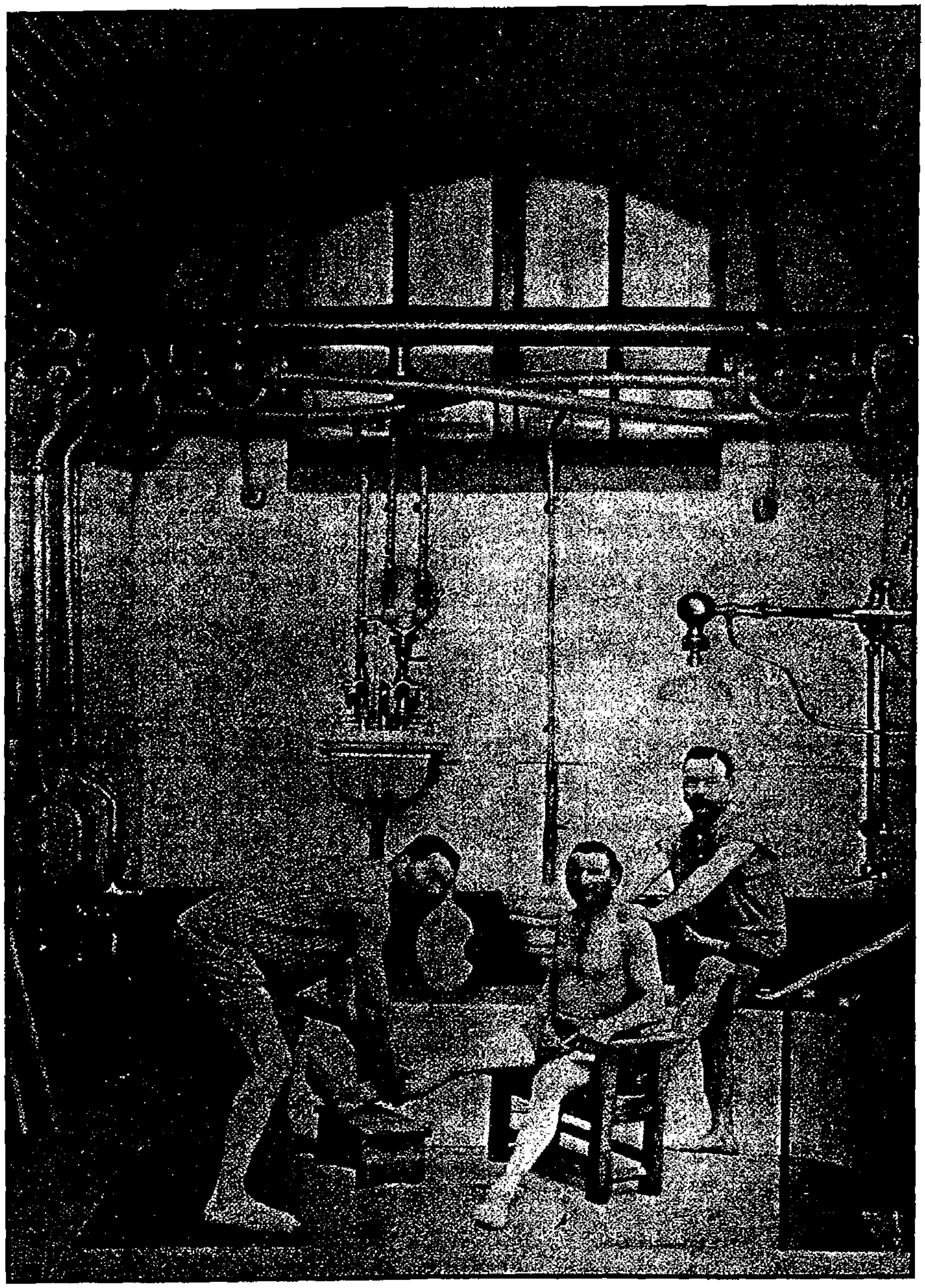
Underdosed

COULD TOXINS—AND RADIATION—BE GOOD FOR YOU?

BY TOM BETHELL



For centuries, the wizards of alchemy believed that with the addition of heat and esoteric knowledge, base metals could be transmuted into gold. Isaac Newton and Robert Boyle were among the last noted investigators of this false theory. By Newton's day it was becoming nonrespectable, and he found it prudent to conceal his interest. By the mid-18th century, alchemy had been fully demoted to the realm of sorcery and superstition and was never revived. The natural elements were seen as fixed and stable.

In the 19th century, Russian chemist Dimitry Mendeleyev devised a periodic table of these elements, including gaps that correctly predicted the existence of some that were yet to be discovered. But, strangely enough, the age of elemental stability proved short-lived. In the early years of the 20th century, scientists discovered that some elements—particularly the final 12 on the periodic table—were not fixed after all. Of their own volition they spontaneously transformed into other elements, which in turn broke down into still others. Transmutation lived.

The sorcerers had been onto something—they just got it all back to front. It turns out that lead was not the initiating element but, in most cases, the end product. And heat didn't need to be added—it was emitted. The philosopher's stone, the missing ingredient so sought after for so many centuries, had been discovered. But now that it was real, it was destined within a few decades to be transformed itself, from the most desired to the most dreaded thing in the world. Its name was radioactivity.

But there is a curious coda. For a small but persistent minority of scientists, one aspect of the old philosopher's stone did not disappear at all. As the *Encyclopedia Britannica* had put it, the philosopher's stone was "sometimes said to be a common substance, found everywhere but unrecognized and unappreciated." In addition to being able to transmute metals, it was also "thought to cure illnesses and prolong life." Within years of its discovery, some scientists did believe that that was indeed true of radioactivity. Radium was thought to be an elixir. But in high doses, radioactivity was found to be fatal, or to cause cancer. And then radioactive material became the essential ingredient of the atom bomb.

Senior editor Tom Bethell profiled cancer fighter Bruce Ames in TAS, May/June 2002.

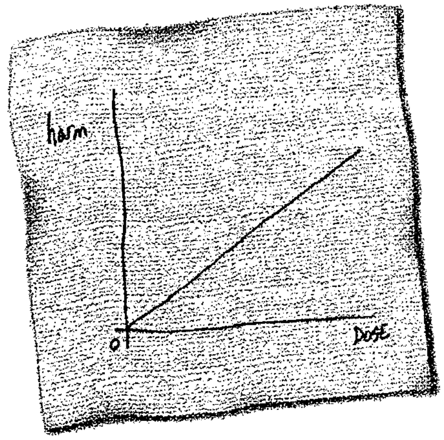
So it was a death ray, not an elixir—both U.S. government policy and conventional opinion on the subject have been based on that assumption for almost 50 years. But some scientists today still do believe that in low doses, radiation does indeed "cure illnesses and prolong life." Likewise, they believe that in small quantities otherwise highly toxic chemicals can have beneficial effects. The idea that chemicals and radiation in low doses have a stimulative effect is known as the theory of *hormesis*—a term first used in 1943, and based on the Greek verb "to excite."

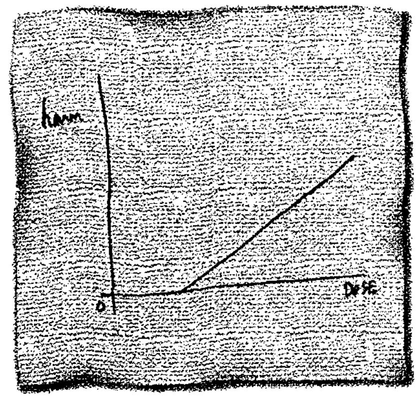
The data supporting hormesis are persuasive; the question is whether the theory will be accepted by the scientific community. Its acceptance would rescue the study of environmental health risks from its present sterile path. Nothing less than a new biological law is waiting to be formulated—the stuff of which Nobel prizes are made. And in the public arena, accepting hormesis would puncture decades of carefully cultivated paranoia about minuscule amounts of radiation and PCBs. Dioxin is good for you—imagine that.

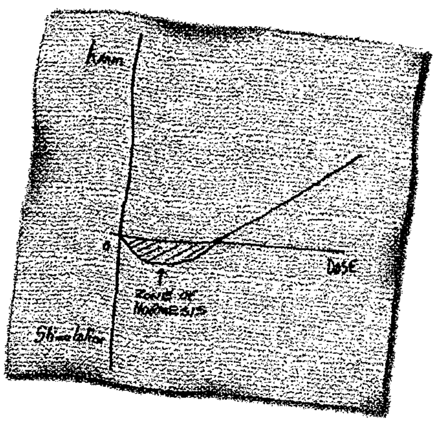
In looking into this neglected but remarkable subject, we have three theories about toxicity to consider. They are simple in outline and may be represented by three graphs drawn on a napkin.

The first graph at the top depicts the doctrine that reigns within the political establishment today. It has guided the U.S. government for almost 50 years. Called the "linear, no threshold" theory, it is often abbreviated as LNT. (This whole subject is replete with dismaying thickets of acronyms and baffling units of radiation, which I shall try to keep to a minimum.)

The premise here is that if a body experiences a high dose of something, be it mineral or chemical or ionizing radiation, it will indeed do a lot of harm, possibly fatal. With respect to radiation, the reigning theory simply holds that however low the dose, some harm is to be expected. There is no threshold below which *no* harm is done. Hence, "linear no-threshold." It is supposed that, however expensive it might be, getting rid of that last trace of chemical or radiation will always do some good: always eliminate at least some cases of cancer. Opponents are immediately put in the defensive position of making cost-benefit analyses in which they implicitly or perhaps explicitly argue that a life isn't worth







a billion dollars (or however many it may be).

The second graph is shaped like a hockey stick, and the theory behind it simply states that below a certain dose, chemicals and radiation do no harm. They are imperceptible to the body. They have no biological effects. It is not a theory that we will pay much attention to, except to say that it is out there and that some quiet skeptics who labor at the EPA and in university science departments believe it is true with respect to some chemicals and radiation sources.

It is the third graph showing the curve of hormesis that is the subject of growing interest. Its J-shape gives visual expression to the idea that low doses of both chemicals and radiation are good for you. Their "harm" is negative within a certain range. They improve your health, the theory goes, and other thir being equal, increase your lifespan.

The linear no-threshold theory for radiation was first popularized by Linus Pauling in his debates with Edward Teller about nuclear testing in the 1950s. If just one stray neutron can initiate cancer, Pauling argued, then by adding up all the people in the world and multiplying by some risk factor, you can claim that halting nuclear tests will save thousands of lives. Summing up the linear no-threshold theory, the Harvard Nobelist George Wald has said, "every dose is an overdose." This case was more recently made by John Gofman, who did graduate work in nuclear physics at U.C. Berkeley during World War II. Once fervently pro-nuke, Gofman in the 1950s and '60s supported a "plutonium economy" based on breeder reactors, urged the licensing of a thousand nuclear power plants and even wanted to nuke the Rockies to liberate natural gas. Then he turned fervently anti-nuke in the late 1960s. More recently, in a "letter of concern" published in 1999, he declared that "there is no safe [radiation] dose, which means that just one decaying radioactive atom can produce permanent mutation in cell's genetic molecules."

The late H. Wade Patterson, who was editor in chief of the journal *Health Physics*, recalled: "I lived in Berkeley, California, and worked at the Radiation Lab from 1945 onward. My memory, and it's excellent, is that citizens there and elsewhere had no fear of radiation until the great debate on nuclear testing. The public exchanges between Pauling and Teller exemplified this controversy. It's an interesting footnote that during the Pauling-Teller debates, John Gofman made many public speeches arguing against the linear no-threshold theory. It was only later that, for mysterious reasons, he made a diametrically opposite change. Anti-nuclear activists and the media seized on the no-threshold theory as the basis for their opposition to testing [and] used the LNT as the basis for all their dire predictions about nuclear power."

The main political outcome of the linear no-threshold theory has been to undermine support for nuclear power. Although nuclear power plants emit levels of radiation that are far, far below the background levels of radiation that we all experience every day of our lives (coming from the earth, from cosmic rays and even from the body's own metabolism), the idea has taken hold that even a tiny additional amount of radiation poses a threat to our lives. So we have become increasingly dependent on coal for the generation of electricity, and coal really is hazardous in numerous ways. Its emission of greenhouse gases is just one of them.

As the decades passed, agencies of the U.S. government and their friends and allies in the burgeoning safety and risk abatement business became increasingly captured by exponents of the linear no-threshold theory. Government money was doled out to exposed victim groups, including uranium miners and shipyard workers. The measurement and abatement of radon gas became a $100-million-a-year industry; safety experts in various fields acquired lifetime tenure. The beneficiaries of existing policy will put up a fierce resistance to changing it. Above all, "linear no-threshold" became the formula that kept the Environmental Protection Agency fully funded for a quarter century.

One day, while working on this story, I met a senior scientist who has toiled for years at the EPA. "Career bureaucrat," was how he described himself, and somehow he had reached the point where he viewed the agency's activities and his own career there with a kind of amused detachment. Close to retirement, he may even pull the Republican lever in the privacy of the voting booth. When I told him I was interested in low-level radiation, he rolled his eyes. Good luck on that, my friend, he seemed to say. Don't expect any sympathy from the EPA in that department! "The anti-nukes are among our strongest supporters," he said. When the subject of the Hiroshima and Nagasaki survivors came up—an interesting story in itself, as we shall see—he leaned over and said in a stage whisper that eight people had survived "both Hiroshima *and* Nagasaki." This conjured up a dreadful picture, but somehow his conspiratorial tone and his emphatic *and* made us both laugh.

He told me the story of Rosalyn S. Yalow, who won the Nobel Prize in 1977 for some radiation research. At about that time, she got into trouble with the New York authorities for discarding waste that was mildly radioactive, but quite harmless. For the next 20 years, Yalow tried to straighten out the world on the overblown danger of radiation: wrote articles, testified before Congress, was quoted in many places. When Senator Edward Kennedy touted an NIH study of cancer deaths near nuclear power plants, she pointed out that the research was a "response to political pressure," and—because many such studies had already been done—"cannot be justified on the basis of scientific merit." But her period of activism coincided with the time of Three Mile Island and Chernobyl, when any rational discussion of radiation became close to impossible in polite society.

"What surprises me is the extent to which EPA is still worrying about *non*-ionizing radiation," the EPA scientist told me. He was referring to the supposed threat posed by cell phones, power lines and visible light. Radiation comes in two varieties. "Ionizing"—which is what most people think of when they hear the word radiation—means that the ray or particle has enough energy to knock an electron out of its orbit. This creates an ionized atom or molecule, which in its altered state has a greater affinity for chemical recombinations. Alpha particles and gamma rays, if intense enough, can also break chromosomes, which sometimes does have the effect of transforming a normal cell into a cancer cell.

He suggested that the non-danger of non-ionizing radiation be measured in non-units called *brodeurs*, named after Paul Brodeur, a novelist manqué who wrote endless articles on the perils of power lines for *The New Yorker*.

It occurred to me that I had never seen an article on hormesis in *The New York Times*, so I called their reporter Matt Wald, who often writes about nuclear issues for the paper. I told him I was interested in the subject of hormesis. "Hot subject," he said. When I asked if he or anyone else at the paper had written about it, he looked it up on his computer right away, and told me that an article in the *Times* had indeed mentioned hormesis, in 1982. He forwarded it to me on the spot. It involved a discussion between scientists, among them John Gofman and Edward Webster, then the chief of radiological sciences at Massachusetts General Hospital. The following exchange occurred:

> Dr. Gofman: I do not believe that there is any dose at this time that has been shown to be without effect. Moreover, I think it is public health irresponsibility to assume that such a dose exists when one is not absolutely certain.
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> Dr. Webster: I would disagree with that. I would say that there is considerable uncertainty. There are some interesting examples of increased lifespan at very low doses in animal populations. In fact, there's a whole body of thought which is developing called hormesis, which means that maybe a little bit of radiation could be beneficial. I'm not saying I agree with this, but it is a school of thought, which is the exact antithesis of saying that all low doses of radiation are bad. I don't think we can resolve this controversy, because the low-dose information we have, in general, is too poor to make a decision. I suspect some of the studies Dr. Gofman is talking about are exactly in this category.
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> Dr. Gofman: Not at all, Dr. Webster. The studies I'm referring to which show increased effects at low dose are based upon Hiroshima-Nagasaki. . . . I think it is a public health responsibility to assume effects all the way down.

The New York Times science reporter Gina Kolata wrote an informative article for the paper's "Science Times" last November. Addressing 9/11 concerns, it was headlined "For Radiation, How Much Is Too Much?" It is one of the very few times that the newspaper has addressed, if only obliquely, the subject of hormesis (though the word itself did not appear).

> Some scientists even say low radiation doses may be beneficial. They theorize that these doses protect against cancer by activating cells' natural defense mechanisms. As evidence, they cite studies like one in Canada of tuberculosis patients who had multiple chest X-rays and one of nuclear workers in the United States. The tuberculosis patients, some analyses said, had fewer cases of breast cancer than would be expected, and the nuclear workers had a lower mortality than would be expected.

John Boice, scientific director of the International Epidemiology Institute in Rockville, Maryland, was quoted by the *Times* as saying that these studies "were flawed by statistical pitfalls." But Arthur Upton, a former director of the National

Cancer Institute, who headed the group that studied the studies, said that the data "do not exclude" a hormetic effect. As to the 80,000 to 90,000 atom bomb survivors, "it has been hard to find excess cancers," Kolata wrote. Dade Moeller, an emeritus Harvard professor and radiation expert, said that although the survivors were exposed in 1945, "nearly half are still alive." Of the children who survived the bombing of Hiroshima and Nagasaki, over 90 percent were still living 50 years later. And there has been no statistically significant increase in birth defects among the children of survivors, nor any increased risk of death among these children up to the age of 20, the period when hereditary diseases are likely to be seen. Excess birth defects have not been seen in the grandchildren either.

In 1997 a staff writer called Joby Warrick wrote an article about low-level radiation for *The Washington Post.* It was one of a kind: something to be clipped, enclosed in clear plastic and filed away for safekeeping. It began:

> The statistics seem clear and compelling and completely at odds with common sense: In Japan, site of the world's only nuclear attacks, radiation victims are outliving their peers. It's one of the stranger twists in 50 years of scientific monitoring of atom bomb survivors. As expected, the people closest to ground zero have died in high numbers of cancers that began in a white hot flash of nuclear radiation. But as one moves further from the blast site, the death rate plunges until it actually dips below the baseline.

Hmm. They received a low dose and are living longer. In the course of researching his article, Warrick spent several hours with Theodore Rockwell, who worked on the Manhattan Project at Oak Ridge (producing enriched uranium), and in 1949 was hired by Hyman Rickover to work in the Naval Nuclear Propulsion Program. He became its technical director and wrote *The Reactor Shielding Design Manual,* which is still in use. Later, Rockwell helped found an organization called Radiation, Science and Health, Inc. He lives in Chevy Chase, Maryland, so one day I went to see him. Bearded and energetic at the age of 80, he talked non-stop, darting about his study to collect reports and documents, swooping down to floor level without strain.

He guessed that the *Post* editors must have given Mr. Warrick a talking-to after his article came out, because the reporter strayed no further and in later articles stayed on-message. At almost every newspaper in the country, for the past 25 years, that message seems to have been the intentional arousal of fear of radiation. In the reports of the recent scare about a "dirty bomb" (radioactive material wrapped around conventional explosives), the papers were filled the next day with warnings that our main worry was not so much the radiation, but the fear that it would arouse. That was true, but the press itself laid the groundwork for that fear over the last 25 years.

Describing his experiences with the nuclear-powered Navy, Ted Rockwell said that 220 nuclear power plants have been installed on ships, compared with 103 civilian plants in the United States. American nuclear-powered ships have been running since 1955 without any significant release of radiation. "You sleep within a few feet of the reactor," Rockwell said. On submarines, "you get less radiation than you do at home because the surrounding seawater protects you from cosmic radiation." NASA is now looking at nuclear power for its Mars mission. This will reduce the crew's exposure to radiation. They will arrive in a quarter of the time, and cosmic radiation will be that much less.

Background radiation is important to understand, because every day we are exposed to radiation levels that are far higher than anything that EPA regulates from man-made sources. Natural sources include cosmic rays, radiation from uranium and other radioactive rocks; from radon, a gas emitted by radium; from medical equipment; and from our own bodies as a result of normal metabolism. The key point is that the level of this natural radiation varies greatly from one part of the earth to another. This sets up a natural epidemiological test of the theory of hormesis. More on that later.

Radiation is always and everywhere fading away and dying down, at a rate determined by the half-life of the radioactive material in question, which may vary from billions of years (in the case of uranium) to a fraction of a second (in the case of certain gases). If we go back millions of years, when man is said to have evolved on the African savannas, radiation levels were higher, so an evolutionary case can be made that we now live in an environment that is deficient in radiation. Overall, Rockwell told me, natural radiation is decaying more rapidly than man-made radiation is accumulating. So the idea that we are not getting enough radiation to keep us in good shape is a distinct possibility.

One of the most striking studies of the effects of radiation was presumably intended to demonstrate its danger to workers, but instead showed the opposite, Rockwell told me. The $10 million study, released by the Department of Energy in 1991, summarized 10 years of epidemiological research by the Johns Hopkins School of Public Health. The study covered no fewer than 700,000 shipyard workers, 108,000 of whom had been occupationally exposed to radiation while installing or servicing nuclear reactors in Navy vessels. (No civilian nuclear power plant has been ordered since 1973, but nuclear-powered ships are still being built.)

Researchers carefully matched exposed workers with similar workers in the same shipyards who had not been exposed. The exposed group had received radiation doses about 10 times that of the unexposed. But researchers found that the irradiated workers had 24 percent lower death rates and 25 percent lower cancer mortality than the unexposed workers. Although this report was released, Rockwell told me, it had never been properly published in a way that drew attention to its anomalous findings. Data was buried in the text, but not plotted out for all

to see in revealing and unambiguous graphs.

It's important to note that evidence for hormesis is seen with chemicals as well as radiation, and Rockwell illustrated chemical hormesis in the simplest possible way. He read off the contents of a multivitamin bottle on his desk: zinc, magnesium, selenium, copper, manganese, chromium, molybdenum, nickel, boron. Noting the caveat of Paracelsus, the 16th century doctor who said that the dose makes the poison, Rockwell commented on these ingredients: "These are all serious poisons. Especially selenium and chromium, which are highly toxic."

I asked him about Chernobyl, the "site of the worst radiation accident in history," as *The New York Times* puts it. A nuclear reactor exploded there in April 1986, and the disaster has since been extensively investigated by numerous bodies, including the U.N.'s Scientific Committee on the Effects of Atomic Radiation. Rockwell promptly retrieved the latest report, the size of a phone book, from a nearby shelf and dumped it in my lap.

"What it says is that some 30 people who were inside the plant died," he said.

> Some died from the original explosion, some from fire, and I don't doubt some died from radiation. But they were all inside the plant. So it was an industrial accident, and we have seen far worse. As to the general public, they checked iodine in the thyroid, and sure enough they found 1,800 children with thyroid nodules. But that part of the world is iodine-deficient—they were already having a serious public health problem. Two kids with thyroid nodules were brought in and they died. But it turns out they were nowhere near the radiation. A third child died of something else entirely. As to the 1,800 people, they did not correlate with radiation dose at all. Some high-dose kids had no nodules; some low-dose did. So it's not at all clear that they ever were related to the radiation, and the charter chairman of the original U.N. committee doesn't think they are related.

So how many died as a result of the Chernobyl accident?

"The official story of this U.N. report is that they have not yet reported any deaths outside of the 30 who died in the plant," Rockwell said. "A number of men who went in later as clean-up crews got very high doses, came down with radiation sickness and have since recovered. Today, the radiation level in Chernobyl is lower than the natural radiation in my sister's backyard in Denver."

In a front-page story on June 6, 2000, Elaine Sciolino and Michael R. Gordon reported for *The New York Times,* inaccurately, that the Chernobyl accident "spewed radiation over vast stretches of northeastern Europe and caused untold thousands of deaths and illnesses." Untold is the operative word.

Humans were evacuated from the area, but the animals remained, and the latest word is that they are "thriving," according to a report in the London *Sunday Times* in April. John Smith of Britain's Center for Ecology and Hydrology said that people think of Chernobyl as a "post-apocalyptic wilderness, whereas it appears to be the exact opposite." Cham Dallas, a toxicologist from the University of Georgia, has visited the area 12 times and studied mice living close to the dead reactor. "You'd expect them to be in a really bad way. What is weird is that they seem to be unscathed," he said. "They just seem to soak it up." When he released clean mice around the reactor, they at first showed signs of DNA damage. But that disappeared with time. "It appears that life is far more resilient to high levels of radioactivity than we anticipated," he said.

The one error here is that the level is not really high at all. It is 25 percent higher than it was before the accident. The mice are no doubt experiencing a dose within the hormetic region.

I had several conversations with Bernard L. Cohen, an emeritus professor of physics at the University of Pittsburgh. Now 78, he has written books about nuclear physics and nuclear power, which he strongly supports. For years he has been trying to spread the word about the exaggerated fear of radiation. Natural radiation (except radon) averages about 80 millirem a year in the United States, he said, but in Colorado it's about double that, thanks to uranium and thorium in the Rockies, and reduced atmospheric protection from cosmic rays. In the Gulf States, on the other hand, natural radiation is a good deal lower. "Cancer rates in the Rockies are only about two-thirds of the national average," he said. By contrast, cancer rates are high in the Gulf States. The inverse relationship is striking and needs an explanation. Cohen himself does not attach significance to the figures because confounding factors could be at work. He mentioned ethnic differences or cultural factors as possibilities. Researchers like Bruce Ames at Berkeley ("Cancer Crusader," TAS, May/June 2002) might point to differences in diet, smoking or other risk factors. Maybe the people in the West have better air? No one has offered a satisfactory explanation, but hormesis is obviously a possibility.

Cohen himself has done a much more striking and detailed study, comparing the levels of radon and the incidence of lung cancer. As the linear no-threshold theory is causing the U.S. to spend tens of billions of dollars to protect against dangers which may not exist (or may in fact be benefits), Cohen thought it essential to test the theory more rigorously, and to do so in humans. And this required more subjects than could be obtained from accidental, occupational or medical exposures.

One source of radiation recommended itself, and that was radon, a radioactive gas emitted by radium. The EPA says that radon is "extremely toxic" and causes 15,000 lung cancer deaths a year in the U.S.—about 10 percent of the total. About 15 years ago the EPA recommended that levels in homes should not be above a certain level (4 picoCuries per liter). Uranium miners surely have been harmed by high radon doses, but what about the risks posed inside homes? A great experimental advantage of radon is that its natural level varies considerably—by a factor of 10—from one place to another, thereby permitting comparisons. The incidence of lung cancer in the U.S. is well reported. With his team at Pittsburgh, Cohen compiled hundreds of thousands of radon measurements to give an average level for 1,729 counties in the U.S., comprising 90 percent of the population. The data showed a clear tendency for lung cancer rates, whether corrected for smoking or not, to *decrease* with increasing radon exposure. This information was analyzed for over 500 possibly confounding factors, whether socioeconomic, geographic, environmental or ethnic association. But the conclusion stood: The linear no-threshold theory is not supported.

Cohen found that his own house in Pittsburgh had high radon—five times the level recommended by the EPA. By then he had installed radon-abatement equipment, but once he saw his own results, he switched the machine off. Before moving two years later, he lived in a (relative) radon bath. The results of his county-by-county study were published by *Health Physics* in 1995, but he has found it difficult to publicize them. He has offered a $5,000 reward (which another group will match) to anyone who could offer an explanation for his results consistent with the linear no-threshold theory. (Earlier, in the late 1970s, when Ralph Nader said that Cohen was trying to "detoxify plutonium with his pen," he offered to detoxify it with his alimentary tract. He told Nader that he would eat as much plutonium as Nader would eat caffeine. Nader never took him up on it. Later, Cohen offered to eat a certain quantity of plutonium, asking only for a certain level of publicity in return. Again, nothing came of it.)

Matt Wald of *The New York Times* told me that for everyone who claims to have studies showing a hormetic effect, there are others with studies showing the opposite: Low-level radiation is bad for you. Meanwhile, he added, linear no-threshold is *policy*. Behind the veneer of professional agnosticism, one sensed, there lay a quiet champion of that policy. As far as the *Times* is concerned, obviously, the subject has still not risen to the level of controversy. The weakness of the linear no-threshold theory is apparent, all the same, in the weak language in which it is defended. A group called the National Council on Radiation Protection and Measurement, which reflects the established wisdom, said in 1995 that

> few experimental studies, and essentially no human data, can be said to prove, or even provide direct support for the concept [of linear no-threshold] ... It is conceptually possible, but with a vanishingly small probability, that any of these [damaging health] effects could result from the passage of a single charged particle ... It is a result of this type of reason that a linear no-threshold dose response relationship cannot be excluded.

In June 2001, after six years of study, the same organization recommended that the linear no-threshold theory be retained, but conceded: "It is important to note that the rates of cancer in most populations exposed to low-level radiation have not been found to be detectably increased, and that in most cases the rates have appeared to be decreased." Those last words put the hormesis argument in a nutshell.

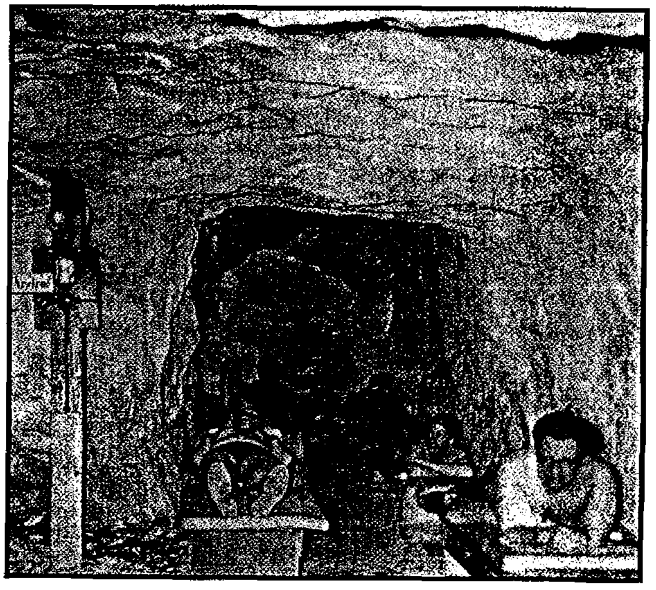
Wald asked me if those who believe in the stimulative effects of radiation are willing to expose themselves to it. A good question, and I was able to reassure him that indeed they are. As far as the advocates of hormesis are concerned, a more important question is how long will it be before low-level radiation ceases to be vilified and begins to be used therapeutically?

Even as I spoke to Wald, a group of about 90 scientists was meeting in Amherst to mull over new findings on hormesis. The subject of the conference was "Non-Linear Dose-Response Relationships in Biology, Toxicology and Medicine." Over three days, speakers from 17 countries addressed the conference in the Murray D. Lincoln Campus Center at the University of Massachusetts. One speaker discussed the interesting case of the 1,700 Taiwan apartments that were constructed with steel girders accidentally contaminated with cobalt 60, one of the more dreaded radioactive substances (some may recall the cobalt bomb fears). Over 16 years, some 10,000 occupants were exposed to levels of radiation that should have induced cancers many times in excess of background expectations. Taiwan health statistics predicted 170 cancers among an age-matched population of this size. But only five were observed. Describing this "incredible radiological incident," Y. C. Luan suggested that this might point to "effective immunity from cancer" from the very source thought most likely to give rise to it.

Ramsar, a town in northern Iran, near the Caspian Sea, was also on the conference agenda. Rocks used in local houses contain abundant radium; the 2,000 Ramsar inhabitants receive an annual absorbed dose of beta and gamma radiation about 15 times higher than that permitted for workers at many nuclear power stations. Over several generations, inhabitants also ingested considerable radium in food and inhaled lots of radon. Experimenters tested blood cells in vitro, comparing residents with matched controls from normal background areas. When these blood samples were subjected to a "challenge dose" of gamma rays, it was found that those from Ramsar had only half the number of chromosomal aberrations that had been induced in the normal contro[ls].

After the meeting, some of those who had attended made their way to the Free Enterprise Radon Health Mine in Boulder, Montana. I managed to reach a group of them by phone as they waited outside, before entering the mine to catch some (gamma) rays (and alpha particles): Jim Muckerheide of the Worcester Polytechnic Institute in Massachusetts; Klaus Becker, who was head of applied dosimetry at Oak Ridge National Laboratory, and now is retired in Germany; and Philippe DuPort, who recently founded the Center for Low Dose Research at the University of Ottawa.

Montana's radon mine is apparently the only one in the U. S. that is used as a health spa. The "therapy area," 85 feet below ground, is accessible by wheelchair. Customers pay $150 for 32 one-hour sessions, or $5 an hour. I was told that about 50 people a day go there in the summer. The radon concentration, 1,700 pico-Curies per liter, is over 400 times the EPA-recommended level. Originally a silver and lead mine, an engineer discovered radioactivity there in 1949 and he acquired a lease. Two years later, a L[os] Angeles woman visiting with her miner hu[s]band noticed that her bursitis disappeared after several visits underground. The mine's owners recommend it today for chronic pain and autoimmune disorders.



Therapeutic radium tunnel in Heilstollen.

Klaus Becker told me that the Romans loved to go to what we would now call radon spas—there was one on the island of Ischia, near Capri—long before the radioactive gas itself had been identified. In fact, many of the famous European spas correspond to radon sites. Bad Gastein in southern Saxony is one. There, customers pay $550 for 10 hours' inhalation of radon at over a thousand times the EPA-recommended level. There are 11 radon spas in Germany, three in Austria, three in the Czech Republic. Japan also has them. "The funny thing is the German government is spending $2 billion in remediation measures, while at the same time, in the same area, a new radon spa has just been officially opened, and the public health service pays for treatment," Becker said. About 75,000 people a year seek such treatment in Germany, mostly for rheumatic and asthmatic conditions. Philippe DuPort told me that in Russia they treat about a million patients a year. "But they don't send them down the mines," he said, "they have radiation sources in hospitals." In Japan, also, therapeutic radiation has begun to be used officially.

The conference at Amherst was organized by Edward J. Calabrese, who for 20 years has been a professor in the School of Public Health at the University of Massachusetts. He is perhaps the leading expert on hormesis in the country. His own emphasis tends to be on the hormetic effects of chemicals, but he stresses that the same hormetic curve is found across the board, whether with chemicals or radiation. Whatever the "end point" under study, whether longevity, reduction in disease or pain, better growth, increased fecundity, lack of mutations, reduction of birth defects or improved mental function, the curves tend to be "remarkably generic," he said. It also doesn't matter which animal, plant or bacterium is studied. Hormesis curves tend to have the same relative amplitude and width, compared to unexposed controls.

"Scientists at the meeting presented information on all kinds of biological systems, whether they were muscle cells or brain cells or tumor cells, you name it, the whole range within biological systems," he said.

> And when they are given a slight stress, they all show the same basic hormetic dose-response. The amplitude of the response and the width of the response are remarkably the same. Regardless of the laboratory and what end point they were looking at, or what animal model—from insect to man—they basically saw that relationship. That was the most significant thing.

Calabrese, 55, first became interested in the subject as an undergraduate in 1966. His professor in a plant physiology course explained that an experiment wasn't working out as predicted—a chemical thought to inhibit the growth of peppermint plants was instead stimulating them. The professor didn't know why. The plants had always been inhibited when earlier classes had done the experiment. Anyone interested in following up on it was invited to see the professor at the end of the semester. "I was the only one who did," Calabrese said. He found that the group conducting the experiment had made a dilution error, accidentally putting the plant into the low-dose zone. "When we did it the way he had wanted, we did get the expected inhibition." It was replicated many times, "and we predictably found this low-dose stimulation, high-dose inhibition. We ultimately published it in a plant physiology journal." They never called it hormesis, just low-dose stimulation. "It was an unassuming start to what has now come back to dominate my life," Calabrese said.

In 1985, when Calabrese was teaching at the University of Massachusetts, he received a flier about a conference on radiation hormesis from the Electric Power Research Institute. He didn't know what that word meant, but from the description he saw they were talking about something very much like his discovery with peppermint plants. He told the conference director, Leonard Sagan, of his experience, and was invited to attend the meeting in Oakland. Four years later, in 1989, Sagan debated low-dose stimulation with Sheldon Wolff, an expert in the field of radiation biology, and it was published in *Science*. Calabrese told Sagan that he was glad to see the subject aired in so prominent a journal, but they were rehashing old evidence. There was a lot of new material to consider. Sagan agreed.

"So I came up with the idea of bringing him and about 15 others to Massachusetts for a retreat on what to do about radiation and chemical hormesis. One of the participants, Don Hughes from Procter and Gamble, came up with the acronym BELLE—'biological effects of low level exposure.' That was in 1990, and BELLE was created that week." Since then, the Department of Energy (spurred by Senator Pete Domenici) has started a $20 million program to study the effects of low-level radiation, and (with EPA, the U.S. Air Force and other government agencies) they helped pay for the conference in June.

For a long time, Calabrese said, academic toxicologists were not much interested in low doses. The EPA's policy of "no threshold" notwithstanding, they just assumed a threshold and assumed there were no biological effects below it. Their thinking and experiments had always been dominated by high-dose considerations. All they cared about was coming up with the level below which there was no observed adverse effect. "It's like looking at the electromagnetic spectrum and just seeing the visible range and not being aware that there is anything outside it," Calabrese said. "But a lot of important things are outside the visible, and I think that many toxicologists have had blinders on. They emphasized high doses to protect workers, to make sure they killed bacteria and pests and so forth. And when they did see a little bump or curve down there, they blew it off as just random variation or chance. They didn't really take it seriously."

What caused all that to change were the regulations to clean up soil at drastically low doses because of concerns about cancer. This gave toxicologists a reason to pay attention to low doses. "Hormesis got a big shot in the arm because EPA's regulations have been so conservative, so overly protective," Calabrese said. Clean-up had become so costly that people were given a real reason to study what was happening."

Support for hormesis is now growing, Calabrese said, and in the world of environmental toxicology—which studies the effects of substances on plants, bacteria, invertebrates and fish—hormesis is not even very controversial today. It is widely recognized. In contrast, the radiation debate has been much more polarized, with a history of controversy and acrimony. The subject is "hotter," both literally and metaphorically. "I haven't seen that same controversy on the chemical side," Calabrese said. In the study of mammals, however, toxicologists still find it difficult to accept that hormesis happens. "Supporters are more in the minority. But it is a fast-growing minority. And we have made great strides." Pharmacologists never call it hormesis, incidentally; they refer to a "biphasic dose response." Calabrese adds that the evidence for chemical hormesis is about four times as strong as it is for radiation. Yet in the chemical field, too, the government (notably the EPA and the Food and Drug Administration) operates with a linear no-threshold assumption.

I asked him what the connection was, if any, between hormesis and homeopathy. And what about vaccination? Surely they were related. "Homeopathy usually operates at a much lower dose range," Calabrese said. Hormesis, on the other hand, "is very close to a toxicological threshold. The hormetic effect could involve a dose that is at least several thousandfold higher. I think that hormesis and homeopathy are different phenomena." There may indeed be an analogy to vaccination, because people are today using low doses of radiation and chemicals to stimulate the immune system, "but usually in a way that is nonspecific." The low-doses are applied as stimulation that could go after any kind of toxin.

I told him that Ted Rockwell, Rickover's man, had illustrated the idea of chemical hormesis by listing the contents of his multivitamin pills. But Calabrese is inclined to consider separately the "essential nutrients" that are contained in vitamins, even though they are toxic at some dose, and focus instead on those elements that are not known to be nutrients and probably never will be. Lead, for example, or cadmium. Or dioxin. "They still show the same basic hormetic dose-response and have what is most likely a beneficial effect in biological systems at a low enough dose. This makes it very intriguing. It is hard for people to deal with that."

"Dioxin shows a hormetic response?"

"Yes, even though some have referred to it as the most toxic chemical ever known to man. It's an unintentional byproduct of a chemical synthesis. You'll find it essentially any place you have chlorinated compounds that have been heated. You'll find it in toilet paper, just about anything that has high levels of chlorine and is dealt with at high temperature. Rodents have been shown to be better off in general after exposure to dioxin."

"What about PCBs?" I asked.

"We have PCBs showing a hormetic effect as well. It's pretty universal. This is what makes it so intriguing to people. Mercury is another—a very damaging, neurotoxic compound. We have so many examples of a hormetic dose-response with mercury. Organic mercury, inorganic mercury. You name it; it shows up. We have the data to back it up. It's really a revolution that is taking place very quietly. After a while, the opponents are just going to have to look at the data."

What Calabrese and his colleagues and supporters are looking at here is nothing less than the stuff of Nobel Prizes—discovery of a new biological law. In their interesting surveys of the historical background of hormesis as a biological hypothesis and its subsequent marginalization, Calabrese and his assistant Linda Baldwin point out that such a "law," known as the Arndt-Schultz law, was in fact formulated in the late 19th century. It was based mostly on work with yeast and bacteria. The idea that low doses of radiation were beneficial was also widely accepted in the early decades of the 20th century. In the 1920s and '30s the Mayo Clinic was using whole-body radiation to treat people with gangrene and suppurating wounds and they had great success. Amputation rates went down by 80 percent. "With the advent of antibiotics in the late '30s and early '40s, they dumped it," Calabrese said. But now there are problems with resistance to antibiotics, and "so here you had a tool that could be useful as an adjunct, an inexpensive tool, that has been basically thrown away. Physicians who treat people today don't know the history of its use."

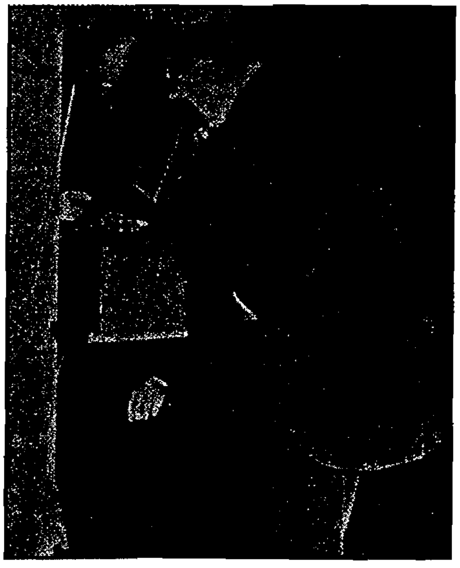
Hormesis lost ground because by the 1930s X-rays were understood to cause mutations, and radiation was known to cause cancer, with a possible delay of decades between cause and effect. Influential scientists increasingly opposed the theory of hormesis, sometimes with data that was not accurate. In particular, the low-dose range was rarely studied properly. Mostly, researchers found deaths at high doses and were content to extrapolate in a straight line back to zero.

So it looks as though Calabrese and others who have been working on hormesis for the last 20 years have been unearthing something that had already been guessed at, rather than coming up with something completely new. He agreed, and added they are making the earlier formulation "a lot stronger." The earlier researchers had "unique insights," he said. And sometimes they had other agendas. "They thought that you could use this concept to sell fertilizers or to try to use radium as an elixir, and they didn't understand just what they were getting into." They also didn't always understand what they had to do to meet the demands of proof.

"So we have also had to re-establish it with statistical power and significance," Calabrese said.

> All they really had were experiments with plants and microbes. And we now really have the whole broad spectrum of every in vitro system, every organ system and all these other models. What has really happened is that they had the intuitive insight and some data. We have been able to answer most of the challenges and questions that people had, as well as to strengthen it profoundly.

I noted earlier that the linear no-threshold theory put its opponents into a difficult and defensive position. They must take the economist's side in a cost-benefit debate, reduced to saying that saving a few lives isn't worth spending a billion dollars. That is a debate that cannot be won. But if the supporters of hormesis get a fair hearing, the cost-benefit argument can be turned on its head. For if low doses confer medical benefits, the hormesis proponents will be able to argue that *they* are the ones who are trying to save lives, while the bureaucrats and other beneficiaries of the present system are merely trying to preserve their jobs and cash payments. While hormesis may not be proven, the linear no-threshold theory certainly has been shot full of holes. It is time for the hormesis debate to begin.



Edison with his fluoroscope.