?v=Qaptvhky8IQ](https://www.youtube.com/watch?v=Qaptvhky8IQ)
17) I am grateful to Sir John Polkinghorne for this enlightening analogy.
18) The telegram written in Pauling's hand is shown in Figure 2 of the paper by Cuttler "What becomes of Nuclear Risk Assessment...." Dose Response 5, 80 (2007) [http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2477701/](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2477701/)


27) SARI [http://www.radiationeffects.org]