DOE/EH-0480

# HUMAN RADIATION STUDIES: REMEMBERING THE EARLY YEARS

*Oral History of Biophysicist*
*Cornelius A. Tobias, Ph.D.*

Conducted January 16, 1995

**United States Department of Energy**
**Office of Human Radiation Experiments**
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# 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 As part of this initiative, the Department of Energy undertook an effort to identify and catalog historical documents on radiation experiments that had used human subjects.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 BIOPHYSICIST CORNELIUS A. TOBIAS, Ph.D.

*Conducted on January 16, 1995, in Eugene, Oregon, by Prita Pillai of the Office of Human Radiation Experiments, U.S. Department of Energy (DOE), and Anna Berge from Lawrence Berkeley Laboratory.*

*Dr. Cornelius Anthony Tobias was selected for the oral history project because of his extensive biophysics and medical physics research activities while he was employed by the University of California at Berkeley and San Francisco and at the Donner Laboratory.*

## Short Biography

Dr. Tobias was born in Budapest, Hungary, on May 28, 1918. He received his M.A. (1940) and Ph.D. (1942) in Nuclear Physics from the University of California at Berkeley. Upon completing his Ph.D., Dr. Tobias was employed by the University as a physicist from 1942 to 1945. From 1945 to 1955, he taught Biophysics, first as an instructor and then as an associate professor. From 1955 onward, Dr. Tobias was a professor of Medical Physics at the Donner Laboratory of the University of California at Berkeley. From 1960 to 1967, he was the vice chairman in charge of Medical Physics for the Department of Physics. From 1967 to 1971, he chaired the Division of Medical Physics; from 1969 to 1973, he chaired the graduate group in Biophysics and Medical Physics. In 1965 he became a professor of Electrical Engineering and, from 1977 onward, he was a professor of Radiology at the University of California, San Francisco.

During his teaching career, Dr. Tobias also held the following positions:

- 1945 to 1947—Fellow in Medical Physics at the University of California at Berkeley
- 1956 to 1957—Guggenheim Fellow, Karolinska Institute, Sweden
- 1960—Visiting Professor at Harvard University
- 1960 to 1963—Member of a subcommittee of the Natural Resource Council, Member of the Committee on Radiology of the National Academy of Science, Member of the Radiation Study Section of the National Institutes of Health
- 1969 to 1972—President of the Radiation Biophysics Committee, International Union of Pure and Applied Physics

Dr. Tobias has received a number of professional awards, including:

- 1963—Lawrence Memorial Award
- 1972—Annual Award, American Nuclear Society Aerospace Division
- 1981—Alexander Von Humboldt U.S. Senior Scientist Award

Dr. Tobias's main research focused on the biological effects of radiation; cancer research; and space medicine. He has published numerous scientific journal articles on his research findings. He is married with two grown children.

## Forthcoming and Planned Publications

**BERGE:** Interview of Dr. Cornelius Tobias by Anna Berge of the Lawrence Berkeley Laboratory [(LBL)] Archives and Records Office and by Prita Pillai of the Department of Energy's Office of Human Radiation Experiments in Washington, on January 26, 1995, in Eugene, Oregon.

So, Dr. Tobias, I thought maybe we could start with a little bit of a general question, which is, could you tell us a little bit about the development of research trends as they pertained to radioisotopes?

For example, in the early years: you started with studies of xenon [and] argon; other people started with iodine; and from then it developed, say, through studies with iron, phosphorus, and so on. I was wondering if there's anything you can say about that.

**TOBIAS:** First, I wish to state that the interviews I have conducted with Sally Hughes will be appropriately edited and [will] be available to the public at the Bancroft Library of the University [of California at Berkeley]. Secondly, I am preparing a manuscript now which relates to my scientific history. The title is, *People and Particles*, that I hope to publish sometime in the future. Thirdly, I am engaged in a more detailed scientific volume that is only about a third completed. If it gets completed, it may have technical information. Thank you.

**BERGE:** Okay.

**TOBIAS:** You wanted to ask about the isotopes?

**BERGE:** Yeah, the development of the studies of radioisotopes. Was there a particular development in the focus of interest, or was it just haphazard which ones you happened to have at the time?

## Wartime Studies of Effects of High Altitude on Aviators

**TOBIAS:** During the war, I was working with Dr. John Lawrence,[1] and our group decided to accept responsibility for research on a disease, decompression sickness.[2] In order to do this, it was necessary to use radioactive

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[1] John Lawrence, M.D., brother of Ernest O. Lawrence, was Director of the Division of Medical Physics at the University of California, Berkeley. He operated a clinic at Donner Laboratory, where he treated leukemia and polycythemia patients with radioactive phosphorus. For a colleague's recollection of Dr. Lawrence's clinic, see the interview with Dr. John Gofman (DOE/EH-0457), the sections "From Research to Laboratory Production of Plutonium," "Medical Treatments With Radioactive Phosphorus ($^{32}P$)," "Conflict Between University of California San Francisco and Berkeley," "Heparin and Lipoprotein Research With Human Subjects," and "Radiophosphorus Therapy for Polycythemia Vera."

[2] "the bends." The bends are caused by tiny air bubbles released into tissue by a too-rapid decrease in air pressure after staying in a compressed atmosphere, such as the too-rapid ascent of a diver from deep in the sea to normal atmosphere at sea level. It is potentially fatal. Aviators experience a similar phenomenon in ascending too rapidly to high altitude in an unpressurized cockpit without the protection of a pressurized flightsuit. In this circumstance, aviators are at high risk of blacking out and losing control of their aircraft.

inert gases, which we [could produce] at the cyclotron.[3] It was almost the only source.

So, the initial research was revolving around the use of radioactive nitrogen, argon, krypton, [and] xenon, toward discovering the nature of decompression sickness, which was a disease, or a condition, that aviators who fly to high altitude were getting. It was very important for the American war effort to know the mechanism and to protect people from bends.

**PILLAI:** Were those studies funded by the Manhattan Engineer [District][4]?

**TOBIAS:** No. At the time, they were funded by the [U.S.] OSRD, Office of Scientific Research and Development.[5]

**PILLAI:** Did someone from the OSRD oversee these studies, or did you and other researchers have leeway in how you were conducting the research?

**TOBIAS:** [There was some] leeway [for our group], but the OSRD had a committee which was headed by John Fulton, professor, I think, of Scientific History at Yale University; and a number of other gentlemen were on it.

**PILLAI:** And what kind of committee was that? Was it a committee that oversaw the studies on humans?

**TOBIAS:** I don't know [what] their full authority [was]. I do know that decompression sickness and everything we were doing [that was] related to this [was discussed]. The committee did not have [full] authority over us. They were an advisory committee to OSRD and to us [in order] to correlate research and suggest how it might be done.

**PILLAI:** How did you choose the subjects for these studies?

**TOBIAS:** We chose [the field] because, after Pearl Harbor, the United States went to war, and we wished to make the best contribution we could to the war effort.

We had two choices. One was to work on medical and physiological problems of high-altitude aviators, which were very critical at the time, because both the English and the Americans were sending many, many bombers over to Europe, and we wanted our aviators to survive [their high-altitude flights].

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

4 the U.S. Army Corps of Engineers organization set up to administer the development of the atomic bomb under the top-secret Manhattan Project. Originally headquartered in New York, it was moved to Washington, D.C., and finally to Oak Ridge, Tennessee, in the summer of 1943.

5 established by an executive order June 28, 1941—six days after German troops invaded the Soviet Union. The OSRD's Director reported directly to the President and could invoke the prestige of the White House when dealing with other Federal agencies. The National Defense Research Committee, at the time headed by Harvard President James Conant, became an advisory body responsible for making research and development recommendations to the OSRD.

[Another possible choice] was the question of what was the toxicity of fission products and fissionable materials. Within the [Radiation] Lab,[6] it was decided that the aviation [research] would be headed by Dr. John Lawrence, and the fission [research] would be headed by Dr. Joseph Hamilton.[7]

So, we had two [separate] subgroups, each with a completely different mandate. Dr. Hamilton's work was supported by the Manhattan Project.

**BERGE:** Well, I was going to go on [to the research] that you conducted. I'm interested in the [specifics] of the experiments, the particular procedures, [the] people you worked with, and the particular radioisotopes you used.

**TOBIAS:** You're asking a big question.

**BERGE:** Yeah. For example, after the uptake studies of inert gases, you did some studies with carbon monoxide. Perhaps you could tell us a little bit about that?

**TOBIAS:** [First, let me take] the aviation medicine part. [This] was very much a rush-service project to help the Air Force.[8] We also had direct liaison with the Air Force.

We knew that bends might be caused by nitrogen dissolved in our body, which, when you [fly] to high altitude, becomes supersaturated, and, if it's not eliminated via the lungs, [might] cause bubbles [within the tissues]. The bubbles cause joint pains, possibly passing out, even, and another [symptom] called *chokes,* which is choking the lungs.

So in order to find out about this, we chose [to use] radioactive nitrogen. We thought [nitrogen] was the culprit. The problem was that the only isotope available had 10 minutes' half-life, which was too short, although we did some studies [with it].

We [then] realized that the other inert gases—neon, argon, krypton, xenon—were similar in their behavior, so finally we ended up with most of these studies [using] radioactive krypton.

[Our] aim was to find out the mechanism [that causes the bends], but also to give our forces a technical advantage. A lot of the studies related

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6 The UC Radiation Laboratory was founded by Ernest Lawrence in 1936 on the campus of the University of California at Berkeley. Upon Lawrence's death in 1958, the lab's name was changed to Lawrence Radiation Laboratory. The name changed again, in 1971, to Lawrence Berkeley Laboratory, a National Laboratory under the U.S. Department of Energy.

7 Joseph Hamilton, M.D., worked at Crocker Laboratory, then the site of a 60-inch cyclotron that he operated to produce radioisotopes in support of research and some medical diagnosis and treatment. Crocker was part of the Lawrence Radiation Laboratory. Hamilton is discussed in several transcripts of this series, notably in the interviews with John Gofman (DOE/EH-0457, June 1995) and Earl Miller (DOE/EH-0474, June 1995). Hamilton spent most of his career at the Lawrence Radiation Laboratory before dying prematurely of leukemia brought on, colleagues believe, by occupational exposure to radiation.

8 then a generic term for the U.S. Army Air Corps, which became the U.S. Air Force, a separate service, in 1947

to a quick test of aviators with radiokrypton, [which might tell us whether individuals] were susceptible to bends.

We did find out that, basically, these gases were responsible for the [bends]. We wrote a detailed paper on this [in the] *Journal of Clinical Investigation.*

We also found out where the disease struck, by doing experiments with injected bubbles in our own joints, and how to get rid of [bends] by breathing oxygen for five hours before [each] flight. And, finally, we did flight tests in an actual high-altitude bomber plane. Our subjects, who were aviation cadets, were taken along and tested. So this went on, more or less, all through the war.

And incidentally, with that, we developed a delayed-parachute-opening device, because we found out that it wasn't safe to fly [at] high altitudes, because [you] couldn't bail out. If [you tried to] bail out, it would either tear the parachute apart, or tear [your] arm off, or things like that. So, I donated the patent [for a parachute-opening device] to the United States Government.

Then, also, we realized that another very important problem was that people do not know when their oxygen masks did not work properly. [On each flight over to Germany] there might may be 1,000 bombers with 10,000 Americans on these bombers. Some of the [demand oxygen valves] would fail, and the [aviators] wouldn't know it. So, then, they might pass out and die.

I developed an oxygen warning system, which [was given to Air Force] committees, [who] took a lot of time trying to figure out how to use the system. By that time, the war ended.

## Study of Carbon Monoxide With Radioactive Tracers

**TOBIAS:** Now, the carbon monoxide and other studies came immediately after the war. At that time, we were liberated from the war responsibility, and we decided to go back to the development of the tracer method and to the study of various diseases.

But, it was a period there of about four years. The war ended with victory. The Manhattan Project told us—that included both Hamilton and Lawrence—that we could become part of the rejuvenated Manhattan Project, and we were told that basic medical research with radiation and radioisotopes would be A-okay.

We were perhaps one of the foremost small groups that knew about biomedical studies with radioisotopes. The whole country was so busy at war, they didn't teach [about radioactivity] in schools. So, we had to give some introductory courses to [members of] the Manhattan Project, and [independently] there were literally dozens of scientists from all over the world who tried to come in to work with us.

One of the first of [our peaceful studies] was the carbon monoxide studies. A gentleman [(F.J.W. Roughton)] came to us from Oxford University in England. We decided that we could make an exploratory study of how radioactive carbon is utilized in the body. We already knew about carbon dioxide.

The question became, "[Since] carbon monoxide is very toxic, can it be metabolized by the body?" So, Roughton and I set up an experiment with carbon monoxide, where we [were the guinea pigs].

We inhaled it and found out that a small part of this carbon monoxide was oxidated by the body to carbon dioxide. That was new knowledge not available [earlier]. And also, this experiment, apparently, was the world's first experiment where radioactive carbon was given to humans.

I might just add here at this point, since you're interested in human use, that all of these gases were used on myself and on our staff members, [who] all volunteered to [be participants]. For example, I took one millicurie[9] of radiokrypton, and there seemed to be nothing [extremely hazardous] about this.

And the air cadets whom we used—there must have been a couple of hundred cadets—volunteered for the short-time tests. They all volunteered and signed a piece of paper.

**PILLAI:** Did the volunteers, when they signed the paper, were they given an explanation of what was—

**TOBIAS:** —Yes.

**PILLAI:** And did they know that it was an experimental procedure?

**TOBIAS:** Yes.

**PILLAI:** Do you still feel the same way now as then? How about the safety effects?

**TOBIAS:** It was perfectly okay and safe. Let me just explain that these gases, you would inhale them for maybe 2 minutes, or less than 10 minutes, and all of it is exhaled within a few more minutes.

The material we would give to these people would be microcuries,[10] and nothing would be left in a few minutes. Completely safe. Nobody in the whole world can tell me it was not.

**PILLAI:** How about the other types of tracer studies, where isotopes were injected into subjects? Do you feel that those studies were also safe?

**TOBIAS:** Yes, the radiokrypton and the radioxenon [that were] also inhaled, I felt they were very safe, and I'm still here 50 years later to tell you this.

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

10 a millionth of a curie

And, there were some other isotopes that I was involved with that you could start an argument about.

Dr. Ernest Lawrence[11] drank radiosodium, and several other people [did this] along with him. Professor [J.] Robert Oppenheimer[12] drank the radiosodium, which is [radioactivated] salt. When the radioiron was discovered, some of us took a little bit of radioiron [and] injected [it] into our bodies. That's a longer-lived substance, iron, 49 days' half-life.

**BERGE:** Is that iron-55 or iron-59?

**TOBIAS:** Fifty-nine. But, then, that was only done on a few members of the scientific laboratory personnel, and [several had] Ph.D.s [or M.D.s].

**BERGE:** So in other words, when you were interested in finding out the effects of, say, iron-59 for later experiments, [you] used it on others?

**TOBIAS:** Now, let me clarify this. First of all, the so-called later experiments: We never did any on humans. Now, I'm talking about the John Lawrence group. I wasn't quite so familiar with [what] Hamilton [was doing].

The materials were used [by us] only on people with very serious diseases like leukemia[13] [or] polycythemia vera,[14] and [with the intent] only to cure them. So, that part did not really involve scientific exploration. That was an attempt at therapy. [Initially, there were no "Human Use Committees" or "Health Physics" departments. However, Ernest Lawrence insisted that all scientists should be able to measure radioactivity and calculate what procedures were safe. We used accepted standards for safety, such as the 0.1 roentgen[15] per day [exposure limit, modified by a special factor for neutrons.]

When we used the material on ourselves, that involved exploration. I might just say that, historically, I grew up with the belief that a physician should test all drugs and procedures on himself, taking that risk. I still believe that's the correct procedure, and I am upset at the [policy which] changed that. Later on—we were told by the AEC[16] not to use radioactive material on ourselves. That was wrong on their part.

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11 U.S. physicist, 1901–1958; a pioneer in nuclear physics who built and operated (with M. Stanley Livingston and Milton White) the first cyclotron in 1930 on the Berkeley campus of the University of California; established University of California Radiation Laboratory in 1936 and served as its director until his death. His ingenuity and drive made the Berkeley-based Radiation Laboratory the unofficial capital of nuclear physics in the United States.

12 U.S. nuclear physicist (1904–1967) who played a principal role in the development of the atomic bomb

13 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

14 a class of diseases characterized by overproduction of red blood cells

15 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

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

The proper thing, as I have later found—I worked also in other countries, in Sweden—is for the doctors to use the material on themselves before they have to use it [on others].

**BERGE:** So, by the time you used it for therapeutical purposes—or the John Lawrence group used it for therapeutic purposes—it was already beyond the experimental stage?

**TOBIAS:** The materials that were used in what we might call massive amounts were only for the treatment of disease, and we knew as much as we could know about it. Of course, if you take leukemia, you don't know the cure for leukemia, so there's a limit to what we can know.

But, then, we also used it diagnostically. The diagnostic use involved short-lived substances. Say for example, we would not use long-lived radioactive carbon-14 at all for any kind of diagnostic test. But we would use radiosodium [(sodium-24)], which [has a] 15[-hour] half-life, or these gases. They're all short-lived. We knew that they went in and out and that the dose during that time is minuscule.

## Blood Studies With Radioactive Iron

**PILLAI:** Can we talk about some of the other studies that you were involved with, like the studies that you did with radioactive iron?

**TOBIAS:** Radioactive iron was discovered in our laboratory by Drs. Livingood and [Glenn T.] Seaborg.[17] Until that time, there was no way to understand the formation of hemoglobin[18] in the body. We knew that hemoglobin is an important part of blood. We knew nothing [more] about it, zero.

So, when that was discovered, this seemed very important to medicine, to knowledge. So, Dr. Lawrence and his group, and I included, decided to make a basic study of that in mammals, including man—usually first on rats and then eventually for man.

And in this, our laboratory—I might say, I am myself proud to say that our laboratory essentially uncovered the entire [detailed] mechanism [of radioiron].

So, several years later, we knew how iron passed from food to [bone marrow]. We discovered two new proteins that are carriers in the blood; how [iron] gets into the bone marrow; how, in the bone marrow, it synthesizes into hemoglobin; how, in the red blood corpuscles,[19] it goes into the body and lives for 120 days; and finally, how the body itself realizes the red corpuscles are old and kills them, but reutilizes the iron, which

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[17] U.S. chemist, born 1912, professor of chemistry at the University of California, Berkeley, discoverer of several heavy elements and Nobel Prize recipient in 1952

[18] a protein in red blood cells that transports oxygen from the lungs to the tissues of the body

[19] unattached cells

is then deposited in the liver. So, almost this entire story was due to the scientific effort of our group.

**PILLAI:** Were only patients used for that study, or were normal subjects used as well?

**TOBIAS:** Well, as I told you, normal subjects and some demonstrations, even, were used. For example, I probably had some radioiron, and my friend, Dr. Myron Pollycove, who is a hematologist,[20] had it, and I don't know how many other people [might have been involved].

When we used it on ourselves, they were only very [minute] trace amounts, and in some small part of the mechanism. Like, for example, when we wanted to know how iron is transported in the blood, well, we had at least to give a very small amount, perhaps in food, [to] make the food a little bit radioactive and see where it goes, then take a blood sample and find the protein that had it.

Now, there [are] only two proteins that had it. So, after a few experiments, we knew. And, also, I don't [remember whether] that experiment was done on a human, because that could be done on a rat and on a dog. So it's a little difficult for me now to know if this was done on a human. We used humans only when it seemed important.

I can just tell you one thing that maybe I should feel guilty about, but I don't. There was a class in Physics which I had to teach [to] 500 people, [in a] jammed-full auditorium. I wanted to show them the basics of how radioactive materials are handled by the body.

So my friend, Dr. Pollycove, in the class, got injected. Maybe I injected him; I don't know. And then we had the counters[21] all set up, and the students could watch the results. We did this just once, and it was a small amount.

I don't feel guilty about it at all. Dr. Pollycove is still alive. He's in a high advisory position in Washington, D.C. So, we did things like this, but as I say, I can't think of anything like that that makes me feel guilty. I'm proud of it.

The guilty ones are the regulators who make silly regulations that, "You should use not yourself, but some poor person from the street who doesn't understand what goes on." That's wrong, but that was done by the regulators, not by me.

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20 a medical specialist who studies the nature, function, and diseases of the blood and of blood-forming organs

21 radiation-detection instruments for counting the rate of radiation emissions from radionuclides inside a subject's body

## Human Use Committees

**PILLAI:** Who made those decisions?

**TOBIAS:** Probably the AEC. Go back to your office and find out. At a certain point, the AEC told us officially, "No more experiments on yourself." "What if you have to use a few subjects?" [we asked]. And they said it was okay to pay these subjects, [if you] get permission.

By that time, they set up a so-called Human Use Committee. At this part—we're talking about this very early part—probably there was no Human Use Committee at all.

But as soon as the [AEC] took us over, we had to set up both a local Human Use Committee, a university-wide Human Use Committee, and, probably, a national—I don't know about the national. So, we couldn't use anything [or] anybody without the Human Use Committee passing over it, all right.

That's after the war. I don't know exactly when, but after the war.

**BERGE:** Did you ever have any trouble getting approval for a project?

**TOBIAS:** Oh, sure. Well, maybe not so much trouble, because [I personally] didn't ask for projects that were not safe.

I should explain to you the procedure. There was this austere committee. The [UC Radiation] Lab had five members on the committee, but [that meant very little]: The university itself had to pass on everything we did. That was a 16-member committee, from various departments, probably some of them from—I don't know, Spanish Language, or Physical Education, something like that.

And so, for those [members], we have to prepare a written, elaborate proposal where we would say why we want to do this scientifically and how much [radiation] dose we'll be giving and why that's safe. And we never asked for anything unless we felt it was safe.

## Approval for Studies on Ionizing Cosmic Particles

**TOBIAS:** But let me just give you an example of what we did. At a later time, I decided to explore, myself—see, I'm still the old-timer; I like to do things myself, because I know what goes on—what the effect of the primary particles of cosmic rays[22] is on people. [We asked], "Can we see the cosmic ray particles, the heavy ions going through our eye?"[23] So, we did that experiment on myself.

After that, several others wanted to do it. And so, we presented it to the Human Use Committee. One of the persons who wanted to do this,

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

[23] The particles would appear fleetingly, as flashes of light.

because he didn't believe me [that] I saw the particles—was Dr. Ed McMillan, the Director of the Lab.

So, we got a clearance on him from the Human Use Committee, and they said, "Okay, but you cannot use more than 1,400 particles on Dr. McMillan or anybody else." 1,400 particles. Okay. So we did this, and we did it once. He saw the particles! All we used were 800, so we [were] really well within the 1,400.

Then, he [(McMillian)] wanted to do it again, because he became so interested. And, then, we denied him. He was quite upset about this, because we didn't want to give him more [particles] than necessary. We found that the necessary thing [(test)] was done [(completed)], and so we denied Dr. McMillan.

**BERGE:** Why 1,400? Where was that figure coming from?

**TOBIAS:** We wanted to be more safe than the usual professional worker might be from other radiations. The professional workers were reactor operators and cyclotron operators, people like that.

There was an allowed limit for them, which, at this time—this was probably 1950 or somewhere [around then]—it was 0.1 rad per day. And, then, we calculated what the worst possible effect of a particle could be, and made it so that the person exposed would get less than the professional workers in one day.

The committee deliberated on that, and finally decided 1,400. So, I had to spend a lot of time making sure that each particle was measured before it got into the eye of the person.

**PILLAI:** Were you part of the committee itself that made the decision?

**TOBIAS:** No, no.

**PILLAI:** No? Okay.

**TOBIAS:** Oh, no, definitely not.

**PILLAI:** Who was on the committee, as far as the people in the Lab? Do you recall? Was Lawrence?

**TOBIAS:** Well, there were three people from our Lab. Now, this time, it's the Donner Lab[24] because we were the medical arm. The director, who was at this time James Born, and one of the physicians, Dr. [Thomas] Budinger, and another physician.

I don't know who the other one was. We had several physicians, and they rotated around. But the [whole committee had] 16 people. And Budinger, himself, also tried the eye experiment. And, then, what they

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[24] a laboratory set up at the UC Radiation Laboratory in Berkeley during the 1930s specifically to conduct experiments in medical physics

did in the committee, I wouldn't know, because I would not be surprised if Budinger walked out before they voted.

## Heavy-Ion Research With the Bevatron

**PILLAI:** Were all these eye experiments funded by the AEC, then?

**TOBIAS:** I didn't receive any money. I was employed by the Lab, and I just did it because I felt like doing it. We didn't receive money from the space agency[25] or from the DOE[26] for it.

But, after the experiment was done, this created a sensation. It was done, well, over several weeks, but [it was] more of a crucial experiment, when Dr. McMillan was in the [bevatron[27]]. By that time, about ten of us had done it.

But that was done at the bevatron, and we were trying to convince the DOE to fund the Bevalac.[28] And so that was, in fact, on the night of the day that we announced that a bevatron can accelerate heavy ions, for the first time.

We already were doing it for a while, but we wanted to make an announcement to the public and to DOE and so on. So the night before, McMillan volunteered for this experiment. He wanted to do it *then.*

So, we gave him [800 of the allowed] 1,400 particles, and he saw the effect. He verified it, and he was quite excited, because up until then, he didn't believe us.

So, the morning of that day [the news conference convened] with about 50 newsmen already thinking [that] we are going to announce the acceleration of heavy ions. But then, McMillan stood up and said, "Not only did we accelerate it, but I"—McMillan—"have seen them!" This created quite a sensation around the world.

Many of the papers brought [the news out], and it was good for us, because we were proposing that the Bevalac should be built in order to be able to study the properties of heavy particles which are present in space every day. Space fliers have to go through these, have to fly through these particles.

And it just happened in a good way, because there's excitement. We showed that the Lab could do this, and, within a few weeks, the DOE

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[25] National Aeronautics Civilian Administration (NACA), the predecessor to the National Aeronautics and Space Administration (NASA)

[26] The U.S. Department of Energy was established in 1977. Tobias may be referring to the U.S. Energy Research and Development Administration (ERDA), a predecessor agency established earlier that decade.

[27] an accelerator in which protons are raised to very high energy levels, measured in billion electron-volts (BeV), by modulating the frequency of accelerating voltage. Derives its name from BeV + *a* (connective) + tron.

[28] a hybrid of two accelerators: a bevatron and a super-HILAC or **H**eavy **I**on **L**inear **AC**celerator

and the space agency both approved the changeover from the bevatron to the Bevalac.

**PILLAI:** Did you know of other studies that were being conducted? Like, at Sandia National Laboratory,[29] they were also doing studies on light flashes. Were you aware of those studies?

**TOBIAS:** No: Nobody else was doing it at the time.

**PILLAI:** At the time, right.

**TOBIAS:** Not only that, but the space agency spent a lot of money on a learned committee who came out with the conclusion that the light flashes seen by the astronauts up in space were a psychological delusion.

That's one reason I had to do the experiment, because I knew they were wrong. Ten years before, I [had] predicted that human beings could see heavily ionizing particles if they went through their eye.

And these people were all wrong. The whole committee was wrong. So that, in fact, this helped my own decision to do something to get the national agencies into the right direction.

And then, when we did it, another group at Brookhaven National Laboratory[30] had a countertheory, namely that—my theory was that it was a direct effect of ionization of the particles going through the visual cells that were sending this. The other group felt that they were a so-called *Cerenkov effect*. The Cerenkov effect is due to visible light, and also to that light that accompanies the motion of a particle.

Dr. Bond, who was director of the Brookhaven medical study, and others believed that theory. And he turned out to be wrong—or 90 percent wrong. Then he came to [UC] Berkeley.

Nobody else could do this except Berkeley, and they, themselves, in their own eyes, again, showed that heavy particles can be seen and it was the same effect as [they believed was] the Cerenkov effect.

The Cerenkov effect already was seen in the eye due to beta rays by a Russian scientist two years before that, and it exists, except that this effect, the space radiation effect, is not due to Cerenkov. So I feel very, very good that we have done this.

Then, after the space agency began to give us money, as well as the DOE, that—maybe you don't want this on this record, because it doesn't make DOE look too good.

**PILLAI:** We want whatever you have to say about it.

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[29] Albuquerque, New Mexico

[30] Upton, New York

## Boron Isotope Research and Therapy

**PILLAI:** Since you just mentioned Brookhaven National Laboratory, I'm curious: Do you know anything about the boron neutron capture therapy [(BNCT)][31] that they were conducting on patients there?[32]

**TOBIAS:** Yes.

**PILLAI:** What is your opinion about that? Because, just a few months ago, they just started the program up again.[33] Do you—

**TOBIAS:** —That's another chapter in my book. But, first of all, this idea came from Berkeley. It was first done on animals in Berkeley around 1940 by [Professor] Krueger. He showed, using animals—I guess, probably rats, rats or mice, I don't know which—that the neutron capture effect has potential.

That was in 1940. In 1947, after the war, I, myself, and some of my colleagues figured out that it wasn't just boron and lithium, but [that] uranium could do it, too. The Manhattan Project donated some $^{235}U$ [(uranium-235)], and we tried these experiments on mice at the Oak Ridge National Lab [(Oak Ridge, Tennessee)]. So, that was some of the origin of that.

**PILLAI:** Are you saying that you worked at Oak Ridge National Laboratory on this experiment?

**TOBIAS:** I went there for a couple of weeks. Oak Ridge donated the reactor, and Dr. Stapleton, who was from Oak Ridge and later in DOE, helped in the experiment. But that was 1947.

Then, about 1950 or 1951, the MIT[34] reactor with Dr. [William] Sweet tried this in human brain, and it wasn't very successful. Later on, the Brookhaven Lab also tried it, and it wasn't very successful.

But the reason that it wasn't very successful is, they didn't really do [enough] basic research. This should be a lesson for both DOE and the space agency: that if you neglect to fund the basic science, you're going to waste people and spend a lot of money and not find out what goes on.

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31 Brain tumor patients were injected with a discrete amount of boron that was intended to deposit in the tumor. The tumor was then bombarded with a beam of neutrons that was directed to the boron in the hope of destroying the tumor.

32 From 1951 to 1961, Brookhaven conducted boron neutron capture therapy on 45 patients. All were suffering from aggressive and otherwise untreatable types of brain tumors; all had received conventional radiation treatments. The therapy was unsuccessful. Patients so-treated generally lived only as long as patients with the same types of brain tumor who were treated with conventional radiation therapies. The work was funded by the U.S. Atomic Energy Commission. Source: *Human Radiation Experiments Associated with the U.S. Department of Energy and Its Predecessors* (213 pages), DOE/EH-0491, July 1995.

33 Advances in technology that deliver higher concentrations of boron to tumor tissues for potentially improved therapy have brought about the return of boron neutron capture therapy. As a result, Brookhaven is currently involved in BNCT research and clinical trials.

34 Massachusetts Institute of Technology, Cambridge, Massachusetts

Anyway, in this case, nobody had a good boron isotope to make sure that it goes to tumors.[35] And they already were trying it on human beings. Also, they didn't have a good method to measure boron in tissues, unless they [would] make a tissue slice, take the brain of the human and slice it; then we might see. So that was the situation until five to ten years ago.

Meanwhile, the Japanese took it up. They claimed that they had a compound that worked in humans, and they [got] ahead of us, because they have a somewhat successful therapy project.

So then, [much later], one of my former students developed a method to measure boron in tissue in vivo, by nuclear magnetic resonance. That came 30 years after we knew of the possibilities. And then, [there] was a man at Argonne Laboratory[36] who made some uranium compounds that seemed to be going to tumors.

**PILLAI:** Do you know who that is?

**TOBIAS:** No, I forgot his name. Also, a Swedish [scientist] named Börje Larson suggested making antibodies against tumor cells and loading the antibodies with boron. This did look promising, and I believe this may be one of the things they're trying. It's very, very promising for liver tumors. But I think the methods are still very far from being successful.

There was a hint, not followed up scientifically by DOE or anybody else (but, it would have cost money), namely that some plant cells contain boron in their nuclei. And so, I suggested to DOE to please explore this, but they didn't.

And nobody knows how, but the boron is contained somewhere in the [plant] cell nucleus. It makes the cells extremely sensitive to neutron rays and, maybe if we knew what that compound was, we could then, perhaps, make a compound that would be therapeutically useful.

## Shared Knowledge and Coordination of AEC-Funded Research

**PILLAI:** About some of the other collaborations, it seems that researchers at the Donner Laboratory were working with or knew of research activities going on at all of the other AEC-funded Laboratories. Is that correct?

**TOBIAS:** I would say so. The AEC's program includes a meeting of the Laboratory Directors at various times and places. It was [held] as often as every month, or as rarely as four times a year. There they would meet and discuss everybody's program and make scientific presentations.

So, we always participated in that. Not me, necessarily, but the Laboratory Director, John Lawrence and, later, James Born, and, still later, other people. And, sometimes, I went to it, too.

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[35] an uncontrolled, abnormal, circumscribed growth of cells in any tissue; neoplasm

[36] Argonne National Laboratory outside Chicago

The Laboratory programs were so big, they couldn't possibly tell us everything. They would choose a few topics, and we would [then] discuss [those]. And sometimes they would have classified sessions, too.

**PILLAI:** Do you think that the same type of research was being conducted at different Labs at the same time? Was there any mechanism in place to ensure that that wasn't happening?

**TOBIAS:** My general feeling about DOE is that this very seldom happened. There's a whole raft of officials in Washington, D.C., trying to make sure that nobody gets [repeat] grants on the same thing.

**PILLAI:** I'm talking about more [in the early years, by] the AEC.

**TOBIAS:** We couldn't just "work on something." Most of the time, we would have to get money first. But earlier, at the time when I mentioned to you, it was [easier to work on your own ideas]. And initially in the AEC, investigators had a good amount of freedom on what topic they would choose.

But then, later on, the agency tightened more and more and more, and, finally, I couldn't even breathe without the DOE knowing and disapproving or something.

**BERGE:** So if you became interested, say, in radioiron, radioiodine, radiogold, whatever, and someone else across the country [was experimenting with it]—

**TOBIAS:** —Because, first of all, you have to make a [distinction] between the classified research and the unclassified. Most of the biomedical research was unclassified, completely open. People could come to a lab and learn everything.

So if I worked on radiogold and somebody in New York was interested, they could just phone me and come and see, for two weeks or whatever he wanted, take everything away, and I would have no control whatsoever in what he will be doing with it. Assuming that he gets money someplace, but that wasn't my concern. He could copy me, and sometimes he did copy me.

And, for example, I thought [that] I discovered a wonderful method for microanalysis of tissue—it's early after the war—*neutron activation analysis.* Turned out I didn't discover it, because a couple of other people more or less knew about it.

Anyway, I had a project. My group developed what they thought were very nice ways to analyze 35 different elements in tissues. And then, a [scientist] showed up from Memorial Sloan-Kettering Foundation [(New York, New York)] who wanted to learn this. So we said, "Fine. Learn it." And before we knew it, this same guy went home and published the whole thing, including our method, under his own name. And that was that.

And so, [after this scientist] did other bad things, they fired him. But I, myself, finally didn't continue this line of research.

But for the programmatic research, at the time, the Lab Directors were given [some] latitude. We were told general guidelines. We would know, for example, that basic medical biological research is okay with radioisotopes as part of the AEC's mandate.

We justified it because the AEC has almost all the instruments that could make the radioactivity and that could measure it. We knew we could work on cancer [research].

[From time to time, the AEC] would tell us what the national priorities were. National priorities, in those days, were to understand the mechanism of the biological effects of radiation and the hazards; to do experiments on it, maybe put up an animal group; and to find ways to prevent or cure the radiation-caused things.

That was the more programmatic part of the agency. We did the two together at times [(mechanisms and biological effects research)]. The two goals seemed to be similar.

## Classified Research Involving Human Subjects

**PILLAI:** You were saying that most of this research was unclassified. Do you know of any research that was classified that was done on humans?

**TOBIAS:** During the war, we had the Manhattan Project, and they had their own committee. I believe Dr. Stone[37] in San Francisco was involved in that committee, and, also, Dr. Stafford Warren[38] at UCLA, and [other] people, [such as] Dr. [Shields] Warren[39] in Boston, at the Harvard Medical

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37 A pioneer in radiation therapy, Robert Stone, M.D., had conducted human radiation studies before World War II. He was an early researcher at the Lawrence Radiation Laboratory and became a major figure in radiobiology research. When Joseph Hamilton began operating his 60-inch cyclotron at Crocker Laboratory, Stone requested that fission products be made on the cyclotron and that their fate in mammals be systematically studied in small animals. That information would be used for radiation protection proposes. In 1942, while chairing the Department of Radiology at UC San Francisco's medical school, Stone was recruited to lead the Medical Division of the Manhattan Project, overseeing all biological, medical, and radiological protection research. Accordingly, he moved to the University of Chicago, where he served as Associate Director for Health under Arthur Compton. In the 1950s, after serving in the Atomic Energy Commission, Stone returned to his post at the UCSF as head of the Department of Radiology. Under Stone, UCSF acquired a 70-MeV synchrotron for conducting therapeutic research.

38 A professor of Radiology at the University of Rochester (Rochester, New York), site of research involving plutonium and human subjects. 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.

39 Shields Warren, M.D., was Chief Pathologist at New England Deaconess Hospital and Professor of Pathology at Harvard Medical School. He joined the U.S. Navy Medical Department in 1939 and wrote with others on what was then known about radiation during World War II. Dr. Warren served on the first U.S. team to visit Hiroshima and Nagasaki after they were bombed with atomic weapons and was involved in creating what became the Atomic Bomb Casualty Commission. He was the first director of the AEC's Division of Biology and Medicine and, later, established his own cancer research institute at New England Deaconess Hospital. See "Recollections of Shields Warren" in DOE/EH-0471, *Human Radia-*

School, who was the head of the AEC biomedical group—all those people were involved in setting the priorities, allocating the money and reviewing the work.

Now, the Manhattan Project [portion of this work] had a continuing part, as far as I know. I wasn't participating on it, so I know very little. But in our Laboratory, Dr. Hamilton took a leading role in that field. I wasn't even cleared for some of it. Some of that was secret information. I was not told what they were doing. So I simply don't know.

We have to make a big [distinction] between that and [the work of] John Lawrence, who did not participate in that at all, as far as I know. John Lawrence's [interest] and our interest was to use isotopes and radiation for [human] welfare and the cure of human disease.

And we used humans, and that was done by certain groups. The patients had to volunteer, and the doctors had to volunteer their patients. We didn't have a medical practice. We didn't get money for it.

The DOE and the AEC supported some of those investigations which reached into the human level. They've supported the pituitary[40] radiation of humans and other brain irradiations.

[Later,] they told us to go to the National Cancer Institute for support, and they told us they were collaborating with the National Cancer Institute. So, we then got some support for the general problems of cancer from the National Cancer Institute, while still being an AEC or DOE Lab.

Now, the AEC received from us monthly and quarterly progress reports. Most of the ones I knew about were all unclassified. But they could classify [some part of a report]. Somebody would read it and then come back with, "Well, you ought to classify that paragraph." So then, somebody [would] put a [rubber] stamp on it.

**PILLAI:** How often did that occur? Was it a frequent occurrence?

**TOBIAS:** They declared something classified?

**PILLAI:** Um-hmm.

## Classification of Fallout-Induced Radioactivity Detected in Animals

**TOBIAS:** I don't know. I don't know how often, because I didn't see all the papers, but I can tell you one example. It made me a little bit upset at the time. This was around the [time of the] atomic tests [by the United States] at Eniwetok [Atoll in the Marshall Islands]. I don't know the

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*tion Studies: Remembering the Early Years; Oral History of Radiologist Henry I. Kohn, M.D., Ph.D.* (June 1995).

[40] the small gland attached to the base of the brain, constituting the master endocrine gland affecting all hormonal functions of the body

year, 1950-something. I had a postdoctoral fellow from Tennessee, [Chester Middlesworth], who came into my lab and was doing things.

He became interested—I don't exactly know how. I believe what may have occurred is that he went to the slaughterhouse in San Francisco, where we used to get parts of the bodies of animals, you know, for our studies. We might get brains, something like this.

So, he got some parts. And one of those parts, the thyroid,[41] was radioactive. Okay. So, he came to me and asked, "What's going on?"

I said, "Well, I didn't know that, but why don't you get a few more of these thyroid glands from animals and see?"

So, he got several more thyroids. They were all somewhat radioactive. And so then, by that time, a newspaper here was writing about it as a radioactive cloud [from the bomb tests] coming over the United States.

So, this guy began to take—I don't know what kind of samples—a bunch of samples, wherever he could get them, and he wrote a paper which showed that some of the cattle had small amounts of radioactivity, and what's in grass, and things like that. So, he wrote the paper. He was not cleared, because we were just doing unclassified research.

So I said, "Well, this is great. Let's publish it." So at this point, we sent a copy of our paper before publication to [a reviewer] in the [UC] Radiation Lab. [They] came back and said, "That's classified stuff you are working on!" I [had] never even heard that anybody was working on it, and [Middlesworth] was so upset.

[The AEC] decided to classify it. They came into our lab and got all the copies. This guy was very upset, and I was a little bit upset, because he was just doing science that anybody else could do, the Russians could do, or whatever. It was valid science. It was showing us something, but they did classify it, and they decided not to clear that individual for secret [information].

He spent half a year on this paper [and then] he couldn't read his own paper! I couldn't give [a copy to] him. Somehow, there was a copy somewhere in our safe, but I couldn't give it to him. And he would get very upset, and he went home [to Tennessee]. But, that's the one time I know that this sort of thing occurred.

At that time, the agency [apparently] did not want to alarm the American population that something becomes radioactive in this country, or what we did. We just basically stopped working on it. I wasn't so interested in it. It wasn't my specific line of research. And that was that.

But, at other times, there were some times [when my work] may have [been] related to national security. When I did the uranium experiment,

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

I agreed in advance [how much] uranium [we could use per mouse], and I followed that.

[Some] atomic accidents [did] occur on people. They certainly did not rush to the New York *Times* to publish the [details].

There was an accident at the Idaho reactor where a person got propelled into the roof, and, also, the reactor grounds got contaminated.[42]

Dr. Hamilton's group had to do some of the histopathology.[43] They did the histopathology on several of these accidents. Dr. [Patricia] Durbin[44] was doing it. So I knew about it. I didn't know the details.

There was another time when we were just rambling all around. Sometimes we would realize that we have information of potential value to the national defense effort, and your office in Washington[45] would try to turn us off, sometimes for not very good reasons.

## Heavy-Particle Radiography

**TOBIAS:** For example, I have invented a method for radiography with heavy ions, *heavy-particle radiography,* which made rather very good pictures, similar to x rays, of people and things.

So, I don't know who suggested—maybe I thought of it myself, or maybe somebody in my group. At that time, a part of a Russian satellite fell down in Canada, containing plutonium. It contaminated the countryside in Canada, and there was a big flap about this.[46] They [(the Cana-

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42 The Idaho Falls National Laboratory accident, SL-1, was a reactor accident that resulted in the death of three workers. 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).

43 the branch of pathology dealing with the structure of normal or diseased tissue

44 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).

45 AEC Headquarters

46 In January 1978, the Soviet military space satellite, *Cosmos 954,* broke up during an uncontrolled reentry and scattered radioactive parts and fuel from its on-board nuclear power plant over a 483-mile-wide swath in the vicinity of Great Slave Lake in the Northwest Territories of Canada. *Cosmos 954* was a Soviet radar ocean reconnaissance satellite (RORSAT) that had been sent into orbit to detect and track U.S. Navy aircraft carriers worldwide. Because the power demands of the satellite's radar exceeded the capability of solar power systems of the day, the Soviet low-earth-orbit RORSATs were powered by a small nuclear generator. The U.S.–Canadian North American Air Defense Command (NORAD) detected the fact that *Cosmos 954*'s orbit had experienced unplanned decay, leaving the time of reentry predictable to within a day, but the point of reentry impossible to foretell. Civilian emergency service organizations in many parts of the world were placed on secret alert (without being told why) until after the reentry. The crash of *Cosmos 954* in Canada resulted in no reported human injuries. Under an existing treaty, the Soviet Union was liable for all costs associated with cleanup. The event led to further international negotiation to limit the use of nuclear power in space. Later generations of Soviet RORSATs were redesigned to separate and boost their nuclear power plant into a higher parking orbit at the end of their mission life.

dian people)] felt they [(the Soviets)] should clean up the place. The thing shattered. There was fissionable material and other radiation all around.

They [(the U.S. government)] sent groups of teams up there and then they got some radioactive pieces back. We got [these] back to Livermore, but the [pieces] were so radioactive, there was nothing much you could do about it. You have to put it behind a shield and just wait [for the radioactivity to decline].

So my method worked out great. I put some things behind a thick lead shield. And then, I made the heavy-particle beam go through [the assembly]. It imaged these things behind the lead shield rather nicely. So I became quite excited about it. I said [to myself], "Here is a method that Livermore and other people could use for investigating highly radioactive pieces"—not [only to determine] the [amount of] radiation, but [also] the shape [of the object].

So I wrote a letter to Dr. [Robert] Wood at the DOE, [or] whatever it was at the time, describing the method and saying, "We want to give you a priority on this. We haven't published it. I think it should be followed up, and it could be done at the bevatron. You would have to get a separate beam [channel]. It would be somewhat expensive, but I think it would be very good."

So Washington went into a flap, and I still don't know why. Maybe they were doing the same thing that I was trying to do, but they didn't tell me. I was the inventor of the method.

Anyway, they didn't follow up, as far as I know, any part of this at all. Then, somebody mentioned [that they had an] ultrasonic method that they hoped was going to work out. And that was that.

And I still feel, up to the present day, that this technology is needed and that you should use accelerated heavy particles for it, and I'm upset at DOE, or whoever [it was who] cut this in the bud. And it was classified, so there's nothing I could do: [I] just let them have their classified letter and I went on to other things.

## Heavy-Particle Beams and Medical Research

**BERGE:** I have about two more questions. You mentioned the pituitary irradiation, which was supported by AEC, and I was wondering if you could tell us a little bit about the development of those studies and [their applications] for breast cancer.

**TOBIAS:** Nothing went wrong, but things just got delayed. Some of [this was] just due to officialdom: the lack of insight at the DOE that heavy-particle beams are very important for medicine. That's the main reason.

In fact, I feel—as long as I can complain, I'll do it right now. I spent my life on this! It's a good [method] for breast cancer and other human

disease. But, by the time it gets to the [headquarters of] DOE, science becomes low priority. High priority is politics.

So, what did they do? Briefly, they stopped the whole Bevalac project. They mothballed the Bevalac, and they spent more money [(perhaps a billion dollars)] on trying to clean up the place[47] than [they spent] on the scientific research. I think that's criminal on the part of the agency, because they were cleaning up things that didn't need any cleanup,[48] and the research should have continued.

Now the United States is behind because it doesn't have a heavy-ion accelerator. The space program is behind. The breast cancer research is behind.

Well, luckily, other countries recognized the value, so now there is a good project in Germany, a beautiful heavy-ion accelerator. They will do the very same things, copying exactly what I said, and they're getting to human use, and [I hope that] part of it will be breast cancer [treatment].

The Japanese accelerator: The Japanese didn't hesitate spending money on their heavy ion accelerator, and they will use it in cancer therapy all-around.

[Both of these countries think heavy-ion research is worthwhile] except the United States. That, I think, is practically criminal conduct on the part of our agency and I'm upset about it.

## Pituitary Irradiation Studies

**BERGE:** Can you tell us a little bit about the theory behind pituitary irradiation?

**TOBIAS:** Yes. Dr. Robert Wilson, as you know, suggested the use of fast particles for medicine, but Wilson accepted another job. So, Ernest Lawrence asked me and John Lawrence to develop this technology, which we did.

A few years later, when the 184-inch cyclotron was operating, Ernest Lawrence very generously gave us a [treatment] room, and we developed the beams. At the time, the only beam that [we had] was deuterons and helium ions.

The protons were too high-energy for physics, and they were not willing to spend the money and the effort on the protons. So, we threw out the protons.

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47 Hanford Site, near Richland, Washington

48 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, DC: 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.

But the helium and deuteron[49] beams became very good, and we demonstrated on animals that it cured at an amazing rate some mammary cancers in rats.

Also, Ernest Lawrence and myself decided that these beams can be aimed so accurately that we should look for problems in medicine that cannot be handled [by other means], [but] that could be handled by the particle beam.

Dr. Donald Van Dyke and I started to study the pituitary gland of animals. That's because the pituitary is a tiny gland in the center of the head. It's the master gland of the body. And we were just curious to see, "Can this beam selectively inhibit the pituitary?" Well, that turned out to be very successful.

We demonstrated in rats that we can hypophysectomize[50] the rats without a drop of blood. And then, we carried it to [other animals and to] monkeys. We could hypophysectomize the monkeys, too. And, again, no blood and no great discomfort to the animal.

So about that time, a Swedish doctor, Herbert Oliecrona, published a paper whereby he removed the pituitary gland from breast cancer patients. He did 12 patients, initially, and this was a miraculous thing. Not only did the breast cancer disappear, but also the extensions of the cancer. The metastatic[51] extensions were also improved.

So we became quite excited and said, "Here is our application. We already have the technique developed in animals. Let's do it in humans." We convened a national committee—a professor at Harvard, and Chicago, several people [were] on it—who voted [that] this is a desirable project. I was not a voting member of the committee.

We then tried [the beam] on several dogs with cancer. There was a large Doberman pinscher that had cancer that was ulcerating and oozing milk all the time. That was one of the signs that the cancer was there.

We irradiated this dog in the pituitary and, within two weeks, the secretion of milk stopped and the tumor began to regress, even though we irradiated [only the pituitary].

So Dr. Huggins, who is a Nobel Prize winner, got very excited. (He was a member of the committee surveying this.) He wanted to be a member working with us, and he came out [to Berkeley] and we started a human project.

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49 a positively charged particle consisting of a proton and a neutron, equivalent to the nucleus of an atom of deuterium (an isotope of hydrogen having twice the mass of ordinary hydrogen)

50 remove (or, in this context, destroy) the pituitary gland

51 relating to metastasis, 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

We did about 50 or 60 patients with the helium beam, and about half of them showed regressions of the tumor; not only of the initial tumor. Every one of these patients had metastases, and they were doomed to die. So half of them got well, some of them for a prolonged time.

We discovered we had to aim the beam at the pituitary gland, which is about one centimeter [(0.4 inch) deep] in the body. We developed an elaborate [instrument] for this.

But some of the patients, about a year after treatment, developed some neurological[52] symptoms—[mainly] double vision (diplopia). The reason was because we affected some of the cranial nerves.

So we finished this project, and then we decided [that] we needed a better beam, and the better beam [was] to be a carbon beam. The reason is because carbon can be aimed more accurately. The helium and proton beams scatter too much: If you try to do this with protons, you also irradiate the optic nerve and other parts of [the] brain, so we decided to do some other things "until" the carbon beam [would become] available.

Well, that took my whole rest of my scientific life—20 more years—and not due to my fault, but, again, if you want to point fingers, you could say that the learned officials in Washington, D.C., never understood this matter completely and never really gave enough support. They supported physics [with] a thousand times more [money] than biology. We were just [riding] piggyback.

So, finally, the bevatron committee said, "Why just pituitary tumors, or pituitary irradiation? [Treat destroying all kinds of] tumors in the body [with the bevatron]."

Dr. [John] Lawrence retired, [and] the initial team was gone. I had to make an agreement with the Radiation Oncology Department, [UC] San Francisco. The doctors became more interested in irradiating direct tumors, so most of the Bevalac project was done with heavy neon and other beams rather than on breast cancer.

But I'm a patient person, waiting, waiting, waiting, waiting. So, what happened? I might as well tell you that, because I'm still upset about that, too.

## Failed Private Venture to Build an Accelerator for Medical Research

**TOBIAS:** Finally, a private group of individuals decided there was enough promise, so they wanted to build their own accelerator for medicine, because the Bevalac was never built for medicine; it was too expensive to operate. This group [was ABC].[53]

The hospital complex of four hospitals in Oakland[, California,] was going to be donating land to build the accelerator, which we called

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[52] relating to the nervous system

[53] the Advanced Biomedical Center at Oakland, California

"Libra." I wrote detailed [reports] about it. I had officials of [AEC] visit, officials of NCI[54] visit. All kinds of officials were visiting all the time.

By that time, the [AEC] had a program from Washington: ["technology transfer"].[55] The agency was told to help the private users of the results of the work of [AEC].

The Lawrence Berkeley Lab [received] monies to do this, and, naively, we thought that maybe they will help us build our machine.

In fact, the Director of LBL at one time officially told us that he not only will help with planning and engineering design, but also we can have several of the parts of the Bevalac when the Bevalac will be dismantled so that we can install it at some saving of cost in our machine.

So what happened? First of all, the personnel at the Radiation Lab appropriated my ideas. All of a sudden, they were *also* designing a Libra to be [installed] at the Radiation Lab at Government expense.

That, of course, cooled off my private donors. This required several million dollars. [They figured,] "If the Government is going to do it, why should we give private money for it?"

Secondly, the [AEC] didn't approve the project, but [instead] they decided to mothball the Bevalac. So, what do we have now? We have zero. No private machine [and no technology transfer].

The technology [for which AEC] spent probably more than $50 million to develop is not being used, and there is no machine, as far as I know, being planned or built in the United States. We very nicely taught everything we knew to [our colleagues] the Japanese and the Germans, and now they have the technology and are moving ahead, and I can retire and die.

## Selection of Patients for Research

**BERGE:** A quick question, actually, based on what you were saying. You were talking about the patients who were irradiated in the pituitary, and I was wondering: You said these were patients who were in the terminal stages of their illness?

**TOBIAS:** Well, they were not necessarily terminal, but they were advancing and metastatic. We set up certain criteria.

I think the [medical] doctors will tell you that when you can diagnose, by objective methods, [the existence of] bone metastasis or skin metastasis, other [metabolic ions], then the patient['s cancer] is advancing. Those are the patients we used. We used private doctors and private patients.

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[54] National Cancer Institute

[55] In this context, technology transfer means the transfer of Government-sponsored research results or benefit of facilities to the private sector.

The private doctors had to agree in advance. [After treatment,] we were going to return the patient to the care of his doctor, but he had to agree to make all the necessary tests in collaboration with us and to follow this patient to death and, then, make the data available to us. It worked out very well.

Now, the national project [is] completely different. It's set up for protecting the doctors and make the doctors richer. The patients are a low priority somewhere. But the national project used—[it is] difficult to describe this in a few words.

First of all, there is a statistically blind study. The doctor cannot decide what his patient gets. The patient has to agree, without seeing anything, to participate in this project. Right there, that cuts out some of the patients.

Secondly, they're choosing [treatment by lottery]. Then they treat the patients. The patients in our study, presumably for scientific validity, are getting exactly the same as the other patients, perhaps, in an x-ray department somewhere.

Well, this does not protect the patient. It doesn't do much for the patient, because the doctors won't put the patient into this group until the patient is really terminal. Until that time, they want to milk the patient's money, if I may say that, and try to "save" the patient.

When a doctor decides his patient is really beyond help, then he becomes a member of this group, and, by a lottery, [a patient may be] assigned to us but, perhaps, the patient is already so far-gone [that] there is really nothing much we can do. But the doctor's responsibility is greatly decreased.

But what does the doctor do? He doesn't try to cure this patient; he looks at the protocol. So, now they want to treat this guy with x rays, the other guy with heavy ions.

It's what [the doctor is] going to do. [He will not] worry too much when that patient develops a metastasis on his ear or anyplace else: "Let somebody else do that."

I think that [national program is not helping]. [It is] the wrong thing to do to the patient. It's the wrong way to proceed, and yet the whole National Cancer Institute is following it. I think it's very bad.

Anyway, it doesn't have to be this way, but you have to be a private hospital to do it the other way, which is the way we did it initially.

So, those studies, however, are progressing, and with all the bad things I'm saying, I should say that the doctors who have [worked on] it are dedicated and they have shown that in several classes of disease the heavy ions are useful.

Two of the large classes, one of them prostate cancer and the other lymph cancer, are still being studied. Now, that is an interesting thing,

because —[presumably,] the doctor is my friend, but he won't tell me how the patients are doing, because the same NCI study prevents him to do so.

The study is supposed to be secret for a number of years, until it's finished. *Then* he will tell me the statistics. But during these years, we cannot plan a new accelerator based on the results or do anything. The patients are dying left and right, and there's nothing I can do. I have to sit here and just wait. So, I just submit to you that this is not the right way to do it.

**PILLAI:** During the '40s and the '50s, when you did different studies on different types of patients, how were the patients selected then?

**TOBIAS:** Well, how were they represented?

**PILLAI:** How did you select—how were patients selected to be in the studies during the '40s and the '50s?

**TOBIAS:** Well, there was a group of doctors who agreed to be—these were private doctors, mostly, some university doctors—the University of California, or—either private or university... But, we would work with the individual doctors. The individual doctor had a discussion with us, and he had to agree—he could select his patients.

First of all, he would select a patient from several patients, and he feels that this patient might benefit. We weren't trying to do a blind statistical study. We were asking the doctor to send us patients, even though far ahead, but nevertheless patients who might benefit from this new method, patients who are willing to undergo a new thing. Okay?

So, the doctor had to agree, for example, not to give other medications unless we agreed afterwards, or other operations. We wanted to know everything, and to follow the patients in a way that he would agree to. And then—and send them the patients from time to time, et cetera, so they could follow the patient.

There was no control group, as such, because Dr. Lawrence and I felt, too, that a responsible physician would be very uncomfortable, if he can see any hope for the future life of this patient, to put him in a blind trial when [the doctor] doesn't know what [the patient is] getting.

It's a different method from what they use today, and, you know, I could spend the rest of my time until I die trying to convince the medical profession. I don't think I can do that, but I just tell you how it was.

I might just say that the doctors we chose were good doctors.

At one time, we were referred a patient who didn't have breast cancer at all, and, then, it was decided that maybe we don't want to work with that doctor because [of that].[56]

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[56] Since the candidate was already tumor-free, the risk-to-benefit ratio would have been unnecessarily high.

And then, the patient—the volunteer would be told [in detail] what the procedure [and risks are], and they would be treated [only if they volunteered]. And then, the doctor could withdraw the patient either before or after the [irradiation], but we would have to know.

If he withdrew the patient [and] then decided to use boron, then we would have to make a note in our notebook and put that in [a special] group.

Now, right now, in this other study which is going on now, I don't have any influence on that. It turned out that some of the patients we treated with the Bevalac also have gotten or are getting chemotherapy, and the doctors don't have to give me their promise. I find out after the person had it, maybe. Maybe I won't even find out.

So therefore, the group I am studying now doesn't have the same validity as the group we did at that time.

**PILLAI:** For the groups that you did at that time, during the '40s and '50s, for those patients, were the private physicians explaining the procedures, or were you and Lawrence and others?

**TOBIAS:** The private doctor would call in his patients first. I don't know what he would say, but I would say, maybe he would say, "Well, I would like to refer you to Dr. Lawrence, and you go and see Dr. Lawrence," something like that.

And then, we would also get all the x rays, and we would make our own x rays, do all kinds of studies on the patient before we decide that this is a proper candidate, being a person who has advancing disease and metastases.

If they didn't have metastases, and if the disease seemed to be arrested, we would not treat that patient. So, we may send the patient away, say[ing to the patient], "I'll be in touch with Dr. Smith, and if you get worse, call Dr. Smith, and maybe he will want to send you back here." That happened a few times.

Also, at the time, Dr. Smith would send patients who really needed this already. So, we would then investigate. Then we would tell the patient everything they wanted to know about it. I can't remember if they signed papers or not, but Dr. Born, who at the time was Associate Director [of the Radiation Lab] under Dr. Lawrence, had the job of [handling the] relationship with the patients and explaining [all] things [in detail]. We didn't have a single patient complain who went through this.

**PILLAI:** You said something about papers that were given to these patients. Do you know if there were any consent forms?

**TOBIAS:** Well, I'm sure there were, but I am a physicist, not an M.D. I tell you who may have it: Dr. Lawrence had an elaborate file, which was inherited by Dr. Born, and, then, all the papers are with that file. They had very good individual forms.

There is a lady—she retired, but in the Rad Lab,[57] you might find her; I don't know. [I believe] Miss DeMoore is her name. She was working on the data [from] patients. They were doing it, but I have to be careful not to transgress on a physician's [domain].

## Remembrances of Dr. William Siri

**PILLAI:** Did you do any studies with or do you recall William Siri?[58]

**TOBIAS:** Yes.

**PILLAI:** Siri was doing some studies on body composition.

**TOBIAS:** Yes.

**PILLAI:** Did you have any involvement in that, or do you know anything about that?

**TOBIAS:** Well, he was independent of me. He was another member of the Lab. I know about it. What do you want to know?

**PILLAI:** Do you know anything about any studies that he would have done on professional football players?

**TOBIAS:** He had all kinds of groups of people. He developed the whole-body [counter]—patients were enclosed in a whole-body box and, then, the helium gas or whatever gas he put in there was measured. But he is alive; you can go and interview him.

**PILLAI:** Yes, we're going to see him.[59] It's kind of skipping a little bit to something else, but at Oak Ridge, they were doing studies on total-body irradiation. Do you have any opinions on that, or can you give us your opinion on total-body irradiation?

## Policy on Radiation Exposure Levels

**TOBIAS:** I knew [of] it at the time. I had no official relations whatever [to that project]. I knew at the time they were doing it, and probably I may have seen the room; I can't remember. But I know that they were giving a low-level whole-body radiation to terminal cancer patients. I didn't form any particular opinion at the time. It was another project of somebody else.

I can just tell you something, however, about radiation in general and how I think it has turned out, after I retired, that a lot of the things that I accepted while I was officially working, I am now liberated to criticize.

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[57] in the Archives and Records Office of the Lawrence Berkeley Laboratory

[58] William Emil Siri, (1919–), a physicist, worked on the Manhattan Project at UC Berkeley from 1943 to 1945. Afterward he conducted research at Donner Laboratory. Siri researched the application of radioisotopes to biology and medicine. He also studied high-altitude physiology, leading expeditions to the Peruvian Andes, the Himalaya Mountains, and Antarctica.

[59] The subsequent interview with Siri proved unusable as it was full of lacunae.

One of the things I accepted was the determination of permissible dose for radiation workers [and sick] patients, and I now think that all the committee, the United States committee,[60] has been woefully, completely off on that, because they finally adopted the linearity hypothesis.

That [linearity assumption] means that [the] smallest dose of radiation is already bad. At the time, I knew that this is not so, but what they are telling me—and it didn't come through to the public, I think—[is] that they did this to be "extra safe": "To be extra safe, we assume linearity." It's not a scientific conclusion.

Well, I am convinced that it's a wrong conclusion, [convinced] that small doses of radiation are not necessarily bad. [I think that it is incorrect to think of radiation as] pristine [(by itself the cause of any kind of effect)]. It is radiation [added to] the rest of the environment [that must be considered as a whole].

[Several] of the committees I know about, said, "Well, we're not concerned about carcinogenic agents in the environment, any of that stuff. We're just interested in radiation."

That's completely wrong and fallacious, scientifically, because radiation acts by cooperation with all the rest of the environment, and there are many other agents in the environment that [can] make radiation look bad.

It may be, also, that [these agents] would themselves cause even more cancer, or whatever, than radiation. But, this is all left out, and the agency [(NCRP)] is holding the bag on this scientifically wrong conclusion—that radiation is all bad.

I know radiation is not all bad, because all of life has developed—all of the complexity of life—in the presence of more [celestial, solar, and geological] radiation than we receive today. The whole earth owes its existence to some celestial events which include uranium in the body of the earth.

If we didn't have uranium in the earth, uranium and radium and all those "bad substances," already there would have been a cold death of the earth, and nobody would live, because the uranium content and the radium content of the earth help to keep the earth warm [and] just at the right temperature to allow the prolongation of life for at least another billion years.

And so, I know as a physical scientist that to put scientific validity to those low-dose effects is completely wrong. As a result, the agencies [(DOE, Environmental Protection Agency, et al.)] have spent billions of dollars in cleaning up things when they could have just let it alone.

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[60] National Council on Radiation Protection. Although the words "and Measurement" were later appended to the name, the council's initials remain NCRP.

I'm telling this to you, and I have not written any papers on it. But I can tell you, and I would tell any other scientist, that this is the case.

**PILLAI:** Can you give us an example of something that you feel that the Government spent money on cleaning up where it wasn't necessary?

**TOBIAS:** Well, I cannot give you a real quantitative example, and, also, I don't know exactly what they are cleaning up, because it's not my field. But somebody told me they are going to have to chip off all the concrete off the Bevalac building and either purify it or ship it away someplace, because it's all contaminated. I think that's rubbish.

In fact, I tried to get some of the [shielding] blocks [for] Libra. We could have saved a lot of money by using some of the blocks. But, it turned out [that] the [AEC] was not free to give it to me.

Then, the port of Oakland was interested in using some of the blocks for shoring up the Oakland harbor. Again, they [(DOE officials)] just said, "No, you can't do that, because it will cost billions of dollars to clean this up."

Now in my opinion, that is just rubbish because, first of all, most of the radioactivities are decaying relatively fast, and they're in the concrete. They're not going to harm anybody.

But then, if I go off to Hanford[61]—I don't know any details there, but I did talk to some scientist friends at Hanford recently, because of another problem. I know the director of the Biology Division at Hanford, and he was telling me that they've spent $2 billion to clean up Hanford!

I became interested because of this uranium problem. I am interested scientifically in uranium in the earth, not for reference, but [to answer such questions as] "Where is the uranium, what is its role in the earth, where did it come from?" It's a very interesting thing. It may have come from a supernova that exploded about the time when the sun was made.

Anyway, when I found that out, it turned out they are spending this couple of billion dollars. But not only that, but that in the cleanup procedures, they used extremely carcinogenic and bad organic compounds.

This enters into another interest I have. The thing I remember is aniline compounds, compounds that have the organic dye, aniline, in them. [I believe that] they are using it, and they're throwing it out into the earth around Hanford. Aniline is one of the worst carcinogens, particularly when radiation is also present.

These words you don't have to take as gospel truth, because I don't know, really, what they are doing, but one of the scientists told me [that] this is what they are doing. The reason I was interested [is] because I am interested in aniline carcinogenesis.[62]

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[61] the DOE's former site for plutonium production located near Richland, Washington

[62] the development of a cancer

So there. I gave you not a really quantitative reason, but a reason why I, as a citizen, am worried [about] what is DOE doing with aniline and with other bad substances like this, trying to clean up something.

Well, actually, the earth knows what it can do, and the earth will detoxify, render harmless most of the substances sooner or later. I don't know about plutonium in bombs and things like that.

I'm talking about decontamination of low, low-level radioactivity from a big part of the earth. I think it's useless; it shouldn't be done. They should turn those billions of dollars on health research, such as what I tried to do, because that will cure people.

**PILLAI:** Are there types of research that you were involved in that you would like to talk about?

## Criticism of Insufficient Attention to Cosmic Radiation

**TOBIAS:** Well, as long as I'm playing the bad person, I can just tell you that the space agency[63] is also doing inadequate things for the future of space flight, and I am upset about this. Again, it gets back to the accelerator.

They have a whole list [of research to be done]. Their scientific biology funding backing is less good than the DOE's. And they are very political, also. Well, anyway, let me just give you a couple of examples.

The basic thing that I am complaining about is that the space agency is doing next to nothing to find out what are the possible bad effects from the heavy component of cosmic rays, which is quite a serious component.

Every astronaut that gets up there gets much more than the permissible daily dose, [but they] are not doing this research [on it].

And why not? I think the reason, now, is interagency and politics both. NASA says that DOE should do it; the DOE says that NASA should do it. Both of them told me, "No money for it."

Now, my group was involved in space research, both basic and applied. One thing I found out in two different experiments—it relates now to plants: not even humans, just plants. If you are going to have a long-term sojourn in space or go to another planet, the plants that you will use to get food and oxygen have to live.

So, the heavy particles [in space] bombard these plants all the time. So, I was interested in damage by heavy particles, and Dr. Slater and I discovered a kind of damage which is unique. Okay.

Since that time, in two different sets of experiments, we found this developmental malformation. It's a streak on a leaf that's developing [in a growing plant]. We thought it was not a nuclear effect in the cells, just a thing that would go away.

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[63] the National Aeronautics and Space Administration (NASA)

Well, now we found out that the kernels of the corn are on the end of the streak, and you have a number of mutations in the second generation from heavy particles received in the first generation.

So I think this is an indication that the space agency [(NASA)] and DOE should know about this, because here is an effect that may inherit for several generations and, among other things, it might make the plant population in, say, 10 years or whatever—it's a long-term thing—completely useless, because they will be so full of damage.

So, what did [NASA] do? They don't support this research, and neither does DOE.

So let's get to carcinogenesis. Dr. [Webb] Haymaker has shown in primates, in monkeys, that space radiation, particularly, is dangerous in producing brain tumors.

Ordinary radiation doesn't do so much of it. Ordinary radiation goes to the parts of the body, like bone marrow, that replicate themselves a lot. Brain cells don't replicate; they just sit there. But the damage from the heavy particles is permanent, and, eventually, can cause brain tumors.

So, I have very clearly [reported this] to the Department of Energy and to NASA, and do you think they would do anything? Zero. Zero research on this field. I could say that they don't understand good science, or [that] they are political, and [supporting brain research,] that doesn't earn them political [advantage].

But since [the demise of the Bevalac] the United States doesn't have a heavy-ion accelerator in the first place. They [could not] do it. [However,] the Germans could do it, and probably will.

If somebody gets a disease that I think heavy ions might cure, I have to send him to Germany or to Japan. I have already thought, but I haven't done it yet, to ask Japan to conduct breast cancer research in relation to this. [My group has] demonstrated already before the Bevalac died that the carbon particles have the desirable properties.

## Penalties of Not Educating Physicians in Nuclear Science

**TOBIAS:** But strangely enough, I still have to sell that to the medical people in the community. You don't have [a] very good "dictionary" between medical people and physicists. Not only this, it takes a while for the medical people to take up what the physicist realizes is definite knowledge.

That's because the medical people don't get an education in nuclear science. That's another place where the DOE is sadly deficient. In the early days of AEC, [it] used to have a number of projects at different universities, helping with fellowships for master's degrees and doctoral degrees.

Then they decided to stop all this support because [of], again, a political reason. Some other department—Health, Education and Welfare[64]—was responsible. And what happened? Health, Education [and Welfare] probably didn't think radiation—they hated radiation: "We shouldn't educate people about [radiation]!"

So, now the physicians don't get the education and the physicists don't get education. Believe it or not, there's hardly any radiation physicists [around] anymore who understand the basic physics of radiation that's necessary to understand biological effects. That's because all these agencies have neglected the training.

So, that's what I get for my old age, when I used my whole lifetime to research this. Instead of progression, there [seems to be] regression.

As I say, in Japan and Germany and now France, the European community of nations have proposed two different accelerators like Libra, like my Libra. They will perhaps build it.

What I think, now, [is that] DOE is trying to get off radiation. I think that's a big mistake, because radiation is part of the earth and part of life, and their initial mandate was to study it, and they should keep studying it.

But you know, I am too old to do these things. I am hardly [strong] enough to give a single interview.

## Radiation Therapy for Skin Disease

**PILLAI:** I have a question that I had wanted to ask before. You did some studies on skin changes, using pigskin.

**TOBIAS:** Yes.

**PILLAI:** Do you know if any of those studies were carried out on human subjects?

**TOBIAS:** No, but they were for the purpose of knowing the therapeutic effects of everything: of neutrons, x rays, and of heavier particles. They were only used to know how we should limit [therapeutic doses].

As you may know, with radiation therapy, there's a limit. You cannot give too much dose to skin. [You try] to stay away from that. So therefore, for any kind of a therapeutic use, we would have to know the response of human skin, but the time-honored tradition is to do that on pigskin, because pigs have skins and dietary habits like humans.

**BERGE:** *(smiling)* We eat garbage?

**TOBIAS:** That's what we eat. Most everybody I know in the field of radiation therapy would not study a human being; they would study a pig.

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[64] predecessor to the U.S. Department of Health and Human Services

Well, that was fairly recently. There is a disease, the name of which I forgot. Its name is very prominent in the daily newspapers, because people with AIDS get this disease. It has become quite prevalent.

**PILLAI:** Is it a skin disease?

**TOBIAS:** Well, it's regarded as a skin disease, but it's also deep in.

**PILLAI:** Kaposi's sarcoma? Are you talking about Kaposi's sarcoma?

**TOBIAS:** Yes, Kaposi's sarcoma. He's a Hungarian.[65] Kaposi is the real name.

Anyway, there was a patient with Kaposi's sarcoma. I know he was very advanced in his disease. He wasn't going to live very long, and he had many lesions on his skin. So, he was given controlled doses [of radiation]. There were so many lesions that you couldn't treat them all, so I have to say this person was hopeless.

So, he was given, in about 12 different areas, a heavy-particle [irradiation], and in 12 other areas, betatron[66] or therapeutic radiation. He may have also received some gamma rays,[67] all on the same patient, because, to help the patient and, also, because we needed to know how to calibrate the skin effects of these radiations against each other.

I wasn't involved in that, but I know at least of one patient where it was happening.

**PILLAI:** And was this at the Donner Laboratory? Where did this happen?

**TOBIAS:** Well, it happened at the Lawrence Berkeley Laboratory. The physician responsible is professor [Dr. Joseph Castro] of the University Medical School. And I'm sure that has been published, also.

## Publication of Medical Research

**PILLAI:** Were most of the studies published that you know of? Were most of the studies that you've worked on or that involved human subjects, do you think most of those studies were published?

**TOBIAS:** I think that's a very big question. Let me put it this way.

**PILLAI:** How about for your research? Or for researchers that you worked with?

**TOBIAS:** Well, you're just asking a very difficult question. What happens in medicine—I don't know any other example, except this one, where you might say there is some experimentation, some calibration, whereby we calibrated or did anything else, except trying to cure a person.

For that purpose, there were various criteria. For example, I mentioned to you that the stage III[68]—all of the stage III studies, which involve the heavy ions against some other radiation—they're not published, and

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65 Tobias, likewise, was born in Hungary.

66 an accelerator in which electrons are accelerated to high energies by an electric field

67 highly penetrating photons of high frequency, usually $10^{19}$ Hz or more, emitted by an atomic nucleus

68 Phase III clinical trials, to establish the validity of a therapy compared to other current methods.

they're secret, because the people [(the researchers)] are not supposed to know who is who.[69] I may be a patient. I don't [know] whether [I received] heavy ions or something else.

**PILLAI:** Right.

**TOBIAS:** And, that remains secret for five years. I just found out that there's no publication on our prostate[70] study, which must have had 100 patients, because of this. They have to wait until the study is deemed final, and then both groups, the control and the other, will be published. That's just an example.

Now, most other things, people tried to publish, if not the details, at least something about it, because there are so many medical meetings. The doctors have to go [to the meetings] and give talks. They always try to put in the most recent stuff in their talks.

Now, for my other things, I have not been involved [with] human [research]. My involvement has been less and less since the retirement of Dr. [John] Lawrence. Well, I can just tell you an episode from my own life.

I did become very involved with breast cancer, and I went every day for a while into our hospital. We had our own hospital at Donner [and] did everything the doctors do with them [(patients)].

At a certain point, the [UC Berkeley] medical school suggested that I actually get an M.D. degree, and they offered it to me free. I could even maintain my job. I had a deep talk with Dr. Lawrence and other doctors. They unanimously said that I am much more useful as a physicist [than] as an M.D., because there are hundreds of M.D.s, but few biophysicists. I decided not to get the medical training, and, at that same time, I reduced my involvement with the patients. I realized that, you know, there are hundreds of M.D.s who can do this. What I am involved with is new research and in trying to understand the mechanism of the disease, which does not involve me [getting] deep into medicine.

If I [were to] use a patient [now], (I don't use [patients] myself), maybe [it would be] a patient that excelled on some procedure that I have just studied. So, I have gotten less and less into medicine and more and more into basic, general biophysics.

**BERGE:** I have a question that goes back to something we were discussing quite a while ago with regard to the 1940s and 1950s.

**TOBIAS:** Yes.

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[69] To ensure statistical validity, the study had to remain "double blind": neither researcher nor patient was to know whether the patient was receiving heavy ions, an alternative form of radiation, or (for certain control groups) none at all.

[70] a partly muscular gland that surrounds the urethra in males at the base of the bladder and secretes an alkaline fluid that makes up part of the semen

## Studies With Various Isotopes

**BERGE:** And I was wondering if you have any knowledge of studies that were conducted using zirconium, columbium, yttrium, and other daughters[71] of fission?

**TOBIAS:** I've known, at least, of—what are these isotopes?

**BERGE:** Sure: zirconium, columbium, yttrium.

**TOBIAS:** Strontium is not—

**BERGE:** Strontium, also.

**TOBIAS:** I never studied with yttrium. There was a study at Donner Lab, many years back. I believe the person was a Dr. Sol Winchell. [The technique was developed by [Dr.] Jack [(John)] Gofman.[72] They] proposed yttrium irradiation for a number of diseases because yttrium has as tendency to go more—my recollection is—this is now very dim—yttrium will go more to the formed cell elements of the bone marrow and less to other types of cells and tissues.

The idea was to replace whole-body x ray in bone-marrow transplantation studies. You probably know that's a big field, now. You usually use whole-body x ray, which [would be] lethal to [a bone-marrow] patient. This form of yttrium, Winchell hoped, would not be lethal.

It has gone [away]. I don't know whether they did any human patients or not, but I know they did dogs. And then it died; it wasn't followed up. So, that's the yttrium.

Strontium: You know that [in the] early days, strontium was used quite a bit instead of calcium, because it [is absorbed into] to bone, as is calcium. So, there are a number of papers on animals. I don't know [of] any human [studies] at all—[only] on animals—using strontium.

**BERGE:** Do you have any knowledge, did you—do any work for the United States?

**TOBIAS:** I have grants from NIH.[73] I have met several of the medical officers with the [U.S.] Public Health Service. The only one I recall is a study of weightlessness that didn't involve radiation at all.

**BERGE:** Did you ever work in collaboration with doctors at—Laguna Honda?[74] It was in San Francisco.

**TOBIAS:** No, I didn't, but I had visited there, and I know they had a number of terminal cancer patients.

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71 isotopes formed by radioactive decay of another isotope

72 For the transcript of the December 20, 1994 interview with Gofman, see DOE/EH-0457, *Human Radiation Studies: Remembering the Early Years; Oral History of Dr. John W. Gofman, M.D.* (June 1995).

73 National Institutes of Health, Bethesda, Maryland

74 Laguna Honda Home—a hospice for people dying of cancer

**BERGE:** Yeah, the Cancer Research Institute was partly doing work out of there, and I was wondering if you—

**TOBIAS:** —I don't know that connection, except just a couple of casual visits. See, our project didn't use that kind of patient at all.

**BERGE:** Cancer patients?

**TOBIAS:** Well, as I was saying, our patients were referred from private doctors, not from a place like Laguna Honda.

## Participation in International Research

**PILLAI:** Did you have any other research project that you were in that were collaborations with other institutions, or even international, like with the International Atomic Energy [Agency]?[75]

**TOBIAS:** It's such a general question. I went to all kinds of meetings, with NATO,[76] for example.

**PILLAI:** How about with the International Atomic Energy [Agency]? Do you recall any studies that were done in collaboration with the International Atomic Energy [Agency]?

**TOBIAS:** I went to a meeting in Vienna[, Austria,] of the international agency on, I guess, on cancer therapy. It was an international meeting where all the different modalities of radiation came in. But I didn't have any collaboration.

I had proposed to them—which, after a great deal of debate, they decided not to fund—a situation where we would take in our lab a number of postdoctoral fellows from India or Africa or places like that, that perhaps they could select, who would come in and study both our modern therapeutic methods and the biophysics.

They were very enthusiastic when I was in Vienna, and so we spelled this out for them. We didn't even need money, just fellows; send in the fellows.

They were so bound up with red tape, it never became realized. At the start of that, there was all kinds of [interest from] the delegates from India. I think that came up.

So, the delegate from India, who was a physician, suggested that the United Nations set up, maybe even build, an accelerator or [fund] a larger study where India would supply the patients for this United Nations–approved study.

That, to me, sounded good also, because here was endless material, people who maybe don't get any medical treatment or very poor medical treatment. The United Nations could have moved in and done good things.

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75 an agency of the United Nations headquartered in Vienna, Austria

76 North Atlantic Treaty Organization

But again, it didn't—in fact, I'm sorry to tell you that several of these what you might call "initiatives," which went through the United Nations, did not materialize.

And the same with the World Health Organization.[77] I have visited them a couple of times in Geneva, [Switzerland,] and, again, they were talking about things like that. They would bring it up: "How we can get the underdeveloped nations into this?"

The obvious thing was education, usually, and they saw [that] our university is quite big. It could have been useful, but nothing ever happened in terms of anybody putting money down. It may be just as simple as money.

I have collaborated with Sweden quite a bit. I went to Sweden for a year, and they used protons at the time. They did different things, different from us.

For example, their first patient became irradiated because of mental disease. They wanted to use the rays to cut some nerve bundles in the head. They did a certain amount of that, but that was not my responsibility. I was a visitor; it was their responsibility.

## Guggenheim Fellowship at Harvard University

**PILLAI:** When you were working at Harvard for some time—

**TOBIAS:** —Right.

**PILLAI:** You were a visiting professor there.

**TOBIAS:** Yes.

**PILLAI:** Were you involved in research when you were at Harvard?

**TOBIAS:** Yes.

**PILLAI:** Was any of that research run by the AEC? Did any of it involve human subjects?

**TOBIAS:** No, I had a Guggenheim Fellowship to go to Harvard, so my work was not supported by the AEC at all. There was an argument with the AEC whether or not they would want to pay part of my salary. I can't remember what happened, but I think they didn't pay my salary. It was all Guggenheim.

I gave a course, and the topics we took were [all related to] fundamental biophysics. Even though the people were there—visitors, disciples, and all that stuff—but I didn't [irradiate anyone].

However, we trained a couple of the people who are now doing medicine at Harvard with particles. One of them was a physicist, Dr. Gojleen,

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[77] an agency of the United Nations

who is now their prime radiological physicist. Another was a neurosurgeon, [Dr. Kjellberg].

They did treat pituitaries and other things at Harvard later on, but our role was merely to train these people.

## Oak Ridge Chosen to Become the Isotope Production Center

**PILLAI:** From the other oral history, the one [you gave to interviewer] Sally Hughes, I was reading something in there how, when originally the AEC was trying to decide as to who would be the isotope distribution center, [there was] discussion about Berkeley being the isotope distribution center. Could you just [comment on how] Oak Ridge became the distribution center?

**TOBIAS:** I don't know how truthful I am, because it's a little old—long ago. But, let me put it this way. For a while, the cyclotron [at Berkeley] was the only source for isotopes, and I had to do a lot of the chemistry, which turned out to be very time-consuming and thankless, because the people always wanted—sometimes the cyclotron wouldn't work, and then, to mail this stuff someplace, and the people were unhappy because it got there late, or it wasn't enough, or something. So it wasn't a very happy situation.

But, we realized that we could build, for example, a bank of cyclotrons to supply the whole country, if you like. Then, at the same time, Oak Ridge proposed that *they* become the center. The person involved was Paul Aebersold, who used to work at Berkeley, and, eventually, he was working in Washington, D.C. He was the head of the [AEC's] isotope branch.[78]

Part of the thing boiled down to whether or not medicine needs carrier-free isotopes[79] or you carry and it doesn't matter. I voted for the carrier-free, or at least for some carrier-free.

It turned out that Ernest Lawrence, who was still alive at the time, was not anxious to become a supply agency. We talked, you know, quite a bit about who is going to do this. Each time, you're pointing at each other, "I don't have to do this anymore; *you* do it." And it turned out that the milieu of the Lawrence Berkeley Lab was not really ready to become a supply agency.

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[78] Dr. Paul Aebersold established the administrative system for distribution of radioactive isotopes. After working on the Manhattan Project at Los Alamos, New Mexico, and Oak Ridge from 1942 to 1946, he served as director of the Atomic Energy Commission's Isotopes Division at Oak Ridge from 1947 to 1957. He retired as the Director of the AEC's Office of Isotopes Development in 1965. Two-and-a-half years later, he committed suicide. For additional information on Dr. Aebersold, see "Safety of the Nuclear Industry" in the interview with Merril Eisenbud (DOE/EH-0456, May 1995); "Remembrances of Personalities" in the interview with Earl Miller (DOE/EH-0474, June 1995); and "Oak Ridge Committees (Isotope Distribution, Human Use, et al.") and "Vanderbilt University Study of Pregnant Women and Iron-59" in the interview with Karl Morgan (DOE/EH-0475, June 1995).

[79] the radioactive isotope in pure form, without an added amount of stable isotope of the same element

And that was also true for reactors. It came up, "Should we build reactors?" And, again, Ernest Lawrence wanted us all to do research and not to get down to what would be an everyday job.

So Berkeley wasn't very anxious, and Oak Ridge was rather anxious to do the job at Oak Ridge. So, we let them have it. They were talking about banks of cyclotrons they were going to build, and a private company was going to enter in.

[When] we didn't have to supply anybody anymore, I, myself, breathed with relief, and I don't know what happened after that.

**PILLAI:** You don't regret not having [LBL be the isotope distribution center?] (*Tobias begins to speak after "having."*)

**TOBIAS:** —Well, not personally, not as a scientist, because I realize there are things involved there I certainly don't even know about, like how do you mail—how do you send isotopes around by mail, and how do we make sure that the shielding doesn't have contamination, things like that.

It just didn't seem to me like it's a kind of science [that] I, myself, would want to do. I was anxious to be at the forefront of research. Since we had three accelerators [at UC], I knew that we could make all the isotopes we wanted right there, locally. And so, why should I make it for other people, when [other] people are very eager to do this?

## Research Collaboration Between Berkeley and Other Researchers

**PILLAI:** Another issue with collaborations: do you know of any collaborations between the Argonne Cancer Research Hospital[80] and Berkeley?

**TOBIAS:** Right now, you mean? Currently?

**PILLAI:** No, no. Not currently—in the '40s and '50s.

**TOBIAS:** Oh. Well, there was a lot of collaboration, a lot of good collaboration. There was, first of all, Leon Jacobsen, who was the head—he was the one who discovered that [a] bone marrow [transplant] can cure radiation illness. He was a personal friend to Lawrence and myself.

And there's a host of other people. Dr. Goldstein. Most of these people are doing bone marrow research that I mentioned. Our unique thing at Berkeley was that we had—the isotope—the iron isotopes are invaluable.

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[80] one of three clinical facilities created by the AEC in 1948. While the AEC owned the 58-bed Chicago hospital, the University of Chicago medical school administered and staffed the facility. Patients were admitted on a selective basis: physicians chose persons whose condition best suited the hospital's research and treatment applications. The hospital admitted its first patient in January 1953. The AEC terminated its contract with the hospital in 1974.

And, also, [we had] the decompression chamber from the other work.[81] So our tests for blood cell production was to put rats into the decompression chamber.

Dr. Lawrence went for a couple of expeditions to the Cordillera Mountains[82] in South America, with the high-altitude labs, where we studied human beings as they increased their own blood volume. Will Siri was involved in that.

So Dr. Jacobsen, always, we had close collaborations. I feel that our Lab has supplied, perhaps, some of the essentials when it was discovered that the kidney is producing the hemopoietic[83] hormone.

Now, another collaboration came with [University of Chicago professor] Dr. Charles Huggins, who was a cancer expert and Nobel prize winner, and he was asked to be a member of the committee that would pass [(decide)] on the pituitary irradiation of humans. I didn't even know him until that time.

He turned out to be a wonderful person, and so we had an ongoing collaboration with him. Right away, he supplied some of our patients, and then, also later on, every time, we exchanged a lot of information.

I discovered estrogenic receptor in breast cancer. We found that only half of the patients were benefitted by pituitary irradiation. The thought was that the estrogenic receptors in breast tissue are an indication, that if there are such receptors, then the pituitary irradiation might be effective.

So the Jensen test we were going to use, had we [done so, might have identified] patients with breast cancer [who would benefit from pituitary irradiation]. So, I would say there was close intellectual collaboration.

**PILLAI:** How long was the decompression chamber used? Was it used for a whole set or series of experiments, even after the decompression sickness studies?

**TOBIAS:** These went over to the study of hemopoiesis, then.

**PILLAI:** Were those studies of hemopoiesis only done on rats, or were they also done on humans?

**TOBIAS:** As far as I know, only on rats. Somebody developed a new oxygen mask; there was a big flap about it. If somebody developed a new oxygen mask, he may ask the Lab Director to come in and test it. Things like that.

I don't know about everything that went on with it, because, after the decompression sickness, I got off of that. Our Lab was big enough [that] I had other things to do. That's when I decided to study cancer as a

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81 research into preventing "the bends" in bomber pilots

82 Cordillera Mountains; a range of the Andes in Peru and Columbia

83 relating to the formation of blood

cellular disease, and my group was going in that direction, rather than the decompression sickness.

Dr. Siri will know more and, also, there's another physician, Dr. Donald Van Dyke. He is still alive, I think. If there's any other human work, I think Van Dyke or Siri might know.

**BERGE:** I just want to ask you for some spellings of names.

**TOBIAS:** Okay.

**BERGE:** You mentioned Dr. Krueger, who worked with the—

**TOBIAS:** —Krueger. That's K-R-U-E-G-E-R.

**BERGE:** K-R-U-E-G-E-R, okay.

**TOBIAS:** And he—I used to know his first name. I don't know his first name; I have it at home.

**BERGE:** Sure.

**TOBIAS:** He was a professor at the University of Illinois, and he initially proposed that method, and he came to Berkeley to test it out on rats and mice.

**BERGE:** And the next one was Dr.—I didn't catch his first name—Dr. Larson.

**TOBIAS:** Yes, Börje. Larson is *L*, like Larry-A-R-S-O-N. Some people spelled it double-S; I don't know. His first name is Börje, B-Ö-R-J-E. He was deeply involved in the cyclotron-proton therapy studies in Stockholm, in Upssala, and, also, he became a consultant on the Russian use of particles. The Russians also used pituitary irradiation.

**BERGE:** And Dr. [Huggins].

**TOBIAS:** H-U-G-G-I-N-S, Charles Huggins, professor at the University of Chicago.

**BERGE:** The person who worked on brain tumors, Dr. Heineker?

**TOBIAS:** Haymaker, that's H-A-Y-M-A-K-E-R. He was for a while the head of the Armed Forces Institute of Pathology in Washington[, D.C.].

**BERGE:** Okay.

**TOBIAS:** Or in Bethesda[, Maryland]. And then he worked for NASA on the San Francisco Peninsula.

**BERGE:** How do you spell *aniline*?

**TOBIAS:** Aniline, A-N-I-L-I-N-E. That was the first—this was the first big-study carcinogen known. It was discovered in Germany. It's an interesting study, because—some of the worst carcinogens that were used in animal research are aniline derivatives, derivatives of the aniline dye. Aniline is a dye.

I just found recently that all this has been relaxed, because several drugs that are being used in the United States have aniline derivatives in them. The arm of the Government that is—well, I don't know what it is.

I'm involved right now with a former student of mine who is a dental surgeon, who has discovered that his anesthetic has this stuff in it, and he has had a project on this, and the national agencies have finally awakened to the fact that he is correct. So, right now, there's a lot of activity on this.

If you're interested, I can get his name, but I forget his name, too. He's in the Lafayette-Berkeley area.

**PILLAI:** Can I ask one more question? Were you involved in any way in the $^{32}P$ [(phosphorus-32)] studies to treat cancer that [Dr. John] Lawrence was in charge of?

**TOBIAS:** More or less after the fact: Dr. Lawrence proposed that before I got to the Lab. But when he hired me as a medical physicist in 1942 or 1943, my first job was to make radiophosphorus at the cyclotron and purify it for medical use. And I did that for some time.

And also I made other isotopes for them. In those days, the physicians did not realize all the things a physicist can do.

The reason they hired me is because, presumably, I knew about radioactivity and how to separate, chemically, radioisotopes. So, the first job they gave me was that. I was the liaison person at the cyclotron for the medical studies.

And sometimes, I made it for Dr. Lawrence, sometimes for other people, mailed some off to Dr. Hevesy in Sweden, and so on. We gave it to people on campus for their studies. So, it has got a few isotopes included in that.

## Reflections on Research Accomplishments

**PILLAI:** Of all of your research activities, which do you feel are the major contributors to cancer therapy or treatment?

**TOBIAS:** The most practical thing is the one that the United States decided not to use. That's the acceleration of heavy ions, and the study of the biological effects. If you look at my publications, most of my publications are on that.

But at a more fundamental level, I think I am one of the leaders of the theoretical interpretation of radiation injury—again, at the cellular molecular level.

I was closely involved with pituitary irradiation in both acromegaly[84] and breast cancer, and I was the head of the group—the Bevalac turned [out] to be quite a large group, about 57 people at one time—for all kinds of cancer therapy and basic studies.

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[84] a disorder of the pituitary gland in which too much growth hormone is produced, resulting in enlargement of the head, hands, and feet

I regard myself as sort of one of the pioneers of modern biophysical science and biophysical science in medicine. The university founded a department around me.

I also think I am involved now in the basic understanding of the relationship between physical science and biological science. The conception [that I held] during most of my life was that all of biological science is explainable on the basis of physical science, but [now I believe] this is wrong. Instead, what has to be done is to explain all of science, including physical science, on the basis of the actions of the human brain.

So I'm trying to turn that relationship around, from physics explaining everything to biology being necessary, first, to know whatever we know—we know we are all brains—and, secondly, to understand and to interpret whatever science man can produce. So, I am trying to write a book that will establish these relationships and, hopefully, turn around the general ways people are looking at things.

**BERGE:** Thank you very much.

**TOBIAS:** You're welcome.

**PILLAI:** Thank you very much. It has been very helpful.

**TOBIAS:** I hope so. Some of that tirade I gave you on the heavy ion, I don't know what you want to do with it. But in a way, the agency [(DOE)] should know that they have made, in my opinion, big mistakes, both about not supporting heavy-ion research and spending lots and lots of money on cleaning up things that don't need to be cleaned.

Unfortunately, all of humanity is guilty of that, because radiation is a kind of a dirty word, now. It shouldn't be a dirty word at all. It's an essential ingredient of life.

**PILLAI:** Can I ask you one more question? What you were just saying, the last part of what you were just saying, what do you think about the cleanup for the Marshall Islanders?[85] Do you think that that was unnecessary?

**TOBIAS:** No, they had heavy contamination of the islands. That was absolutely necessary. No, that was okay.

It's kind of a different thing. Maybe I should separate the Marshall Islands and the hot reactor and race for the real hot stuff at Hanford and elsewhere from the relatively trace amounts which occur at the Lawrence Berkeley Lab or in many, many places, which have some trace contamination. I am not happy that the contamination happened, but, [that] is not necessarily a reason to spend a big part of our national wealth on cleanup. ❐

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[85] 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.