

# Radiobiology and Radiation Hormesis: New Evidence and its Implications for Medicine and Society

## Chapter One

### MOVERS OF RADIATION HORMESIS

*If you can't explain it simply, you don't understand it well enough (Albert Einstein)*

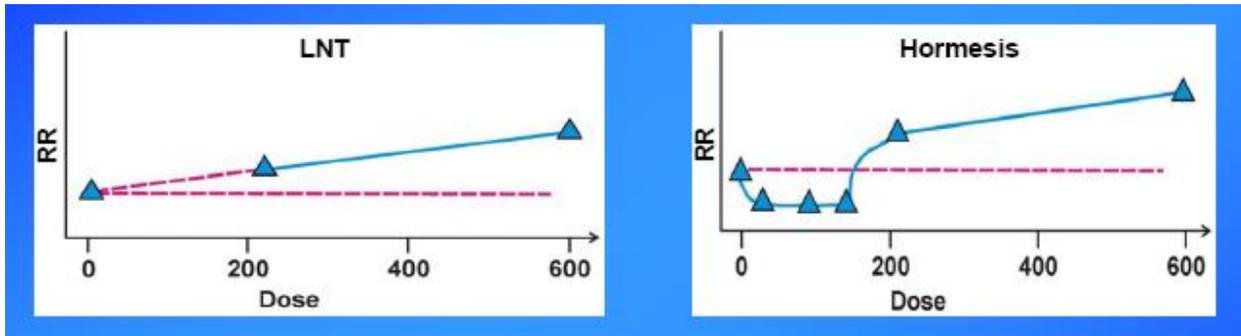


Figure 1. Models of Relative Risk (RR) for biomedical effects following exposure to ionizing radiation: Linear-No-Threshold (LNT) and Radiation Hormesis. (With kind permission of Dr. Bobby Scott <sup>46</sup>).

A mover is a person who makes formal proposals and sets things in motion and who is especially suited to effectively interact with others to get their message across. Among them were the early discoverers in atomic physics. They were followed about fifty years later with the seminal books written by Dr. Don Luckey <sup>2-3</sup> that elucidated the benefits of low dose ionizing radiation in spite of an overwhelming professional commitment in radiation protection to the Linear-No-Threshold (LNT) assumption and an atmosphere of political correctness that borders today on scientific corruption (Figure 1). A mover completes the narrative of the LNT and radiation hormesis <sup>42</sup>.

A few of the early researchers were exposed to high doses of ionizing radiation. Marie Curie isolated radium and polonium from tons of pitchblende ore. She died of aplastic anemia at the age of 67. Her daughter, Irene Joliot-Curie, continued her mother's research during which she was exposed to polonium sealed in a small capsule that exploded in her laboratory. She died a few years later from leukemia at the age of 58. Previously, both Marie and Irene served as battlefield radiology nurses in WW I for about three years near the front lines exposing themselves to X-rays from lightly shielded machines <sup>40</sup>.

The possibilities that ionizing radiation offered for medical diagnostics were first demonstrated by Wilhelm Roentgen, one month after his discovery of X-rays, by publishing in Nature in January 1896, an X-ray photograph of the hand of his wife. Wilhelm lived for 78 years. In 1902 Pierre Curie <sup>34</sup>, together with two physicians, Balthazard and Bonchard, discovered that radium rays were useful in cancer therapy. The theoretical basis for this therapy was provided in 1906 by Bergonie and Tribondeau as the result of their experiments with rats <sup>15</sup>. They showed that X-rays were more effective on undifferentiated cells which had a higher proliferation rate. The beneficial or hormetic effects of low doses of ionizing radiation were first described in 1898, when an increased growth rate was seen in blue green algae exposed to X-rays <sup>16</sup>.

Otto Hahn and Lise Meitner, were exposed to radiation during their careers as they explored radioactivity and nuclear fission. Hahn was the father of nuclear chemistry. He isolated an

isotope of radium that he called mesothorium. In 1912 his research institute in Germany was visited by Kaiser Wilhelm II. Hahn presented the Kaiser with an unshielded sample of mesothorium in a small box equivalent in radiation intensity to 300 mg of radium and showed the Kaiser how it produced luminous moving shapes in the dark when shown on a screen<sup>1</sup>. The Kaiser lived to be 82, dying in 1941 of pulmonary embolus. Hahn and Meitner both lived to the age of 90. Glen Seaborg, who discovered plutonium and other transuranic elements, lived to be 87.

Lauriston S. Taylor (1902-2004), founder and father of early American radiation protection, was one of the most influential persons in the promulgation of radiation protection standards. Taylor founded the National Council of Radiation Protection and Measurements (NCRP) and became its first and only president for the next 48 years. It was Taylor who said: The LNT is a deeply immoral use of our scientific heritage. It was Taylor who said: No one has been identifiably injured by radiation while working within the first numerical standards set first by the NCRP and then the ICRP in 1934<sup>4</sup>. Standards in 1934 were 1 mSv/day for the NCRP and 2 mSv/day for the ICRP. Lauriston Taylor died at the age of 102 despite receiving a cumulative whole-body radiation dose of about 10 Gy when he was age 27 and several smaller doses for radiation therapy of inflammatory diseases.

Other major participants in radiation protection and hormesis were Maurice Tubiana who lived to 93; Ted Rockwell to 90; Bernard Cohen to 88; Zbigniew Jaworowski to 85; and Myron Pollycove to 92. Dr. Ted Rockwell worked on the A-bomb during World War II and then with Admiral Rickover on the nuclear navy. Later, Rockwell was a tireless campaigner for radiation hormesis<sup>19</sup>. Dr. Maurice Tubiana was an oncologist, radiotherapist and member of French Academies of Science and Medicine, IARC, WHO and IAEA. Tubiana was an early proponent of radiation hormesis. Dr. Zbigniew Jaworowski was a Polish physician and biophysicist, and Chair of UNSCEAR and member of IAEA. Jaworowski believed in the benefits of low dose radiation<sup>17-18</sup>. Dr. Myron Pollycove was a pioneer in the development of isotopes for use in diagnosis and therapy and professor at UCSF Medical School. His work later in life focused on radiation hormesis. Ludwig E Feinendegen, born in 1927, is a professor in nuclear medicine at Heinrich-Heine University, Germany, and author of many publications on radiation hormesis including several in press today<sup>33</sup>.

Bill Bair, my mentor at Battelle Northwest in Richland, WA, spent his working research life in radiobiology of transuranics; he died in 2015 at the age of 90<sup>43</sup>. Allen Brodsky was exposed to a whole body dose of about 300 mGy while recovering neutron spectrometers off Enewetok right after the second and third U.S. H-bomb tests. He is alive at the age of 87. Robert R. Brownlee was a navigator on a B-29 in WWII; his bomber was parked near the *Enola Gay* on the pacific island of Tinian. Brownlee participated in about 300 A- and H-bomb tests in Nevada and the South Pacific. A 1956 H-bomb test at Bikini Atoll was associated with an unexpected high yield and shift in winds covering him with a cloud of radioactive coral dust for 30 hours. Brownlee was at Los Alamos, New Mexico, when a group of men accidentally breathed in a high level of plutonium particles. Fifty years later they were found healthier than the control group<sup>31</sup>. Today, Brownlee is 93, attending my church in Loveland, CO.

Don Luckey (1919-2014) carried on an active scientific life that included 282 professional publications. Following a career as a professor in Notre Dame and the University of Missouri, Luckey became interested in radiation hormesis. He continued to travel and publish after his retirement in 1984. Luckey wrote two books on radiation hormesis: Hormesis with Ionizing

Radiation (1980)<sup>2</sup> and Radiation Hormesis (1991)<sup>3</sup> He continued his work until his death. In a study of about 250,000 nuclear workers, he found an average mortality in nuclear workers that was 33% less than unexposed controls. The control groups were chosen to minimize the use of the healthy worker effect as an excuse for radiation hormesis<sup>24-25</sup>. Luckey felt lifespan could be prolonged by 30% by increasing exposure to low-dose radiation<sup>26</sup>. He found that supplementation with low dose irradiation decreased heart disease, sterility, infections, lung diseases, cancer and premature deaths<sup>26</sup>. Luckey believed that these benefits would be cumulative if we lived with 20 times more ambient ionizing radiation than we have now (~50 mGy per year). Ed Hiserodt called Luckey pivotal in his research; Hiserodt wrote an excellent book about the benefits of ionizing radiation<sup>27</sup>. Luckey was also pivotal in my research<sup>5</sup>. Luckey slept for many years next to a yellow radioactive granite rock; he was 95 when he died.

A policeman who survived the Hiroshima A-bomb carried a message to his fellow police officers in Nagasaki. He told them that a bright light would be followed a few seconds later by a deadly shock wave. Tsutomu Yamaguchi was the reason why few policemen died in Nagasaki; he lived to be 93. The same duck and cover strategy was taught to school children throughout the Cold War.

Ivan Shamyank, is a 90-year-old villager who refused to leave after the Chernobyl nuclear reactor explosion in 1986. Ivan lives in the Belarusian village of Tulgovichi, which is nestled on the very edge of the exclusion zone created in 1986 to protect humans from fallout. Ivan has lived here without serious health ramifications for 30 years. He drinks a glass of vodka before every meal to boost his appetite. But for the others who left, Tulgovichi said: they have not fared so well. My sister lived here with her husband. They decided

to leave and soon enough they were in the ground<sup>6</sup>. Anecdotal evidence of elderly people who refused to leave the Chernobyl exclusion zone shows a consistence testimony of relief from arthritic pain and feeling much healthier than others their age<sup>37</sup>. Holly Morris did a TEDMED video presentation entitled: Chernobyl: Flourishing lives in the dead zone. She had visited Chernobyl and found about 100 now elderly women who refused to leave their homes in 1986. They are thriving with a longevity that is 10 years longer than women who had moved in 1986<sup>38</sup>. Naoto Matsumura returned to live in the abandoned restricted zone around the Fukushima reactor accident to feed a wide range of animals<sup>7</sup>. Domestic and wild animals in high radiation zones around Chernobyl and Fukushima thrive with no harmful effects from radiation<sup>7, 25, 38</sup>.

What we as proponents of radiation hormesis write, can change the way people of integrity think. James Muckerheide during his career in nuclear science was an out-spoken critic of the LNT and founder of Radiation Science and Health, a non-profit organization of scientists that opposed radiation protection standards based on the LNT<sup>32</sup>. Rod Adams is founder of Adams Atomic Engines, Inc. and has made frequent comments about hormesis on his internet blog. In one he narrates how a long time nuclear critic had changed his mind after reading my book<sup>5</sup>. Lawrence Solomon is a Canadian writer and columnist and a leading environmentalist for many newspapers including The Financial Post, Energy Probe, CBS News and The Wall Street Journal. He was an advisor to President Jimmy Carter on the environment. Solomon was for thirty years an opponent of nuclear energy. Adams wrote<sup>24</sup>: Since Energy Probe adopted its anti-nuclear position in the 1970s, hundreds of nuclear plants that were on Canada's drawing boards have been cancelled and no new nuclear plants have been completed. Energy Probe is also a leading critic of nuclear power on health and safety grounds. Lawrence Solomon is one of the primary writers for Energy Probe; his anti-nuclear and pro-gas commentary is frequent and predictable<sup>24</sup>. With all of that background, it was therefore quite a shock to read an article from (the) Financial Post titled 'Radiation's Benefits' and to see that the by-line was no other than Lawrence Solomon<sup>21</sup>. Not only did the piece have

an intriguing, positive headline related to nuclear energy, but it also started with a rather surprising admission. Low levels of radiation, science is increasingly telling us, are not only safe, they are actually healthful. It may be more prudent to worry about getting too little radiation than too much <sup>21-23</sup>. Why did Solomon change his mind? The answer comes quickly – he read a book, but not just any old book.’ The latest book to question the conventional wisdom on radiation comes from Springer-Verlag, a venerable academic science publisher whose stable of writers over the years has included some 150 Nobel laureates...and its intimidating title, Radiation Hormesis and the Linear-No-Threshold Assumption <sup>5</sup>.

Dr. Jay Lehr made several national TV news interviews after the Fukushima Daiichi nuclear disaster on March 11, 2011 that followed an earthquake-induced tsunami, flooding and shutting down the cooling system of several coastal, Japanese nuclear reactors. Lehr is science director of The Heartland Institute based in Chicago. He is an internationally renowned scientist and author of 30 books including Wiley Interscience’s Nuclear Energy Encyclopedia. In his tweet written on May 4, 2011, Lehr says: Charles L. Sanders latest book, Radiation Hormesis and the Linear-No-Threshold Assumption, is among the finest scientific research publications I have ever read...we have all witnessed in recent months after near-total distortion of potential harm to the Japanese population...Such distortions are fueled by proponents of the linear no threshold (LNT) assumption. Lehr interviewed Bernard Cohen about the health effects of radon in 2001 <sup>26</sup>. Lehr was invited to lunch by Newsweek magazine in New York City. He told them that one of his top three issues for the nation’s environmental priorities was reducing the unwarranted fear of low-level radiation that grips most of the world’s population <sup>28</sup>. Ann Coulter of Fox News also believes that low dose radiation is good for you <sup>1</sup>. John Stossel, host of ABC’s 20/20 program, dispelled the myth of health risk from low dose radiation in a May 18, 2006 program.

Dr. Ed Calabrese, one of the nation’s leading toxicologists, initially believed in the LNT (Figure 2). After examining the evidence, he said: My interpretations were pretty much wrong. Calabrese is a professor at the University of Massachusetts and author/coauthor of about 750 papers and 26 books, many on hormesis. He is founding Editor-in-Chief of Dose-Response journal. In 2009 he was awarded the Marie Curie Prize for his work on radiation hormesis. Calabrese found that the fundamental dose response in toxicology, pharmacology and radiobiology was the hormetic-biphasic dose response relationship. It is Dr. Calabrese who is substantially responsible for the surge in interest of radiation hormesis during the last twenty years <sup>39</sup>.



Figure 2. Edward Calabrese (With kind permission of Dr. Edward Calabrese <sup>45</sup>).

I communicated with Dr. Bobby Scott in 2005 during my first year as a professor at KAIST (Korea Advanced Institute of Science and Technology) in Daejeon, South Korea. Bobby started his hormesis research in high school (Webster High, Minden, Louisiana) by conducting a mutation-induction study using the fruit fly model and  $\beta$ -radiation. He won first prize in a regional science fair. Bobby mentored me in basic radiation hormesis and co-authored a paper with me <sup>9</sup> which was presented in the 2006 Dose-Response annual meeting at the University of Massachusetts; the meeting was chaired by Dr. Calabrese.

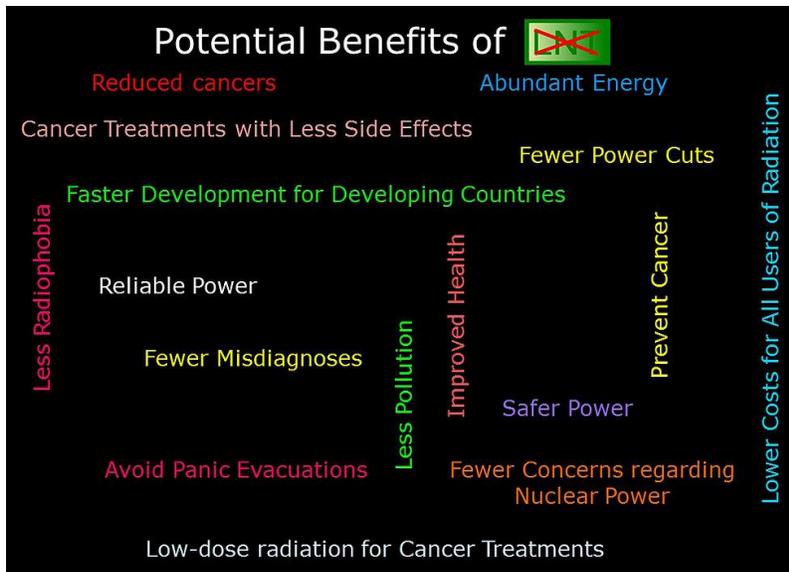


Figure 3. Blog that supports the LNT model pointing out why those should not be relied upon <sup>36</sup> (With kind permission of XLNT Foundation of which the author is a member).

In 2013, I contacted Dr. Scott, a now retired radiobiologist from Albuquerque, New Mexico, about starting a cohesive group for advocates of radiation hormesis as well as those who opposed the LNT assumption. Bobby took the idea and made it happen. The early members decided to call the group Scientists for Accurate Radiation Information (SARI). Radiationeffects.org is a blog established to share their views. SARI has grown to about 100 members found in a several countries of the world and has gained professional respect; their position letters are quoted in

professional publications and news organizations. SARI statement of purpose is: The objective of SARI is to monitor for and counter nuclear/radiological misinformation that could adversely impact the world's ability to effectively respond to nuclear and radiological challenges to the end point of saving lives. SARI is multidisciplinary and includes expertise in radiation source characterization, radiation transport, external and internal radiation dosimetry, radiobiological effects (both harmful and beneficial), dose-response modeling, radiation risk and benefit assessment and nuclear/radiological emergency management. A new organization has recently been formed by SARI members, Dr. Mohan Doss and Dr. Jerry Cuttler, called XLNT Foundation (Figure 3) <sup>36</sup>. The Health Physics News for January 2017 provides a comprehensive description of the history and purpose of SARI <sup>41</sup>.

SARI members recently made presentations at a 2015 symposium in Japan about the Fukushima accident. Earlier a SARI document was sent to Mr. Shinzo Abe, Prime Minister, Japan <sup>35</sup>: Dear Prime Minister, We, the undersigned members of Scientists for Accurate Radiation Information (SARI), are writing to support your efforts of calming the Japanese people and to provide a short discussion on what is known about the health effects of low-doses of ionizing radiation such as may have been received or may be received by down-wind populations of the Fukushima nuclear power plant. Casualties have already occurred among some members of the Japanese population related indirectly to radiation phobia-promoting misinformation about the health effects of low radiation doses. The misinformation mainly relates to hypothetical harm (e.g., radiation-induced cancers) based on the linear no-threshold (LNT) model. The LNT model of radiation-induced stochastic effects assumes that every dose of ionizing radiation, no matter how small, constitutes increased (linear with the dose) risk of the effect of interest. The LNT model is presently used for cancer risk assessment by advisory bodies and as such it is the basis for radiation safety regulation. The LNT model is also widely accepted by the general public. However, the scientific validity of this model has been seriously questioned and debated for many decades.

Advocates of the LNT assumption routinely avoid discussing thousands of published papers that demonstrate radiation hormesis. Newspaper op-eds are often highly negative, biased and misleading concerning the effects of ionizing radiation. Recently the International Commission



Figure 4. From left: Dr. Jerry Cuttler, Dr. Maurice Tubiana, Dr. Myron Pollycove and Dr. Kiyohiko Sakamoto. Dr. Sakamoto has carried out clinical trials with low dose radiotherapy<sup>30</sup>. Dr. Cuttler's wife received Sakamoto's half-body low-dose radiation treatment for prevention of cancer recurrence. Cuttler believes a single-whole body dose of 150 mGy or a continuous annual exposure of 700 mGy are safe and beneficial (With kind permission of Dr. Jerry Cuttler<sup>44</sup>)

of Radiological Protection (ICRP) stated that: While prudent for radiological protection, the LNT model is not universally accepted as biological truth, and its influence and inappropriate use to attribute health effects to low dose exposure situations is often ignored<sup>8</sup>. The LNT assumption would suppose that high natural background radiation is harmful. This has been proven to be false throughout the world<sup>20</sup>. In fact, many studies show benefit from Low Dose Radiation (LDR) with less than expected cancer increased longevity and clinical efficacy (Figure 4).

The Health Physics Society (HPS) position statement for 2016 says in part: Due to large statistical



Figure 5. Auto license plates in Ontario, Canada (With kind permission of Dr. Jerry Cuttler<sup>44</sup>) and in Montana, United States.

uncertainties, epidemiological studies have not provided *consistent* estimates of radiation risk for whole-body equivalent doses less than 100 mSv. This new somewhat ambiguous statement is an

improvement on the previous version. One positive aspect of the statement is that it calls the LNT model questionable, and another is that it refers to adaptive response and to the French Academy of Sciences Report by Tubiana<sup>10-11</sup>.

The question of the validity of the LNT hypothesis, in connection with radiation exposure, is very important since the LNT model has been the basis of environmental and public health policy for several decades. Inaccurate extrapolation of risks from high dose to low dose (top down approach) is dangerous to our health<sup>14</sup>. The LNT is responsible for the fear of any radiation common among the general public, the reluctance seen among some individuals regarding diagnostic or screening procedures involving exposure to radiation, the fear of contamination from nuclear plant accidents or negligence, and concerns about dirty bombs employed for terrorism. Research results clearly suggest the existence of thresholds and beneficial effects of low dose radiation below the threshold, such that many of the concerns enumerated are unjustified. Those who believe in the LNT model regard such statements of benefit as heresy, reckless and dangerous. Numerous epidemiological studies, confirmed by experimental animal studies, conducted throughout the world, show that low dose rate of ionizing radiation is beneficial to human health<sup>5,12-13</sup>.

Twenty-seven million Americans suffer from various forms of arthritis with 700,000 artificial knee replacements and 300,000 hip replacements performed each year. I greatly admire Patricia Lewis for maintaining a passion for the benefits of radon for over twenty years that has given thousands of people hope by helping them deal with a wide variety of often painful inflammatory conditions by visits to the Free Enterprise Radon Health Mine in Montana. Lewis has done this at great cost and perseverance (Figures 5-6).



Figure 6. Patricia Lewis, a member of SARI and previous owner, Free Enterprise Radon Health Mine, Boulder, Montana.

Examples of recent conversations by SARI members during 2014-2016 at their blog site ([radiationeffects.org](http://radiationeffects.org)) are instructive: The LNT is not a model, it is merely a system to legislate the issue of societal and individual hazard from ionizing radiation in man, to be used for regulatory purposes only, and not for science (Mike Waligorski). I know what adaptive response means. But others do not want to use the H-word (Hormesis) nor talk about beneficial effects of a low dose. Instead, they will use the term "adaptive response" (Jerry Cuttler). There has been a rapid loss of classical radiation physicists, radiation chemists, radiation biologists, and radiation toxicologists that are mostly not being replaced. As a result it has become more difficult to convince the public of the enormous benefits of nuclear energy and medical applications of ionizing radiation which far outweigh so-called associated risks, much less the benefits in disease prevention and therapy of LDR.

## References

1. Coulter, A. 2011. A glowing report on radiation (<http://www.humanevent.com/article.php?print=yes&id=42347>).
2. Luckey TD. 1980. Hormesis with ionizing radiation. CRC Press, Boca Raton, FL.
3. Luckey TD. 1991. Radiation hormesis. CRC Press, Boca Raton, FL.
4. Taylor LS. 1980. Some non-scientific influences on radiation protection standards and practice. *Health Physics* 32:851-874.

5. Sanders CL. 2010. Radiation hormesis and the linear-no-threshold assumption. Springer-Verlag, Berlin Heidelberg, 217 p.
6. Prentice A. 2016. A rural retirement in Chernobyl's radioactive shadow. Reuters, April 14.
7. [imgur.com/gallery/AWah](http://imgur.com/gallery/AWah) 2016.
8. Gonzalez AJ, M Akashi, JD Boice et al. 2013. Radiological protection issues arising during and after the Fukushima nuclear reactor accident. *J. Radiat Prot* 33:497-571.
9. Sanders, C.L. and B.R. Scott. 2008. Smoking and Hormesis as Confounding Factors in Radiation Pulmonary Carcinogenesis. *Dose-Response* 6:53-79.
10. Tubiana M. 2003. The carcinogenic effect of low doses: The validity of the linear-no-threshold relationship. *Intern J Low Radiation* 1:1-33.
11. Tubiana M, LE Feinendegen, C Yang et al. 2009. The linear no-threshold relationship is inconsistent with radiation biologic and experimental data. *Radiology* 251:13-22.
12. Ware W. 2014. Retired professor, University of Western Ontario, Canada.
13. Sanders, C.L. 2008. Prevention of cigarette smoke induced lung cancer by low LET ionizing radiation. *Nuclear Engineering and Technology* 40:539-550 (Korean Nuclear Society).
14. Ulsh, BA. 2010. The new radiobiology: returning to our roots. *Dose Response* 10:593-609.
15. Bergonie J. and L. Tribondeau 1906. De quelques resultats de la radiotherapie et essai de fixation d'une technique rationnelle. *Comptes Rendus des Seances de l'Academie des Sciences* 143, 983-985.
16. Atkinson GF. 1898. Report upon some preliminary experiments with Roentgen rays in plants. *Science* 7:7.
17. Jaworowski Z. 1999. Radiation risk and ethics. *Physics Today* 52(9), 24-29.
18. Jaworowski Z. 2001. Ionizing radiation in the 20<sup>th</sup> century and beyond. In: Symposium "Entwicklungen im Strahleschutz", Munich, Germany.
19. Rockwell T. 1997. Our radiation protection policy is a hazard to public health. *The Scientist* 11:9-11.
20. Vaiserman. 2010. Radiation hormesis: Historical perspective and implications for low-dose cancer risk assessment. *Dose-Response* 8:172-191.
21. Solomon L. 2010. Radiation's benefits. Will a gamma ray a day keep the doctor away? A new book says low-level radiation may prevent cancer. *Energy Probe* (<http://www.energy.probeinternational.org/print/2010>).
22. Solomon L. 2010. Lawrence Solomon: Port Hope—a hot spot that may be cool. Nuclear workers in Port Hope contract fewer cancers. *Financial Post* (<http://opinion.financialpost.com/2010/11/12/lawrence-solomon-port-hope-%e2%80%94>).
23. Solomon L. 2010. Lawrence Solomon: The scan that cures. CT scans may not just detect cancer, they may actually prevent it. *Financial Post* (<http://opinion.financialpost.com/2010/11/05/Lawrence-solomon-the-scan-that-cures/>).
24. Adams R. 2010. Radiation Hormesis – A Profound Truth that Might Induce a Few More Converts to Support Nuclear Energy. *Atomic Insights* (<http://atomicinsights.com/radiation-hormesis-a-profound-truth-that-might-induce-a-few-more-converts-to-support-nuclear-energy/>).
25. Bukowski JA and D Wartenberg. 1997. An alternative approach for investigating the carcinogenicity of indoor air pollution: Pets as sentinels of environmental cancer risk. *Environ Hlth Perspect* 105:1312-1319.
26. Lehr J. 2001. Interview: Risk in perspective: Radiation, reactor accidents and radioactive waste (<http://www.radonmine.com/pdf/riskinperspective.pdf>).
27. Hiserodt E. 2005. *Under-Exposed: What if Radiation is Actually Good for You?* Laissez-Faire Books, Little Rock, AK.
28. Lehr J. 2011. Low-level radiation benefits health. *Environ & Climate News*, August ([http://radiationreality.blogspot.com/2016/05/radiation-myths-harming-public-health\\_8.html](http://radiationreality.blogspot.com/2016/05/radiation-myths-harming-public-health_8.html))
29. [https://en.wikipedia.org/wiki/Tsutomu\\_Yamaguchi](https://en.wikipedia.org/wiki/Tsutomu_Yamaguchi)

30. Sakamoto K. 2004. Radiobiological basis for cancer therapy by total or half-body irradiation. *Nonlinear Biol Toxicol Med* 2:293-316.
31. Voelz GL, J NP Lawrence, and ER Jonson. 1997. Fifty years of plutonium exposure to the Manhattan project plutonium workers: An update. *Health Phys* 73:611–619
32. Muckerheide J. 2000. It's time to tell the truth about the health effects of low-dose radiation. *21<sup>st</sup> Century Science & Technology Magazine*
33. Feinendegen LE. Evidence for beneficial low level radiation effects and radiation hormesis. *Br J Radiol* 78:3-7.
34. Pierre Curie, husband of Marie Curie, was killed in 1906 when he slipped and fell under a horse-drawn carriage. He had been awarded the Nobel Prize in Physics along with his wife and Henri Becquerel in 1903.
35. Scott, B and nine other SARI members. 2013. Scientific bases for assessing potential health effects of low-dose ionizing radiation related to Fukushima.
36. (<http://www.x-lnt.org/>).
37. Sacks B and C Pennington, SARI, October 28, 2016.
38. (<http://www.tedmed.com/talks/show?id=542870>).
39. Calabrese EJ. 2016. A hormesis revival and its reflective champion. You Tube (<http://www.youtube.com/watch?v=c3pzasNegVA>).
40. Mould R. 1993. A century of X-rays and radioactivity in medicine: With emphasis on photographic records of the early years. Taylor and Francis Ltd.
41. Feinendegen LE and M Doss. 2017. Scientists for Accurate Radiation Information (SARI). *Health Physics News*, January, Volume XLV (Number 1). Excerpts: “Though the health effects of low-dose radiation (LDR) have been studied for many decades, there is still considerable disagreement in the scientific community about whether LDR exposure is harmful or beneficial. The prevailing view, supported universally by international advisory bodies since the 1950s, is that LDR is harmful and can be represented by the linear no-threshold (LNT) model for radiation-induced cancers. This model has been the basis of radiation protection regulations and practices worldwide since the 1950s. In the authors’ opinion, research over the past few decades has shown that the LNT model is not valid conceptually. In addition, experimental and epidemiological investigations have demonstrated its invalidity while the opposite view of radiation hormesis has proved to be conceptually valid and is supported by experimental and epidemiological observations. In view of this situation, many scientists have objected to the continued use of the LNT model. However, these objections have been overruled by advisory bodies and regulatory agencies. The main evidence usually quoted in support of the LNT model or carcinogenicity of LDR is the atomic bomb survivor data... These new data contradict the LNT model because of the significant curvature in the dose-response relationship due to the lower-than-expected cancer mortality rates in the 0.3–0.7 Gy region. Radiation hormesis, however, would be able to explain the curvature in these data. The advisory bodies and regulatory agencies have so far refused to recognize this change in the atomic bomb survivor data and continue to support the LNT model. They have also ignored much additional evidence in support of radiation hormesis. Another issue with the use of the LNT model is the calamities that result from its use, disproving the claim that it is a conservative approach to radiation safety. A case in point is the socioeconomic trauma following the nuclear reactor accidents in Fukushima in 2011. The accidents provoked fast and prolonged evacuation of the surrounding areas, causing considerable suffering and casualties, destroying the local economy, and harming Japanese society, all for no benefit. The advisory bodies have refused to modify their recommendations even after observing the tremendous amount of harm caused by the LNT model. This deplorable scenario of social harm caused by the use of the LNT model has galvanized many professionals into joining forces in an attempt to overcome the use of the LNT model in favor of a hormesis-oriented model to be applied in a public-health-relevant manner... SARI members, and the membership has grown to over 100 professionals from a wide variety of backgrounds from 15 different countries. The group includes

professionals representing a broad range of expertise, practices, and technologies involving the use of ionizing radiation. Thus, there are physicists, biologists, radiation biologists, epidemiologists, statisticians, physicians, radiologists, nuclear and other engineers, reporters, columnists, news editors, etc. SARI is a very active group with vigorous discussions/debates on many relevant topics... An independent nonprofit organization, the XLNT Foundation, was formed in 2015 by several SARI members in collaboration with additional interested individuals. The foundation's goal is to facilitate taking these and other additional steps to overcome the LNT model problem".

42. Sacks B. 2017. Sacks (SARI) wrote: "People tend to be more convinced by a complete narrative than by a few facts or an incomplete narrative. The relevance of this for SARI arises in at least two ways that come to mind. For one thing we have had the disagreement among ourselves as to whether we should concentrate merely on showing that LNT is false without bringing in hormesis versus bringing in the complete narrative. Some have felt that to bring in hormesis makes it more difficult for people to be convinced by the argument because that is asking too much. It's hard enough, the argument goes, to convince people that LNT is false, let alone that hormesis is true. But the other side of the disagreement says that by completing the story by explaining hormesis it becomes more convincing, and that more people will therefore be convinced. Another relevance for us to the completion of the narrative is that by showing that LNT only considers the damage but not the biological response, i.e., LNT is incomplete, and that consideration of the biological response as well as the damage is necessary to arrive at the net effect. This completion of the narrative – damage plus response – is more convincing, if it is true that people really need completion for understanding a phenomenon".
43. Kathren R. 2015. In memoriam: William J Bair (1924-2015). J Radiol Prot 36:196-199.
44. Jerry Cuttler. Cuttler & Associates, Toronto, Canada (2014).
45. Edward Calabrese. Professor, Environmental Health Sciences, University of Massachusetts, Amherst, and editor journal Dose-Response (2016).
46. Scott BR. 2008. Low-dose radiation risk extrapolation fallacy associated with the linear-no-threshold model. Hum Exper Toxicol 27:163-168.