

HUMAN RADIATION STUDIES: REMEMBERING THE EARLY YEARS

*Oral History of Radiation Biologist
Marvin Goldman, Ph.D.*



Conducted December 22, 1994

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MASTER

FOREWORD

IN DECEMBER 1993, U.S. Secretary of Energy Hazel R. O'Leary announced her Openness Initiative. As part of this initiative, the Department of Energy undertook an effort to identify and catalog historical documents on radiation experiments that had used human subjects. The Office of Human Radiation Experiments coordinated the Department's search for records about these experiments. An enormous volume of historical records has been located. Many of these records were disorganized; often poorly cataloged, if at all; and scattered across the country in holding areas, archives, and records centers.

The Department has produced a roadmap to the large universe of pertinent information: *Human Radiation Experiments: The Department of Energy Roadmap to the Story and the Records* (DOE/EH-0445, February 1995). The collected documents are also accessible through the Internet World Wide Web under <http://www.ohre.doe.gov>. The passage of time, the state of existing records, and the fact that some decisionmaking processes were never documented in written form, caused the Department to consider other means to supplement the documentary record.

In September 1994, the Office of Human Radiation Experiments, in collaboration with Lawrence Berkeley Laboratory, began an oral history project to fulfill this goal. The project involved interviewing researchers and others with firsthand knowledge of either the human radiation experimentation that occurred during the Cold War or the institutional context in which such experimentation took place. The purpose of this project was to enrich the documentary record, provide missing information, and allow the researchers an opportunity to provide their perspective.

Thirty audiotaped interviews were conducted from September 1994 through January 1995. Interviewees were permitted to review the transcripts of their oral histories. Their comments were incorporated into the final version of the transcript if those comments supplemented, clarified, or corrected the contents of the interviews.

The Department of Energy is grateful to the scientists and researchers who agreed to participate in this project, many of whom were pioneers in the development of nuclear medicine. □

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DISCLAIMER

The opinions expressed by the interviewee are his own and do not necessarily reflect those of the U.S. Department of Energy. The Department neither endorses nor disagrees with such views. Moreover, the Department of Energy makes no representations as to the accuracy or completeness of the information provided by the interviewee.

ORAL HISTORY OF RADIATION BIOLOGIST MARVIN GOLDMAN, Ph.D.

Conducted December 22, 1994, at the Lawrence Berkeley Laboratory in Berkeley, California by Loretta Hefner, archivist for the Lawrence Berkeley Laboratory, and Karoline Gourley, an attorney and researcher for the Office of Human Radiation Experiments, U.S. Department of Energy (DOE).

Marvin Goldman was selected for the oral history project because of his work at the Lawrence Berkeley Laboratory on an Atomic Energy Commission project and his work on bone-seeking radionuclides. The oral history covers Dr. Goldman's research while a graduate student at the University of Rochester, his work at University of California at Davis administering strontium-90 in beagles, and his general observations about radiation safety concerns in places he has visited, including Chernobyl and Chelyabinsk, Russia.

Short Biography

Marvin Goldman was [REDACTED]. He received his B.A. in Biology from Adelphi University in 1949, his M.S. in Zoology-Physiology from the University of Maryland, and his Ph.D. in Radiation Biology from the University of Rochester in 1957. In 1951, Goldman began his career working at the Nevada Test Site on the Buster-Jangle Series to determine the inhalation pathway in animals of hazards from fallout of nuclear weapons tests. That same year, he detected the first "hot particle" of plutonium in lung tissue. Subsequent to his work at the Nevada Test Site, he completed his Ph.D. at the University of Rochester, where he studied under Dr. Newell Stannard.

In 1958 Goldman began working for the University of California, Davis (UC Davis), where he embarked upon the long-term project of determining the effects of low-level, chronic exposure to strontium-90 (one of the main by-products of nuclear fallout) in beagles. In 1966 Dr. Goldman became the Associate Director for Science at UC Davis, and in 1973 he became the Director of the Davis Radiobiology Laboratory. Currently Dr. Goldman is at UC Davis, where he is a professor of Radiobiology in both the Department of Radiology, School of Medicine and the Department of Radiological Sciences, School of Veterinary Medicine.

During his career, Dr. Goldman has been the recipient of a number of awards:

- Patent: x-ray Fluorometric Matrix Correction, 1968
- The E.O. Lawrence Memorial Award, presented by the Atomic Energy Commission in 1972
- Citation from ERDA for contributions to the Voyager Space Program, 1977
- Distinguished Scientific Achievement Award, Health Physics Society, 1988

He has served on two committees of the National Academy of Sciences (NAS) to assess the risk from radioactive materials: the Ad Hoc Committee on Hot Particles and the "BEIR IV" Committee (also known as the National Research Council Committee on the Biological Effects of Ionizing Radiation).

Dr. Goldman has published many times on the effects of radiation on biology systems, including long-term effects of strontium-90 and radium-226; hot particles; the effects of fossil-fuel effluents; biomedical models for risk assessment; toxicity of organophosphate agents; whole-body counting and gamma ray spectrometry; thermoluminescent dosimetry; and radiation effects on cells.

Educational Background; Early Involvement in Radiation Research

GOURLEY: Hello, it's December 22, 1994. Lori Hefner and Karoline Gourley are here speaking with Dr. Marvin Goldman for the purposes of preparing an oral history. Welcome.

GOLDMAN: Welcome, good morning. Your letter to me said you wanted to focus on my work at the [Davis] Radiobiology Laboratory when it was an AEC¹ project, and my own work on bone-seeking radionuclides² and other information. You must have a format you like to follow, so I'll let you lead off.

HEFNER: How did you become interested in science? What is your background and education?

GOLDMAN: I was raised in Brooklyn, New York, and went to public schools there. I went to a very fine high school, Erasmus Hall High School, which was founded by the Dutch in the 1600s. It was probably the biggest high school in America; I think it had 8,000 students when I was there. As a consequence, each year [there were] about 2,000 classmates, [and there was] an honors system, and I got into some of the honors programs and got turned on in science. New York State at that time had (I guess today still has) a Regent's system where there is an established statewide curriculum, which everyone in the state must follow. This high school completed the [required Regent's] curriculum in the first month of the term, and then we went on to do other things.

So when I got to college, I kind of slept through the first year or two, since I'd had the material all before, only with better teachers. It was the end of the Depression, and [many of] the high school teachers had Ph.D.s. It was a totally different era than what we have today. I only now realize now what a fortunate happenstance that was, because public schools cover a wide range and this wasn't a special science school or anything. It just had very high-quality, very competitive student body.

Then I went on to Adelphi College (as it was known at the time). It's now Adelphi University in Garden City, New York.

My family had [little] money. I was the first to go to college. I was studying pre-med at the time. I was a youngster who was now competing with the entire demobilization of the American [Armed Forces at] the end of the Second [World] War, so there were a lot of guys ahead of me in line

¹ the U.S. Atomic Energy Commission, predecessor agency to the U.S. Department of Energy and Nuclear Regulatory Commission (NRC); established January 1, 1947

² atomic species in which the atoms all have the same atomic number but different mass numbers according to the number of neutrons in the nucleus

to get into med school and schools hadn't built up yet. It was still pre-war establishment. I didn't get in, [but] I [did get] into graduate school at the University of Maryland. I [received] a fellowship there and I was doing Aviation Physiology. I was going to be an expert on breathing and respiration, and learn about hyperbaric [(high-pressure)] and hypobaric [(low-pressure)] [atmospheres] and submarines and airplanes. There was a lot of money from the Office of Naval Research for this sort of work. One day a guy asks me, "You're finishing up your Master's; now what are you going to do?" I said, "I don't know, maybe take a year off and decide where I'm going." I was being romanced by the Office of Naval Research to go to Groton, Connecticut, where there is a big submarine school and research program, and I could see myself maybe going in that direction.

They said, "Why don't you go over to the NIH [(National Institutes of Health in Bethesda, Maryland)]?" I was at College Park, Maryland, and it was little bus ride over.

This was 1951, and I went into the NIH and they said, "We'd like someone who knows about breathing to come and do a project with us for a year." I said, "What's it about?" They said, "We're not going to tell you what it's about but it will be very interesting."

The next thing I knew I was on a train on my way to Las Vegas, Nevada, and I went out to the Las Vegas test site.³ Sure enough, they wanted someone who knew about breathing because they were about to [test] the [atomic] bombs in the series called Buster-Jangle,⁴ and this was the first set of tests in America to study the effects of radiation on animals as a prelude to trying to figure out what would happen if there was, God forbid, a nuclear war. The earliest tests had to do with, "Does the bomb work?" and so forth.

So I was involved in tethering animals in [radial arcs] around ground zero.⁵ The bomb would go off and then I'd hurry in there, suited up like a Martian, to rescue the animals and bring them back to be studied. It wasn't an idea of killing them [with radiation]; rather it was to find out what happened. The doses were poorly known. They hadn't invented the

³ Nevada Test Site, the location where most nuclear weapon tests within the continental United States were conducted

⁴ Operation Buster-Jangle was a series of seven nuclear weapons tests conducted at the Nevada Test Site, in which nuclear explosives were detonated between October 22, 1951 and November 29, 1951. Ranging in yield from 1.2 kilotons to 31 kilotons, the tests included four airdrops and a tower, surface, and crater shot. The last three types of tests generated large quantities of fallout because the explosion sucked up rock, soil, and debris from the crater it created and from the surrounding surface area. During Buster-Jangle, the first three of eight Desert Rock troop exercises were conducted by the Department of Defense to explore nuclear battlefield conditions and tactics. Source: Robert S. Norris, Thomas B. Cochran, and William M. Arkin; *NWD 86-2 Known U.S. Nuclear Tests, July 1945 to 31 December 1985*; February 1986; Washington, D.C.; Natural Resources Defense Council, p. 13.

⁵ the point on the earth directly below or at which an atomic or hydrogen bomb explodes

word "rad"⁶ yet. It was called "REP," the Roentgen equivalent physical.⁷ It was a precursor [between] Roentgen⁸ to rad.

I learned how to do a [procedure] called autoradiography,⁹ which is to take radioactive tissue and lie it on a [photographic emulsion] which is layered on a microscope slide. As tissue radioactivity decays, it exposes the film underneath, and by developing this, you can see the tissue on top and then focus on radioactivity underneath and see where it was. This technique had not yet been [well]-established.

It was heady time because you'd go in the lab every Monday and [could] publish a paper every Friday if they'd let you declassify it.

There was no textbook. Nothing was known. Everything was by the seat of your pants; good fundamental science, but there really wasn't any textbook.

So I did these autoradiographs and discovered something which we now call "hot particles."¹⁰ I found [a] plutonium hot particle in the lung of an animal, and that was the first autoradiograph of a hot particle.

[There's] been a big brouhaha ever since about them and what their efficiency, effectiveness, carcinogenicity¹¹ is.

I went in to see my boss at the NIH. I was working in Building 2 of the NIH campus and worked for a [scientist] named Dr. Neil in the Laboratory for Physical Biology of the National Institute for Arthritic and Metabolic Diseases. That's where they put it. The [scientist] in charge of this project was named Howard Andrews. Howard Andrews was a pioneer in radiation biology. He and Ralph Lapp had written the textbook that was available at the time.

GOURLEY: So you worked with Howard Andrews?

GOLDMAN: For him. I was one of his [team] running around in a white coat doing the work. And Howard Andrews was in charge of this overall program, and under him was a public health officer, who was really a physiologist,¹² and his name was Falconer Smith. Falconer Smith hired me on. Dennis Boddy, myself, and Falconer were the team.

⁶ a measure of the absorbed dose to tissue from exposure to radiation

⁷ REP (Roentgen Equivalent Physical) was a measure of absorbed dose to tissue after exposure to an external source of x- or gamma rays; it is now called the "rad."

⁸ a unit of radiation dosage equal to the amount of ionizing radiation required to produce one electrostatic unit of charge of either sign per cubic centimeter of air; named for Wilhelm Konrad Roentgen, 1845-1923, German physicist, who discovered x rays in 1895 and received the Nobel Prize in Physics. The Roentgen was a measure of the ionization of air by radiation, *not* a unit of absorbed dose to tissue.

⁹ a technique whereby photographic film is placed over thinly sliced tissue to record, in image form, the radiation tracks from the tissue that pass through the film's emulsion

¹⁰ multiatom particulates of radioactive material that emit many alpha or beta particles

¹¹ tendency to produce cancer

¹² a biologist who studies the functions and activities of living organisms and their parts

I still remember vividly Project 2.7 of the Buster-Jangle series. We had our own little corner out in the desert to do our thing. We were going to find out about the metabolism of radionuclides from fallout data, data which didn't [yet] exist; there were no data. The early [information was], they knew about gamma rays¹³ and neutron¹⁴ doses and thermal yields,¹⁵ but this ["radiopharmacy"] was the second level of importance. We found the decay [(biological clearance)] of the material as it was excreted from the animals; and then, at periodic intervals, we'd sacrifice the animals and autopsy them and see what the distribution [in tissues] was. There was no whole-body counter¹⁶ or anything like that, yet. And so, by radiochemical analysis you can reconstruct what the animals had [absorbed], and that's what we did.

They [(radiation researchers)] would collaborate on ground and air sampling. (A lot of this is written up in our reports.) That got me into it. I said, "You know, this is a heck of a lot better than sitting in a centrifuge,¹⁷ or in a hypobaric chamber,¹⁸ pre-simulating high-altitude and undersea environments. How do I get more training in this?" I liked the idea that every time I asked a question, they said "Go into the lab and get the answer, because it isn't in writing yet."

The fellow who taught me autoradiography was a [scientist] named [Herman] Yagoda, who was famous for cosmic-ray¹⁹ physics. He would send balloons up very high—miles up—with packages of [black and white print] film to record cosmic rays and [determine whether they came] down. He developed this special film and got the [cosmic-ray] tracks [recorded on the film]. That's where it [(the work in radiography)] was—there was no application in biology—so he taught me how to make [film] developer. I mean, I had to go back, like George Eastman [of Eastman-Kodak film fame], and mix the different chemicals to this, because you couldn't buy it [(the developer)] off-the-[shelf]. The film had to be very clean: you didn't want background radiation [to have already partially exposed it].

I [made] an arrangement where I would get Ilford film flown in twice a week in a diplomatic pouch from London (this was a British film company), because Kodak didn't make thick emulsions that would allow you

¹³ a highly penetrating photon of high frequency, usually 10^{19} Hz or more, emitted by an atomic nucleus

¹⁴ elementary particles found in the nucleus of most atoms and having no electrical charge

¹⁵ the fraction of atoms absorbing a thermalized neutron and changing into a heavier isotope of the same element per unit neutron flux

¹⁶ an apparatus that measures radionuclides in man, using shielded detectors and multichannel energy analyzers. The sensitivity and non-invasive nature of this instrument permitted studies at levels 10 to 100 times below established limits of exposure. It opened an entire area of clinical diagnosis and the development of new diagnostic methods.

¹⁷ an apparatus that rotates at high speed and separates substances of different densities

¹⁸ a chamber that simulates the low-atmospheric pressure experienced in aircraft at high altitudes

¹⁹ radiation of high penetrating power originating in outer space and consisting partly of high-energy atomic nuclei

to [do] this [kind of highly sensitive particle track recording]. It was very fascinating [as] we got it all together.

Falconer Smith said he had a good friend named [J.] Newell Stannard²⁰ who was setting up a program [at the University of] Rochester, [in Rochester,] New York, and if I was interested, he was sure he could make an appropriate phone call and something could happen.

So, Marvin Goldman finds himself making this phone call on Friday, and on Monday, I'm in Rochester, New York with a fellowship and a scholarship and I am one of the first "guinea pigs" in the radiological fellowship program of the AEC. I was the third person from Rochester to get a Ph.D. in Radiation Biology. The first was Bill Bair;²¹ he was Newell Stannard's student. The second was Robert Thomas,²² who I'm sure you have spoken to; and I [believe I] was the third. They debugged the system on those two and it was easier [for me]. I worked at Rochester from 1952 until 1957.

I got my Ph.D. in Radiation Biology and Biophysics [at the University of Rochester] and I worked in [the] Laboratory of Radiation Toxicology, working on radionuclides. It was a very interesting experience. (Of course, you never know these things at the time.) We had a fantastic faculty, and the AEC was paying for this, and it was one of the three centers for advanced training. I [had gone] through the standard health physics fellowship program of one year with a summer at Brookhaven [National] Laboratory [in Upton, New York]²³ and they asked me to come back [to Rochester] and enroll for an advanced degree, rather than [stop at the level of] a health physicist, [a master's-level program]; it seemed like a good thing to do. Things were heating up on the Cold War front, to make a terrible pun, and so it looked like an area that was going to be well-funded. We were starting to talk about civilian nuclear energy and this whole business about biophysical research was fascinating to me.

I've had a good background at Adelphi in Biology and a good background in Physical Sciences and Physiology at Maryland, and they filled in my lack in Physics at Rochester. It was a heady time. I built one the first heart-lung machines²⁴ and studied the effects of radiation and hor-

²⁰ a professor of radiation biology and biophysics at the University of Rochester, Rochester, New York

²¹ For the transcript of the October 14, 1994 interview with Bair, see DOE/EH-0463, *Human Radiation Studies: Remembering the Early Years; Oral History of Health Physicist William J. Bair, Ph.D.* (June 1995).

²² After receiving his Ph.D., Thomas went to Albuquerque, where with Tom Mercer, he initiated the inhalation toxicology program at the Lovelace Foundation and Clinic. He subsequently went to Los Alamos and DOE.

²³ Brookhaven, located on Long Island, is managed and operated by a consortium of universities known as Associated Universities, Inc., under contract with DOE. The Lab conducts basic and applied research in the physical, biomedical, and environmental sciences, as well as selected energy technologies.

²⁴ a pumping device through which diverted blood is oxygenated and returned to the body during heart surgery, temporarily functioning for the heart and lungs

mones on lymphocytes²⁵ [from the] spleen,²⁶ which I took out of dogs. I learned to be a dog surgeon. I built this heart-lung machine, which didn't exist either, and they now use them all over the world, but this was all made by hand. I built pumps and a lung with a coil of plastic tubing and then took blood from the dog and cross-matched it, put the spleen in so that other organ influences wouldn't be [present]. [The question was] whether lymphocytes, which are sensitive to radiation [and] which [appears in the bloodstream] after a dose of radiation, are being formed in response to radiation, or are they just being released because they're stored [in tissues].

This is where we were in 1951, so that was my [dissertation]. Cortisone²⁷ had just been invented and it, too, had a lymphocytic effect: it kills lymphocytes. So I found out about the combined effects of radiation and chemicals. There's a whole lot of interest today in people downwind from various atomic sites, as to whether there's a synergistic²⁸ effect in being exposed to small doses of radiation and small doses of chemicals and whether the consequences are larger than the sum of the two. Of course, I didn't know that [at the time], but I did know that I got my thesis done and approved.

Newell Stannard was my senior advisor. I worked for a man named Larry Tuttle. Larry Tuttle was a biochemist who came from the University of California at Berkeley.²⁹ [I also] had a lot of guidance from the other professors. It was a very collegial atmosphere. We were all their academic children. Every professor helped everyone else. This wasn't an era where competition for grants made more enemies than friends. People worked together. If you had a problem you walked down [the hall] and talked to someone in this lab or that lab, and the three of you got together and invented a whole new technique. You didn't have to fill out any 189s³⁰ or 5120s and all these other [DOE] worksheets.

This was a good experience for me. Tuttle was interested in radioactivity. He had done some work on plants with [phosphorus]-32 and I was getting interested in radioactivity. I learned a lot about it the hard way at the Nevada Test Site and I was learning more in a more orderly way. I was very interested in the long-term effects of radiation—these are called stochastic [(random)] health effects and not deterministic. These are not effects where increasing doses show you increasing damage,

²⁵ a type of white blood cell important in the production of antibodies

²⁶ an organ, located at the cardiac end of the stomach, that helps form mature lymphocytes, destroys worn-out red blood cells, and serves as a reservoir for blood

²⁷ a steroid used chiefly in the treatment of autoimmune and inflammatory diseases and certain cancers

²⁸ being greater than the sum of the parts

²⁹ site of groundbreaking early research in nuclear science and location of Lawrence Berkeley Laboratory

³⁰ Form 189 (Research Proposal), a funding document used by the National Laboratories for preparation of short-form scientific proposals to the Atomic Energy Commission, and later the Energy Research and Development Administration, the Nuclear Regulatory Commission, and the Department of Energy

which is how radiation was described in those days [according to the “linearity model”].³¹

And I have to tell you—because I think it’s important for what you’re doing—that I probably had some of the most premier educators in the world teaching me. They were all [at the] cutting edge. I can still remember sitting in the classroom listening to people talking about the reparable and irreparable injuries from radiation. Everything was taught in toxicologic³² terms. You received a dose of radiation and then you recovered from it and what [“injury”] was left over was unrecovered: it was measured in terms of life shortening. There was never any mention that this was a risk for cancer. It was all in terms of organ injury and organ repair and response. As a result, there was this impression of a threshold and that small doses of radiation, if they had no clinical manifestation, really were innocuous. Therefore, you had respect for it[s hazards], but it wasn’t a problem.

This was before we started taking about linearity and that all risk was proportion[al to] dose. It’s rather interesting that today we seem to be moving back a little that way, because there is no scientific support for linearity, although it [may be] good prudent philosophy [in regard] to regulation to assume that every dose has a proportional risk. But the biology [today] seems to show that, [with] very small doses, there is no evidence that there is any risk.³³ What is not repaired is apparently not passed on to future cell generations, which [might] then rise up and become a tumor 25 years later. That debate will go on for some time, until molecular biology³⁴ peels out some of the answers to the sequence of steps between initiating events and conclusions.

It’s probable that the risk follows not a straight line, but an S-shape curve, and [at] the low dose is a [concave] slope that is so shallow [that] it is close to no [really positive] slope, and therefore looks like a threshold. After certain dosage, if [the dose gets] even higher it’s sort of “overkill”: the molecular lesions have already been done, and adding more damage doesn’t do any more [to increase the] risk, so it looks like

³¹ According to the “linear hypothesis,” all ionizing radiation is harmful; the harm rises in direct proportion to the dose. Over time, some radiologists and health physicists came to find this assumption simplistic and proposed more complex models, most of them based on a linear quadratic equation.

³² relating to the branch of pharmacology dealing with the effects, antidotes, detection, etc. of poisons

³³ John Gofman, a physician and biophysicist, held that there is no safe level of radiation exposure. His public views and outspoken style brought him into frequent conflict with the AEC. For Gofman’s account of these conflicts, see “The Controversy Over Nuclear-Armed Antiballistic Missiles (1969)” in DOE/EH-0457, *Human Radiation Studies: Remembering the Early Years; Oral History of Dr. John W. Gofman, M.D.* (June 1995). For Gofman’s views on “no safe level,” see “Concern Over Low-Dosage Harm; Public Acceptance of Nuclear Energy” and “The Controversy Over Low-Dosage Harm” in the Gofman transcript. For a conflicting view, see “Livermore Biomedical Division; Conflicts With John Gofman (1962–72)” in the John Totter transcript (DOE/EH-0481, September 1995) and “Controversy Over Interpretation of Radiation Effects Data” in the Bair transcript (DOE/EH-0463, June 1995).

³⁴ the branch of biology that deals with the nature of biological phenomena at the molecular level through the study of DNA and RNA, proteins, and other macromolecules involved in genetic information and cell function; also called *new biology*

[the radiation is] less efficient per dose at high levels. [At that point, the now-convex risk curve levels off.]

This follows almost every other toxicologic database, and there is no reason why radiation has to be uniquely different. Our tools, one of which is called epidemiology,³⁵ are too crude to ever, by sheer mass of numbers, find these things out. So we are going to have to find out the molecular story through the Human Genome Project³⁶ or something like that. Adding another 10,000 people to an epidemiological study [does not improve] a thing we call the signal-to-noise ratio—just kills you. You have to go up a factor of ten in [your sample] number for every factor-of-two [increase in] precision [in] standard statistics.³⁷

Brookhaven Acquaintances and Early Hospital Research (Circa 1952)

GOURLEY: You had mentioned that while you were at Rochester you spent a summer at Brookhaven [National Laboratory]—

GOLDMAN: The program there was a year of formal class training [at Rochester] and a summer of field training in Health Physics, which was held at the Brookhaven Laboratory. We'd run around the [nuclear] reactor³⁸ and the cyclotron³⁹—it was the "Cosmotron" in those days—and learn how to do field measurements, and that is what the summer fellowship was. It was a 12-month fellowship: 9 months in Rochester and 3 months in Brookhaven.

The buildings are still there and still not air-conditioned. These were delightfully historic barracks, which were residue of World War I. Brookhaven was Camp Upton in the First [World] War, and that's how it started. I remember: that was the summer I was engaged to get married, so I remember it clearly. In any event, that was the Brookhaven work. I didn't do any work with [any of] the human studies that were going on at Brookhaven.

GOURLEY: Did you know any of the people involved?

³⁵ the branch of medicine dealing with the statistics of incidence and prevalence of disease in large populations and with detection of the source and cause of epidemics; *also*: the factors contributing to the presence of absence of a disease

³⁶ a broad-scale program sponsored by the National Institutes of Health and the Department of Energy to map the location of every gene of all 47 human chromosomes

³⁷ If a conclusion drawn from an epidemiological survey of 10,000 subjects is accurate to within ± 2 percent, doubling the conclusion's accuracy to ± 1 percent would require a survey of 100,000 subjects.

³⁸ an apparatus in which a nuclear-fission chain reaction is sustained and controlled

³⁹ an accelerator in which particles move in spiral paths in a constant magnetic field

GOLDMAN: Yes. I know Victor Bond,⁴⁰ Robert Conard;⁴¹ Eugene Cronkite⁴² and Fred Cowan were the head health physicists there. I still have dealings with [Bond].

There were other things going on. I was strictly one of the kids learning health physics, and so we went around and did class exercises, such as calibrate instruments and go out and do a field trip. My triumph of the summer was discovering that the "sky shine" from the cyclotron, went up and hit the ceiling and it bounced down right into the lap of the operator, and [pointing out] that they should move the [concrete] blocks around so that it shielded him [better]. That was really interesting. As I got closer to the operator, the dose went up. I was closest to the shielding but it was bouncing off the back shielding, so we learn about a thing which we now call "sky shine," which was interesting.

GOURLEY: What happened to the operator?

GOLDMAN: It is in the records there. I don't remember.

Now, I should tell you that when I finished the project at NIH, and before I went up to Rochester, I went up for an interview, but the school year started in September; I had the summer free. I'd finished my NIH [work in] April [1952]. I went back up to New York. I got a job with the City Department of Hospitals, and I was now a walking expert on Geiger counters⁴³ and radiation, because I knew how to turn a Geiger [counter] on.

I was trained briefly at the Francis Delefield Hospital in New York under a fellow named Carl Braestrup. He's a [famous] pioneer in this business. And I was then sent out to Bellevue Hospital and to Kings County Hospital, which at the time, I was told it was the largest hospital in the world. Everything was big in Brooklyn [at Franklin Delefield Hospital]. It had 4,000 beds.

I was assigned to the isotope unit. We were diagnosing people with thyroid⁴⁴ problems, using radioiodine.⁴⁵ In those days we used to call it

⁴⁰ Victor P. Bond, M.D. (1919–), was a radiation biophysicist with the Naval Radiological Defense Laboratory (1948–55) and Brookhaven National Laboratory (starting 1955). He conducted research on the biological effects of radiation. At Brookhaven, he conducted pioneering research in bone marrow transplants and served as an Associate Laboratory Director.

⁴¹ Robert A. Conard, M.D. (born 1913), was a medical scientist with the U.S. Navy and the Naval Radiological Defense Laboratory (1941–56) and Brookhaven National Laboratory (1956–79). He conducted environmental health studies among the Marshallese exposed to radioactive fallout.

⁴² Eugene P. Cronkite, M.D. (born 1914), was a physician and hematologist at the Naval Medical Research Institute (1946–54) and Brookhaven National Laboratory (1954–79). He conducted research on control of hemopoiesis in health and disease conditions.

⁴³ portable instruments for detecting ionizing radiation and measuring dose rate

⁴⁴ an endocrine gland located at the base of the neck and secreting two hormones that regulate the rates of metabolism, growth, and development

⁴⁵ Radioiodine (¹³¹I) is widely used to diagnose thyroid function and also is a highly effective therapy for hyperthyroidism, Graves' disease, and thyroid cancer.

an "atomic cocktail." I can remember, it was 50 microcuries⁴⁶ in a little square bottle, and we'd give it to [patients] in a paper cup and they'd drink it; and 24 hours later they'd come back [to be counted⁴⁷].

I had a rig where I set up this very crude [radiation counting system]. I'd put a test [radioiodine] dose in and calibrate it; that's [the] 100 percent [standard]. Then I'd put the detector the same distance from the [patient's] thyroid gland and count that and get the relative uptake⁴⁸ [(the percentage of ingested iodine that had found its way to the thyroid)]. Fifty microcuries is a [large] dose of radioiodine. But that's what you [needed] when you had crude [(insensitive)] counters. We'd count for, I think it was five minutes, or two minutes, or one minute; I don't remember.

I worked for a doctor named Aza Friedman; he was Chief Endocrinologist.⁴⁹ We [did a variety] of things with radioisotopes. Well, one time we got in a load of gold-198, which is a very, very energetic beta emitter.⁵⁰ I remember helping to use an air tank to move the syringe. We had to build a [remote] rig, because you couldn't hold the syringe; it would burn your fingers. We injected this into a woman who was dying of cancer. She was so [distended] with the ascites⁵¹ cells that we were going to [inject] this into her peritoneal fluid⁵² and slosh it around and kill the cells and maybe give her a little relief. That was a big-dose experiment. [(It didn't work.)] I don't remember how many millicuries;⁵³ it was a lot of radiation.

Another thing was that [patients] suffering from congestive heart failure, who were really almost terminal, were thought could possibly be helped by reducing their metabolic rate, putting less strain on their feeble heart. They certainly were not [strong enough to be] candidates for surgery, so we were going to do "radiation surgery": we were going to burn out the thyroid gland with radioiodine in large doses. I can remember giving a few *millicuries*—not microcuries—millicurie doses to some of these patients who were very, very ill. I would frequently [return] the next morning, when the patient wasn't in [his] bed. I [would] have to go find [him] in the morgue and put a red [radiation-hazard] tag on [him] because he was so radioactive. There were no [radiation] precautions like we [have] today. I'd have to track them down. I'd go into the morgue with my Geiger counter. We [didn't] know where he [was]. I'd find

⁴⁶ a millionth of a curie; a curie is a unit of measure expressing activity of radioactive substances. A curie denotes 37 billion radioactive decays per second.

⁴⁷ to have the rate of radiation emissions counted from radionuclides inside one's body, using a Geiger counter

⁴⁸ an excess assimilation of radioiodine in the thyroid, indicating abnormality

⁴⁹ a medical professional who studies endocrine glands and their secretions, especially in relation to their processes or functions

⁵⁰ a radioactive substance that emits electrons or positrons during radioactive decay

⁵¹ accumulation of serous fluid in the peritoneal cavity as the result of ovarian cancer or other cancers

⁵² the fluid bathing the intestines and other organs of the peritoneal cavity

⁵³ a thousandth of a curie; one thousand microcuries. A curie represents 37 billion radioactive decays per second.

him—*(makes a noise like an active Geiger counter)*—"Yeah, that's him: he's in that drawer!" But this is 8-day iodine⁵⁴; it's not long-lived.

GOURLEY: This is ¹³¹I.

GOLDMAN: Yes. But it's an energetic beta emitter. It emits a 350-kilovolt⁵⁵ gamma ray, so it's easy to detect.

Another [patient] was a criminally insane dentist who was dying of thyroid metastasis⁵⁶ to his brain, which [may have] made him crazy, and he had committed some crimes. I had to go in with some armed police to scan this guy. I was sitting there, carefully going over his head with a Geiger counter, recording at each position where the radioiodine had gone, so we'd see where the tumor [had grown]. No one had invented a scanner yet.⁵⁷

We were hoping to kill thyroid metastases with radioiodine. You can't go in and surgically remove these. What we didn't know at the time was the metastatic thyroid tissue doesn't [always] metabolize [or absorb] iodine as well as normal [or "functional" thyroid tissue]. So the uptake was poor, but these were things we had to do. These [were] large doses of radiation given to patients. [I don't] know whether there was an informed-consent form. Who knows whether anyone wrote anything [about patient consent]? Who knows?

GOURLEY: This was what—1951?

GOLDMAN: Summer of 195[2]. Maybe Rosslyn Yalow⁵⁸ has some information on that, but—

HEFNER: Could [you] comment also, given that this gentleman was a prisoner—right? This dentist, at this point.

GOLDMAN: He was in the hospital. He was medically terminal; [that] was his [main] problem, and I think he was at Bellevue or Francis Delefield Hospital; I don't remember which. But they asked me to come up and do this. I think he had committed a crime, and when they examined him, they found out he had cancer, and it had gone to his brain. I don't remember any details. My impression was that they thought that's why he had committed the crime, because his brain had [been affected by the cancer]. He wasn't a prisoner on whom they were doing studies, like [in] Oregon⁵⁹ and Washington.⁶⁰ This [patient] was dying; he wasn't sick.

⁵⁴ iodine having an 8-day half-life

⁵⁵ (keV) one thousand electron-volts

⁵⁶ the spread of disease-producing organisms or of malignant or cancerous cells to other parts of the body by way of the blood or lymphatic vessels or membranous surfaces; or, the condition so produced

⁵⁷ an imaging apparatus such as a CAT scanner, PET scanner, or MRI unit

⁵⁸ Roslyn Sussman Yalow (1921–), U.S. medical physicist; received 1977 Nobel Prize for discovery of the technique of in vitro radioimmunoassay

⁵⁹ From August 1963 to May 1971, the Pacific Northwest Research Foundation in Seattle, Washington, used inmates at the Oregon State Prison in Salem to determine the effects of ionizing radiation on sperm production (continued...)

Vulnerable Populations and Acceptable Risks

HEFNER: It leads me to ask you the question: There has been such a controversy about vulnerable populations—for example, minority groups, children, prisoners, state mental hospitals, [the] mental[ly] retarded, etc. Would you comment on that?

GOLDMAN: I not only commented on it, I wrote an article in the *Health Physics Newsletter*. I'm President of the Society this year. I have to write an article every month. And, I think two or three months ago I wrote one and I gave it to Mark Goodman⁶¹ or one of [the staff] in your office in Washington.

GOURLEY: That would be the Advisory Committee [on Human Radiation Experiments].

GOLDMAN: Yes.

I said basically that in those days, the feeling was that [there] really were safe doses of radiation. The studies that we were talking about, at least with the Fernald School,⁶² were not radiation experiments. Very clearly, they were not radiation experiments. They were called "tracer studies." There is a distinct difference. It's not just semantics, it's a whole mindset. In a tracer study you're just tracing an element, whether it's calcium to see how it goes [to bone] and how it's absorbed [from] different foods in children or anything else. It was not to see the effects of radiation, and it was at the lowest level consistent with the sensitivity of

⁵⁹ (...continued)

and to determine minimum dose levels for initial effect and permanent damage. Sixty-seven healthy volunteers ranging in age from 24 to 52 years were irradiated by x rays one or more times. For details and a list of references, see OT-21, "Testicular Irradiation of Oregon State Prison Inmates," in *Human Radiation Experiments Associated with the U.S. Department of Energy and Its Predecessors* (213 pages), DOE/EH-0491, July 1995.

⁶⁰ From 1963 to 1973, the University of Washington, Seattle conducted studies on the effects of radiation on human testicular function, using inmates at the Washington State Prison in Walla Walla as subjects. Initially, 232 healthy volunteers were accepted into the study program. Sixty were subsequently irradiated with acute doses of x rays, ranging from 7.5 to 400 rads to the testes. The work was supported by the U.S. Atomic Energy Commission. See OT-14, "Testicular Irradiation of Washington State Prison Inmates," in *Human Radiation Experiments Associated with the U.S. Department of Energy and Its Predecessors* (ibid.).

⁶¹ Goodman is a research analyst for the Presidential Advisory Committee on Human Radiation Experiments.

⁶² In the early to mid-1950s, various radiation-related studies were carried out at the Fernald State School in Waverly, Massachusetts, using mentally deficient students as subjects. In a study addressing calcium metabolism, nine adolescent males, institutionalized for mental inadequacy but otherwise physically normal, ranging in age from 10 to 15 years, and one 21-year-old male participated as subjects. A second study addressed thyroid function in Down's syndrome subjects and their parents. Twenty-one male and female Down's syndrome students ranging in age from 5 to 26 years participated, as did 5 female and 2 male normal parents of these students. These studies were supported in part by the U.S. Atomic Energy Commission. For details and references, see OT-19, "Radioisotope Studies at the Fernald State School, Massachusetts," in *Human Radiation Experiments Associated with the U.S. Department of Energy and Its Predecessors* (213 pages), DOE/EH-0491, July 1995. For a perspective on these experiments from a researcher who used data from the Fernald subjects, see the oral-history transcript of Constantine J. Maletskos, Ph.D. (DOE/EH-0473, September 1995). For an outside researcher's perspective on the Fernald experiments, see "Use of Children in Research" in the Merril Eisenbud transcript (DOE/EH-0456, May 1995).

the detection instruments used in the study.⁶³ That's something [which] in my opinion [adds confusion] in the way I've seen the publicity on this issue. I call this the "gee whiz" era: "Gee whiz, we can now put carbon-14⁶⁴ into milk and see how it goes and makes bones and we can now find out [how] iron gets into red cells and how they're formed, etc." You could never do those things with stable chemicals. So those "gee whiz" [radioactive labels]⁶⁵ were tracing the metabolic path ways of all of these elements or labeled compounds that get [metabolically] broken down and [are synthesized to] reappear in other forms. Hevesy⁶⁶ in the '40s wrote a book called, *Biological Indicators* [on this technique], which later became radiation tracers or radiotracers [technology].

HEFNER: I've noticed through this controversy the past year that there's a great deal of difference between [the] scientific community and the general population, and you're saying that these tracer studies were from this "gee whiz" era of just trying to track these.

GOLDMAN: There was never any intent [for the radiotracers] to do harm, and there was never any knowledge in the medical literature that harm would be a consequence. What we knew about was that high doses of radiation damaged tissues and when you damaged tissues you had problems, but these [tracer studies] were not considered high doses. They were considered a dosage of an innocuous tracer (the same as taking an aspirin); it was really considered that way. When you add that to the environment in which there was—not an official acknowledgment of [a risk] threshold, but there was a feeling: "You can [then] understand this." Now, I know a lot about the history of radiobiology, and I'm sure you've already interviewed Newell Stannard, who is the walking encyclopedia on this.

Or have you not?

GOURLEY: I don't think there is a plan to talk to him. I think that they thought he'd written everything he had to say.

GOLDMAN: Well, I think that was a big mistake, because what he's written in his volume is a careful archivist thing, but what he remembers is a goldmine for things that are not written [down].

GOURLEY: I'll certainly pass that on.

GOLDMAN: I've mentioned it more than once and they've given me the same thing—"Well, we've got this mighty tome of his"—but that was just plain archivist.

HEFNER: Good, that's great advice.

⁶³ The Fernald adolescents in the first study received two doses of calcium-45, in 0.7 and 0.74 microcurie. The students in the second study received 70 microcuries of iodine-131.

⁶⁴ a radioactive isotope of carbon having a half-life of about 5,730 years: widely used in the dating of organic materials; also called *radiocarbon*

⁶⁵ radioactive isotopes incorporated to make a substance traceable

⁶⁶ George Charles von Hevesy (1885–1966), Hungarian-born chemist who won the 1943 Nobel Prize in Chemistry for his discovery of hafnium and his work on the use of isotopes as tracer elements

GOLDMAN: And it's really very important, because he was intimate to all of these discussions, which are not written up. And his neurons are still functioning quite well. So, I would [ask] him.

HEFNER: Would you also comment on—

GOLDMAN: Let me add more to this. There was [information] in the literature because we knew about the radium dial painters [who, earlier in the century, had ingested small amounts of radium as they tipped their brushes with their lips while painting], didn't we? [Also] we knew about the uranium miners. What we knew about the uranium miners and dial painters is that they got cancer when the doses were "incandescent" [(that is, very high)]. The smallest alpha [particle]⁶⁷ dose that caused the bone cancer in the ladies that did the brush tipping with their lips (because that's the work I worked on in the animal model); the smallest dose was a thousand rads, and when you multiply this by [what we call the] quality factor, it's 20,000 rem⁶⁸—that's not a tracer dose. A tracer dose is not a rem [dose], it's sometimes not even a millirem⁶⁹ [dose].

You and I are walking around getting a third of a rem a year [of background radiation] just from natural sources [and] from what's in us.⁷⁰ What comes down from [the sun and cosmos] above and [the earth] below, it's all natural. So the idea of [the] study where you weren't [getting exposed to] the equivalent of more than 50 percent of background having any kind of a consequence was never raised. To this day, I don't think there's any support for that.

But then we say, "Well, what about the sensitive subsets of the population?"—[for] the young, fetus, mentally retarded. [Well,] if you look at what sensitivity means, it's usually [only] a factor of two [increased radiosensitivity]. We're not talking about a thousandfold or a millionfold difference. Maybe 20 percent or 30 percent, but at worst a 100 percent difference between the average and the most sensitive. It's just the nature of biology that you can't be too far away or you don't [survive as] part of the species.

The second thing that I wanted to point out is that scientists knew that life evolved on this planet, [an axiom] which is almost [so universally accepted as to be considered] a religion—this planet started [out] as radioactive; and [they knew] that whatever life has evolved to now, has made it through an evolution in which the [radiation] background was much more hostile with regard to [natural] radiation [levels]. The radioactivity of the

⁶⁷ a positively charged particle consisting of two protons and two neutrons, emitted in radioactive decay or nuclear fission; the nucleus of a helium atom

⁶⁸ a unit of radiation dose equivalent, or "rads times the quality factor, Q." The limits for occupational exposure of workers to radiation range from 2 to 5 rem per year for most countries.

⁶⁹ a thousandth of a rem

⁷⁰ In the United States, an individual's exposure to background radiation averages about 350 millirem per year; the amount will vary with elevation and other factors. Daily fluctuations in the background occur proportionately with the amount of cosmic radiation striking the earth.

planet is [decreasing], despite the best efforts of the Russians and the Americans to turn the tide the other way [(with weapons testing)]. So, almost all of the lead, on this planet [originally was] uranium (billions of years ago); [lead is] the end product of the decay. Any life form that could make it through *that* has [developed] some kind of quality control system that doesn't allow small doses of radiation to wipe it out. Because if it gets wiped out, it [cannot survive]. So by a kind of idiot reasoning, I have always felt that we are very hearty, in view of this history.

This is what we were taught about places like the Massif of France,⁷¹ places in China, and Kerala Coast [on the Arabian Sea] in India. The geology [there] is such that the background radiation [from uranium and thorium in the ground] is ten times higher than background here. People live there and have for millennia. There [were] some really careful epidemiology studies done. They have not shown a [radiation-related] difference [in cancer rates].

There was once this big brouhaha about increas[ed levels of mongolism]⁷² in the children along the Kerala Coast. The monazite⁷³ sands [cause a high background because they] are very high in uranium. It turns out that the control [study] group was different [(lower)] than any control group in the world, and the so-called exposed group [showed] the same [mongolism level] as any other normal group on the planet.

In any event, you've got this "background game," you've got the evolutionary story and the few bits of clinical information that were available in the early '50s. The [studies] said that when doses were really big—such that you saw clinical injury—you then were at risk for subsequent health effects. I have, somewhere in my library, which I can find—maybe you can find—is a 1950 addition of the Atomic Energy Commission's book called the *Effects of Atomic Weapons*. It came out periodically during the civil defense era. [It contains nothing] under the biological effects of radiation about cancer, except at the very end of discussing the terrible clinical situation in Hiroshima and Nagasaki,⁷⁴ with all kinds of gory photographs and a lot of clinical acute-radiation stuff. Then, in the end, it said, "Of course, there may be a risk for low-level latent health effects."⁷⁵

The epidemiology out of Japan had not yet started. That program [was] begun in 1950—five years after the war ended. It wasn't until another five years [passed], maybe 1955, [when] we first started to get this story about radiation-induced leukemia risks related to distance from the

⁷¹ a band or zone of the earth's crust raised or depressed as a unit and bounded by faults

⁷² Down syndrome, a genetic disorder associated with the presence of an extra chromosome 21, characterized by mental retardation, weak muscle tone, and epicanthic folds at the eyelids

⁷³ a reddish brown mineral, a phosphate of cerium, lanthanum, and thorium; the principal ore of thorium

⁷⁴ the Japanese cities on which U.S. bombers dropped atomic bombs on August 6 and August 9, 1945, respectively, killing and injuring hundreds of thousands and ending World War II

⁷⁵ After exposure to a carcinogen, it takes 5 to 15 years or longer before evidence of cancer is apparent.

ground zero and then the world started getting really interested. This was [in] 1956 or 1957.

Of course, the "retrospectroscope"⁷⁶ always has "20/20 hindsight" in it, and you don't think everybody in [this] business knew immediately [(about the hazards of radioactivity)]. Although we have annual meetings at the Radiation Research Society, my Health Physics Society started in 1956. We started talking about this, and at that point, the fall-out⁷⁷ scare was getting terribly heavily emphasized. We had problems [and] concerns about atmospheric weapons testing. [Weapons were] getting bigger and bigger, and more and more [testing] on the Russian and American side [with resultant] fallout. From fallout studies we get a lot more of the "gee whiz" metabolism [information].

Then we found [out] about strontium[, a major component of fallout that is particularly threatening to children].⁷⁸ It was dropping out of the sky from American and Russian bombs[, atmospheric testing of nuclear weapons]. I was involved in that.

When I was at Rochester doing my thesis, one of the projects that we had was to learn about radiostrontium. We had a [small] study on a few monkeys, because monkeys are more like people than [are] inbred rats.

My lectures in radiation to the students are that you can prove anything with a rodent. We have "designer mice." You want a mouse that only gets lymphoma?⁷⁹ I've got a strain [for that]. You want a mouse that will never get any lymphoma? I've got a strain [for that]. You want a leukemia⁸⁰ model? You use RF[-strain mice]. These are terribly inbred animals that don't give you an accurate picture of the risk to a hybrid species such as people, but it does give you a tool to study leukemia, or lymphoma or, bone cancer, or lung cancer, etc. But that's all they do; these animals aren't [genetically] "complete." There is some DNA surrounded by fur, but they are really not complete animals. You have to be very careful, because I can show you a whole battery of mouse studies, each strain of which got the same dose, the same treatment, and one [strain] goes up through the roof [with effects] and one goes along if nothing has happened. So this is really important.

They said, "Let's try to do this thing with some monkeys." I was younger and faster then, so I was catching the monkeys and we would intubate⁸¹

⁷⁶ a facetious term for an imaginary optical device that reveals the truth in hindsight

⁷⁷ radioactive debris from a nuclear detonation or other source. Fallout is usually deposited from airborne particles.

⁷⁸ Don Petersen discusses the concern over strontium's fallout threat in the section, "Nuclear Weapons Fallout Studies (1946-54)," in his oral history (DOE/EH-0460, August 1995).

⁷⁹ a tumor arising from any of the cellular elements of lymph nodes

⁸⁰ any of several cancers of the bone marrow characterized by an abnormal increase of white blood cells in the tissues, resulting in anemia, increased susceptibility to infection, and impaired blood clotting

⁸¹ to insert a tube into a hollow anatomical structure, as the larynx, especially for admitting air or a fluid

the esophagus⁸² and squirt some strontium into their tummies and then catch the feces, which was usually thrown at you by the monkeys. When I think back on it, if I'd been a radiation safety officer, I would have closed the place down. We were dealing with not-insignificant doses.

Some of those monkeys lived for a long time. They were [sacrificed], and I got some of them out here and I gave some of them to Pat Durbin.⁸³ She and I have worked together for many years on this. I had built, at Davis, a whole-body counter. One of the first in the world. We could measure bremsstrahlung.⁸⁴ We invented a trick to measure beta particles [using] the whole-body counts. In any event, we were doing the strontium-90 work at Rochester as a part of [the AEC] program.

There was another laboratory where we were studying polonium⁸⁵ by injection in rodents. These were parts of this radiation toxicology program of my section of that department. While I was off doing my thing, a strange thing [was reported], called DNA,⁸⁶ which had just been [discovered] by somebody named Crick.⁸⁷ In those days you labeled [DNA] with phosphorus, because they hadn't [yet] invented carbon-14 labeling. I wanted to see, [with] phosphorus labeling of the lymphocytes, whether they were formed because the [tissue was irradiated], in which case they would be radioactive, or whether they were sequestered and just released because of the radiation, in which case they would not have incorporated [phosphorus-32] because they weren't dividing.

[At the time,] that was really cutting-edge science. But [at the University of Rochester] I learned all about radioactivity in this experience over the years at the lab. I helped design some of the studies. I would go down and talk to George Casarett, Newell Stannard, John Hursh, and [biophysicist] Bill [(William F.) Bale, [who] were all pioneers in this [radioactivity science].

⁸² a muscular tube for the passage of food from the pharynx to the stomach

⁸³ From 1951 to 1977, Durbin worked as a chemist and radiobiologist at the Crocker Laboratory of the Lawrence Radiation Laboratory (Lawrence Berkeley Laboratory). For the transcript of the November, 11, 1994 interview with Durbin, see DOE/EH-0458, *Human Radiation Studies: Remembering the Early Years; Oral History of Dr. Patricia Wallace Durbin, Ph.D.* (June 1995).

⁸⁴ radiation, especially braking radiation, gamma rays, or x rays, emitted by decelerating charged particles

⁸⁵ a radioactive metallic element, chemically similar to tellurium and bismuth, that emits a helium element to form an isotope of lead; i.e., polonium-210

⁸⁶ deoxyribonucleic acid—a type of nucleic acid, particularly found in cell nuclei, that is the basis for heredity in many organisms. DNA molecules are constructed of a double helix held together by hydrogen bonds.

⁸⁷ Francis Harry Compton Crick (1916–), an English biophysicist who received a Nobel Prize for his 1953 codiscovery of DNA, together with James Watson, in 1962

Research at the University of Rochester (1952–57)

GOURLEY: What work did you do with Bale? I've seen his name on some items.

GOLDMAN: Oh, Bale was one of the original radon⁸⁸ physicists at Rochester. It used to be [called] the Atomic Energy Projector (AEP). In fact, I have a story that I guess that we could put down now. When I got there, the fellowship hadn't quite caught up to me, I got there so fast. They wanted me to eat. I had a scholarship, but I didn't have any [living expense] money, so they got a job for me as night watchman at [the] lab, which was fantastic. I had the 4:00 [p.m.]–to–12:00 [a.m.] shift. No distractions: no women, no television, no beer, no nothing—just study. I had to do rounds and go through all the atomic energy projects at night. The cockroaches were as big as mice in that place because there was a lot of mouse food. I was [working with] 85-year-olds, who were looking through coffin catalogues. I had to do rounds for a half-hour and then I had to guard the desk for a half-hour. Suddenly Marvin's grade point average became straight A. I got nothing lower than an A; in fact, I got nothing lower than an A thereafter. It was a good disciplinary thing, because I decided that looking at coffin catalogs was what happened if you didn't study. I also learned a lot about the labs.

I learned that Kurt Altman always left the faucets running and you'd frequently go in and it would be a flood in the biochemistry lab, tubing would be [found] broken. It was a [fascinating] time. So that was Rochester.

GOURLEY: You were there when the plutonium injections happened, too?

GOLDMAN: No, I think they were [earlier]. They were in the '40s or early '50s. But if they were going on roughly the time I was there, I was not aware of them at the time, as a student.

HEFNER: When did that information hit the student population? When does that come into the literature?

GOLDMAN: It was after I was a student. It was at least a decade later. It had been written up. We had a very fine laboratory library, and there was the MDCCC series,⁸⁹ the whole Manhattan [Engineer] District⁹⁰ world that published [the wartime research in] a series of volumes. We used those as textbooks.

There was [also a] constant profusion of these paperbound reports from all the labs about [their research]. I'm sure that amongst them was Pat Durbin's [work] on measuring some of the plutonium. I think a lot of that [work] was classified early on, because of the "P" word. When I was doing the [work] at the Nevada Test Site, what we dealt with was

⁸⁸ Radon is radon-222, a naturally occurring, heavy, radioactive, gaseous element formed by the disintegration of radium-226.

⁸⁹ McGraw-Hill National Nuclear Energy series—the final scientific report of the Manhattan Project

⁹⁰ the U.S. Army Corps of Engineers organization set up to administer the development of the atomic bomb under the top-secret Manhattan Project

something called "Product," that was the "P" word, not plutonium. It was classified. Now I had Q clearance⁹¹—I've [had] it since then—but I didn't have a "need to know," as they called it.

It [(the plutonium injection experimentation)] was going on—I knew you'd ask me that. I really racked my brains out. Was I really aware of any of this? No. Did I have any of this presented in my classes? No. I don't remember that.

HEFNER: Newell Stannard never discussed it?

GOLDMAN: I think there were a couple of seminars. We had a very good seminar series about once a week on interesting topics. My memory isn't that great that I could tell you that there was a seminar on the plutonium series. That is something I'd [suggest you] ask Newell. I encouraged him to write an article about that.

HEFNER: Did he have a response?

GOLDMAN: Well, you just encourage him; you don't wait for a response. You just do this in a ploddingly careful way. But I keep telling Newell, "The clock's ticking, we've got to get [as much recorded as possible]!" [I think] he'd like to do this.

GOURLEY: He's done a lot of interviews with a lot of other people.

GOLDMAN: Yes. But [it] is usually, "When did you stop beating you wife?" kind of questions [designed to prove him guilty of something]. I think if you just gave him free rein to—

We have a Newell Standard Annual Lectureship that we created in our society. I introduced him to the last one and videotaped the whole thing. Then he gave a talk for about an hour, which we also videoed. George Anastas at Sacramento State [University] has some copies of it. I don't know whether your archives has it. It was already professionally done. It was done this last year; it might be interesting to look at that.

HEFNER: You mentioned that there were two other training sites that AEC had established.

GOLDMAN: There was an instant need, with the advent of the atomic era, to have a [supply] of radiation protection people. There weren't many. They were all [recruited] from some other area—industrial hygienist, medical technicians, or whatever. And they were given basic training. Or, like myself, a bunch of kids out of school with good physical[-science] and biological background. There was one [program] at Vanderbilt [University in Nashville] with a marriage to a summer [field] program at Oak Ridge [National Laboratory (ORNL)].⁹² There was one at Rochester

⁹¹ a high-level security clearance issued by AEC (and later DOE), comparable to a Top Secret clearance from the U.S. Department of Defense

⁹² During World War II, the Manhattan Project had built a vast complex of highly classified facilities in and near Oak Ridge, Tennessee, to process uranium for use in atomic bombs. The Atomic Energy Commission (continued...)

with a tie-in to Brookhaven, and there was one at the University of Washington with a tie-in to Hanford.⁹³ They would study under Herb Parker⁹⁴ at the Hanford Laboratory and under K.Z. Morgan⁹⁵ at Oak Ridge. And under Fred Cowan at Brookhaven [National Laboratory]. These were some of the health physics "scoutmasters" during those early programs. Since then, other programs have evolved at different universities, but this was really unique, in that the AEC set up the Laboratories at the universities.

One of the problems today is that the need for health physicists isn't going to be met. Although there may be a few fellowships for students, there are no inducements for the professors who will train the students. So, if the professors can't get a professorial training grant, if there is nothing [from] the department to do it, why should they bother? Even though the students come funded, there is no program. University departments won't [support] a program [alone].

I'm not suggesting that we need three programs, but you sure need to do something about the seed corn [(training young scientists in the various fields)], because some of us [old-timers] are getting tired of going around putting out fires. It's a serious problem. I don't mean to use your tape to proselytize, but it is one of the things I, as President of the Society, am looking at [in] the crystal ball down the road. Whatever you think of decontamination and decommissioning of all the DOE sites, it isn't going to happen in five years. It's going to be [more like] 30 or 50 [years]. It's going to be [run by] a whole generation [of] people who are merely going to be looking at regs [(regulations)] and DOE orders and not know what they're doing. And you're going to get into all kinds of difficulty.⁹⁶

⁹² (...continued)

took control of these facilities upon its creation and, today, they belong to the Department of Energy. For a history of ORNL, see *ORAU From the Beginning*, written by William G. Pollard with Gould A. Andrews, Marshall Brucer, et al., and published by Oak Ridge Associated Universities, Oak Ridge, Tennessee, 1980.

⁹³ the DOE's 570-square-mile former site for plutonium production, located near Richland, Washington

⁹⁴ For more than a half-century, Herbert M. Parker was a leading force in radiological physics. He was codeveloper of a systematic dosimetry scheme for implant therapy and the innovative proposer of radiological units with unambiguous physical and biological bases. He made seminal contributions to the development of scientifically based radiation protection standards and helped the Hanford Laboratories achieve prominence in radiation biology, radioactive waste disposal, and characterization of environmental radioactivity. For his inside view of the maturation of medical physics and the birth and evolution of the parallel field of health physics, see R.L. Kathren, R.W. Baalman, and W.J. Bair, *Herbert M. Parker: Publications and Other Contributions to Radiological and Health Physics*; Columbus, Ohio: Battelle Press; 1986; ISBN 0-935470-36-0; 864 pages.

⁹⁵ For the transcript of the interview with Morgan, see DOE/EH-0475, *Human Radiation Studies: Remembering the Early Years; Oral History of Health Physicist Karl Z. Morgan, Ph.D.* (June 1995).

⁹⁶ See Tara O'Toole, et al., *Hazards Ahead: Managing Cleanup Worker Health and Safety at the Nuclear Weapons Complex* (80 pages), OTA-BP-O-85, Washington, D.C.: Congressional Office of Technology Assessment, February 1993. O'Toole is now DOE's Assistant Secretary for Environment, Secretary, and Health. For DOE's perspective on the need for a cleanup, see *Closing the Circle on the Splitting of the Atom: The Environmental Legacy of Nuclear Weapons Production in the United States and What the Department of Energy is Doing About It* (106 pages), DOE Office of Environmental Management, January 1995.

You've got the whole [spectrum] of the nuclear business and who are the people that are going to prevent accidents from happening? You've got the demilitarization of the whole nuclear navy, which is going to go on. All of these are specialty areas (possibly help with overseas places). There's probably a constant need, although the matrix that we're dealing with is continually changing.

Relationship With Newell Stannard and Stafford Warren (1952–57)

HEFNER: Does this pretty well cover your Rochester days? Maybe we shouldn't leave this without you describing your relationship with Newell Stannard.

GOLDMAN: Well, he was sort of the white-haired father. He was the Associate Dean for students. So, any of us who had any problems would go talk to Newell or "Rosebud"—Rose Sternberg was his secretary, and she was the "mama" for the group. We'd have 30 students a year going through this program with the usual problems of very young men. She was very sweet about always helping. I remember she helped me get a house.

He[, Stannard,] taught courses. He had set [up] an alpha laboratory, which [was for] an inhalation toxicology program. One of the first in the country, at Rochester. I was peripherally involved in that. He wasn't my personal major advisor, although I looked to him to get more advice than I could get from [the others]. As I said, we were all one big family. There weren't that many graduate students. There was constant processing of these 30 health physicists, but then you had the cadre of [senior] graduate students, who help run laboratories.

I worked with another pioneer, named Leon Miller. He is an M.D. at Rochester, who was doing [work] on liver perfusion,⁹⁷ learning about how the liver detoxifies compounds and how it produces certain enzymes. He taught me a lot about this perfusion technique, he was doing it on little mice.

Harry [(Henry A.)] Blair was the director of the whole program. He had more of a cosmic view of the radiation scene at the time. He was the one who was pursuing this business of the reparable and irreparable [cell] damage. I can still see the curve on the blackboard that he would draw [—the "Henry Blair curve."]

There was one other man there that was doing a study on fruit flies—his name was Robert Baxter—who passed away a couple of years ago. He probably had more experiments than [have been reported on in] any five other theses. He had volumes. He would do a study where each data point had a thousand individuals. He was studying the [effects of] fractionation⁹⁸ of radiation on fruit flies' survival. So, I remember the molasses odor, with all of the fly food that he had prepared. When you have

⁹⁷ the process of passing (fluid) through blood vessels or the lymphatic system to an organ or tissue

⁹⁸ study of the biological effects of many small doses of radiation, compared to those from a single exposure of the same total amount; fractionation, over a long period of time, permits cellular repair of radiation damage.

5 million flies in vials, it's a lot of odor. He would anesthetize them with ether, which could blow up the place, but at the time I didn't know that. There was the aroma of a mixture of ether and molasses in that lab that was hard to describe. These were things that were going on.

What was happening on the medical side of the house, I don't remember. The dean of the school was a Nobel Prize winner named George Whipple. George Whipple had discovered [vitamin] B₁₂, I think. There were things going on—the radiation atomic energy project was part of Strong Memorial Hospital [in Rochester]. [It] was part of the medical [complex] and was a mile away from the main Rochester University campus.

HEFNER: Am I incorrect in thinking that Stafford Warren⁹⁹ was also—

GOLDMAN: Yes. Stafford Warren was there. [He] went out and set up a duplicate program at UCLA,¹⁰⁰ called the Laboratory for Radiation Biology. That's Rochester ["Expanded"].

I got an offer to stay on [at Rochester] for a year as a post doc [(postdoctoral research fellow)]. After finishing my thesis, I stayed on and did the strontium-90 project full-time and tried to put [(add)] some scientific planning. As I mentioned earlier, the concern was getting worse and worse about the burden of radioactivity from increasingly larger and more frequent atmospheric weapons testing. We were measuring strontium-90 milk everywhere and they were [reporting it in] something called "Sunshine Units."¹⁰¹

Participation in "Project Sunshine" and Move to the University of California, Davis (Mid 1950s to 1958)

GOURLEY: So, you were part of Project Sunshine?¹⁰²

GOLDMAN: I'm one of the "papas" of that. And so, the AEC decided to embark, in the mid '50s, on a study in long-lived animals to find out what the low-level effects are of plutonium, americium,¹⁰³ of a whole bunch of actinides.¹⁰⁴ And [so they thought], "By the way, let's look into strontium because of the fallout." They set up this battery of "dog laboratories," that you've heard about. One of them at Lovelace in Albuquerque,

⁹⁹ a professor of Radiology at the University of Rochester. Dr. Warren worked on the Manhattan Project in Oak Ridge as head of the medical section and headed an Intramedical Advisory Committee. After World War II, Dr. Warren became dean of the University of California, Los Angeles Medical School.

¹⁰⁰ University of California, Los Angeles

¹⁰¹ equivalent to a certain activity of strontium-90

¹⁰² Project Sunshine was initiated by the AEC in response to the urgent need for more information about the potential hazards associated with radioactive fallout. The Project began as an evaluation of the hazards associated with nuclear war and grew into a worldwide investigation of radioactive fallout levels in the environment and in human beings.

¹⁰³ element number 95

¹⁰⁴ any element of the actinide series—the series of mostly synthetic radioactive elements whose atomic numbers range from 89 (actinium) through 103 (lawrencium)

at the Lovelace Foundation, which is called the Inhalation Toxicology Research Institute.¹⁰⁵ [Another dog laboratory performed] plutonium inhalation studies at Hanford [and was] run by Bill Bair,¹⁰⁶ [and there was also] a group of injection studies on radium and plutonium in dogs at the University at Utah under [Tom Dougherty]. Later, a study of ingestion of radioactivity in dogs at [the University of California at] Davis, where I went.

So it's now 1958, and [my] wife is pregnant, and it's time to think about making a living and getting a career. I got an offer to go out and work with Bill Bair, my friend from Rochester, who had gone a year before to set up the program at Hanford. [He wants to know,] "Would I like to go out and work with General Electric?"¹⁰⁷ I decided I didn't want to work for General Electric [because it] looked like a company town and I did not have a company mentality.

And then they said, "Well, they're also setting up this program at the veterinary school in Davis at the University." I said, "Well, that sounds interesting. Why don't I go down there?" So, I went down and took a look at that and they offered me [a job when they learned that I knew] about strontium: "We'd like you to come here, we're going to offer you \$7,000." I said, "But they are offering me \$10,000 at Hanford." "But we are not allowed to do that." I said, "Well, you'll have to get somebody else." And, not having read all these books on how you get a job, so I said, "Why don't you look into it?" And, I went home and they called and said, "We can match that." I said, "Fine, I'll be there December 1."

So, on December 1, 1958, I came out to Davis with my wife and our newborn child, and it took her six weeks to stop crying, because the campus at Davis was a [small agricultural] experiment station with 4,000 acres and 3,000 students. When I told my relatives back in New York that I had finally found a University that had more acres than students, they just rolled over laughing. Davis now has 25,000 students, just a few thousand smaller than Berkeley—in those days it was interesting. There was this whole program to set up. I was in Fat City.

I was hired as a radiation biophysicist at the University of California at Davis. I was to be the scientist to do this. There was a veterinarian there who knew about dogs, whose name was A.C. Andersen. And A.C. Andersen was the first head of this [study], called the Atomic Energy Project at Davis, which I later directed. Andersen, in 1951, had been

¹⁰⁵ Here, Goldman is referring to the Lovelace Inhalation Toxicology Research Institute outside of Albuquerque, New Mexico (along one part of the Kirtland Air Force Base), *not* the Lovelace Hospital.

¹⁰⁶ From 1956 to 1968, Bair managed the Inhalation Toxicology Section of Pacific Northwest Laboratory's (PNL's) Biology Department. His research at Hanford focused on the inhalation of radionuclide aerosols, mostly various forms of plutonium, by various animal species, primarily rats and beagle dogs. Bair's Hanford work is discussed throughout the Bair transcript (DOE/EH-0463, June 1995), particularly in "Radionuclide Inhalation Studies at Hanford."

¹⁰⁷ General Electric Company. General Electric became the prime contractor in charge of operating the Hanford Laboratories for the AEC in 1946.

given an Atomic Energy [Commssion] contract, which was gotten by the dean of the veterinarian school, named George Hart, to discover the consequences on life span of [exposing] beagle dogs with a single dose of radiation or [with] fractionated doses. We were just becoming aware that there was something more than radiation dose: it was the quality of the dose;¹⁰⁸ there is a dose rate [effect (how the animal is affected by the length of time over which a given dose is administered)]; and these sorts of things. And so, that study was already ongoing.

[In 1957,] on our [graduation] celebration national tour of the country that my wife and I did after I got my degree, before I started a post doc, we stopped off (having heard about this Davis Project) [to] visit [Andersen and his project] in July in Davis, when it was about 110 degrees and air conditioning hadn't [arrived] yet. My wife said, as we drove away to visit San Francisco for the first time, "Boy, am I glad you don't work here!" Little did she know. When she was in the labor room [with our first child, I told] her, "Finish up—we're about to go to Davis!"

Anyhow, the project was all about x[-ray] irradiation, and Andersen knew about beagles and dog [reproduction]. He knew [less] about [internal] radiation. So I was going to be the radiation person.

Participation in Beagle Studies at the University of California at Davis (1958–60s)

GOURLEY: Just briefly for the tape, why beagles?

GOLDMAN: Why beagles? Well, we knew that we were dealing with late effects of radiation. So you'd want animals that were going to be there later. And, dogs are there longer than are mice (long-lived).

GOURLEY: Right.

GOLDMAN: Secondly, we wanted an animal that had humanlike diseases. And the diseases of rodents aren't parallel to those of humans, especially the diseases of old age.

The other reason for beagles was that it was the only dog breed that was tractable, that didn't eat you out of house and home, that were not vicious, and that had a very large, wide genetic pool. All of the other specialty breeds, if you go back two or three generations, you're dealing with the same sire or dam. So you have an inbreeding problem. Or, you're dealing with a situation where [there] are certain diseases that are unique to particular inbred dogs. So [our feeling was,] "Let's get something that is as outbred as we can, that is parallel to people."

We then designed this study. The AEC put together an advisory committee; I think Stafford Warren might have been on it originally. But the

¹⁰⁸ the linear energy transfer and relative specific ionization, energy distribution in tissue, the exposure rate, etc., that influenced the biological effectiveness of the radiation

ones I remember were Wright Langham¹⁰⁹ from Los Alamos [Scientific Laboratory],¹¹⁰ Austin Brues¹¹¹ from Argonne Laboratory,¹¹² Harry Blair from [the University of] Rochester, and Robley Evans¹¹³ from MIT [(Massachusetts Institute of Technology)].

Robley Evans is the pioneer that did a lot of the original radium work. Radium was the radioactivity benchmark for the planet. There was no other database. [Data from] the uranium miners wasn't really [about] deposited radi[oa]ctivity. So much as it was, inhaling radioactivity and exhaling it, but it wasn't so much the deposition. The radium dial painter is definitely [a deposition problem,] the radium behaved like calcium, went into bone and [ir]radiated osteoblasts¹¹⁴ and caused osteosarcomas.¹¹⁵

[There was] a program of bomb building and nuclear powerplant design, and [the United States was] going to be dealing with radioactivity. We already knew, from preliminary laboratory benchtop studies, that alpha particles are much more nasty [when] they look at a cell nucleus, then [are] beta particles [or] gamma rays.¹¹⁶ We didn't have it as fine-tuned as we do today.

Radium emits alpha particles. So the only [information] we had on alpha particles in people [was from] radium, so we invented this [concept] called a *toxicity ratio*: everything is related to the equivalent effect of radium in people. They injected radium into beagle dogs at Utah and then injected the same number of microcuries [of] plutonium into beagles at Utah. The radium and plutonium went to bone, and the plutonium made bone cancers and the radium made bone cancers. The plutonium [caused cancers] four times better than radium did. Therefore, the plutonium got a toxicity factor of four.

¹⁰⁹ Langham, regarded at the time as "Mr. Plutonium," led the Los Alamos Health Division's Radiobiology Group from 1947 until his death in 1972.

¹¹⁰ the National Laboratory near Santa Fe, New Mexico, where nuclear bombs were assembled before and during the Cold War; operated by the University of California for the U.S. Department of Energy. Since World War II, Los Alamos has been a research and development center for nuclear weapon designs and other scientific studies.

¹¹¹ Brues, a physician, was a professor at the University of Chicago and Senior Biologist, Division of Biological and Medical Research, Argonne National Laboratory.

¹¹² located outside Chicago; operated by the University of Chicago

¹¹³ In the early '30s at MIT, Evans investigated the bioeffects of radium on dial painters in New Jersey and Connecticut. By 1941, Evans with others had set the first standards for a tolerance level for radium in the human body. The first "tolerance level" for radium was set at 0.1 microgram body burden: Evans judged that there would be no bone cancers below 0.1 microgram ²²⁶Ra in the skeleton. Later he served on the AEC's Committee on Isotope Distribution. At a 1967 symposium, he proposed that the AEC establish a National Center for Human Radiobiology so the AEC could follow up and combine all the radium cases being studied at MIT, Argonne National Laboratory, and elsewhere. On September 1, 1969, the center opened at Argonne, headed by Robert E. Rowland; Evans maintained a satellite office at MIT. In the early 1990s, Evans's pioneering basic research earned him the Department of Energy's Fermi Award.

¹¹⁴ bone-forming cells

¹¹⁵ malignant tumor of the bone

¹¹⁶ Goldman means here that internal alpha-emitting radionuclides present a greater health hazard to man than do beta or gamma emitters in the body per unit dose to sensitive tissues.

Now [(having assembled the various data)] we know about radium in people and we know about radium in dogs and we know about plutonium in dogs, and we can [then] make a proportionality [(B is to A as Y is to X)]. X is now plutonium in people, which we didn't know about. So the ratio of dog plutonium [(A)] to dog radium [(B)] is a radionuclide ratio; [and that ratio, A/B] times the ratio between dogs and people radium [(B/Y)], that's a species ratio [($A/B \div B/Y$)]. It allows you to predict; it's a very classical toxicology [approach]. That [pair of known ratios, A/B and B/Y ,] underwrote all of these programs.¹¹⁷

We had plutonium [beagle] inhalation [studies] at Hanford, which we could relate to uranium miner inhalation and was a little more crude because we didn't have the neat dosimetry¹¹⁸ that you could get with the radium, since it [(radium)] emits a very fat gamma ray which is easily counted in vivo.¹¹⁹ We now had this beginning of the first truly quantitative study of the effects of internal emitters. This now relates to your sensitive subpopulations in the "gee whiz" tracer studies, because this is now the basis for our understanding of the effects of radionuclides.

The deficiency of having a nonhuman species and not lots of numbers is made up for by [the] fact that there is no uncertainty about the radiation dose, as there is in all these human studies (which you are doing retrospectively). So you trade off one kind of an uncertainty for another. Exactly how does a dog-year relate to a human-year, or a dog cancer relate to a human cancer?

But, that's something we've now researched the hell out of over the years. And we have a very good feeling as to where that animal fits in the test's species (just as you do today). We've got a whole battery of testing every time there is a new compound [for which] you have to learn about the efficacy and carcinogenicity—you know, these "designer [test] animals," I call them. They allow you to come up with [a] pretty good [risk] estimate. Except for a few accidents or errors, like thalidomide,¹²⁰ where they just picked the wrong species [on which to test its safety]. We'd done very well at it; it's a very good track record.

GOURLEY: Actually, I believe it was Robley Evans [who] said that there was no correlation or that the only way you actually get data for people—

GOLDMAN: The only suitable experimental animal—to study man is man. Except people don't like to volunteer for things where there is a real uncertainty about the risk. So what with us [(workers at Los Alamos and Hanford in

¹¹⁷ These ratios were developed by Professor Charles W. Mays, a radiation biophysicist at the University of Utah.

¹¹⁸ the process or method of measuring or calculating the dose of ionizing radiation, or energy absorbed per unit mass, using data from bioassay and other radiation measurements

¹¹⁹ inside the body

¹²⁰ a drug, formerly used as a sedative, that in the mid-1950s caused hundreds of British infants to be born with abbreviated limbs after their mothers took it during pregnancy. In the United States, the drug had been prohibited by the Food and Drug Administration.

particular)] handling tons of plutonium to make [nuclear] warheads and all sorts of things, we had to know that the workers would be protected.

All of these studies except mine, every single one of them, was an industrial-hygiene accident predictor. These were an acute sudden accident where [a] glove box¹²¹ blew up, or there was a fire, or somebody spilled something. It was an instantaneous—it wasn't eating a bit of it every morning in your breakfast cereal.

But, the strontium-90 fallout thing was, indeed, one in which the doses were not achieved instantaneously, but were chronically [accumulated]. My program was the only one in which you literally fed the animals a radioactive diet from the onset of fetal ossification [(bone formation)] until [adulthood]. And, so they had a chronic level of radioactivity and we had different [exposure levels]. We studied one thousand animals, with a thousandfold range of dose from the highest to lowest.

The beagle was chosen for a very significant reason, and that is the skeleton of the beagle. That mammal is very similar to the human in terms of the spongy bone and the compact bone, in terms of the bone marrow and its quality and the progenitor cells that [produce] the white cells and the red cells of the body. [There is a] very, very close tie-in, which you cannot find in rodents. This was an ideal animal [to study].

We had the earlier x-ray study as sort of a benchmark. What kind of cancers come from an x-ray dose? How does that relate to internal [radiation] emitters. Strontium-90, being an alkaline earth divalent cation,¹²² will only behave as does calcium and will not cause lymphoma or lung cancer because it doesn't go [and irradiate] those tissues.

Now we had a new concept, partial-body radiation. Wow! Not just putting your hand in an x-ray machine, but here is something that selectively irradiates only certain tissues. Strontium-90, being a beta emitter, only irradiated within a millimeter [or so] of where the atoms resided. I kept saying, "But the strontium emits energetic beta particles which go both ways, it's going into the bone and it's going where else, into the bone marrow!" We were very shocked (although I had predicted this) to find that the high doses of radiostrontium also caused leukemia.

GOURLEY: Because of the red cells.

GOLDMAN: No, not red cells. White cells. Red cells are not involved in leukemia. Red cells are involved in something called polycythemia.¹²³ Cancer of the blood is called leukemia, and that's [from the Greek root] *leuko-*, it

¹²¹ an enclosed compartment fitted with long gloves, used in a laboratory for handling contents without causing or incurring contamination outside the container

¹²² divalent cation—a positively charged species, with a valence of +2, needs to be balanced with two negative charges, i.e., Sr^{++} balanced with $(\text{Cl}^-)_2$, SrCl_2 .

¹²³ polycythemia vera, a disease characterized by overproduction of red blood cells

means white. So, sure enough, we got myelogenous¹²⁴ leukemia, and guess what? Myelogenous leukemia is predominantly found where? In Japan—Hiroshima and Nagasaki. Now we had the only model in a laboratory situation that related radiation dose to leukemia risk.

However, Japanese experience was acute exposure. The [University of California at] Davis experiences [are] any[thing] but acute: it's chronic. So now we have an ability [to address] something called *dose-rate amelioration factor* or *dose-rate effectiveness factor*¹²⁵. This is really very important. The strontium that went into the bone caused osteosarcomas, similar to radium. We had run a parallel study on radium-226 in dogs, giving fractionated doses to simulate the short [radium] dosage time radium dial painters had at the time they were being exposed, which was generally a few years. These were generally young women, 15 to 22 or so, who were in these watch factories. They did all kinds of bad things with radium. There was not [anything called] industrial [hygiene]: (this was the '20s). It wasn't until [Dr. Bloom, a] dentist, noticed his [watch-dial-painting] patients' jaws falling apart. I'm sure you've got lots of information on that.

Therefore, I did this [study] where [we were] going to replicate in the beagle dog exactly the canine equivalent of the human experience with dial painters at [a] young age. In this case, [dogs] between 14 and 18 months of age, would [get] eight semimonthly injections, kind of [like] a sawtooth dosage. Then you stop and follow them forever. This was just about the [dog's age] of epiphyseal¹²⁶ closure of the bones, [which is equivalent to the young adult human]. There is my benchmark, and so, I would now have a beagle tie-in to the human studies. I was forced, because of this study, to always keep track of what was going on in the human radiation "studies"; even though I wasn't [directly] involved, I had to be aware of that. I became a member of the Orthopedic Research Society and I learned all [I could] about bones and bone metabolism. I designed a scanner that you could use to detect osteoporosis and all other kinds of side issues. Using the Anger camera¹²⁷ at [the University of California at] Berkeley, I did the first detection of a bone cancer, using this camera and fluorine-18.

GOURLEY: That was a long time later, though?

¹²⁴ produced in the bone marrow

¹²⁵ The leukemia in survivors of Hiroshima or Nagasaki was caused by acute (instantaneous) irradiation. However, some theories hold that the effects of radiation at low dose and low dose rate are less than for those from a single acute exposure of the same total dose.

¹²⁶ of the epiphysis, either of the ends of a long bone separated from the shaft by cartilage but later ossifying with it

¹²⁷ a large, flat, circular crystal of thallium-activated sodium iodide, backed with photomultiplier tubes arranged in honeycomb geometry, for obtaining an image of gamma emitting pharmaceutical in the patient; named for its inventor, Hal Anger, of the University of California at Berkeley. The camera is still widely used in modern nuclear medicine clinics to image gamma-emitting radiopharmaceuticals used in the diagnosis of cancer and other diseases.

GOLDMAN: 1970. That was exciting. Back in the 1960s we started building this thing [(cancer detection instrument)]. I had [to] design a radioactive waste treatment plant because I'm feeding radioactivity into the dogs and they don't just hang onto it: they excreted 98 percent of it; only 2 percent was retained. What are you going to do with all this radioactive poop?

So, we had to design the "radioactive poop machine," which is scientifically called an "Imhoff tank," which is a special sewage treatment facility at Davis. It had the unique feature at the very end, after biological digestion and chemical precipitation, that [would] run off all of the liqueur or effluent out through ion-exchange¹²⁸ resins, similar to water softener, which are designed to wash out all of the radiostrontium. First, you had to get rid of all the organic garbage; this was a very odiferous process. We had something about three times the size of this room—a 50,000-gallon tank, with compartments—and we got some of the sanitary engineers here at Berkeley to help us design this thing. Ed Edgerley and Warren Garrison—I think an engineer here. We cooked this thing up, and [Ed] actually got his engineering thesis out of it.

We had a running program. The radioactivity would now all be absorbed onto the ion-exchange resins, just like your water softener absorbs calcium. The resins were encased in sacks, like socks. When they were contaminated, we would take the socks out, package them up, and send them off to Hanford for low-level waste disposal. That's how we got rid of the radioactivity. It worked. We got "ten to the fourth" (10^4) decontamination: we left only one out of ten thousand atoms behind. It was very, very efficient. Then, at the end, I'd have this treated fluid, which met drinking water standards at the time for radiostrontium, which I then pumped out into a leaching field next-door. You've heard of the rear end [of] a fuel cycle, but this is the rear end of the dog cycle we had to take care [of].

HEFNER: The carcasses and everything also went up to Hanford?

GOLDMAN: There were no carcasses yet. The dogs [were] young and they were living a long, long time.

[But] when the animals died, we would do a careful autopsy and take samples. The residuals were kept in a big walk-in freezer. We had storage for all of the animals onsite. At the very end, when the program was finished—everything was closed—the remains were all sent up to Hanford for disposal. But early on, it wasn't considered waste; it was considered biological material, which we might want to go back to when other questions arose.

These animals got much better care than [First Lady] Hillary Clinton ever thought imaginable [for her proposed healthcare reforms]. This was cradle-to-the-grave, 24-hour surveillance, a staff of veterinarians, quarterly medical exams, annual physicals that were unbelievably sophisticated, even for people at the time. We had these batteries of blood

¹²⁸ the process of reciprocal transfer of ions between a solution and a resin or other suitable solid

tests—all kinds of good information—because we wanted to find out early indicators of late effects. We didn't find any. We also didn't find any radiation effects, except in the very highest levels. So the three lowest exposure levels, each of which was a factor of three higher [than the level just below it], these animals' life expectancy and medical history [were found to be] identical to the unexposed control.

GOURLEY: Were these dogs bred at all?

GOLDMAN: No. There wasn't enough money even in the rich AEC to do [a] generation study.

"Why don't you do the genetic effect?," [I suggested]. By the way, I forgot to [mention it that] back in Rochester when I was being taught, the dominant [long-term] problem to worry about was genetic effects, not somatic [effects]¹²⁹ or cancer.

The concept of linearity came out of H.J. Muller, who got the Nobel Prize for discovering the genetic effects of radiation in 1928. That [effect] was linear: The more dose he gave them, the more genetic effects he saw in the fruit flies. That is the origin of this thing of linearity, but it wasn't cancer. What he was really measuring [were] "initiating events." In cancer, you have an initiating event followed by a whole sequence of additional steps in the cell. Each of which has its own probability of being completed or repaired or not repaired. Therefore, it's not possible for low doses to be linear at the same slope as high doses because of this probability that each cell step is going to be in proportion to the initiating events.

Budget Concerns; Goldman's Other Radiation Research Projects (1965 to Late '60s)

GOURLEY: This is based on drosophila?¹³⁰

GOLDMAN: [No,] It's based on biology.

What drosophila was measuring was only the first step. These [fruit flies] are mature animals whose genetics [(genetic determination)] is all over with. It's all in the larval stage; the cells don't divide in [mature] fruitflies. In any event, that's a whole other seminar.

All these things really point to the fact that there is very little scientific support for linearity down to what I call a zero intercept, relative to what we know about. I did these studies at Davis, the program built up, and at its peak we had about a four-million-dollar-a-year program and maybe about 100 employees. I was the associate director under A.C. Andersen.

They [later] brought in a fellow from Hanford by the name of Leo Bustad, who was a veterinarian. He became [lab] director in 1965, and

¹²⁹ affecting somatic cells—any cells of the body that are not sexually reproductive cells

¹³⁰ any of numerous similar yellowish flies of the family *Drosophilidae*, which feed on the yeasts of fermenting fruit, used in laboratory studies because of its large chromosomes and short life cycle

I was his associate director. By that time the program [was] more sophisticated and the project became a radiobiology laboratory. We had built up a 25-million-dollar facility over the years.

I think I calculated once [that] I personally brought in about 60 million dollars [during] my whole scientific career, which I think was a record. If you use 1950, 1960 dollars. So I felt good about that. This was a unique study because the AEC had never funded something that went on and on and on. Usually it's a two-year grant or three-year grant.

These "founding fathers" would meet annually, and we would review the progress of these studies and occasionally add some subsidiary or ancillary studies to it. In their infinite wisdom, they [in effect] said, "Whatever the budget is on doing this, we realize it's not exciting and you're not writing a paper every year. The crème de la crème is going to be one master paper 20 years later, and in order to keep you from converting to vegetables, we'll sort of look the other way, and you have about ten percent of the budget to do other radiobiological things. [But] don't interfere with the sacred dogs." [In other words,] these animals were not to be used for every hairbrained idea you came up with. So we had a few extra animals that we could do studies on, including learning how to do cancer detection and a whole bunch of stuff.

I had to learn about the radiostrontium in bone. I had to actually do the strontium, elemental strontium. Strontium-90 doesn't just go in by itself: it's diluted with a pool of stable, nonradioactive strontium that's in all of us. How do you measure it? There is no easy way to measure it. So I went to the geologists and they said, "Well, we can use an x-ray-diffraction fluorescent gadget." So I learned about x-ray fluorescent spectrometry.¹³¹ We bought an x-ray spectrometer and I started measuring elemental strontium. This way I could talk about the strontium-to-calcium ratio on a mass basis, as well as radioactive strontium per gram of nonradioactive calcium in bone, as a way of learning about the doses.

I actually got [a] patent on how to detect strontium and correct the background interference in an x-ray fluorometer.¹³² That was another serendipitous thing. I went in and found out how to use something called "Bragg's Law,"¹³³ which was a fundamental piece of nuclear physics that I was taught in Rochester, to solve a biological problem. It was

¹³¹ the use of a spectrometer, an optical device for measuring wavelengths, deviation of refracted rays, and angles between faces of a prism

¹³² an instrument for measuring fluorescence, often as a means of determining the nature of the substance emitting the fluorescence

¹³³ Bragg's Rule defines an empirical relationship whereby the mass stopping power of an element for alpha particles is inversely proportional to the one-half power of the atomic weight. The rule applies to other charged particles.

really nice; it worked. So hey, the AEC was so happy they gave me a dollar bill for the patent. Unfortunately, it wasn't a transistor chip.¹³⁴

[There] was another sideline. I discovered that when you thermally ashed tissue, which we had to do to get the radioactivity measurements, if it was from a pre-tumor tissue and, you then ran this [thermoluminescent]¹³⁵ spectrometer on it, it was different [from] normal tissue. Along about that time, we had discovered a dosimetry technique called thermoluminescent [dosimetry]—TLD. Thermoluminescence dosimeters replaced film badges¹³⁶ as a means of detecting radiation. It turns out that anything that's a crystal, when irradiated, certain electrons rise up [to an excited state] in a lattice. (I'm sure you remember your physical chemistry background.) They stay there, but if you then warm up that crystal and heat it, the electron drops back to the resting state; and [in] dropping back, [it] emits light. So the light output was proportional to the input of radiation. This is the technique called TLD, and these crystals are used over and over again. You'd sit around getting dosed all-year-[long] and you put the [TLD] in a dark box with a phototube looking at it, and warm [it] up on a certain cycle. The light [is emitted in proportion to] the radiation that had gone in, and you got a very uniquely linear sensitive [response].

HEFNER: And that came from your lab?

GOLDMAN: No, it came from somebody else. What *I* said was, "Why do have to use lithium fluoride?" which is the crystal that's used, which is very sensitive. It should be *any* crystal. So I said, "When we thermally ashed this tumor tissue, what is left is powder, but the powder [contains] crystals in it that are formed by the heat." So, I was irradiating the ash from the tumor tissue and from normal tissue and then, pretending it was a thermoluminescent dosimeter, putting it into the dark and heating it up, and light would come out. Interestingly, the amount of light that came out was proportional to the amount of carcinogenicity¹³⁷ in the tissue, whose cancer quality had disappeared when we put it in the oven and ashed it.

So then I had a friend of mine who was doing [a] mouse cancer study give me some blind [(coded)] tissue. I had 17 samples of tissue. *I* didn't know what they were, [but] *he* knew what they were. I ranked them all, and I came out predicting which were the cancer [samples]. I said, "Well, we all know that cancer cells concentrate calcium more than normal cells, so I must be looking at calcium salts [rather] than calcium crystals." We did an x-ray fluorimetric examination, and it wasn't calcium: it was a kind of potassium crystal that's formed in cancer cells.

I said, "Hey that's exciting. Here is a way of taking a biopsy, and when it's questionable, you can do this test and find out which side it flips!"

¹³⁴ The patent on the transistor, a solid-state semiconductor, went on to be quite profitable for its inventor, which was not the case with Goldman's patent.

¹³⁵ becoming luminescent when heated

¹³⁶ dosimeters worn routinely to measure accumulated personal exposure to radiation on photographic film

¹³⁷ the likelihood of inducing cancer in the live animal, as well as the aggressiveness or severity

Along about that time, we had another annual report to write, so I stopped that research and went on and did something else that was new and never finished it. It's one of those Nobel Prizes that you never had a chance to do. *(laughs)*

I really got involved in radiation hematology¹³⁸ and leukemia [science], and I learned a lot about bones. I did some of the best work on it and I wrote a book in 1972. I continued to become lab director [in 1973] and in 1985 I decided I had [over] 30 years of this, and I retired. [Later, I was] recalled [to] the University system, and I've been doing [work] with the Russians ever since.

And, what [were] they doing? Feeding people strontium-90 in Chelyabinsk, [an Asian city near the] Ural [Mountains and one of the Russian centers for plutonium production]. They'd been doing it since 1950, and [of course] they didn't know it [at the time and perhaps then] they didn't care. So I have now seen [a parallel] in the human studies in Russia. Unbeknown to me, they were doing in humans what I was doing in beagles. When Yuri Moskalev from Moscow came to visit me in 1960, he was taking pictures of my whole-body counter. I didn't know that when I visited Chelyabinsk in 1991 I would see my whole-body counter in this secret city, used to count people the same way I was counting beagles. And so, I have a kind of internal commitment now to reach closure, because I know about the dosimetry and all of the basics [of what] they're doing from the other end, epidemiologically.¹³⁹

Of course, it wasn't a planned study [in Russia]; this was [the way] during Stalin's era. There was no retention of radioactivity [on the site]: it just went out the back door, into the stream. The stream went by the villages—the village [dairy] cattle were eating the grass that was contaminated by this [and then] feeding [the contaminated milk] to the kids. To this day, I can go up to [those] kids, who are now 50 years old, with a Geiger counter against their teeth, and it goes off-scale because of the radiostrontium that's buried in their enamel that will never [be eliminated,] and many of them have died of leukemia.

And, that's where I'm going in January to continue the studies that we've been doing there. So, there is a human-study evolution here, and the DOE is involved now in a collaboration exercise called the Joint Coordinating Committee for Radiation Effects Research, which may be a [supplement to] the Hiroshima/Nagasaki [cooperative efforts] that DOE is doing—may [be] an expan[ded program]. They may add the radioactivity question, because the DOE's problems today are very much intimately involved.

The problem that you're facing is primarily an ethical one. Did things get done in an unethical way, without the equivalent of informed con-

¹³⁸ the study of the nature, function, and diseases of the blood and of blood-forming organs

¹³⁹ the branch of medicine dealing with the statistics of incidence and prevalence of disease in large populations and with detection of the source and cause of epidemics

sent, even though it wasn't codified as it is today? The docs [(doctors)] really didn't say anything to their patients or should have.

There is another facet of this that says that if you're an innocent bystander living downwind from something and the AEC is spewing stuff out and you're being inadvertently exposed—this is not a designed study now, this is just unfortunately being downwind when [you] should be upwind. Do we have a[n ethical] problem there [that needs redressing]? And I don't know whether that's excluded specifically from your [DOE] mandate or not, because I think you're dealing primarily with experiments, in which there was a purposeful administration of radioactivity or radiation, rather than accidental or inadvertent. But the public perception doesn't make that distinction.

GOURLEY: Yeah, you're right about that.

GOLDMAN: And so, the lesson learned from this is: You're not going to be able to compartmentalize these and keep them apart: it's all related to perception. My upcoming article (I have to give a plug for this *Health Physics Newsletter*) is that the politics of perception does not link to the science of detection. I wrote a whole essay on that and brought this thing up. What we're learning from these human studies, I think, is that although these studies may have wronged people, in that they were not informed—even informally—[it] is not necessarily true that they were harmed. If they were wronged, in my opinion the United States owes them an apology. And, if they were harmed, which is different than being wronged, it's possible that some kind of compensation scheme has to be thought up. But I don't believe, and I would never support the idea of a compensation scheme because you were wronged.

So now, we're back to how do you prove harm, and back to linearity. If you got dosed, your molecules [were] disturbed, therefore you were harmed, therefore we pay. We would pay in proportion to dose and you don't have to show anything clinical[, but] I think that's ludicrous. It's not acceptable, because I could demand that God give me money for the disturbance of my DNA from cosmic radiation. It's no different—my DNA doesn't know one ionization from another.

Enough philosophy; I could go on and on here.

I think it's really important therefore that we do what we can to educate. I've been very disturbed that the publicity with your program has come across that we were really doing "megadeath for the kiddies" and we were really abusing, truly abusing in [a] callous manner, defenseless subsets (of the population). I know some of the work of Eugene Saenger¹⁴⁰ is being

¹⁴⁰ Dr. Saenger, a medical doctor, is an expert on radiation effects, acute radiation syndrome, and the proper response to radiation emergencies. Presently, he is a professor emeritus at the University of Cincinnati. His participation in NASA-sponsored studies of low-exposure-rate total-body irradiation (LETBI) led to charges that his therapeutic doses, like those administered by Oak Ridge's LETBI facility, were dictated by NASA's needs rather than by the needs of his patients.

questioned and the thing with the prisoners [in Oregon and Washington], whose testes were irradiated and they gave them a few bucks for doing it.

Davis is near the [California] wine district. There is a big prison down the road called Vacaville, and some[one] who was running the Medical Research Foundation in Vacaville was [using] prisoners for different studies. I was approached in 1965 to see whether I would be interested in helping them do a study in which they would grow grapes with radioactive iron in the soil and see if the iron got into the wine. Then they could see if wine increased the absorption of iron in people who might have iron-deficiency anemia. They proposed using these prisoners by bringing them up to my whole-body counter and count the radioiron; it [(the proposed procedure)] was very noninvasive. They'd drink the wine—lousy wine, but they'd have a drink of wine and we would do this [study].

[The] Vacaville [facility] is for mentally disturbed prisoners—many of them are in there for civil, crimes not violent ones. I didn't have enough confidence that I would only get nonviolent people, and I had this vision of something going wrong and me being held hostage, or something worse happening. I also wasn't comfortable with the way they were doing the dosimetry and things.

So I said, "It's very interesting and it probably would be a nice little 'gee whiz' study. Thanks, but no thanks: I'm not going to do it." And I killed it.

And now they hate me—I forgot what his name was, but boy, I gave Vacaville a bad name, and there was never going to be any more studies.

I understand later a man was relieved of his duties because some of the other studies had not gone well, but I don't know—this is hearsay. This is as close as I got to a "Fernald [School]-type" study. The University administration said, "Yeah, you can do that. You know you have to follow the rules." There were risks all the time. We had [Handbook 52,] which was a precursor to 10 CFR 20,¹⁴¹ and it told about the different doses [from radioactivity intake]. The National Bureau of Standards¹⁴² *Handbook 52* was the first catalog [of] radioactivity doses, and one of the things that went into ICRP¹⁴³ [*Publication 2 (1959)*], which then got codified in the *Code of Federal Regulations* as 10 CFR 20, which today is still our legal guidance for the use of radioactivity.

I didn't do the iron-59 study and they were promising me all kinds of control wine—I could get [it] without the iron in it—I said "No," I think. And we were going to bring in some money to the University. There was a lot of money—I guess it was the Wine Institute, or whatever the indus-

¹⁴¹ 10 CFR 20 provides the Federal regulations dealing with protection of workers from radiation; CFR specifically stands for the Code of Federal Regulations.

¹⁴² In 1988, Congress changed the name and mission of the National Bureau of Standards to the National Institute of Standards and Technology (NIST).

¹⁴³ International Commission on Radiological Protection

try group is for the wine growers. And to this day, there is still a large sentiment that consumption of a glass of red wine a day does improve the absorption of iron. There is a lot of data now to support it, not derived from prisoners, though. But that's as close as I got to being a case in your laundry list [of villains].

The other thing I did with humans with radioactivity was with their own radioactivity. During the late '60s NASA¹⁴⁴ was going to send astronauts into deep space, and we know that if you are in a weightless environment your muscle mass decreases and you suffer from something called *disuse atrophy*. We also know that muscle concentrates potassium-40, and fat does not. One out of every 2,000 potassium atoms on this planet is radioactive [and has] a several-billion-year half-life. Therefore, if I put all three of us into a whole-body counter and measure body potassium, the potassium per kilogram of body weight is an indication of your muscle mass. If your surface-to-volume ratio has deteriorated the way mine has, I won't have as much potassium-40 per kilogram of body weight as I did when I was young and I was a lifeguard.

So if we have these astronaut candidates who are on a long flight and they come back with atrophy, we don't know if they are full of water or if they are full of muscle, [as] they have the same body weight. So instead of measuring skinfold fatness, you would do this: dip them in a tank and see how buoyant they are. A lot of these [are] crude tests. "Why don't we do the potassium-40 [⁴⁰K]?", I reasoned; "it's noninvasive."

I did several studies with Ed Bernauer, who was the professor of Physical Education [at UC Davis]. He got a NASA grant to do this. It was called a bed-rest study. We had one group of student volunteers who volunteered to be paid to lie around in bed for three weeks. These [students] were in the athletic department.

Those were the good old days: We found that some of the students weren't [as] inactive at night as we'd hoped and that their girlfriends were visiting. It interfered with the quality of the study. That's not going to appear anywhere in print.

So we had this group of ten [men] who were active athletes, and ten others who were matched as well as we could, who were asked to then sit inactively for a month, and I would count them weekly and get their ⁴⁰K count and see how it would work out. But [we were doing] a radioactivity [study] in which the people brought their own radioactivity to the laboratory, and we didn't add anything: we just counted what was there and what got lost. That's probably the only study in your list that's going to show human studies on radioactivity where the investigator didn't add the radioactivity, it just [is a natural part of our bodies].

GOURLEY: Why athletes?

¹⁴⁴ National Aeronautics and Space Administration

GOLDMAN: Because they have a lot of muscle mass, and people who are astronauts are generally not flabby AARP (American Association of Retired Persons) members; they are people who are in their prime, pilots or military [personnel]. And athletes have a hell of a lot of ^{40}K —they've got a lot of muscle mass—and an athlete who goes out of training drops off the peak more quickly than someone like me, who's sedentary and who doesn't have that much potassium to lose to begin with. The [potassium-40] signal-to-noise ratio would be less ideal, so that's why they did that. [We found no real ^{40}K loss effect of bed rest.]

I also did some studies in which children who had Duchenne dystrophy, which is a kind of muscle disintegration disease, were brought in, and we [would] count their ^{40}K and see how it related to other children, who didn't have it. These were unique studies, in that no radioactivity is administered to the patient: the patient's natural potassium is the indicator that you're looking at, and it's noninvasive testing. I'd put a little speaker in the whole-body counter—you know, you've seen them, it's a big iron box—you close the door and the kid would get scared, so we had a light in there and a little television set and we'd play cartoons for them and have music. These counts were long, maybe half an hour or an hour to get a significant [count] level.

So those were about the only human studies I really ever did. Either looking at the natural radioactivity, participating in a planned administration study that didn't happen, or relating the animal studies that I was doing to the human data that was not available.

Involvement With Army Nerve Agent Toxicology Research (Early '70s)

HEFNER: In reviewing some of the literature about you, it also appears that you worked at some time with the Army on Dugway [Proving Grounds]¹⁴⁵—nerve agents?

GOLDMAN: No.

HEFNER: Help me out here.

GOLDMAN: I had a big laboratory and we had some very sophisticated cell toxicology models, so toward the end, when the radiation studies were in their final stages, there wasn't any administration [of radioactivity] going on—just minding the store, doing the autopsies when necessary. We got into some in vitro¹⁴⁶ studies and test tube studies, using cells and culture.

Again, back to this carcinogenicity thing, we were looking at genetic toxicology in vitro. Remember now, the AEC had become ERDA [in the early '70s], and ERDA had become DOE [in 1977], and DOE had now gotten diversified into, guess-what—fossil energy [(coal, oil, and natural gas)]—and we had this big thing during the '70s of an increased interest

¹⁴⁵ Operated by the U.S. Army, Dugway Proving Grounds is the field test site for U.S. chemical warfare agents.

¹⁴⁶ developed or maintained in a controlled, nonliving environment, such as a test tube

in alternative energy sources, whereas the origin of this [Laboratory] was atomic energy.

We got interested in coal fly ash and some other things that had a parallel carcinogenetic potential to what we were doing in radiation. So we developed this whole battery of in vitro tests, where you take salmonella¹⁴⁷ or you take bugs and you put them in a petri dish¹⁴⁸ and then you add some coal dust or some other things and see how many of them mutate.

This is a standard battery of these test. We had perfected this during that brief era when [ERDA] was interested in finding out whether other energy sources had long-term health effects. This was at the time [of the] Arab oil embargo and oil was in short supply.¹⁴⁹ We were going to increase the use of coal, but we know coal has only two things wrong with it: You can't [safely] mine it and you can't [safely] burn it. So we would try to see what we could do about clean coal and what happens with fly ash.

We had discovered that fly ash was carcinogenic—well, it was mutagenic [(causing mutations)] to cells, and therefore the question is then whether it was carcinogenic to people. People are not sniffing around sitting coal fly ash.

We found that the smaller the particles, the more they mutated per gram [of ash]. Obviously this was something on the surface of the particles: When you have a gram of small particles, you have a lot of surface compared to a gram of large particles. Unfortunately, the small particles are the ones that get inhaled. It doesn't take an advanced course in imagination to see it. We were onto something.

We wrote some papers on it and made the cover of *Science Magazine*. We started to do inhalation toxicology studies on animals, at the time, that DOE decided this was enough. So all of the funding on that died, as it will again this year with DOE's present budget—assuming DOE survives, because there are some persons that would like DOE to go away. That's one of the plans—to reduce [the] number of Cabinet agencies [and] make it an administration like EPA [(Environmental Protection Agency)] or NASA; but we'll talk about politics after the tape recorder is off.

We have this big program of a battery of these tests, and suddenly I find out that the [U.S.] Army is interested in finding a secure laboratory in which to perform some test on nerve agents. Why? We have 50 thousand tons of [nerve agents] sitting around, and we have to demilitarize it, and we don't know if the people who will be involved in demilitarization will be at risk for a carcinogenic potential.

¹⁴⁷ any of several rod-shaped bacteria that enter the digestive tract in contaminated food, causing food poisoning

¹⁴⁸ a shallow, circular, glass or plastic dish with a loose-fitting cover over the top and sides, used for culturing microorganisms

¹⁴⁹ In response to the United States' military and political support for Israel during the 1973 Yom Kippur War, member states of OPEC (Organization of Petroleum Exporting Nations) refused to ship crude oil to America. The acute oil shortages that resulted led to the first gasoline rationing since World War II and public demands that the nation diversify its energy base.

We know about the neurotoxicity [(tendency to kill nerve cells)].¹⁵⁰ No one ever tested these compounds to see whether they were [also] carcinogenic. I always felt if you got enough of them to get carcinogenic you would die because you had already been zapped by the nerve gas. Well, not quite so—you're dealing with tons of this stuff—a little goes a long way.

So I got a contract with Fort Detrick, which is the Army Chemical Warfare Center [in Frederick, Maryland)]. There was a medical research branch, and [the] contracting technical [scientist] who did this was Jack Dacre. He was a New Zealand toxicologist¹⁵¹ and he [came to] us because we had all of these tests ready to go, and he had all these compounds ready to be evaluated.

So I got this nerve agent money as a "work for others" (is what DOE would call it) program and I was doing a whole series of [tests] on very [nasty (toxic) agents] called VX, GA taboons sarin. These are the worst nerve agents. These are the terrorist dream agents. We had a whole Johnson Island full of 50 thousand tons of nerve weapons in case we ever got into that, and now we [had to] clean it up.

We were going to build some incinerators or something like that, and my lab got little bits of it, under very careful scrutiny, even more careful than we had [when working with] the radium and strontium. We were designed to handle things like radium and strontium so we knew about those types of [security/safety] protocols, which most universities don't do. I had special wash-in, wash-out facilities and airlocks [to do] those studies and it brought in a few million dollars to help the Laboratory at a time when the interest in doing these long-term, low-level [radiation] studies was going away. It's gone now.

Now we do epidemiology, hoping that we are going to find something, and we don't know enough about the mechanistic studies. We're in transition.

There [were] also some of these studies going on at Hanford, at some of the DOE Lab sites; because of the security in there, [they] were places where you could this. You couldn't have such work done on any campus and you couldn't do it in-house, otherwise it wouldn't be credible [because of a perceived conflict of interest].

These were what were called GLP studies (good laboratory practices). They had a complete track record and all that, with very accurate book-keeping, which we had already done before that phrase had been invented (since 1960 with our radiation studies). We had a daily log, complete records-keeping of that study. [The dog studies] went on, and [as] those [were] finished up—we got quite a few interesting papers out of it and got involved in the toxicology club. We just finished [the nerve

¹⁵⁰ tendency to interfere with central nervous system function, or to paralyze the central nervous system

¹⁵¹ a scientist who studies pharmacology, examining the effects, antidotes, detection, etc., of poisons

agent studies] a year ago and then I stepped down, a fellow named Alan Buckpitt—a toxicologist at Davis—continued, and we wrote them up.

That's it—I wasn't at Dugway. I *know* about Dugway—I know a lot about Dugway.

Patricia Durbin's Research

GOURLEY: You were also on the committee to look at Pat Durbin's work—the decision I guess to do the follow-up work?

GOLDMAN: Where did you get that? Is this something *I* wrote or something *you* wrote? I wasn't on that committee. I know about Pat Durbin's work but— (*sarcastically*) is this *my* résumé that I gave you?

GOURLEY: Some things came from that, and some things came from other sources. There might be—

GOLDMAN: Look— (*points to a folder of papers including his curriculum and list of publications*) this file is thicker than my security file.

GOURLEY: It might be something someone in the office [(Office of Human Radiation Experiments)] someone thought was true. Ah, I see where it came from now.

GOLDMAN: Where? Show me.

GOURLEY: It's something someone else thought.

GOLDMAN: [No, I was not involved with Pat Durbin's committee]. I have reviewed her work and I spent many a day with Pat Durbin because she's doing metabolic curves of [excreta from] plutonium patients that she'd been tracking.

GOURLEY: Tell us about the review.

GOLDMAN: When you say "review," that has a formal connotation; this is *informal*. She and I are sitting in her office and we're reviewing it together. I'm not part of an evaluation team that has come in to look at her program. I never was. There is a little incestuous group of maybe 20 of us who know about this business, so we all have been interacting, all through our careers—informally and collaboratively.

I was counting some of her monkeys in my whole-body counter. I was reviewing with her some of these metabolic models that she had come up with for the human follow-up studies, where she'd do the excreta analyses with Marilyn Williams, her assistant. The [studies] I was doing with dogs matches what they were doing with people.

We would have these periodic get-togethers, and one of the things we would do is that all the dog lovers would get together about once a year. We would have a group meeting during the course of these studies, headed up by the Robley Evans/Wright Langham team, the "foundering floundering fathers" we called them; it was ongoing. The AEC assigned

a fellow by the name of H. Dave Bruner¹⁵² to be the DOE coordinator on this. I believe he is retired in Florida. I'm not sure if he is still alive. Robley Evans, I heard he's [not well]. His wife died about a year ago and he married Mary Margaret McClanahan, his secretary for 45 years, and he's got a bad heart.¹⁵³ He must be pushing 90.

Work With Chernobyl Nuclear Plant Accident (1986-88)

HEFNER: You also worked on the Chernobyl nuclear plant accident.¹⁵⁴

GOLDMAN: Oh, yes. I taught a course called the "Bioenvironment Significance of Nuclear Technology." Marvin's "nukey" course in environmental studies at Davis for 20 odd years. Every spring. In the spring of '86, I was about to do the lectures that week [on] radiation accidents. I was going to dust off my Three-Mile Island¹⁵⁵ slides and SL-1¹⁵⁶ accident and all that. And it's Friday night, and I get this news flash that Chernobyl had blown up, and that there were 2,000 dead people in the streets [of] Kiev, and that it was awful and that it was like a nuclear war had gone on.

So I said, "Well, being a good professor, we're going to track this one." By this time, I was well-enough connected [and] I could get information in a hurry. I, as they say, got into the loop and wrote a scenario for my class. I said, "Okay, we know about radiation effects if it's 100 miles away and it's 2,000 dead people, inverse square [law],¹⁵⁷ etc. How much radiation?" I put this position paper together about airborne, waterborne,

¹⁵² a physician at AEC. As the head of the Medical Branch of AEC's Division of Biology and Medicine, Bruner was involved with reviewing research programs at the National Labs.

¹⁵³ Evans has moved to Scottsdale, Arizona for health reasons.

¹⁵⁴ a Ukrainian city in which a Soviet-designed graphite-moderated nuclear reactor in April 1986 sustained the world's worst radiation accident to date. At the reactor site, 31 workers and firefighters were killed. According to contemporary Soviet assessments, 1,000 square kilometers (370 square miles) of land were contaminated, 135,000 people and 86,000 head of cattle had to be evacuated, and fallout spread to 20 countries. An international effort to aid the victims and contain radioactivity at the site ensued, including sharing of technology and research.

¹⁵⁵ a nuclear power generating station 10 miles from Harrisburg, Pennsylvania, owned and operated by General Public Utilities, Incorporated. On March 28, 1979, a combination of system failure and human error led to a partial meltdown in one of the station's two 1,000-megawatt pressurized water reactors. As one consequence, radioactivity was vented into the air. The event at Three Mile Island is the largest nuclear power plant accident to have occurred in the United States to date.

¹⁵⁶ The SL-1 (Stationary Low-Power Reactor) was a 3-megawatt prototype military reactor that was being developed at the National Reactor Test Site in Idaho Falls, Idaho, as a power source for remote bases. On January 3, 1961, while a military crew of three was reconnecting control rods for a scheduled restart of the reactor, a steam explosion occurred that killed all three crew members. These were the first deaths caused by such a reactor accident in the United States. For an extended discussion of the SL-1 reactor accident, see "Fatal Worker Accident at Idaho's SL-1 Reactor (1961)" in DOE/EH-0454, *Remembering the Early Years: Interview With Dr. George Voelz, M.D.* (May 1995). For a discussion of the recovery of the bodies, see "Investigations of Radiological Accidents" in the Lushbaugh transcript (DOE/EH-0453).

¹⁵⁷ Radiation obeys the inverse-square law: through dissipation, its magnitude abates with the square of the distance from its source. It was known how much dose would cause the near-term deaths of 2,000 in a city the size of Kiev. By knowing how much dose reached the city, located 80 miles southeast of the accident, and considering a few other variables, Goldman's students could extrapolate the dose at the source and calculate how much radiation had been released.

and external radiation, and internal radiation and the time, distance, dose rate, and situation. These are the things we have to do. What about the environment? What pathways do we have to deal with? What radionuclide comes out of accident?

I was a coauthor of what's called the "Rasmusen study," the reactor-safety study [(WASH-1400)¹⁵⁸]. This is the basis of all of our stuff, and I was senior on the late-effects modeling.¹⁵⁹ I had all of this experience, and I had been in a lot of reactor licensing hearings, over the years, debating a fellow named Ernest Sternglass. I would be dragged in—because I had all of the strontium experience—to challenge him on what he would be saying about strontium-90. I always won, but he always reappeared like a phoenix—that is another chapter.¹⁶⁰

But I handed this out on Monday and in a moment of weakness, which I've regretted ever since. I faxed a copy of it to DOE in Germantown and I was being funded by Office of Health and Environment Research [(OHER)] of ER, and they passed it around because there was a lot of crazy stuff going on and nobody had really done anything. A lot of secret committees [were] trying to figure out what [had gone] wrong with the reactor. It was all physics; I was the only one doing a bioenvironmental [approach].

About a month later I get a phone call, I guess it was Bill Bair.¹⁶¹ He said, "Marvin, we've gotten hold of this thing you wrote and your numbers are all terrible." He used other words for it—but you got the right idea. "How would you like to do it right?" I said, "What do you mean?" He says, "We want you to head up a committee to look at the effects on the populations of the global impact of the accident and go to it, and we're going to put out a DOE report."

GOURLEY: What made him think your numbers were all *wrong*?

GOLDMAN: Because there weren't 2,000 dead people and there weren't megarads of radiation out there. But I had all the pathways.

HEFNER: The initial reports were wrong.

GOLDMAN: So the generic elements that you need were correct. The *specific data* that I used were all wrong. It was what you get in the press, (it's just like what you read today about these human studies,) all wrong.

¹⁵⁸ A WASH number paper was an official AEC research report widely distributed to libraries, usually dealing with nuclear health and safety.

¹⁵⁹ modeling of biological effects that do not show up until months or years later

¹⁶⁰ Sternglass had performed some calculations and was cited in *Esquire* in a article entitled "The Death of All Babies." His estimate was that 400,000 children would be hurt with genetic disease as a result of the weapons program. For a discussion of that article and AEC's response, see "The Nuclear-Armed Antiballistic Missile Controversy" in the John Gofman transcript (DOE/EH-0457, June 1995).

¹⁶¹ Dr. Bair managed the U.S. Department of Energy's (DOE's) Environment, Health, and Safety Research Program at Hanford from 1975 to 1990.

I contacted [some colleagues], and we got 20 scientists from ten different national labs all over the United States together and I organized the whole matrix about the accident. We wrote a 300-page report in 1987, which was the *Global Impact*—it's in this CV [(curriculum vitae)] thing; 0332 or something *Report*. I got Lynn Anspaugh and some others involved, and it was a lot of fun.

Unfortunately, we had no data from Russia: this was still [the secretive Soviet empire, the] USSR, and so I had this task of literally getting all the pieces and trying to put Genie back in the bottle to see what the bottle was like.

[In] 1987 we put [it all] together, [using a] report from Finland, and a report from Sweden, and everyone was using different numbers, and everyone was screaming about the [mutant] reindeer, or the [giant] mushrooms, or the [huge] strawberries or whatever it was. We would try to get it together and identify what was to be done. Then Lynn Anspaugh and Bob Catlin and I, (we were really the core of this), decided we ought to write this up; and so we condensed it and put it out as a premier invited article in *Science Magazine* in December of '88, and so that was really the only full global report about Chernobyl. Since then, the IAEA¹⁶² and UNSCEAR¹⁶³ and others have tried to do this, but what they've done is essentially get the French report and the Russian report and this report and they put them together. By this time, I got to be known as someone in the "Chernobyl Club" and got invited to Russia in 1988 to attend [a] medical conference that was run by [Dr.] Illyin.

In May of 1988, we were invited to this medical conference[, in Kiev,] sponsored by the Health Ministry in the Soviet Union and we stayed at the Inepro Hotel, which is an Intourist¹⁶⁴ hotel. We went to the session and I finally got some input from the Russian side. I had previously gone to the first meeting in August 1986, right after the accident. It was a big IAEA meeting in Vienna, [Austria,] on Chernobyl, and this was the first time the Russians spilled their guts and told everything. Up until that time, they had said nothing. So they said, "Okay, we'll talk to you, but we're not going to talk until we get to Vienna."

I got to Vienna from Tonga[, the former British protectorate] in the South Pacific (which is a another story because I was on [a sailing] vacation). I got this cable to [go] to Vienna. So the flight [to Vienna] from Tonga where the Capricorn Tropic crosses the [international] date-line and there is no airport—I was sailing, I am a sailor—[from a] chartered sailboat to Vienna is an odyssey that is a story unto itself.

¹⁶² International Atomic Energy Agency, an organization of the United Nations headquartered in Vienna, Austria

¹⁶³ United Nations' Scientific Committee on the Effects of Ionizing Radiation; it has prepared several compendiums of information on the biological effects of radiation, called UNSCEAR reports.

¹⁶⁴ the Soviet agency responsible for hosting—and watching over—foreign visitors

But I got there in 24 hours, bedraggled, and we sat through these things, and I met some of the Soviet scientists, and we had some sidebar conversations and it was all very hush-hush.

[President Mikhail] Gorbachev had just come in[to office], and we were just learning about *glasnost*¹⁶⁵ [(openness)] and *perestroika*.¹⁶⁶ We wheedled a little information out of [the Russians] and came home and wrote a report. Then [we] got this [paper] out in [*Science* magazine] and I've been tracking it ever since.

I'm an advisor to [the Russians] now. I know most of them on a first-name basis and I've had a [group] of them come over here in 1994, and I got a grant from Soros International Science Foundation [to bring] 20 of them to San Francisco, at the Health Physics [Society] meeting last June. I [hope] to bring 40 of them to our meeting in Boston in July [1995]. Maybe [DOE Assistant Secretary for Environment, Safety and Health] Tara O'Toole will come again, as she did the last time.

In doing this, we set up a program on the late effects in humans. One of the facets of the Joint Coordinating Committee on Civilian Nuclear Reactor Safety, which was an agreement between the Soviet Union and the United States run by the Department of Energy and the Nuclear Regulatory Commission to look into these activities. One of these, Working Group 7, was to look into the biological and medical effects of it. When the Soviet Union dissolved, that treaty sort of evaporated, and it's been sort of wandering in the desert looking for a home until this year, when we signed a new agreement with the Russian Federation, called the Joint Coordinating Committee on Radiation Effects Research, which is not confined to Chernobyl but is now looking at Chelyabinsk. The Chelyabinsk experience is the full enactment of every worst-case [occupational health and safety] scenario DOE ever had about the Fernalds¹⁶⁷ and the Hanfords and the Pantexes¹⁶⁸ and the like, because they did all the terrible things in the early days.

I went to Russia periodically on the Chernobyl [program] because I had this grant and I held a workshop, where I brought some Russians over and we talked about the human studies on people who were inadvertently exposed in the early days, when [the USSR's] industrial hygiene practice and radiation regulation enforcement was very limited. Perhaps [it was] due to ignorance, or perhaps just due to Stalin's insistence that they go ahead and get this bomb built quickly—regardless of the cost.

¹⁶⁵ the declared public policy within the Soviet Union of openly and frankly discussing economic and political realities: initiated under Mikhail Gorbachev in 1985

¹⁶⁶ the program of economic and political reform in the Soviet Union initiated by Mikhail Gorbachev in 1986

¹⁶⁷ Feed Materials Production Center, a uranium processing facility near Cincinnati, Ohio, that was part of the defense nuclear fuel cycle. Former workers have filed a class-action suit, claiming they had not been informed of the dangers of working with uranium; for a detailed discussion of the Fernald suit, see DOE/EH-0456, *Human Radiation Studies: Remembering the Early Years; Oral History of Merrill Eisenbud* (May 1995).

¹⁶⁸ Pantex is a DOE weapons final assembly plant in Amarillo, Texas where nuclear weapons used to be assembled but now are taken apart as required by current arms reduction treaties.

In the period from '49 to '52, millions of curies of radioactivity were discharged into the environment, and everybody who was downstream and downwind got some.

There was an explosion called Kyshtym¹⁶⁹ in 1957 that lofted a couple of million curies out of a waste treatment [facility somewhat] similar to the Hanford tanks and dosed another quarter of a million people [with radiation].

Then there was a hurricane ten years later, [in] which [they were dosed from a] dry lake bed that had previously been in an impounding pond for radioactivity. [The re]suspended dust dosed another 50,000 people.

And then there were these villages along the Techa River, which goes into the Iset, which goes into the Ob, which goes into Arctic Ocean, all of whom who are being dosed. The further away you get, the smaller the dose. [In a sense], you almost have a design experiment and the [villages] in close are showing increased leukemia and cancer risks now.

Then [there is] the plant that caused all this, called Mayak, in which "only" 10,000 of the 12,000 workers were overexposed; in which a dozen or so were killed by plutonium inhalation and [perhaps] another 50 are walking around with plutonium[-induced] burnout fibroses of the lungs. None of [this] has ever been recorded in the West. Workers were receiving [(were exposed to)] 200 rads per year, in occupational external exposure, to say nothing about the undocumented [added] internal exposure, and [then they] were fired because they were too tired to work. And they had accumulated doses of 400 rads.¹⁷⁰ This is not linearity down in low doses, and so those medical—

GOURLEY: Where does it stop being linear?

GOLDMAN: That's what I'm leading up to. The thing that I want to see our government do is to work out a collaboration with these people, who are now willing and interested in retrospective dosimetry and in doing the epidemiology study correctly, because the way they did their [preliminary] studies was not acceptable to Western standards. To preserve the data, which are not all on electronic media, and which are in rooms like this, full of chain smokers and paper records, and that's the only record there is. They kept very good records, but no one ever put them [all] together because Room A was not allowed to talk to Room B, and if you moved from A to B your B record stayed there and your A record—

GOURLEY: So secrecy was a problem?

GOLDMAN: It still is. [I am] going to the conference in Chelyabinsk January 9[, 1996] to talk about chronic radiation sickness, first time ever, and we'll get some [more information about the accidents]. They [may wish] to sell it [(infor-

¹⁶⁹ an event covered up by the Soviets for many years, apparently a chemical explosion involving a large tank of uranium solution

¹⁷⁰ In comparison, the limits for occupational exposure of workers to radiation range from 2 to 5 rem per year for most countries.

mation,) and get DOE to fund the research effort,] and the United States [may] not [be] too happy about what the price tag might be. We still don't have a means of getting [access to] that data, but I'd like to see it because it started in the '40s and so [the long-term effects are] all over; you don't have to wait 50 years to find out if something happened.

It's just, is the data there? Is it credible and is it believable? Because it's long-lived radioactivity, you can validate things by measuring people. You didn't have to just take the written word, so if they [(the KGB)] doctored [any of] the books, you could check that out quickly. The environment is contaminated—we should learn about what [toxins] moved [rapidly] into the soil and what didn't.

This has a lot to do with [possibly] saving billions of dollars in our cleanup efforts, because you would have a real database rather than an experimental [generic] model in which you just do the most conservative thing so that you don't err incorrectly. The stakes are enormous, and no one in Washington is really fully prepared to handle it because you're really dealing with maybe \$100 or \$200 billion of cleanup cost at risk. There [are] so many political agendas going on right now that I hesitate to know how it's going to happen, but I would like the science to prevail.

Those are real human studies! These are people who really got dosed. The information from [Russia] will help you a lot to extend this now, in understanding [those] who will now alleged this [occurred], that or the other thing [having] happened because of American activities. That is sort of contemporaneous. So if [American] kids got dosed [from low-level medical studies or global fallout], you got kids in Russia who got dosed more. You can see what the [actual] risk coefficients are to find out if they were really *harmed* rather than just being *wronged*.

So, you know it's all intertwined in my mind—I don't make these bureaucratic compartmentalizations. It's a basic problem with low-level radiation risk assessment in people, which is going to be based on what happened with high levels. We don't have any of that [long-term chronic radiation] data. All we have is the Hiroshima[–Nagasaki] database. Everything is driven by that.

GOURLEY: The Marshall Islanders?¹⁷¹

GOLDMAN: The Marshall Islanders got “incandescent” doses—they got “cooked.” Th[e children] got 20,000 rads of thyroid radiation. We're not talking about 2,000 rads, or 20 rads, or even a 20th of a rad. And it's [primarily internal doses from] iodine. You take the iodine story away from the Marshall Islands and you [may] have a political story—not a medical

¹⁷¹ residents of the Marshall Islands, a group of 34 atolls in the west central Pacific where the United States performed atmospheric tests of nuclear weapons in the 1950s. Since 1986 the Marshall Islands have been a self-governing area associated with the United States. For a discussion of follow-up studies of the Marshallese Islanders by Brookhaven National Laboratory, see “Castle Bravo Atomic Weapon Test (March 1, 1954)” and “Studies on Marshallese at Brookhaven” in DOE/EH-0478, *Human Radiation Studies: Remembering the Early Years; Oral History of Physician James S. Robertson, M.D., Ph.D.* (September 1995).

story. It's true with the bombs, it's iodine with the big [intentional radiation] release in the '40s [from] Hanford.¹⁷² With Chernobyl, [it's the] effect [of] iodine. The only medical consequence of Chernobyl has been an epidemic of childhood thyroid cancer. Besides the 32, who were killed immediately from acute radiation, there is no leukemia. There is not anything else—even in Chernobyl. But it's only ten years, you may have to wait longer. Chelyabinsk [exposures were] in 1950. So it's all there, if it's there. That is why there is a tie-in, not just for the Russian benefit, but ours. I didn't mean to wander into politics, but you have to know where I'm coming from.

Sentiments About the Office of Human Radiation Experiments Records Search and Retrieval Project (1995)

HEFNER: Yeah, we do. You've alluded several times to your sentiments around the human radiation experiment record search and retrieval project the past year that the DOE launched into and then President Clinton committed the whole Federal Government. What do you professionally think about what has happened the past year?

GOLDMAN: Well, first of all, I haven't been privy to everything that's gone on. I've seen a couple of news releases and I asked Ellyn Weiss [(Special Counsel & Director, OHRE, DOE)] to help me with British Television interview.

By the way, the British Television was over visiting me a week or two ago and I think they visited you—a guy named Leif and another—and they're going to do a British Nova¹⁷³ equivalent on this here. But what is really happening is that they're going to be looking to see if there was a similar parallel situation in the UK during that same era. Why shouldn't there have been? We were in bed together on everything else, so I suppose there were some studies done there.

My perception, based on all that I've said [to] you and my knowledge of things, is that the overwhelming majority of these [studies] are going to prove to be what Marvin calls the "gee whiz" metabolic *studies* rather than radiation *experiments*. I think it's a disservice to the public to label all of these as radiation *experiments*, because the public perception [about] that word is that you're testing the *effect* of radiation rather than using *tracers*¹⁷⁴ as a tool to learn about disease or normalcy. There probably are a couple of studies that are going to be peeling out of this that really should have never happened, and it's important that we find out [about them].

¹⁷² Operation Green Run is discussed in *Human Radiation Experiments: The Department of Energy Roadmap to the Story and the Records* (310+ pages), (DOE/EH-0445, February 1995). For more on the Green Run, with an emphasis on its military purpose and the involvement of the U.S. Air Force, see DOE/EH-0455, *Human Radiation Studies: Remembering the Early Years; Oral History of John W. Healy* (May 1995).

¹⁷³ a weekly television series on science produced in the United States by the Public Broadcasting System (PBS)

¹⁷⁴ radioactive tags on biomolecules, used to study a biological, chemical, or physical system

But I don't know if we've got the will to put it in perspective. I know "terror sells," and so if we could terrorize the public once again about the bad bureaucracy, [what we] did to "Joe Sixpack." Because the history of [the relationship between radiation and the public] is that it's always been that way [(negative; something evil and hateful, to be dreaded)], with never any variation. This is just one more example of it.

I'm terribly upset as an educator and as a radiation scientist that this isn't put in perspective. It's like everything else on the planet. If you abuse it, you have bad consequences. If you don't abuse it, it could be beneficial. But in this case, the second part to that sentence [is lacking]. The word "radiation" is negative.

HEFNER: What would it take to put it in perspective?

GOLDMAN: It would [require that] the public understand this quantitative dose-effect relationship, and I don't have the confidence that our public has a sufficient scientific background, that they're going to believe anything.

Secondly, there is a seriously increasing amount of distrust and fear of science—somehow or other that we are all "mad" scientists. We don't have scientific heroes, we have basketball heroes; I don't know why we don't have scientific heroes. There have been a lot of people who have done wonderful things, but they're always on page 15 of the newspaper when they get their science medal or the Nobel Prize. I got the [AEC's] E.O. Lawrence Award, a very high, prestigious award—it got written up in my newspaper, "Obscure Scientist Wins Government Recognition," and that's it. I'm not looking for publicity, I'm just saying that [when] we don't respect scientists, [we're saying] that somehow or other we're some bad guys, and this is negativeness about science.

Yet [our science] is the seed corn for our society's future. If we don't master it, it's going to master us. And, of course, we have to be in charge of it. The tendency [is] to overwhelm people with the [technical] facts: "Here is one more example of how we overexpose people and have all these bad consequences." Never do you see headlines that say: "Hey, you know, we looked at Love Canal,¹⁷⁵ and guess what? There wasn't anything there!" There was a fear that there might be something there, but when we got through studying it, we found out there was nothing there. Nowhere do people believe now that Love Canal is okay; and it is. Same with Times Beach—a lot of these things—they lumped that all together with Bhopal¹⁷⁶ or Hiroshima, and it's not [honest]!

HEFNER: If you had Secretary [of Energy Hazel] O'Leary here this afternoon and you were to give her some advice about how to get this in perspective, what would you tell her?

¹⁷⁵ a site in New York State, near Niagara Falls, that, in the '70s, was believed to be so laden with toxic industrial waste as to make neighboring communities uninhabitable

¹⁷⁶ a former state in central India, now part of Madhya Pradesh, where in mid-1980 an accident at a chemical plant owned by Union Carbide released methyl isocyanate (MIC) fumes, killing thousands. The company settled out of court, and the Indian government has not pursued the case on behalf of the victims.

GOLDMAN: I'd tell her before she goes off and makes any of these statements that she should ask those [who] gave her the information: "Is there another side to this story?" I don't think that [has] happened [yet].

So what you're doing now is to see if there is another side and [ask], "Is there a balancing of it?" Are you capable of handling this, or must you again run off and get another package of "beltway bandits" [(Washington, D.C.-area consultants)] or the Academy [(National Academy of Sciences)] to give you a report that says it's not a big problem?

Then there is always this minority report that says, "Well, on the other hand, it could be that the world is ending and that the sky is falling," and that is what comes out in the press because you're being properly scientifically cautious. I mean, I'm not Secretary O'Leary, but I have to get up and make statements to the press a lot, too. How do [you] say the important thing, then not undo it by putting all the other caveats in, that you must do if you're writing a scientific paper but are really not [part of] the key statement? If she says something like that, then the anti[nuclear [forces are]] going to pull out these [examples]—"But what about this and what about that, and you haven't answered the waste problem, and you haven't done this or you haven't done that!" And they have [done just that].

The obstacle on nuclear waste is a political one; it's not a technical one. They [(nuclear and waste-management engineers)] know how to do it.¹⁷⁷

The obstacle on *this* [(the radiation experiment project)] is that in those days, the Hippocratic oath still existed—oh, and I'm hearing, "Oh you knew about the Nuremberg trials," and "We had these Nuremberg laws and you can't do [certain] things." But the Nuremberg laws [as I understand them] were specifically to prohibit you doing things that [harmed] people, not to prevent people from doing things that were scientifically important in which there might [unknowingly] be a minor risk which you couldn't define.¹⁷⁸ In medical research that is often the case.

And now, in order to [prevent harm], we go through a very elaborate procedure, but there is always a finite, small risk. Anybody who says that we're going to do such things, that there are [absolutely] no risks, is [naive]. There is not such [a] thing as zero risk.

And [also remember that] there is [also] a risk for *not* doing things, as well a risk for doing things. Now, how do you put this all in prospective when all you've got is a 12-second sound bite and they [(the television news producers)] spend all their time on makeup and packaging rather than what the content is? It's very upsetting. I almost thought that we should invent a science court—like the Supreme Court—that was not permitted to have any self-interest in it. Because whatever the DOE says [will be accused of being self-interest and thus, will bear] a lack of credibility.

¹⁷⁷ Nuclear waste from Swedish commercial nuclear reactors is encased in special copper-clad glass capsules, which in turn are stored underground in stable granite formations.

¹⁷⁸ The first stipulation of protecting experimental subjects officially was announced in 1948 in Nuremberg, Germany, the city where former Nazis had been tried in an international court in 1945 and '46.

So then they send it out to some other group that has [presumably more] credibility, but not [necessarily] competence. And because they don't have the competence they're going to be very, very cautious [and conservative] about what they say. Or they're going to bring in people who are then going to be pilloried because, [critics will say,] "You took money from the Army to do nerve stuff, you took money from the AEC to do bomb stuff; how can I believe anything you say?"

All I can tell you is what I'm telling you; and I challenge you to prove in any way that what I said is incorrect or a lie. Then you [have set up] an adversarial climate [and] you don't get anything done. The people I worked with, from my perception, were highly *ethical*, highly *sensitive*, and perhaps a little naive about some scientific stuff that we now know that we didn't know then. I'm not excusing it, I'm just saying that [is my] perspective. I think that you will find—

The other thing that I would ask Hazel [O'Leary] to do is to look at the whole history of American medical research, and you'll find scientists who were injecting stuff into themselves all the time to find out what happened because they couldn't get any subjects. And there was never any thought that this was going to be bad. We're not talking about the Curies¹⁷⁹ and the Roentgens¹⁸⁰ who all died of radiation damage—because they didn't know it was damaging; it was a [novel] toy. The images that this perpetuates [is that] everything that [is] scientific, if you have it long enough and look at it enough, is going to prove to be deleterious. This week's issue is EMF [(electromagnetic fields)] and being [possibly exposed to] magnetic fields and electric power lines. It's got the "bad things" coming out and it's going to destroy your DNA—and it [likely] may be proven to be another tempest in the teapot.

I think I would just get up and say that there have been no abuses of public health, "with these two exceptions"—whatever [they prove to be]. And this study—even the one with the prisoners [who were informed and] paid, and the[ir] testes [irradiated,] which is today rather abhorrent—was something the Government needed to know.

You know, nobody said that we had to make bombs, either. You get into this whole ethical thing, and I use this tired cliché of the "retrospectroscope having 20/20 [hindsight]." We were convinced that [during the Cold War, we were involved] in a life-and-death struggle and that there were some risks we had to take and we would try and keep them minimal.

The thing that comes up next is that there is no such a thing as an "acceptable risk," because what [risk] I will accept, you may not accept. The only thing that is universal is a[n ideal of] zero risk, which is not achievable. There has to be some kind of equivalent of what we call de

¹⁷⁹ Marie Curie and her husband Pierre, codiscoverers of radium, who died from the radiation exposure they received in the course of their pioneering experiments

¹⁸⁰ Wilhelm Konrad Roentgen, 1845–1923, German physicist, who discovered x rays in 1895 and received the Nobel Prize in Physics

minimis,¹⁸¹ or as low as reasonably achievable [(ALARA)], or something like that. My feeling would be that any [value] that is within the factor of two to ten of background [radiation], I would just toss out as being unimportant. Even [for] the plutonium [issue].

Comments on Radiation Standards, Nuclear Material Cleanup; More Advice to Energy Secretary O'Leary (1995)

GOURLEY: How does that compare to today's radiation standards?

GOLDMAN: Well, radiation standards have never [really] been based on health effects. They've been based on [a] calculation of dosimetry, and generally, today's regulations are based upon detection limits. Your Clean Air Act and everything are not tied to health effects, as rigorously as you would like. You would like to say, "Well, here [are] the health effects, and [below that by a] factor of ten take care of sensitive people, and then add another factor of two, and that's the limit."

And as we find out more and more about this, we [can] maybe make it more liberal or more restrictive. Well, in the history of this country, I don't know of any [limit] that [was] made more liberal even though we found out [that] the data are [supportive of less restrictive limits]. Generally, we ratchet it [(the limits)] down because of assessment information [that] is initially incomplete. But don't delude yourself into thinking that the radiation standards are tied to radiation risks—they're not. The history of radiation standards is unbelievable[, because they originated with a damage indexed and not a cancer-risk database].

GOURLEY: You were on BEIR.¹⁸²

GOLDMAN: BEIR is not a standards group. [It is] a standing committee of the [National] Academy [of Sciences], [which] puts out a volume every few years on our estimate [of radiation] risk. But standards are in [the *Code of Federal Regulations*]. Radiation standard, the history of the standards during World War II, was that [scientists such as] Marinelli¹⁸³ and Failla¹⁸⁴ at the Argonne Lab during the Manhattan Project¹⁸⁵ were the only [scientists] in town that were literally measuring blood counts of [radiation in] workers weekly. That was the [biological] precursor to film badges. It was a biological dosimeter. If you got a [large radiation] dose, your white [blood cell] count would drop, and then after a while it would come back up.

¹⁸¹ a level below which a dose is statistically insignificant

¹⁸² National Research Council Committee on the Biological Effects of Ionizing Radiation (BEIR)

¹⁸³ Leo D. Marinelli, a researcher at Argonne National Laboratory; developer of Marinelli-type crystal counters

¹⁸⁴ G. Failla, who also conducted research at the Neurological Institute in New York. The G. Failla award and lecture is conferred annually by the Radiation Research Society;

¹⁸⁵ the U.S. Government's secret project, launched December 28, 1942 by the U.S. Army Corps of Engineers' Manhattan Engineer District, to develop the atomic bomb. Headquartered in Washington, the Manhattan Project was the Office of Scientific Research and Development Section on Uranium and was codenamed S-1 (Section One of the Office of Scientific Research and Development).

They found that there were no radiation effects until you got over 50 rads or Roentgens, or REPs. [They reasoned,] "Let's be conservative, and so we'll make [the value equal to] five." So the original standard was, "You shall not exceed more than (I forgot the numbers) 1 rad a week," so you don't get 50 [rads] in a year. It's based on [about] three technicians who [I think] had blood counts—has nothing to do with [cancer epidemiology], nothing to do with cancer risk.

From that, we got this five-rem-a-year number, and because the public may have sensitive people and because the public isn't being monitored the way workers are for the same risk, we'll make [the public's] standard ten times smaller. So that is 500 millirem a year, one-half [of] a rem a year instead of five rem.

But the 5 rem is related to blood counts that might drop at 50 [rem] (the 1941-mentality end of the database). Now 500 millirem is being [related] to the fact that in the olden days, 100 millirem was considered background [vs. the reality, about 350], and so now we [can say that] an individual in the population shouldn't exceed five times [that amount of] background [radiation]. So it's sort of tied to background [and] indirectly tied to health effects. It's been going on and on since then. [And] we've been justifying it. We've been beating it around the bush, but that's the history of radiation standards. Ask Newell Stannard.

Then we decided [that radiation exposure value was] for an individual for whom we can do retrospective dosimetry. What about the whole general population? "Well, we don't know about them—let's throw in another [safety] factor of three." So that [is] the origin of this 167-millirem-a-year [public limit].

GOURLEY: I thought it had to do with the [fact that] skin reddening was 300 rem.

GOLDMAN: Yes. The erythema dose.¹⁸⁶ That was acute [(single)] exposure. I'm talking about [continual] per week [exposure limits].

GOURLEY: So you're talking about the effective dose equivalent rather than—

GOLDMAN: [No.] I'm talking about the *chronic* radiation problem which the population is concerned with, and you're talking about the erythema dose [for] the occupational accidental-exposure [individual]. We're talking about both of these, [which are *each*] true. Two hundred rad was the erythema dose.

We had these *two* things: *one* was an acute dose, and then we knew [from] the Japanese follow-up that the median lethal dose is a couple of hundred rads—it's about 450 rads, and you don't get acute radiation sickness much below 200 [rads]—and so we have some of that.

But that is [an] acute [dose]. That is killing you right there [in 60 days]. We're talking about cancer four decades later—no data. So, now we're [discussing] this chronic [radiation problem]—1941, we don't even have

¹⁸⁶ the radiation dose to skin capable of causing an abnormal reddening due to inflammation

the radium dial painter [data]. So [instead] they're using [a] chronic indicator of injuries, [where] you get repairable and irreparable injury—you got to realize that that's where the ball was in those days. You haven't heard all this before?

HEFNER: Well, I think the politics of it.

GOLDMAN: No. I mean what I've told you. You've been interviewing people all along.

GOURLEY: Different people are doing different interviews.

HEFNER: Yeah. Right.

GOLDMAN: Okay. Well, that's probably good. It's sort of the 11 blind men describing the elephant when you put this together. Is anyone going to put this together, or are you just going to archive these tapes, transcribe them and put them away, and the have some law clerk [later] read them through to see what they said?

**GOURLEY
& HEFNER:** *(laughter)*

GOLDMAN: No, seriously. I'm interested to know what the fate of my spilling of my guts.

HEFNER: Yeah, we'll answer those questions, but—

GOLDMAN: Okay, back to history. The history of the standards is something that you really should have somebody go through, someone who has been more involved in it. Another person will be Lauriston Taylor. Lori Taylor is the former head of the National Council on Radiation [Protection]. He was the first president. He became president in 1928, when I was born, and he's still alive and [well]. He's an unbelievable guy. (Because low doses of radiation extend life).

(laughter)

That the history of the standards: this concept that millirems have cancer risk is a result of a misapplication of a scientific principle. It's basically this: if you think that there is a population that may be in trouble, you can do [a process] called [calculation of] a collective dose. [Since] you haven't the data to go around measuring everybody, you just say, "Well, this population has a cumulative dose of [this] many rads [in this] many persons," so, you got person-rads. You multiply rads times people; and when you multiply megapersons times microrads, you can come up with big [person-rad] numbers, just as [you make] the reverse [calculation] when you have a few people getting [very large] doses.

And so, for radiation protection purposes, [one way] of getting the first cut of what doses are [is to] have literally used this linearity theory to say that if what we found in high doses is correct, then if a million persons each received one rad of radiation, you'd have a million person-rads. In that population of one million persons, you might see an extra one hundred

cancer cases over that which you would expect, which is [normally] around 20 percent of the [unirradiated] population[']s cancer fatalities.

And therefore, 100 divided by one million person-rem gives you one times ten to the minus four (one ten-thousandth) [1×10^{-4} , or 0.0001] of a cancer risk per rad. You can extend that to 100 million people, each getting 0.01 of a rad, et cetera.

I did this [calculation] to give you the most [extreme example]. [Another] example [is] that if everyone on earth wore a one-inch lift in their shoe for one year, they would all rise in altitude by one-inch and the cosmic ray dose (we know because we got lots of data) doubles for every two thousand meters. So I calculated with all the zeros what the radiation dose per person is and I multiplied it by the population of the planet and I came up with so many person-rads of radiation for that one year. [This collective dose could cause 1,500 fatal cancers,] because [we use the same cancer] risk coefficient, 1×10^{-4} [(0.0001)]. This is my classic of extrapolation of megaperson and microdose, using this collective [dose concept].

Well, that is ridiculous. First of all, you could never see 1,500 cases in the 350 million people [on earth] who die of cancer in 50 years—this is a 50-year risk. So, 350 million plus or minus 1,500 is zero—epidemiology doesn't [have the precision to] talk about that.

Now, you can talk about 1,500 divided by 350 million and get the incremental risk that such a [dose] represents, but [you cannot] go around saying we have a body count. That's the problem Hazel O'Leary has, because [to her,] radiation equals cancer and cancer equals radiation, as if it's the only cause. And, therefore all radiation is cancer incognito. That is the bear trap. I don't know how to advise her, but this is the issue.

I've said a lot of technical things, and she's not able [to express them in a public forum]; she's a politician. She can't talk science [with credibility,] and she's got to exude credibility, and she [conveys] credibility by being very cautious—she is being so cautious as to [possibly] bring the house down on her head, because obviously there has got to be something wrong. You can't pick up a newspaper and read headlines that say, "Guess what guys, everything went okay last night." It's only those things that went wrong that get in newsprint. If she wants news coverage, she's got to show [that,] "I'm Mrs. Clean. I've cleaned up this dirty agency!"

It [may] turn out [that] when you get through with this [review of AEC-funded experiments] if you find there [are] 700 studies and [only] two were "bad," that is probably no different than the whole [national] history of pharmacology research or anything else; it's probably much better.

My feeling is: rather than try to point the finger at someone else, I would like—for my own information—to see what other abuses there were in those days with chemicals [and pharmaceuticals¹⁸⁷] that were also being evaluated. This one[, however,] has [involved] the Atomic Bomb, Cold

¹⁸⁷ drugs approved for human use

War, Military Nuclear Energy— (*facetiously*) all those things the public values so highly on a scale of ethical values, that there is no way that I see her coming out of this [unscathed].

Yet the truth of the matter is that [this history shows] it [(the radiation research)] really [wasn't] an abuse, and there probably were very few[, if any,] instances of wrongdoing and harming. For those [which caused real harm], we should see whether the Government is liable, [and then] do something and do it [firmly].

We [have] this whole [set of groups], the atomic veterans, you [of the younger generation have] the children of Chernobyl—everybody is sitting around looking for deep pockets, big [requests for] compensation. [Such as] the cases I get involved in court, where this [man] was a cook at the Atomic Bomb Test in 1950. He was 50 miles upwind from anything and he dies of leukemia. One in five people die of cancer! You *have* to die of something! He was there, he had a film badge, he got 300 millirem [of radiation exposure], which is one year's background radiation, and [it's alleged that] obviously it caused [his] leukemia. There is no data whatsoever that says 300 millirem could cause leukemia and do it in 3 [to 10] years. It doesn't do it 30 years later! We have [data on the] latent period [for such diseases] after radiation exposure. We have this compensation act [(the Radiation Exposure Compensation Act)], and the "Lawyer Wealth Distribution Act of 1994" lives, so you give them money.

[That is wrong in my view, and] I don't think society can survive that way, just because you allege that something has happened. I don't know that it's necessary that you have to prove that it didn't [do harm, because] proving a negative is difficult. But there are times where we have to get to this idea of a *de minimis* or—there is some [low] level [of exposure] where you really can't say that there was harm. Just because you were there at the right time doesn't mean that you got [seriously exposed].

This is the problem that citizens living around every nuclear site in America are all concerned [about]. Fernald has [possibly] leaked out this stuff, and Rocky Flats¹⁸⁸ [may have] plutonium all over the place. There would be no plutonium all over the place if the DOE hadn't gone in and tried to mitigate it. [As I understand it,] what they did was take the plutonium that was [firmly affixed] in the earth and bring in bulldozers and [literally] aerosolize it¹⁸⁹ and blow it all over [parts of] the state of Colorado in their attempt to remove it. So they took a [very] stable soil problem and [possibly] made an unstable, aerosol atmospheric problem out of it, and now [DOE may have] to pay for it—dearly.

We spent [about] 9 million dollars removing [less than 6] millicuries of cesium from Point Hope, Alaska, the nearest resident of which is [35]

¹⁸⁸ a former DOE weapons site in Colorado where plutonium metal was shaped and machined into sizes required for the U.S. atomic weapons program prior to final assembly as atomic bombs. Now, it faces one of the costliest, longest-term environmental cleanup in the DOE's former weapons complex.

¹⁸⁹ turn it into airborne particles dispersed in a gas, as smoke or fog

miles away. This [was] part of an [environmental] test [some 30 years ago]—at the time, we were going to build a harbor [by using a controlled atomic explosion].¹⁹⁰

I was involved in the review of the DOE [site mitigation] plan. I said, "Give the [local community] the 9 million dollars; let them build a school and an alcohol rehabilitation [center] and [perhaps] some sex education [program]; put the kids through school. There are only 200 people in the whole North Slope." What did they do? They did a "Desert Storm"—[type] invasion by DOE; built the harbor, built the road, put in a hospital for the workers, dug up this six-foot mound, which was very safely covering the radioactivity, and we've moved it (leaving an ecological scar in this fragile place) [by putting] it in steel barrels because it [was radioactive] and sent [it] on a barge all the way down to Hanford to be buried as low-level waste.

As a taxpayer, I'm incensed because of the precedent that this [sets]. It says that the politics wins and the science be damned. I've spent my life doing something which is of no use whatsoever, because I'm just "one of those scientists," and we don't trust them. I'm not paranoid; I'm just angry that we have spent millions and millions of dollars to get answers, and then, when we give [the public] the answers, they are not acceptable because [perhaps] somebody is a little more adept at [handling] sound bites. I don't see how our society is going to manage [and control our] increasingly complex technology if there is no way of developing faith and trust [in science].

Maybe your activity is going to be a step toward more of what you call a stakeholder approach, more of a participatory one. In fact, the early history of this has [had] so much secrecy, and this obviously raised the suspicion that it wasn't [kept] secret to keep the Russians from learning about our atomic bombs, but it was [kept] secret because of all the bad things that we were doing to the public. There is a big difference between those two. I think that is something Hazel should work on talking about. How, I don't know.

I talked to Tara O'Toole, who is Hazel O'Leary's Assistant Secretary [for Environment, Safety and Health]. She's an occupational medicine [specialist]¹⁹¹ from OTA.¹⁹² But her background in radiation [science may be]

¹⁹⁰ For a firsthand, AEC perspective on the harbor project, which was code-named Project Chariot, see "Suspension of Proposed Plowshare Projects (Circa 1963)" in DOE/EH-0481, *Human Radiation Studies: Remembering the Early Years; Oral History of Biochemist John Randolph Totter, Ph.D.* (September 1995).

¹⁹¹ O'Toole has an M.D. and an M.S. in Public Health. Her report on the hazards facing DOE cleanup workers is footnoted earlier, under "Relationship With Newell Stannard and Stafford Warren (1952–57)."

¹⁹² The Congressional Office of Technology Assessment. OTA was created in 1972 as an analytical arm of Congress. OTA's basic function was to help legislative policymakers anticipate and plan for the consequences of technological changes and to examine the many ways, expected and unexpected, in which technology affects people's lives. Located in Washington, D.C., OTA staffed some 140 full-time analysts and a like number of rotating consultants, whose reports were widely respected for their rigor, soundness, and political neutrality. Some 65 reports were completed in 1995. In September 1995, months after a new Congress revoked its charter, (continued...)

limited. I don't know if anyone has [been] invited to give her a broader perspective on it, to show her where the risks are and where they're not.

We cannot have a handling of things which can be dangerous in society with a zero-tolerance [regulation], a [philosophy] which says that [all] radiation is bad, so there can be no radiation.

I can just say smoking is bad, [so] there can be no smoke. I [could] say automobile driving is dangerous, so there can be no cars. You cannot be absolute about it, you have to determine a metric whereby you balance so-called benefits with risks and that you understand that some things which might appear to be a risk really aren't.

[For example, in my] big picture of things, all the radiation I've ever gotten is from [cosmic radiation in] airplanes. God knows what else I got [in] those airplanes in the way of terrible smoke and in the way of [potentially] carcinogenic food, which I call fast food, and so forth. But [on a more serious note], you know that [flying is] volitional, it's not involuntary, and you do this with a perceived benefit, so you know what you're doing. But still, I [too] want my vital bodily cells protected from bad things.

My intuition is that we should have [agreement on] something like a one-in-a-million [lifetime] risk, and if the best [that] science can do [at] the moment is to say that the risk is smaller than one in a million—don't call it de minimis, but just say it's below regulatory concern [or something similar]. Acknowledge that there might be a risk [that could be] higher. As you find out more and more about it, you might find that the one-in-a-million [estimate is really] overestimating the case; [that] the risk is even smaller, so [then you may] slide the [risk number] around a little. Otherwise we are just going to be [frozen] into inactivity or worse.

When I go through plutonium lung [cancer risk issue]—if America was really worried about lung cancer, the billions that we are going to spend looking for [putative] plutonium atoms [if] spent subsidizing the tobacco farmers to grow soybeans[, and other crops,] would do more to reduce health cost than any other single act. Go do it, and then [Senator] Jesse Helms [of North Carolina will] say, "No way, that's my state you're talking about!" And that's the end of the discussion.

I'd like to see a forum sometime where we could sit around with Hazel and the others [like Vice President Al Gore, who is quite interested in this subject,] without a tape recorder or any [reporters] and just have a frank discussion. [I know that they are] all political [people] and they have to respond to what the incoming mail is saying, which is [often] the result of what [was] read in the *National Enquirer*.

¹⁹² (...continued)

OTA closed its doors. The OTA's reports were slated to be put on a set of CD-ROM disks and on a World Wide Web page that would be maintained by the National Academy of Sciences and by universities.

I [happen to be] a member of the Council of Scientific Society Presidents¹⁹³ because my Society is in that group. We represent a million and a half scientists. And, with all this Contract for America¹⁹⁴ talk and the like and a [different tone] in the Congress, I could just see the avalanche of special-interest groups descending from the extreme left, the extreme right, and every[where] else. [At the] Scientists Presidents [Meeting] together early this month—[we] said, “Why don’t we give [Congress *our* view]? The one condition is that you’re not allowed to talk about your particular professional society’s wants, because the rest of us [in the Council] aren’t going to agree to it. But what do you, as a member of the scientific community, think that we million and a half scientists want us to say?”

[We] wrote advice for priorities for the Government. And one of the them [was] that we should base risk assessments and regulations on sound science, period! [We are] not going to tell you *how* to do it or *why* do it, but [we say that] when you avoid doing it you’re not doing anything; you’re getting [us all] in trouble.

They also talked about family planning, and the conservation of resources. We [recommended a focused] national energy policy that will carry us through the next generation, rather than through the next oil crisis, and that with the advent of understanding the limits and the finite sources of fossil energy and problems of possible adverse climate change that we have, we [must develop] a long-term energy policy.

It [(our position paper)] doesn’t say [the long-term policy is] nuclear; it just says it’s a policy and the [support for] efficiency and conservation isn’t the [complete] answer. The[se measures] don’t turn lights on: they just buy you some time, and I want to know what we’re doing with the time we bought.

The DOE keeps [stating, “Here is our National Energy Strategy,” and [when] you get through reading [it, it appears to me to be] unbelievably unacceptable [and] unscientific, but very [politically] palatable. When we [complete] burning up all the gas and oil, we’ll have a big crisis and everyone will get on airplanes and go to Washington and wring their hands, and they’ll come up with [poor] emergency policies that don’t do anyone any good in the long run. I think it’s demeaning for the richest society in the world not to be able to look beyond next month’s stock [market] report. I mean, there [are] some things you just [have] to bite the bullet and do. And, as a scientist, I’m strongly supporting the nation doing that.

Maybe we should evaluate whether we need a science court. Maybe we should see why the National Academy of Science is or isn’t doing these. But the Academy [seems] only [to] respond to a crisis; they [do not act

¹⁹³ an organization of scientific society presidents, representing most of the scientific societies in the U.S.

¹⁹⁴ In 1994, Americans elected a Congress that was predominantly Republican in both houses. Led by House Speaker Newt Gingrich of Georgia, the two houses soon issued a succinct set of goals to reform government in a conservative fashion. These goals were called the Contract With America.

in an] anticipatory [manner]. You leave it to the Brookings Institute or this [think] tank, or that tank, and they're [each] playing a certain game. That's one of the reasons why the public has [little] trust in scientists. We're [seen as] out feathering our own nest, and if we're not the futurologists then we're going to leave [it] to the fiction writers, who are going to put out next month's version of "The sky is falling!" and [thereby] add one more notch to the gun stock of the "fact" that you can't trust science. You know, (*facetiously*) we really all [enjoy] science fiction and [they show us all to be] such ghouls.

[Our society is in such a] fantastic era. All through my life [I've seen discoveries]—why are we wringing our hands and condemning it and destroying it? It's just unbelievable [to me].

The basis, of course, is education. [Sadly,] we have a [scientifically] illiterate population. One in five people in the United States, [I'm told], can't read. How many of them [do] you think [can] understand [the concept of] a graded [quantitative] dose response? Do you know what a graded dose response is? But you didn't when you started.

GOURLEY: (*smiling*) I certainly didn't then and I wouldn't profess to know it now.

GOLDMAN: That is [how it is] with risks. If you pay more money [for risk abatement], you don't necessarily make things better. The first dollars do a lot: when we put the first seatbelts in we tremendously [improved car safety]. Then add the air bags. Pretty soon you get to a point where, until we change our driving habits, you [are] reaching a[n] asymptote [(a threshold that is ever-more-closely approached but never met)]. Each added [safety feature] adds a little bit [to overall] safety, but the biggest [improvement] was just putting seatbelts in and brakes that work [and safety glass] and steel around the cars. So the first 10 percent [of investment got] you 90 percent, and then the next 10 percent of the dollars got you one more percent—you're up to 91 percent, you never get 100 percent safety. We have to focus on that. It's not in the public interest, I think, to discuss everything [only] in terms of fatal cancers. You start out with this mindset that you're going to get cancer and that we're now going to play a roulette game [over] not getting the cancer that we're going to get.

I just [suggest] that for Hazel [O'Leary], when somebody gets up, makes a "nut" statement, all you do is say, "You're absolutely wrong and there is no data to support it," and "Stop." And you [may] find out that no one ever asks you, "What do you base it on?" If you have any credibility, you got it.

Later on, you could have this informal round table, without tape recorders and everybody worrying about spin control [(putting a good face on unflattering news)], [and] you could get some honest appraisals of where science is comfortable and where science [is] not comfortable, and what are the uncertainties, and what can this nation do to reduce them. At what point do we say this uncertainty now [is] irreducible? If there were no uncertainties, we wouldn't be here having this discussion. And this is the nature of life, that we have some [uncertainties]. But its prospect

is that it's [not in] balance. I think our science education, starting in the first grades, is [too often] taught by teachers who have [little or] no science background and to them, science is [threatening].

[Look at] these magazines [telling] you every time you turn around [that] you're going to get breast cancer, you're going to get intestinal cancer, you're going to have a heart attack. It's amazing that anyone is alive, with all of these assaults upon [us] all the time; it's crazy. It's a totally unbalanced [situation]. It's [perhaps] a luxury of an affluent society, that we can have when you're [not] at a subsistence level. You don't have these debates in Botswana about cancer risk. You have a [discourse] about [whether] we eat tomorrow.

[The discussion] doesn't have to be at these extremes, I'm dedicated to trying to reduce [extremism,] and try and have some public forums where nobody's ox is being gored. One [example was] to hold a meeting with science writers in the Bay area. We [would] sit and talk about radiation. Diablo Canyon [Nuclear Plant in California] didn't blow up, nothing happened [that day] at Chernobyl; we're just going to talk about radiation. It's a continual change of [writers], most of whom [may have been] doing [something else] the week before in the newspaper. With the print media you have a chance. With the TV media you have—my society is putting together a hotline, it's about seven people, who when something happens, [there is an expert to call, and] he [or she] is ready to [be helpful in] these areas. There [may be] only about seven [basic] issues in the whole country [on risk and] everything else is a variation.

I'd ask [Secretary O'Leary] do some of this—looking at the history of medical research in the World War II era. We do a lot of [apparently] strange things, allegedly in the national interest, or the scientific interest, and [our] standards [continually] change. But at no time do I remember people playing [Nazi medical experimenter] Dr. Mengele [satanic] games or whatever—where [he was] just out to see how many [people would be killed or injured by his actions]. I don't have a lot of hope that [people like me are] going to win, but [we should not sit idly by]—you know, my cliché on that is that “You're either part of the solution or part of the problem”; you do what you can do.

[My Society, the Health Physics Society, is planning to sponsor] a workshop on Capitol Hill with members of the different committees. And we're going to talk about radiation education, not pushing for anything—we're just saying, “This is knowledge and these are sources of information. I'm not asking you to pass a test at the end of the hour. But you should know that there are sources of information—that we didn't discover radiation yesterday.”

And [what] you're doing is going to be very valuable. It's going to show that there is a long history. There is a tremendous database; there is probably no risk on this planet about which we know more. We [should] give the public the impression that we [do] know [a lot].

It almost leads you to think that the more you know, the less credible you're going to be, and the more you answer the questions, the less anyone is going to believe it. Now how that fiction got out there is a true sociological [(societal)] question and [perhaps some] people have addressed [it], but I don't have any answers. □