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How dangerous is radiation? How much radiation does it take to give us cancer? Are we wasting money on overly restrictive regulations, or are we not being sufficiently protective of our radiation workers and the public? How much clean-up is necessary on our Department of Energy facilities? What about Yucca Mountain and nuclear reactor plants – can they be made safe?

These are only a few of the questions that have been asked, and will continue to be asked, about radiation. Unfortunately, these all come down, in part or in whole, to the question "What is the shape of the radiation dose-response curve at low levels of radiation exposure?" In other words, is all radiation dangerous, or is there a threshold below which radiation exposure is harmless? Not "low-risk," but "no-risk." This is the crux of the issue, and we still do not know the answer.

There are two primary competing models used to estimate our response to radiation exposure. Threshold models assume that, below some threshold dose of radiation, there is no harm from radiation exposure. Variations on threshold models include a straight-line (linear) response in which dose and cancer risk are directly proportional, sigmoidal (s-shaped) curves in which some populations are more sensitive than the majority of the population, and even hormesis curves, showing a slight benefit (reduced cancer risk) from exposure to low levels of radiation.

Alternately, non-threshold models hold that exposure to all levels of radiation is potentially harmful. Variations on non-threshold models include ones that are linear at all levels of exposure (usually abbreviated LNT for linear, non-threshold), as well as linear-quadratic and super-linear models – both of which deviate from linearity at low levels of exposure.

Although it may sound like a purely scientific debate with little practical value, this controversy is quite the opposite because, if a threshold exists, it is within the range of exposures to which many of us can reasonably be exposed. This means that public health policies, radiation safety regula-

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tions, standard work practices, and everyday activities for many of us have the potential to be directly impacted by the manner in which this debate is resolved.

In recent years, reporters have written stories about the potentially adverse health effects on children receiving CT scans, the risk from transporting radioactive waste for disposal in Yucca Mountain, the possible resurgence of nuclear power in the U.S., radiological terrorism, the possibility of nuclear war in South Asia, environmental risks from sunken nuclear submarines, plutonium and radiation exposure to workers at the Department of Energy facilities, environmental restoration of radioactively contaminated sites, postwar impacts of depleted uranium munitions, and more. In each of these cases, the shape of the radiation dose-response curve can have a profound impact on how we view the story, the amount of risk posed by these exposures and, possibly, the number of people who may develop cancer or other stochastic or long-term effects as a result of that exposure.

As of today it is only fair to say that we simply do not know how we respond to low levels of radiation exposure. I have attended meetings in which three respected researchers, presenting papers in the same session, have shown three different interpretations of laboratory and epidemiological data – all to the 95% confidence level. Until we have more information, with smaller error bars, we have to admit that there is no definitive model describing how low levels of radiation affect us.

Progress is being made, however, at both extremes of the spectrum – the cell and the population. Epidemiological studies of populations in natural areas with high background levels of radiation, as well as people who work with radiation for a living and those exposed to radiation from Chernobyl and other Soviet nuclear facilities, and in the atomic bombings of Japan, continue to yield data. At the same time, investigations into cellular DNA damage repair mechanisms, carcinogenesis, and the nature of radiation damage to cells is helping us to understand the exact mechanisms involved in turning a "hit" into a cancer. There is some reason to feel confident that, within the next few years, we will have a deeper and more accurate understanding of these phenomena, leading us to a more accurate model of radiation dose-response at low levels of radiation exposure.

The next question, then, is "so what?" In other words, how might our thoughts about radiation change, how might our regulations and practices change, how will our thinking change once this controversy is resolved? This special edition is an attempt to guess. The purpose of this volume is to examine the possible *non-scientific* impact of resolving the LNT debate, regardless of which model is found to be most accurate. The goal in assembling it was to provide a timely, thought-provoking, and balanced look at how resolving the LNT debate might affect our policies, the ethics of controlling radiation exposure, and the use of radioactive materials on a global scale.

This issue begins with a recap by Ron Kathren, describing the history of the LNT controversy. Professor Kathren has researched and written widely on various historical aspects of radiation safety and, in his contribution, we have a wonderful summary of how we came to regulate radiation exposure according to the LNT hypothesis. Scientific controversies take place over a period of years or decades as ideas, hypotheses, scientists, and fields of inquiry ripen and mature with time. Understanding the time in which this controversy began and the changes in the intervening years may help us to better understand why it has become a controversy of such relevance today.

With the concerns about global warming and air pollution that have arisen in recent decades, many have asked how we can continue to improve the standard of living for the world's growing population without making our planet uninhabitable in the process. Although there are many sources of energy, there are none without environmental impact. Nuclear energy is one technology that has been proposed as a source of energy that emits neither greenhouse gases, particulates, ozone, nor acid rain components. However, fears of radiation have collaborated with other concerns to greatly limit the use of nuclear energy in the U.S. and, indeed, in many European nations. Audeen Fentiman writes about how resolving the LNT controversy may affect the future use of nuclear energy, with some obvious implications about our energy policies. Dr. Fentiman is the Chair of Nuclear Engineering at The Ohio State University. She has published widely on a number of related topics and has extensive experience in all aspects of the nuclear fuel cycle.

Nuclear energy and the use of radiation take place in a global context. Citizens of every nation have access to medical x-rays, have been exposed to fallout from atmospheric nuclear weapons testing, live in a background radiation field, use consumer products containing radioactivity, or some combination of the above, and the spread of nuclear technologies for civilian and military purposes have a potential global impact. International organizations such as the International Atomic Energy Agency (IAEA), exist to help fit the responsible and safe use of radiation into a global framework, and the work of international advisory and oversight organizations helps to ensure that radioactive materials in all their guises are used safely and responsibly.

Abel González, of the IAEA, explores how resolving the LNT controversy might affect the work performed by international oversight and advisory bodies. Dr. González is the IAEA's Director of Radiation and Waste

Safety and is highly respected by his colleagues. In addition to his extensive writing, he has participated directly in the recovery of dangerous sources of radiation around the world. His contribution gives us insights into the world-wide impact of refining our understanding of radiation dose effects.

The papers you will read are uniformly well-written and thought-provoking, written by respected experts in various aspects of the radiation and nuclear sciences. Reviewing them has been a tremendous learning experience for me, and I am sure you will find them equally rewarding.