Nuclear News

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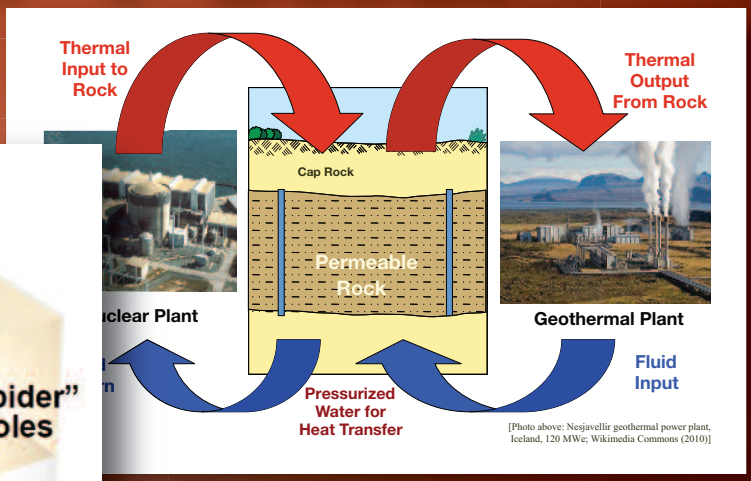
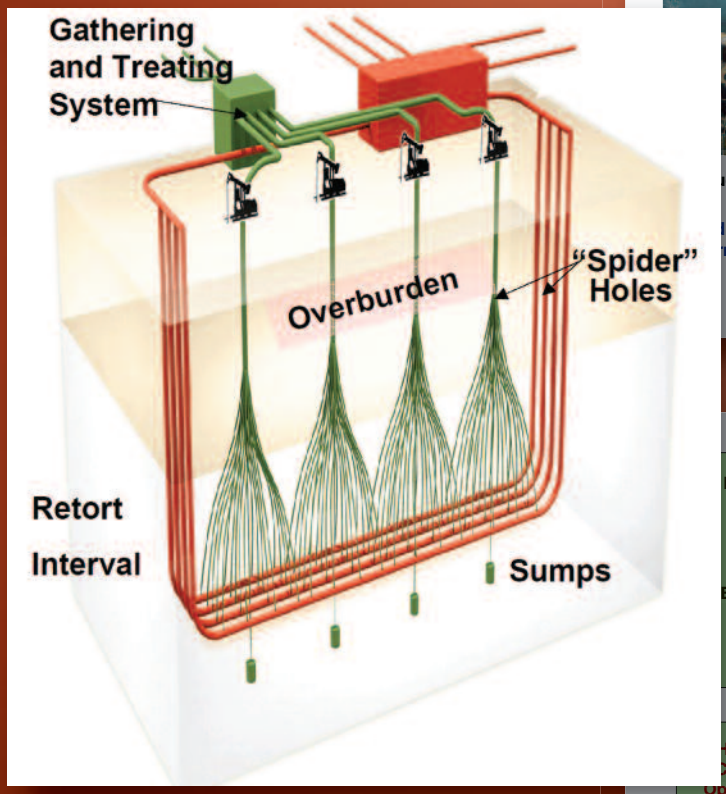
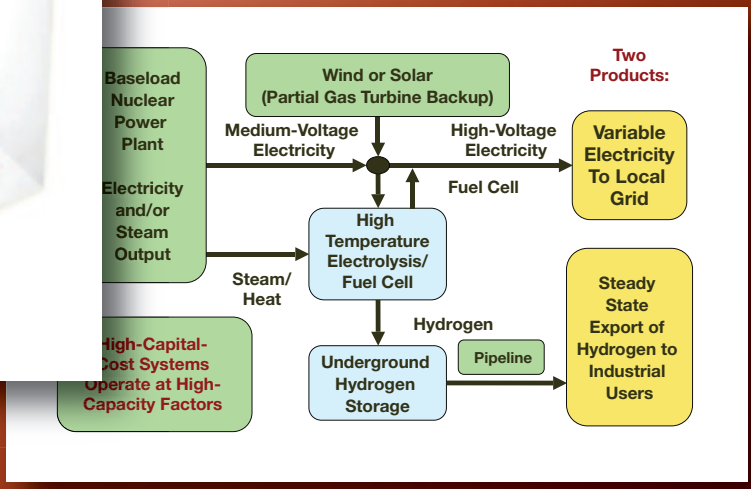
Hybrid Baseload Nuclear Power



[Photo above: Nesjavellir geothermal power plant, Iceland, 120 MWe; Wikimedia Commons (2010)]





Also in this issue

■ Periodic safety reviews, which are typically done on a 10-year basis, were seen as particularly valuable and should be considered by all countries.
■ Containment integrity should be strengthened to ensure that function is maintained even during severe accidents.
■ Additional measures are needed to minimize accidents resulting from natural hazards and to limit their consequences.

As it is vital that countries implement the recommendations, Wanner said, a follow-up process will be defined by the EU regulators to ensure compliance. This will include additional site visits by peer review teams. A more important requirement to Wanner is ensuring that the good practices identified during the reviews are implemented.

Sylvain Costes, a biophysicist in Lawrence Berkeley National Laboratory's (LBNL) Life Sciences Division, described research he has done on the effects on humans of low doses of ionizing radiation. He noted that this research contradicts the linear no-threshold (LNT) hypothesis, the standard model used for predicting biological damage from ionizing radiation. Costes and his coworkers found evidence that the risk of cancer from low-dose levels is actually extremely low and is well below the level predicted by the LNT model, which holds that risk is directly proportional to dose at all levels of radiation exposure.


Costes

Costes described a mechanism by which damaged DNA is repaired, which explains why most DNA damage at low-dose exposure will be successfully repaired, unlike damage at high dose. This, he said, provides an explanation of why a linear extrapolation of risk from damage at high dose to low dose is not valid. He explained that damage to DNA by ionizing radiation involves a "double strand break," which means that the DNA double helix is completely severed. These breaks are repaired—that is, they are reconnected—in the cell at what he called "repair centers," with the repairs made by aggregations of proteins in the cell. At low doses the repair is quite efficient, but at high doses, when there are likely to be a number of DNA breaks (which he said tend to cluster), there is a much greater likelihood of a faulty repair, which can lead to a mutation (chromosomal rearrangement) and cancer. This explains why the risk of cancer is much larger at high doses, he said.

The research done by Costes and his team identified some of the shortcomings of the LNT hypothesis, including, in particular, that it does not take into account a number of factors that he said are essential to the process of damage and repair in the cell. For example, he noted, important biological processes are involved in cell repair that are time dependent, as well as dose-rate dependent. These are not considered in the LNT model, as it does not matter when the break occurs. Costes also noted that the LNT model does not take into account evolution, which would suggest that life forms would adapt to a background of low-dose ionizing radiation, ensuring that it would not be an important risk factor.

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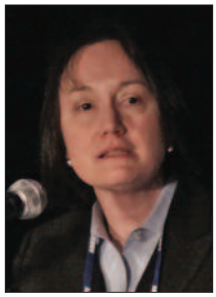
The final speaker was Kristine Svinicki, whose reappointment as a commissioner to the Nuclear Regulatory Commission was confirmed at the end of June. A longstanding member of ANS, she was presented with an ANS Presidential Citation at this session, the second time she has been so honored.


Svinicki

Svinicki said that she particularly appreciated the theme of the opening session. "We need to address impacts of the areas we are working in," she said, as Fukushima made clear. She then looked back at the establishment of the NRC, when Congress decided to separate the regulatory aspects of the Atomic Energy Commission from its other responsibilities, such as nuclear weapons development, the national laboratories, and the promotion of the peaceful uses of nuclear energy.

The NRC's independence, Svinicki said, was a very specific intent of the legislation. The commission's authority comes from the Atomic Energy Act, which has been described by legal scholars as "virtually unique in American statutory law." She noted that this refers to the extremely broad discretion given to the NRC, which is able to give meaning to statutory mandates.

Svinicki also pointed to the NRC's mission statement, which states that the NRC's primary responsibility is "to ensure adequate protection of public health and safety, promote the common defense and security, and protect the environment." The intense focus on protecting public health and safety has resulted in an agency that has a very strong performance record, she added.

Svinicki also spoke of the need to maintain a stable and predictable regulatory environment that is supported by the Principles of Good Regulation issued by the commission in 1991. The principles are used to ensure "the quality, correctness, and consistency of our regulatory activities," she said.

The principles are as follows:

1. *Independence*—The highest possible standards of ethical conformance and professionalism must be upheld, but it does not imply isolation. All available facts and opinions must be sought openly, conflicting public interest must be considered, and final decisions must be based on an objective, unbiased assessment of all information and documented with reasons for the decisions explicitly stated. It is important that people know why a decision was made in a certain way, she said, adding that being able to review the rationale of her predecessors to discover why they made a particular decision has been very helpful to her.
2. *Openness*—Nuclear regulation is the public's business. The public must have the opportunity to participate in the regulatory process, and open channels of communication must be maintained.
3. *Efficiency*—The taxpayer, the rate-paying consumer, and the licensees are all entitled to the best possible management and administration of regulatory activities, which should also be consistent with the degree of risk reduction they achieve.
4. *Clarity*—Regulations should be coherent, logical, and practical, and commission positions should be readily understood and easily applied.
5. *Reliability*—Regulatory actions should always be fully consistent with written regulations and should be promptly, fairly, and decisively administered so as to lend stability to the nuclear operational and planning processes.

Svinicki said that these principles have been helpful to her in considering the relevant issues when making decisions in her role as a commissioner.

Low-dose effects

Two sessions at the Annual Meeting and one at the concurrent ICAPP addressed the issue of whether the long-standing presumption of the potential health effects of low doses of ionizing radiation (and doses received over long time periods) is valid. At

the Annual Meeting, the ANS President's Special Session, "Low-level Radiation and Its Implications for Fukushima Recovery," was followed by a panel session with many of the same speakers (see the session write-up that immediately follows). At ICAPP, a presentation was made by Sylvain Costes, a researcher at LBNL, whose team had published a paper last December on DNA repair mechanisms. He was also a speaker at the opening plenary session of the Annual Meeting.

The special session's organizers had prepared a book-length collection of policy statements, opinion pieces, and scientific articles (most of them reprinted from other publications), and copies were made available to attendees. Despite its title, *President's Special Session: Low-level Radiation and Its Implications for Fukushima Recovery,* the publication does not include the presentations made by the speakers at the session, but it does include earlier writings by four of the speakers. The publication is available at no charge as a download from the ANS Web site, at <www.new.ans.org/about/officers/docs/special-session-low-level-radiation-version1.4.pdf>, or go to <www.ans.org>, and from the "About ANS" dropdown tab, select "Elected Officers"; under Eric Loewen (now the immediate past president), click on the title of the publication.

At the President's Special Session, Kazuaki Matsui, executive director of Japan's Institute of Applied Energy, presented data on the estimated releases of radioactive material from Fukushima Daiichi. The largest estimate of the airborne total, presented as an equivalent of the radioactive isotopes of iodine, is roughly 900 petabecquerels. By comparison, the iodine equivalent release from the 1986 Chernobyl-4 accident was 5200 pBq. Matsui noted that the largest estimate of release to the sea is 27 pBq.

Matsui

Through the end of March 2012, the doses reported for Tokyo Electric Power Company workers at the site included six who had received more than 250 millisieverts, one who had received 200–250 mSv, 139 who had received doses in the 100–200 mSv range, and 3276 with doses below 100 mSv. Also, Matsui said, 21 of 17 600 contract workers had reported doses of more than 100 mSv. The external doses to inhabitants near the plant, in the Iidate and Namie districts, are estimated to be below 10 mSv for 99.3 percent, with the highest dose to an individual stated as 25.1 mSv. Internal dose is less than 1 mSv for 99.9 percent, with two people receiving doses of 3 mSv.

Matsui summarized the effects of the accident on the Japanese economy, including the increase in electricity costs as Japan's operable power reactors were kept off line after routine refueling and inspection outages. (In July, two reactors at one site resumed service; see *NN,* Aug. 2012, pp. 17 and 163.)

While Matsui mainly addressed the accident response, he did state that the low doses received by nearby residents would give rise to "probably minimal or no health effect due to the prompt evacuations." As to whether such doses should be any cause for concern, he closed with a chart showing the average lifetime radiation doses in several countries and in the vicinity of Chernobyl, which, by Matsui's earlier measure, released almost six times more radioactive material than Fukushima Daiichi did. The dose for Finland was the highest in this group, higher even than the region with the greatest radioactivity from Chernobyl. The chart was titled "Finland has not been evacuated."

Sakamoto presented data from his own experiments, starting in 1975, showing low doses to have promoted immunological response, rather than suppressing it.

To a large extent, the other speakers at the session presented material similar to what they would present in the later session (see the session writeup that immediately follows this one). These speakers were Kiyohiko Sakamoto, chairman of the board of directors of the Tohoku Radiological Science Center in Japan; Jerry Cuttler, president of Cuttler Associates, a consultancy based in Canada; Ronald Mitchel, researcher emeritus for Atomic Energy of Canada Limited; and Douglas Boreham, a professor in the Department of Medical Physics and Applied Radiation Sciences at McMaster University in Canada.

Boreham's presentation, on modern tools to understand genetic effects from low doses, cited evidence that low doses could enhance the ability to withstand high doses later. This was also mentioned by other speakers as one of the potential benefits of either administering radiation doses or reducing the concern over whether low doses have been received unintentionally.

Cuttler also cited research results indicating that low doses may prevent damage from higher doses, and he echoed Matsui regarding natural doses in some parts of the world being greater than doses from Fukushima Daiichi. Sakamoto presented data from his own experiments, starting in 1975, showing low doses to have promoted immunological response, rather than suppressing it.

The discussion at this meeting on whether the LNT hypothesis is valid took place in the midst of a growing debate on this topic in the nuclear community, with the most recent scientific developments coming from the paper published last December by Costes's group at Berkeley (*NN,* Feb. 2012, p. 61), and another published mid-year by a group based mainly at the Massachusetts Institute of Technology, stating that no radiation damage was apparent from long exposure to low doses (*NN,* July 2012, p. 78). To varying degrees, some participants in the larger debate call for repudiation of the LNT hypothesis, recognition of radiation hormesis, and wholesale revision of radiation protection practices to allow less cost and effort to be expended in the reduction of doses.

As the tools cited by Boreham become more powerful, however, it may be possible to develop a more precise awareness of dose response, rather than replacing the generalized LNT hypothesis with an equally generalized threshold/hormesis model. In his ICAPP presentation, Costes enlarged on the information in his group's paper from last December, in which double-stranded breaks in DNA molecules were observed to become surrounded by chemicals able to restore the broken strands, making the breaks into "repair centers" for the DNA. In addition to pointing out how DNA in general is thus able to restore itself from the kind of damage that can be caused at the molecular level by low radiation doses, Costes cited the importance of the data gathered so far on individual response. He said that different types of mice used in the study (which was carried out as part of the DOE's research program in low-dose radiation) have been found to respond differently in their DNA damage and repair abilities. It is possible, then, that a radiation dose that harms one organism may help another of the same kind and have no effect at all on a third.

Boreham

The panel session on the health effects of radiation—which was complementary to

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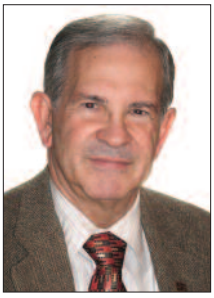
the immediately preceding President's Special Session—aired the views of a distinguished panel of experts from a variety of disciplines, including four participants from the special session—Jerry Cuttler, Kiyohiko Sakamoto, Ronald Mitchel, and Douglas Boreham—who were joined by Wade Allison, professor emeritus of physics at the University of Oxford and author of *Radiation and Reason*; Jim Welsh, a radiology oncologist at Fermi National Accelerator Laboratory; and Myron Pollycove, professor emeritus of laboratory medicine and radiology at the University of California at San Francisco.

All of the panelists, in one way or another, could be properly termed debunkers of the received wisdom on radiation exposure, as each presented evidence suggesting that not only are popular anxieties over radiation overwrought, but that low doses of radiation can, in fact, provide health benefits when properly administered.

Cuttler, the panel organizer and chair, led off the session with a look at some of the scientific research that supports the claims of salutary effects from low-dose radiation and casts doubt on the linear no-threshold (LNT) hypothesis—the model still widely acknowledged as the appropriate basis for radiation protection regulations—which holds that no level of radiation exposure is safe and that risk from radiation increases proportionately with the dosage received.


Cuttler

Research highlighted by Cuttler included work done by Pollycove and Ludwig Feinendegen, professor emeritus of nuclear medicine at Heinrich Heine University Düsseldorf, showing that low doses of ionizing radiation actually stimulate cell defenses that protect against disease in the process known as hormesis; a radon exposure study by the late physicist Bernard Cohen, a critic of the LNT hypothesis, indicating that lung cancer mortality rates were lower where radon was higher; and a 7417-patient study on cancer incidence and mortality following radioiodine treatment for hyperthyroidism, demonstrating a decrease in both cancer incidence and mortality.

Cuttler also discussed a number of historical examples of radiation therapy administered for medical purposes, including radiation treatment of gas gangrene infection and the controversial Nasal Radium Irradiation program, in which from 1945 to 1961, millions of children in the United States received radiation doses as a standard medical practice to shrink enlarged adenoids and tonsils, with no significant increases of thyroid cancer rates, according to Cuttler. Other data he cited included statistics on children who survived the atomic bombings of Hiroshima and Nagasaki, which showed no increase in congenital abnormalities, mortality, chromosome aberrations, or gene mutations.

In Cuttler's view, part of the problem in getting the word out to physicians regarding the benefits of low-dose radiation is that most radiologists are taught the LNT model in school as a matter of course. He singled out one particular well-known textbook, *Radiobiology for the Radiologist*, for specific criticism. "The book does not mention radiation hormesis," Cuttler said, adding that the book ignores copious amounts of scientific data showing that low doses and low-dose rate radiation provide beneficial health effects.

In his concluding remarks, Cuttler offered some recommendations for combating what he regards as the myths and scaremongering that surround the radiation issue, including that scientific societies organize more events to discuss radiation and health, that regulatory bodies and health organizations examine the entire body of scientific evidence, and that public communication programs be developed that include strategies on how to explain the reality of the hormesis effects of low-dose radiation.

Sakamoto (himself a recipient of radiation therapy, having opted for that treatment some years ago to deal with metastases following colon cancer surgery) discussed his research, which began in 1975 with a study of tumor-bearing mice to determine the minimum dose required to suppress immunological response. He discovered, instead, that irradiation with low doses, of 10 to 15 cGy, actually promoted immunological response, a finding he characterized as "a complete surprise."


Sakamoto

The finding led Sakamoto to perform a series of experiments over 12 years, funded by the Japanese government, on the effects of total- or half-body low-dose radiation treatments on some 200 cancer patients. Based on those experiments and other research, Sakamoto said, he has reached the following conclusions: (1) much information is known about the effects of low doses and low levels of radiation on living organisms, especially mice and people; (2) low doses of radiation stimulate immunity to cancer and biological defenses against DNA damage; (3) low-dose radiation can be used to cure/prevent cancer; (4) the dose or dose rate at which radiation starts to become harmful is known; and (5) there is no basis to fear low-level radiation.

Allison began his presentation with an explanation of why he wrote *Radiation and Reason*. "I'm an ex–particle physicist, and I've been spending the last few years getting angry about the discrepancy in attitudes toward different levels of radiation," he said. "So I wrote a book on the subject, with the idea of how can we get across to the general public and the politicians what the hell's going on. . . . Of course, nobody would publish it, so I published it myself."

"I've been spending the last few years getting angry about the discrepancy in attitudes toward different levels of radiation."


Allison

Allison drew a stark contrast between the response of the Japanese people to last year's earthquake/tsunami and their response to the Fukushima Daiichi accident. "When the earthquake struck," he said, "there were 500 000 people in the region subsequently inundated by the tsunami, and within 26 to 45 minutes, all except 18 880 had managed to escape." The reason for this remarkable performance, he explained, was that the Japanese people had been properly prepared for tsunamis. They had not, however, been properly prepared for a nuclear reactor accident like the one that occurred at Fukushima.

"The training and understanding of the Japanese people that was evident for the tsunami was absent for the release of radiation and radioactivity," Allison said. "Faced by an unknown threat, nobody knew what action to take, and few in authority knew either, so that rumor and panic, extending to the highest levels, led to serious social harm, widespread voluntary evacuation, failed businesses, and losses of confidence in society and nuclear power." Allison remarked that he finds it strange that society should fail to cope with such an accident, one for which no loss of life should be expected. "Fear of powerful energy is a protective an-

imal reaction," he noted, "but man has survived dangers through study, understanding, and mutual organization, but not in the case of radiation and radioactivity. Why not?"

Allison believes that the answer, at least in part, is the failure of the nuclear community to adequately communicate the nuclear reality. "Nuclear decay is safer than fire," he said. "It's safer than biological hazards. It cannot spread by contagion. It leaves very little waste, and what it does leave is essentially solid. It eventually diminishes, unlike chemical wastes. It is difficult to imagine that nuclear energy could possibly be physically safer than it is." But, he added, hardly any of that information gets disseminated to the public.

"So we have suffered from 60 years of nuclear-inspired political fear that has run wild, wasting enormous resources and diverting attention from the real global threats to civilization—socioeconomic instability, climate change, population growth, food, and fresh water," Allison declared. "Radiation should not appear on that list."

Mitchel returned to an examination of the validity of the LNT hypothesis, questioning whether it holds true at low-dose rates. A radiation exposure is a change in the environment that creates a stress, he said, and the basic rule of biology in a changing environment is "adapt or die." And, he said, adaptation to radiation has been shown to operate in everything from single-cell organisms to human cells.


Mitchel

"We know that low doses [of radiation] stimulate DNA repair," Mitchel said. "If the DNA repair isn't properly done, if mistakes are made, then the cell is supposed to die through a suicide program called 'apoptosis.' That's what's supposed to happen, and that's stimulated by low doses. But if that doesn't happen, we have something called 'bystander effects,' which means the neighbors of the cell recognize that there's an aberrant cell in their midst, and they send so-called death signals to the aberrant cell, which turn on the apoptosis program that the cell couldn't turn on itself. And if that doesn't work, then we call out the immune system, where T cells and natural killer cells go out and find these aberrant cells and kill them. And if that doesn't work, only then do you get cancer."

There exists, Mitchel said, an ability to repair broken chromosomes in cells adapted by exposure to low doses that is highly nonlinear. He cited a number of studies, including a 1996 study by Azzam, de Tolido, Raaphorst, and himself, showing that spontaneous neoplastic transformation frequencies—neoplastic transformation being the conversion of tissue with a normal growth pattern into a malignant tumor—did not progress in a linear manner. A 10-mGy treatment, in fact, resulted in a lower transformation frequency than a 1.0 treatment, which itself resulted in a lower number than the control category. Another study highlighted by Mitchel indicated that low-dose radiation can protect from chemically induced cancer as well, when the dose is given 24 hours before the chemical carcinogen is applied.

The implications for radiation protection, according to Mitchel, are that at low doses, all the basic LNT assumptions are wrong, and a new approach to radiation protection at low doses is needed.

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Welsh described the radiation therapy he has used successfully on cancer patients as being virtually identical to Sakamoto's approach. He added, however, that it is difficult to conduct this type of research in the United States because of opposition and skepticism from the medical community and the difficulty of getting things through a hospital's internal review board, which sometimes frowns upon this type of work. "Nonetheless," he said, "I do think that Dr. Sakamoto's data stands firm, and as a clinician, I've seen it work, and I believe we should exploit it further and find out what the true mechanism is."

Welsh also mentioned the "abscopal effect," one of the most fascinating observations he made while conducting these treatments. "As has been discussed several times today, a low dose prior to a large dose is protective," he said. "But what about the opposite? What if the high dose has already been given, and the damage has already been done? Can a subsequent low dose activate this adaptive response and undo some of the damage? This, in my opinion, is the most interesting question. If this mechanism is possible, then we would have a new therapy. And I believe the hypothesis is very consistent with Dr. Sakamoto's data."


Welsh

Boreham lightened the mood of the session somewhat by pointing out that due to the natural radioactivity in one's body from potassium-40 beta particles, sleeping next to someone for a year will give you the same radiation dose as getting an X-ray of your hand. "Everyone's worried about getting a hand X-ray, but nobody really worries about sleeping with someone," Boreham said. "Now mind you, one's given over a year, and one's given over a second, but if you believe in the LNT, they both carry the same amount of risk. So, pick your risk."

Pollycove ended the session on an optimistic note. "The reason I can answer the question of what's safe with great conviction and certainty," he said, "is that my attention was first called to this area when T. D. Luckey published a book in 1980, in which he cited a number of locations around the world in which the background radiation is high and the people there are uniformly living [to] between 80 and 100, and here they are living [to] between 60 and 80. And all these places have chronic radiation 30, 40 times, maybe 60, 70 times as much as we have in San Francisco."


Pollycove

DNA, Pollycove said, is not stable—it is constantly being destroyed and reconstituted in a process that is triggered by the chronic radiation described in Luckey's book. The low dose from background radiation in these locations stimulates repair, and the DNA ends up in better condition. "You can be very secure about chronic radiation," Pollycove declared, "and the ability to cope with acute radiation is well demonstrated by the therapy being done now."

Science and policy-making

The session titled "Science in Politics: Getting Scientists Elected" brought together an eclectic group of people to discuss and promote the involvement of scientists and engineers in public policy. The panel members included Dick Simpson, head of the Political Science Department at the University of Illinois at Chicago and a former Chicago alderman; Monica Metzler, chair of the Illinois Science Council's board of directors; nuclear engineer Chad J. Boyer,