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Remedy for Radiation Fear — Discard the Politicized Science

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ABSTRACT

While seeking a remedy for the crisis of radiation fear in Japan, the author reread a recent article on radiation hormesis. It describes the motivation for creating this fear and mentions the evidence, in the first UNSCEAR report, of a factor of 3 reduction in leukemia incidence of the Hiroshima atom-bomb survivors in the low dose zone. Drawing a graph of the data reveals a hormetic J-curve, not a straight line as reported. UNSCEAR data on the lifespan reduction of mice and Guinea pigs exposed continuously to radium gamma rays indicate a threshold at about 2 gray per year. This contradicts the conceptual basis for radiation protection and risk determination that was established in 1956-58. In this paper, beneficial effects and thresholds for harmful effects are discussed, and the biological mechanism is explained. The key point: the rate of spontaneous DNA damage (double-strand breaks) is more than 1000 times the rate caused by background radiation. It is the effect of radiation on an organism's very powerful adaptive protection systems that determines the dose-response characteristic. Low radiation up-regulates the adaptive protection systems, while high radiation impairs these systems. The remedy for radiation fear is to expose and discard the politicized science.

INTRODUCTION

Almost three years have passed since a major earthquake and devastating tsunami damaged the Fukushima-Daiichi nuclear power plant. An evacuation order forced 70,000 people to leave the area, while an additional 90,000 left voluntarily and subsequently returned. Many of those who left under the forced order have not gone back to their homes as removal of radioactivity continues. Approximately 1,600 people died, mainly due to psychological stress, in the evacuation process (Mainichi 2013)—about the same number of deaths in the Fukushima Prefecture from the earthquake and tsunami combined (Japan National Police Agency 2013). The precautions taken to avoid hypothetical health risks have proved to be more harmful than the asserted risks.

The tragedy is that the radiation dose-response characteristic for leukemia in humans had been determined in 1958, but it was disregarded because of the policy decision to adopt the linear no-threshold (LNT) dose-response model. The threshold model had been the "gold" standard for medicine and physiology since the 1930s; however, in 1956, the US National Academy of Sciences adopted the LNT model for evaluating genomic risks due to ionizing radiation. The Genetics Panel members believed there was no safe exposure for reproductive cells. They thought that the mutation risk increased with even a single ionization. In 1958, the National Committee for Radiation Protection and Measurement generalized the LNT concept to somatic cells and cancer risk assessment. Soon after, the other national and international organizations adopted this model for radiation-induced genetic and cancer risks (Calabrese 2013a, 2013b).

RADIATION HORMESIS - A REMEDY FOR FEAR

The enormous social fear and media frenzy surrounding the release of radioactivity from the damaged Fukushima NPP led the author to study again the facts in a remarkable paper by Jaworowski (2010) on radiation hormesis. He described the exaggerated fear of irradiating healthy tissues that arose during the Cold War period with its massive production and incessant testing of nuclear weapons. Radioactive materials from the atmospheric tests spread over the whole planet. People were quite rightly scared of the terrifying prospect of a global nuclear war and large doses of radiation from fallout. However, it was the leading physicists responsible for inventing nuclear weapons who instilled a fear of small doses in the general population. In their highly ethical endeavour to stop preparations for atomic war, they were soon joined by many scientists from other fields. Eventually, this developed politically into opposition against atomic power stations and all things nuclear.

Although the arguments of physicists and their followers were false, they were effective; atmospheric tests were stopped in 1963. However, this was achieved at a price—a terrifying specter had emerged of small, near zero radiation doses endangering all future generations. This became a long-lived and worldwide societal affliction nourished by the LNT assumption, according to which any dose, even that close to zero, would contribute to the disastrous effect. Radiation hormesis (Luckey 1991) is an excellent remedy for this affliction, and it is perhaps for this reason that it has been ignored and discredited over the past half century. What happened more than 50 years ago still influences the current thinking of both the decision makers and those who elect them.

The linearity assumption was not confirmed by early or later epidemiological studies of Hiroshima and Nagasaki survivors. No hereditary disorders were found in the children of highly irradiated parents. The United Nations Committee on the Effects of Atomic Radiation (UNSCEAR) was concerned mainly with the effects of nuclear tests, fulfilling a political task to stop weapons testing. The committee had mixed opinions regarding the LNT model, and its first report, UNSCEAR 1958, contains conflicting statements. Jaworowski states: "hormesis is clearly evident . . . in a table showing leukemia incidence in the Hiroshima population, which was lower by 66.3% in survivors exposed to 20 mSv, compared to the unexposed group (p.165). This evidence of radiation hormesis was not commented upon. Since then, the standard policy line of UNSCEAR and of international and national regulatory bodies over many decades has been to ignore any evidence of radiation hormesis and to promote LNT philosophy."

The very important data in UNSCEAR 1958, Table VII were not presented in graphical form. Figure 1, given here, shows these data (96,000 survivors) together with the LNT model from 1300 to 0 rem. A line through 100 rem was added to take into account Footnote c, which states that the doses in Zone C "were greater than 50 rem."

These Hiroshima leukemia data strongly contradict the LNT model, which predicts an increased degree of risk as the radiation dose increases. The data clearly indicate a reduction in incidence, by a factor of 3, in the dose range from about 0.1 to 10 rem (1 to 100 mSv). The threshold for increased risk is about 50 rem (0.5 Sv). The leukemia data fit a hormetic J-curve; they do not fit a straight line.

UNSCEAR 1958, page 165 in paragraph 31, states: "In zones A (1300 rem), B (500 rem), and C (50 rem), the values of P_L were calculated[1] to be . . . This finding was taken to support the suggestion that the extra leukemia incidence is directly proportional to radiation dose, and conversely to argue against the existence of a threshold for leukemia induction."

The discussion in paragraph 33 states "that a threshold for leukemia induction might occur. In fact, according to table VII a dose of 2 rem is associated with a decreased leukemia rate." But this observation was rejected because "the estimates of dose ... are much too uncertain ..." UNSCEAR should not have marginalized, because of dose uncertainty, the observation of this strong reduction in leukemia incidence for the 32,692 survivors in Zone D, which was far below the leukemia incidence of the 32,963 survivors in Zone E (the controls). This data disproved the LNT dose-response model, and UNSCEAR should have rejected the LNT model in its report.

Fliedner et al (2012) pointed out that bone marrow stem cells, which produce the blood cell components, are very sensitive to radiation, yet they are remarkably resistant to chronic low-dose exposure regarding

[1] P_L is the extra probability of leukemia occurring in an exposed person per rem and per year elapsed after exposure.

function and maintenance of blood supply. Moreover, no increased cancer deaths occurred at doses below 700 mGy per year despite the fact that the latency time for leukemia is much shorter than for other radiation-induced cancers. This clear evidence of radiation hormesis—an absence of cancer risk at low dose radiation—adds to many other data of this kind and should cause UNSCEAR, the NAS and all radiation protection organizations to revoke the generalized link they created in 1958 between low radiation and a risk of cancer; this link is the basis for the fear we see today.

Regarding the present concern about radiation-induced "health effects" on the residents around the Fukushima NPP, UNSCEAR states that that none were observed (UNSCEAR 2012, Chapter IIB, Section 9(a)) and discusses in Chapter III, Section 1 the difficulties in attributing health effects to radiation exposure and inferring risks. Section 2 points out that failure to properly address uncertainties can cause anxiety and undermine confidence among the public, decision-makers and professionals. If it wished, UNSCEAR could have attributed beneficial health effects to the low radiation, based on the extensive evidence in Annex B of its UNSCEAR 1994 report. This report contains summaries of 192 studies on *adaptive responses*. There have also been hundreds of additional scientific studies published during the subsequent 20 years. The World Health Organization's health risk assessment report (WHO 2013) contains estimates of lifetime risks of cancer; however, it uses the invalid LNT methodology.

BENEFICIAL EFFECTS

Positive health effects were identified by medical scientists and practitioners soon after x-rays and radioactivity were discovered in 1895-96. High, short-term exposures were harmful, but low acute doses or low dose-rate long-term exposures were beneficial. Often this was found inadvertently, while diagnosing bone fractures or other medical conditions. Recent review papers describe accepted medical applications, such as, accelerated healing of wounds and infections, cancer cures, and treatments of inflammations and arthritis that occurred before the introduction of the cancer scare in the late 1950s (Cuttler 2013). A new review discusses the historical use of low radiation to cure pneumonia (Calabrese 2013c), a very common occurrence in hospitals.

Beneficial effects have been known and studied for well over a century. The mechanism is explained in a medical textbook, in a chapter by Feinendegen et al. (2013). The key point is the discovery more than 25 years ago that spontaneous (endogenous) DNA damage, by the attack of reactive oxygen species (ROS), occurs at a relatively very high rate compared to the damage rate caused by natural background radiation. The natural rate of single-strand breaks from ROS attacks per average cell is many millions of times greater than the rate induced by ~ 1 mGy per year. Single-strand breaks are readily repaired, but double-strand breaks (DSBs) are relevant to induction of cancer and other genetic changes. Non-irradiated cells contain from about 0.1 to numerous DSBs at steady state. This agrees with the calculated probability of 0.1 for a DSB to occur per average cell in the human body per day from endogenous, mainly ROS sources (Pollycove and Feinendegen 2003). The probability of a radiogenic DSB to occur per day in background radiation is on average only about 1 in 10,000 cells. So the ratio of spontaneous to radiogenetic DSBs produced per day is about 1,000; i.e., the natural damage rate is a thousand times greater than the damage rate due to background radiation.

The critical factor is the effect of radiation on an organism's very powerful biological defences, its protection systems, which involve the actions of more than 200 genes. They act on all the damage that is occurring (and its consequences) due to both internal causes and the effects of external agents. A low radiation dose or low level radiation causes cell damage, but it up-regulates adaptive protection systems in cells, tissues, animals and humans that produce beneficial effects far exceeding the harm caused by the radiation (Feinendegen et al. 2013). The net beneficial effects are very significant in restoring or improving health. The detailed behaviours of the defences are very complex, but the evidence is extremely clear. They range from prevention/cure of cancers to the very important medical applications of enhanced adaptive protections in the responses to stresses and enhanced healing of wounds, curing of infections, and reduction of inflammation, as mentioned earlier. In contrast, high level irradiation impairs these systems.

THRESHOLDS FOR HARMFUL EFFECTS

The evidence of net beneficial effects requires the determination of the threshold for harmful effects. This was known through more than thirty years of human experience when the first radiation protection *tolerance dose*, 0.2 roentgen per day or ~ 700 mGy per year, was established for radiologists in the early 1930s (Henriksen et al. 2013). Figure 2 is the result of a recent assessment of lifespan data for dogs exposed to cobalt-60 gamma radiation (Cuttler 2013). The threshold for net harm is also ~ 700 mGy per year. Similar data are found in UNSCEAR 1958, Annex G, page 162. The threshold for lifespan reduction of mice and Guinea pigs exposed to radium gamma rays is 4 roentgen per week or ~ 2000 mGy per year. Their mean survival time is 7% longer than the controls at a dose rate of 0.5 roentgen per week, which is about 240 mGy per year.

The accepted threshold for recognizing harmful late effects after a short-term exposure, according to a large set of experimental and epidemiological data, is an absorbed dose of about 100 mGy. However, the UNSCEAR data for leukemia incidence among 96,000 Hiroshima survivors, shown in Figure 1, suggests a threshold of about 500 mGy for leukemia.

INVALID BASIS FOR THE LNT MODEL

Calabrese reviewed the evolution of radiation protection from the tolerance dose (threshold) concept to the LNT concept. It began when early geneticists discovered that large numbers of mutations could be induced in germ cells of fruit flies by ionizing radiation. This would enable eugenicists to modify organisms for utilitarian purposes (Muller 1927). A high dose, at a high rate, produced a mutation rate that was 150 times greater than the spontaneous rate. This and other high-dose studies indicated that the mutation rate was proportional to the dose. A radiation target theory was developed by physicists to model the process of radiation-induced mutation, with mathematical calculations related to quantum mechanics (Calabrese 2013a). They established a conceptual framework for gene structure, target theory for the induction of mutations by ionizing radiation, the single-hit mechanism hypothesis to account for the shape of the LNT dose response and the application of this dose-response model for what was to become modern cancer risk assessment. However, bio-organisms do not behave according to this model. The Caspari and Stern (1948) study that irradiated 50,000 fruit flies to a dose of ~ 50 roentgen at a low rate, revealed a mutation rate that was the same as the 50,000 controls. This study was ignored. Recent studies on fruit flies at very low dose rate indicate a mutation frequency far below the spontaneous rate—genetic benefit instead of risk—below an absorbed dose of about 1 gray, see Figure 3 (Cuttler 2013). This evidence clearly falsifies the LNT model.

DISCUSSION

Many researchers use the LNT model to predict the lifetime risk of cancer from a small dose of radiation. They calculate the expected cancer incidence from a very low dose by connecting a straight line between the zero-dose, zero-incidence point and the high-dose cancer incidence data of the atom-bomb survivors. This procedure can only yield a risk of cancer. Most epidemiological studies are designed to measure radiation-induced cancer incidence, so they do not report any observations of beneficial effects. The data are fitted to the LNT model, presuming it is valid. Scott et al. (2008) list seven approaches that make it difficult to recognize bio-positive effects and thresholds, concluding that there is no credible evidence to support the contention that CT scans will cause future cancers. Scott (2008) points out three epidemiological "tricks" that are commonly employed to obtain a LNT curve. Relative risk and odds ratio values are often shown instead of cancer incidence data. In view of the extensive evidence of beneficial health effects and reduced health risks from low doses, misrepresentations of data and deceptions are needed to fit the LNT model.

CONCLUSIONS AND RECOMMENDATIONS

Social concerns about the safety of all nuclear technologies is caused by ideological linkage of any (human-made) radiation exposure to a risk of health effects, namely cancer and genetic harm, using the LNT model to calculate health risks. This link, created in the 1950s to stop the development and production of nuclear weapons, is maintained in spite of the extensive biological evidence of beneficial effects from low dose or low dose rate exposures. Ignoring biological facts and refusing to revert to the threshold model concept for radiation protection has created an enormous barrier against social acceptance of nuclear energy and the use of radiation-based medical diagnostics. The remedy is to discard this politicized science.

This enormous radiation scare surrounding the Fukushima-Daiichi is a very serious crisis. It should be looked upon as an opportunity to make changes in attitudes and concepts that would not otherwise be possible.

The following three fundamental messages should be communicated to everyone in order to explain the real effect of radiation on health and to eliminate the irrational fear.

1. Spontaneous DNA damage, mainly from reactive oxygen species, occurs at very high rate; the rate of double strand breaks (DSBs) is more than 1000 times the rate of DSBs induced by a background radiation level of 1 mGy per year.
2. Biological organisms have very powerful adaptive protection systems against harm to their cells, tissues and the entire organism, regardless of whether the harm is caused by natural internal processes or by external agents.
3. Low radiation generally up-regulates adaptive protection systems resulting in a net health benefit to the organism in terms of response to stress. High radiation generally impairs protection systems and results in more net harm than benefit. The effect of radiation on the adaptive protection systems is what determines the health benefit or risk.

Other recommendations are:

- Scientific societies should organize meetings to discuss the health benefits and risks of radiation.
- Regulatory bodies and health organizations should examine the scientific evidence.
- Radiation protection regulations should be changed. They should be based on science instead of politicized science.
- The basis for radiation protection should be restored to the *tolerance dose* (threshold) concept, in light of more than a century of medical evidence.
- Calculation of cancer risk using unscientific concepts, such as the LNT model, should be stopped.
- Regulation of harmless radiation sources, such as radon in homes, should be stopped.
- Based on biological evidence, the threshold for evacuations from low dose rate radiation should be raised from 20 to no more than 700 mGy per year, i.e., from 2 to ≤ 70 rad per year.

REFERENCES

Calabrese EJ. 2013a. *Origin of the linear no threshold (LNT) dose-response concept*. Arch Toxicol DOI 10.1007/s00204-013-1104-7. Available at: http://link.springer.com/article/10.1007%2Fs00204-013-1104-7

Calabrese EJ. 2013b. *How the US National Academy of Sciences misled the world community on cancer risk assessment: new findings challenge historical foundations of the linear dose response*. Arch Toxicol DOI 10.1007/s00204-013-1105-6. Available at: http://link.springer.com/article/10.1007/s00204-013-1105-6

Calabrese EJ. 2013c. *How radiotherapy was historically used to treat pneumonia: Could it be useful today?* Yale Journal of Biology and Medicine 86: 555-570

Caspari E and Stern C. 1948. *The influence of chronic irradiation with gamma rays at low doses on the mutation rate in Drosophila Melanogaster*. Genetics 33: 75-95. Available at: http://www.genetics.org/content/33/1/75.full.pdf+html?sid=cb861a39-fb63-48c4-bcbe-2433bb5c8d6a

Cuttler JM. 2013. *Commentary on Fukushima and Beneficial Effects of Low Radiation*. Dose-Response 11: 432-443. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3834738/

Feinendegen LE, Pollycove M and Neumann RD. 2012. *Hormesis by low dose radiation effects: low-dose cancer risk modeling must recognize up-regulation of protection*. In Baum RP (ed.). Therapeutic Nuclear Medicine. Springer. ISBN 973-3-540-36718-5. Available at: http://db.tt/UyrhlBpW

Fliedner TM, Graessle DH, Meineke V and Feinendegen LE. 2012. *Hemopoietic response to low dose-rates of ionizing radiation shows stem cell tolerance and adaptation*. Dose-Response 10: 644-663. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3526333/

Henriksen T and Biophysics and Medical Physics Group at UiO. 2013. Radiation and Health. Taylor & Francis. ISBN 0-415-27162-2 (2003 updated to 2013). University of Oslo. Available at: http://www.mn.uio.no/fysikk/tjenester/kunnskap/straling/radiation-and-health-2013.pdf

Japan National Police Agency. 2013. *Damage situation and police countermeasures associated with 2011 Tohoku district - off the Pacific Ocean earthquake, November 8, 2013*. Available at: http://www.npa.go.jp/archive/keibi/biki/higaijokyo_e.pdf

Jaworowski Z. 2010. *Radiation hormesis - A remedy for fear*. Human and Exper Toxicol 29(4) 263-270. Available at: http://www.belleonline.com/newsletters/volume15/vol15-2.pdf

Luckey TD. 1991. Radiation Hormesis. CRC Press

Mainichi. 2013. *Stress-induced deaths in Fukushima top those from 2011 natural disasters*. The Mainichi. September 9, 2013. Available at: http://worldnews.nbcnews.com/_news/2013/09/10/20420833-fukushima-evacuation-has-killed-more-than-earthquake-and-tsunami-survey-says?lite

Muller HJ. 1927. *Artificial transmutation of the gene*. Science 66(1699): 84-87

Pollycove M and Feinendegen LE. 2003. *Radiation-induced versus endogenous DNA damage: possible effect of inducible protective responses in mitigating endogenous damage*. Human and Exper Toxicol 22: 290-306. Available at: http://www.belleonline.com/newsletters/volume11/vol11-2.pdf

Scott BR. 2008. *It's time for a new low-dose-radiation risk assessment paradigm—one that acknowledges hormesis*. Dose-Response 6: 333-351. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2592992/

Scott BR, Sanders CL, Mitchel REJ and Boreham DR. 2008. *CT Scans May Reduce Rather than Increase the Risk of Cancer*. J Am Phys Surg 13(1): 8-11. Available at: http://www.jpands.org/vol13no1/scott.pdf

UNSCEAR. 1958. *Report of the United Nations Scientific Committee on the Effects of Atomic Radiation.* United Nations. General Assembly. Official Records. Thirteenth Session. Supplement No. 17 (A/3838). New York. Available at: http://www.unscear.org/unscear/en/publications/1958.html

UNSCEAR. 1994. *Adaptive Responses to Radiation in Cells and Organisms. Sources and Effects of Ionizing Radiation*. Report to the United Nations General Assembly, with Scientific Annexes. Annex B. Available at: http://www.unscear.org/unscear/publications/1994.html

UNSCEAR. 2012. *Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. Fifty-ninth session (21-25 May 2012).* Available at: http://www.unscear.org/

WHO. 2013. *Health risk assessment from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami, based on a preliminary dose estimation*. World Health Organization. Available at: http://apps.who.int/iris/bitstream/10665/78218/1/9789241505130_eng.pdf

UNSCEAR 1958. Table VII. Leukemia incidence for 1950–57 after exposure at Hiroshima[a]

Zone	Distance from hypocentre (metres)	Dose (rem)	Persons exposed	L (Cases of leukemia)	$\sqrt{L}$	N[b] (total cases per 10^6)
A	under 1,000	1,300	1,241	15	3.9	12,087 ± 3,143
B	1,000–1,499	500	8,810	33	5.7	3,746 ± 647
C	1,500–1,999	50[c]	20,113	8	2.8	398 ± 139
D	2,000–2,999	2	32,692	3	1.7	92 ± 52
E	over 3,000	0	32,963	9	3.0	273 ± 91

[a] Based on data in reference 13 (Wald N. Science 127:699-700. 1958). Prior to 1950 the number of cases may be understated rather seriously.
[b] The standard error is taken as: N times ($\sqrt{L}$/L).
[c] It has been noted (reference 15, 16) that almost all cases of leukemia in this zone occurred in patients who had severe radiation complaints, indicating that their doses were greater than 50 rem.

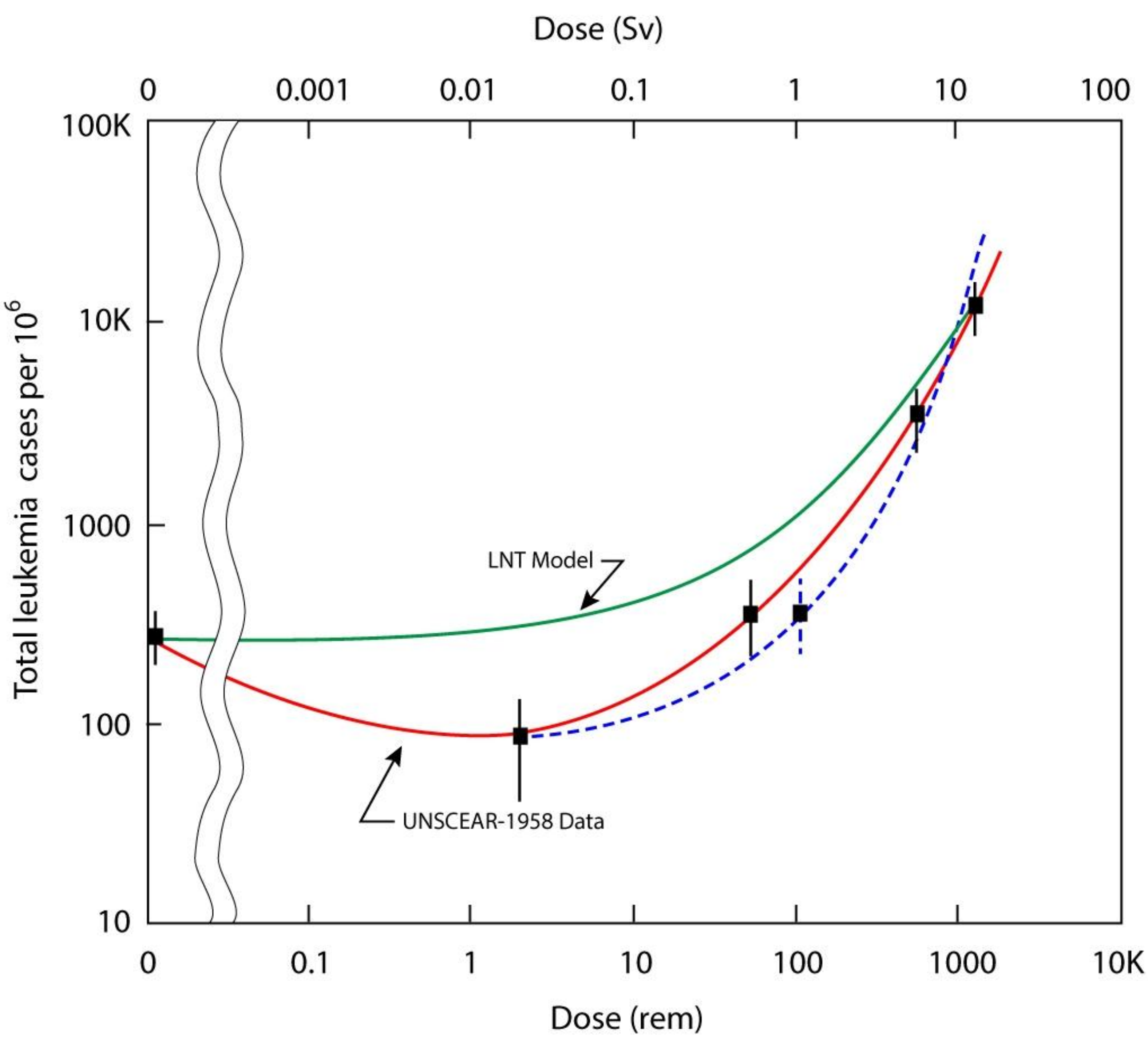

Figure 1. Leukemia incidence in the Hiroshima survivors for 1950-57

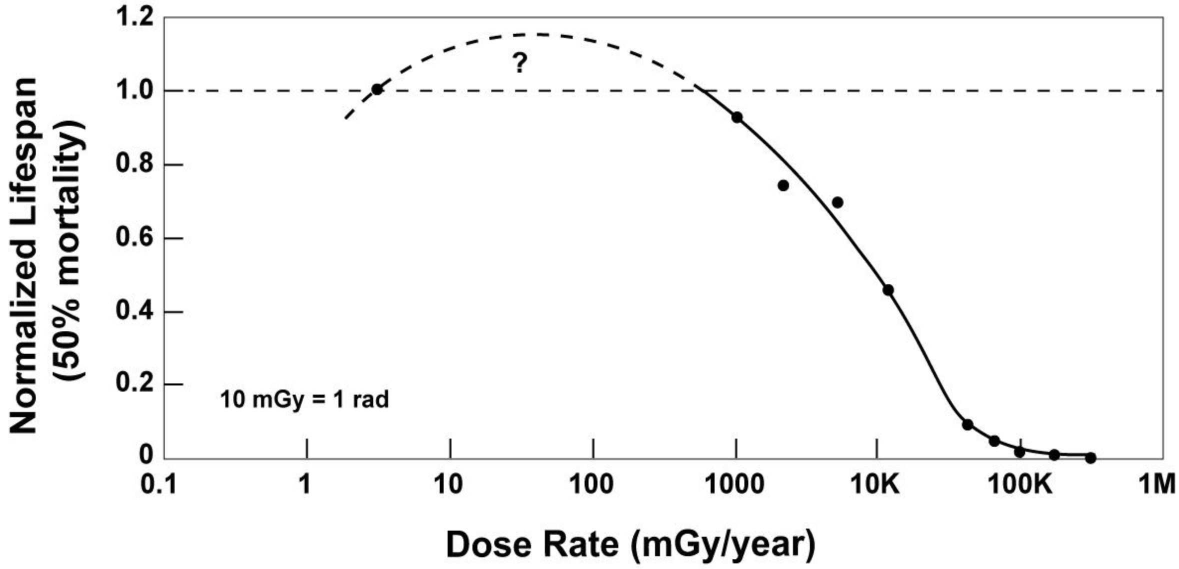

Figure 2. Lifespan versus radiation level (Cuttler 2013)

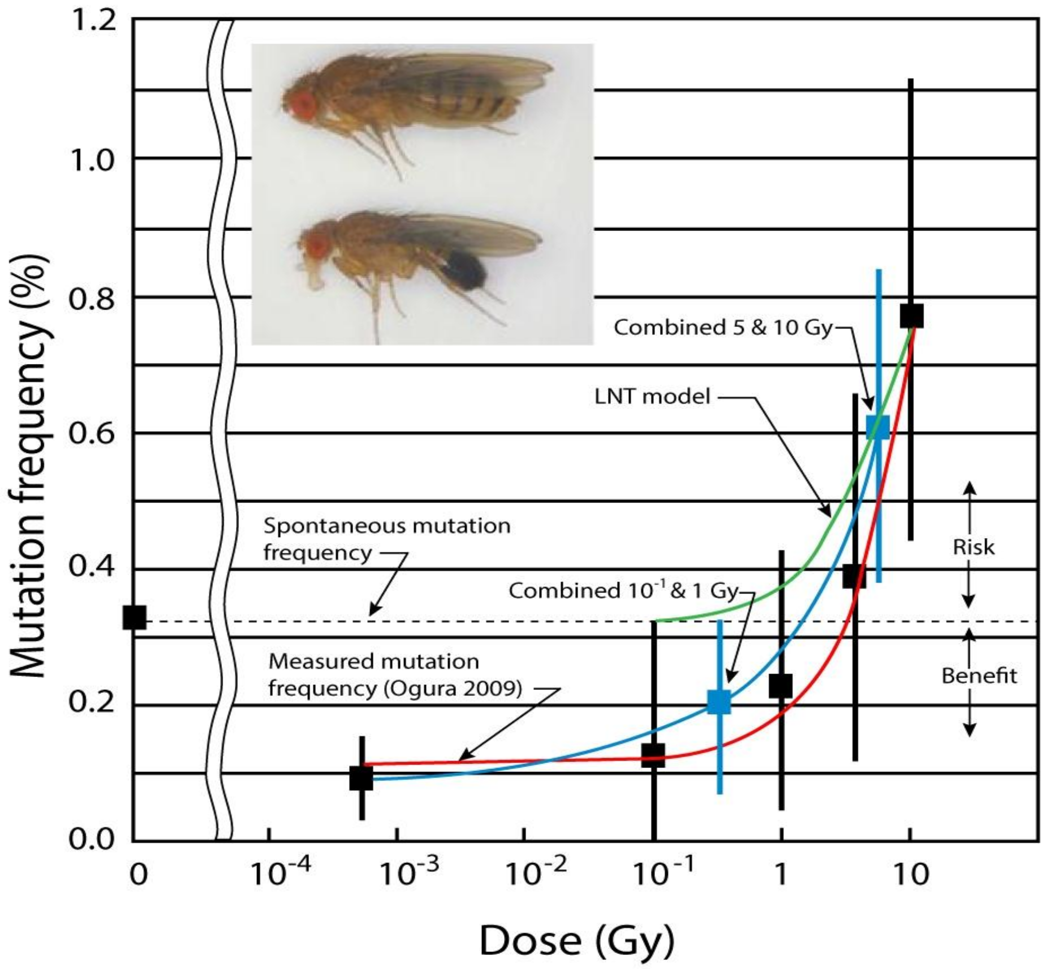

Figure 3. Fruit fly mutation frequency versus radiation dose (Cuttler 2013). A binomial distribution is assumed for the occurrence of the mutations. Each error bar is two standard deviations from the mean frequency. The data points at 0.3 Gy (0.19%) and at 7 Gy (0.61%) are obtained by "pooling" the Ogura et al (2009) data at 10^{-1} and 1 Gy, and at 5 and 10 Gy, respectively. Note that the mean mutation frequency is below the spontaneous level (0.32%) when the dose is below 1 Gy.