covered that the rain contained pollen, and in due course concluded that it "is not a mysterious material," but "the feces of bees excreted while they are flying." Their description of the spots is consistent with Meselson's, and with the U.S. samples of yellow rain.

Meselson reports that in his experience, bee feces are just as confusing to Hmong refugees in Thailand as to Chinese peasants. He writes that he showed bee spots to "16 groups" of refugees in the Ban Vinai camp in Thailand, where the reports of yellow rain originated. He asked people to describe what they saw. Thirteen groups did not know what the spots were; two groups said they were *kemi*, a term for chemical weapon; and one man in the final group said they were insect feces, but later agreed with the rest of his peers, who claimed the spots were *kemi*.

If this response seems confused, it is no more so than Western expert opinion. ■

ELIOT MARSHALL

The UCLA-Occidental-Gorbachev Connection

Putting together the bone-marrow transplant team to treat Chernobyl victims involved private philanthropy, high-level connections, and sophisticated technology

Los Angeles

IT is the end of a long afternoon for Robert Peter Gale, head of the bone-marrow transplant unit at the University of California at Los Angeles. On 7 June, he returned from Moscow where he performed 19 bone-marrow transplants on victims of the Chernobyl nuclear accident. Now he is caring for 30 "horrendously ill" patients at UCLA Medical Center and is trying to juggle the press. The afternoon of 18 June began with a long photo session for *People* magazine. Then *Life* came in. Next it was the turn of a crew from Japanese television, who had waited patiently in the hall for hours. Then *Life* called to complain that they had been promised exclusive photos, so what was *People* doing there?

Gale, a thin and intense man who pads around the building in clogs, seems exhausted yet stimulated by the constant tugs for his attention from the press, patients, physicians, and the hospital staff. And he is understandably excited by the story he has to tell. For he is the one who organized and carried out the bone-marrow transplant operations in the Soviet Union—an undertaking so complex that it rivals any battle plan. Now he is planning to enlist the help of the scientific community to follow, for the rest of their lives, as many as 100,000 to 200,000 Soviets who received doses of radiation that may result in cancer or birth defects in years to come.

Even before the nuclear reactor exploded at Chernobyl, Gale had thought about what he would do if such an accident occurred. So, in a sense, he was mentally prepared.

Gale's first thought on hearing of the accident was to offer help. As chairman of the advisory committee of the International Bone Marrow Transplant Registry, he called other committee members and suggested the group contact the Soviets. Then he devised a plan to transmit their offer of aid.

"That morning, Reagan's offer of humanitarian aid was declined, so I thought of two other channels," says Gale. One was to go through the National Cancer Institute, which had an inactive exchange program with Soviet scientists. The other, which was the plan that worked, was to go through Armand Hammer, the head of Occidental Petroleum, whose headquarters are just a few blocks from the UCLA Medical Center. Gale and Hammer have known each other for years, and Hammer has a relationship with the Soviets that goes back 65 years.

In an interview at his office at Occidental Petroleum, Hammer told *Science* the story of his involvement with the Soviets. He first visited Russia in 1921, just after he graduated from New York University Medical School. He had a 6-month hiatus before he was scheduled to begin an internship at Bellevue Hospital and decided to go to Moscow to help with a typhus epidemic. "When I got to the area where the typhus epidemic was, I found that the principal problem was famine. I said, 'Why don't you buy grain?' They were burning grain in America because they had too much," Hammer says. But the Soviets explained that they had no means to buy it.

Hammer, who was already a self-made millionaire, bought the grain for them. It was the beginning of a long and virtually unbroken trade relationship between him and the Soviets. So, on 6 May, when Gale called Hammer, Hammer sent a telegram to Mikhail Gorbachev, relaying Gale's offer of help. "The answer came back, 'Please send him immediately,' " Hammer recalls. "I told him not to worry about a visa, just go. And I told him to phone me when he got there and tell me what he needs."

Gale left on 8 May. He had, he says, booked reservations on every flight to Moscow that week in order to be ready to go as soon as he got word that the Soviets wanted him. Just before he left, he "mobilized resources." Specifically, he arranged for Mortimer Bortin of the Medical College of Wisconsin, who is scientific director of the International Bone Marrow Transplant Registry, to coordinate transplant centers in case there was a need for donors—and transplant centers—outside the Soviet Union. He also contacted John Hansen of the University of Washington and arranged for him to coordinate computer data from a North American registry of potential bone-marrow donors and for John Goldman of Hammersmith Hospital in England to do the same for a European directory. Although there is only a 1 in 10,000 chance that marrow from an unrelated person will completely match any particular patient, Gale wanted to have the registry donors available. It turned out, however, that he did not need to use them.

In addition, Gale called Paul Terasaki of UCLA, a tissue-typing expert, and asked him to assemble all that he needed for tissue typing as many as 200 people. He also contacted his UCLA colleague Richard Champlin, asking him to put together antibiotics, needles, and other supplies to take care of the Chernobyl victims clinically. And he got in touch with Israeli scientist Yair Reisner, whose specialty is using plant lectins to remove T cells from bone marrow before it is transplanted. In this way, it is possible to overcome some of the difficulties of tissue mismatches. Hammer flew Terasaki, Champlin, and Reisner to Moscow.

The technology that the physicians used was first discussed in 1945, when American researchers began laboratory investigations

of bone-marrow transplants because they suspected that the Germans might have an atomic bomb. If so, and if the Germans used it, the Americans reasoned, bone-marrow transplants might be the only way to save the lives of those who were near the blast.

Radiation destroys preferentially the fastest growing cells of the body—the bone-marrow cells, hair cells, and cells of the gastrointestinal tract. For that reason, people who are irradiated lose their hair, vomit, and lose their immune systems, the cells of which originate in the bone marrow.

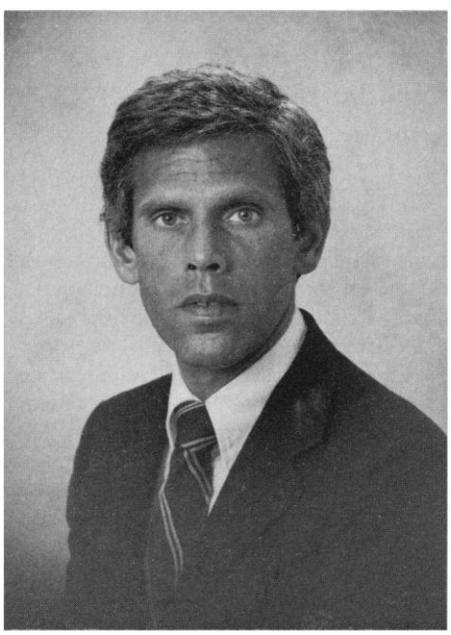
But research on bone-marrow transplantation proceeded very slowly because it took decades for investigators to learn HLA typing, which matches the tissue type of the donor to that of the recipient. If the donor and recipient are not well matched, the T cells of the transplanted marrow attack the cells of the recipient because, to them, the recipient's cells are foreign. The result is graft-versus-host disease, which can be fatal.

One of the first times that bone-marrow transplants were used to treat patients was in 1958, when five victims of a nuclear reactor accident in Vinca, Yugoslavia, were flown to Paris for treatment. Four received transplants and survived. But HLA typing was unknown and the victims received marrow from relatives, which may or may not have matched their own. The patients' radiation doses also were unknown. They may, then, have survived despite, rather than because of, their transplants.

Clinical researchers began doing bone-marrow transplants routinely about 15 years ago. The technology has become quite sophisticated and now bone-marrow transplants, when there is an HLA-matched donor, are the treatment of choice for many leukemia patients and for patients with aplastic anemia, whose bone marrow simply stopped functioning. Some investigators are giving bone-marrow transplants to patients with genetic diseases, such as thalassemia. And Gale's group is using the technique with AIDS patients who have identical twins who can serve as donors. Except for the aplastic anemia patients, all these transplant recipients must first have their own marrow almost totally destroyed through drugs and radiation.

At UCLA, says Gale, about 100 patients receive bone-marrow transplants each year. About 50% survive. The rest die of infections in the period after their transplant when they have no functioning immune system because the new marrow cells have not yet begun to grow, from organ damage caused by the radiation they received, or from graft-versus-host disease—which still occurs in nearly half of the patients, no matter how carefully their HLA types are matched. Only identical twins have no mismatch at all in their HLA types. Still, the patients are certain to die without the transplants, so even 50% odds are good.

Gale says, "I could calculate that only 30% of the patients [from Chernobyl] would have matched donors." Matched donors are almost always siblings, each of whom has a 25% chance of being the same HLA type as a patient. Parents are only partially matched because each person inherits these antigens equally from each parent. So if only parents were available to donate bone marrow, the marrow would have to be cleansed of T cells with the method developed by Reisner or a similar method using monoclonal antibodies.



Robert Gale *performed bone marrow transplants on Chernobyl victims.*

When a patient receives a graft from an HLA-matched donor, the chances of graft-versus-host disease are 45%. Those chances drop to 15% if T cells are removed from the marrow before transplantation. If the marrow donor is not matched to the recipient, the chances of graft-versus-host disease are 75% without T cell removal and are 45% with it. Reisner's procedure works, but the drawback is that the chances of graft rejection increase.

Gale explains that it is virtually impossible to remove all T cells from a patient's bone marrow before transplantation, no matter how much radiation the person receives. So there are still at least a few T cells around to attack the foreign marrow that is transplanted. Ordinarily, the transplanted marrow has its own T cells, and the two sets of T cells battle it out. Since the transplanted marrow usually has far more T cells than the patient's marrow, the transplanted marrow usually takes over. But if the transplanted marrow has almost no T cells, it is more likely to lose the battle and never engraft.

An alternative to cleansing T cells from a mismatched marrow is to use liver cells from fetuses aborted in the second trimester. The fetal liver functions as a bone marrow but has no T cells. Persons who were so badly irradiated that they had essentially no blood cells left to HLA-type would be candidates for a fetal liver transplant. Fetal livers, says Gale, "are universal donors." But they are likely to be rejected for the same reason as marrows that have their T cells removed.

When Gale arrived in Moscow, he met with Soviet physicians who "gave me an inkling of the extent of radiation and the numbers of patients." The Soviets had already begun transplants on the most severely affected patients—they had performed three fetal liver transplants. Three hundred Chernobyl victims were in Moscow's Municipal Hospital No. 6. Hundreds more were hospitalized in Kiev. As many as 100 to 200 persons had received "very substantial doses of radiation—more than 3 grays," and 400 to 500 received "substantial doses—more than 1 gray," Gale remarks. "We are concerned about both groups."

Gale began ordering equipment and supplies. The Russians, he says,"had some equipment, but not enough." Occidental Petroleum has an office in Moscow with a direct line outside the country, which made it possible to call the company's Los Angeles office. "I called Richard Jacobs [in the Los Angeles office] several times a night with a big description of what I wanted. For example, I would say I needed three Baxter Travenol machines for separating blood. I needed European machines because of the [electrical] current difference. The plasticware for the machines was in the U.S. Occidental would launch the machines from three European countries, would send out a technician from a fourth country, and would send plastic-ware from the U.S."

All this was done at Armand Hammer's expense, as a gift to the Soviets. Hammer says the final bill is not yet in, but so far he estimates he spent about $600,000.

One problem that Gale and his colleagues faced was deciding whom to transplant. It was not clear how much radiation the patients had received, and they had to estimate, based on such things as how soon the patients began vomiting and how many blood cells they had left. In this, the physicians were aided by a Soviet publication summarizing the world's data on clinical effects of radiation. "Much of it came down

to the art of medicine, not science," Gale remarks. "We took all the bits of data and gave them weights based on our personal impression."

The physicians ended up performing 19 bone-marrow transplants, six of which were fetal liver transplants. All of those who received fetal liver transplants have died because they were so severely burned by the radiation. "We would have expected one to two to survive at best if they were average patients," Gale says. Because they died of the effects of the radiation, "we can't evaluate the success of the transplants."

Of the remaining 13 transplant patients, five are still alive and are now out of immediate danger. The Soviet physicians, who had done only about 20 bone-marrow transplants in all of Russia before the Chernobyl accident, got an education in the latest techniques for this procedure. For example, they had had no experience giving the antirejection drug cyclosporine intravenously, yet this drug of choice for bone-marrow transplant patients cannot be given orally because, says Gale, "you can't be sure of absorption in irradiated patients. Our mission was not only to do but to teach."

Gale plans to return to the Soviet Union on 20 July to continue following the Chernobyl victims. There can be major complications 3 months after a transplant, he notes.

For the future, Gale wants very much to see an international scientific effort to follow the 100,000 to 200,000 Soviets who received 15 to 30 times the background level of radiation when the radioactive plume from Chernobyl passed over Kiev. It is impossible to estimate the likelihood of cancer or birth defects in this population, he says. Moreover, he continues, "the actual danger to any individual is small and if an individual gets cancer, they can't know if it was caused by radiation or other factors."

"One of our jobs is to reassure," says Gale. "We don't want to cause more harm than Chernobyl. We don't want 100,000 people to live their lives in fear of cancer. Yet we want to follow them medically."

Gale signed an agreement with the Soviets committing both countries to cooperating in the long-term follow-up of this population. "Now we are focusing on what we can provide," he says. "We are calling on advice from radiation specialists and specialists in cancer, genetic disorders, and birth defects. There is a lot to be said for cooperation. And we lend an air of credibility to Soviet publications."

So the consequences of Chernobyl remain to be determined. But there is at least the hope that some scientific knowledge may be gained from all the suffering. ■

GINA KOLATA

Briefing:

NASA Terminates Centaur Development

Citing continued concern about flight safety in the space shuttle program, James C. Fletcher, administrator of the National Aeronautics and Space Administration (NASA), has terminated development of the Centaur upper stage for use aboard the shuttle. The Galileo mission to Jupiter and the Ulysses mission to the polar regions of the sun, both of which had been scheduled to be launched using the Centaur, may now be delayed into the 1990's. They were already facing at least a 2-year delay because of the Challenger explosion last January. Also affected are a number of classified Air Force payloads that depended on the Centaur.

Fletcher's decision came on 19 June, and was not unexpected. The Centaur being developed for the shuttle was a modified version of a booster that has long been used as an upper stage for conventional Atlas and Titan rockets. Its advantage was power: starting from the shuttle payload bay it could place a spacecraft on a trajectory to giant outer planets such as Jupiter and Saturn, or to a rendezvous with a fast-moving comet. The Centaur's disadvantage was the way it produced that power: its liquid hydrogen/liquid oxygen fuel made it an exceedingly hazardous and complex cargo. Because of the possibility of a launch abort, for example, the shuttle had to be equipped with emergency vents so that the Centaur's fuel could be dumped—in mid-air—before the pilot attempted a landing.

After 4 years of development and some $700 million of investment, NASA engineers were still struggling to make this system work in an acceptably safe manner. The agency intensified its safety reviews of the project in the wake of the Challenger disaster, and an independent study was carried out by the House appropriations subcommittee on HUD-independent agencies under Representative Edward P. Boland (D–MA). On 19 June, when it had become clear that the Centaur was not going to meet the safety criteria being applied to the rest of the shuttle system, Fletcher ordered the effort terminated.

Rear Admiral Richard H. Truly, head of the shuttle program, is in charge of NASA's efforts to find alternative ways to launch Galileo, Ulysses, and the other Centaur-dependent payloads. One alternative would be to launch the spacecraft on the shuttle as planned, but with the Centaur replaced by a less powerful solid-fueled booster such as the Air Force's Inertial Upper Stage. The flights could then take place as early as 1989. However, Galileo would then require some 4½ years to get to Jupiter, versus 2½ years with Centaur. Furthermore, the shuttle/Intertial Upper Stage combination offers very little capacity for doing planetary missions beyond Galileo and Ulysses.

The other major alternative is to use the shuttle-modified Centaurs as upper stages on the heavy-lift Titan 34D7's being developed for the Air Force. Such a Titan launch would technically be possible by 1990. Moreover, the Titan/Centaur combination seems adequate for doing all the planetary missions that NASA is currently considering. On the other hand, the new Titans will cost in the neighborhood of $150 million to $200 million apiece, not counting any modifications required for the Centaurs and the spacecraft themselves. At this point, however, agency officials say that they can do no more than guess at what any of the alternatives will cost. ■

M. MITCHELL WALDROP

House Appropriations Committee Kind to Physics

The Department of Energy's proposed 1987 budget for high-energy and nuclear physics has emerged from the House Appropriations Committee almost unscathed. Just a few months ago it seemed that the operations of upgraded accelerators at Fermi National Accelerator Laboratory and the Stanford Linear Accelerator Laboratory (SLAC) might be delayed because of budget restraints imposed by Congress. Both facilities require significant increases in funding to cover higher operating costs associated with the revamped particle colliders.

The Appropriations Committee approved a $213.4-million operating budget for physics facilities, exactly what the Administration requested. Physics research, at $111.6 million is up only $5.3 million, $7 million less than the department request. DOE officials say university-based research and international collaborations may be pinched as a result.

The committee also stripped away $20 million that DOE had identified as potentially available in 1987 for research on the Superconducting Super Collider if a decision is made to start constructing the facility in 1988. Stating that it was "concerned by the lack of commitment by the Administration," the committee directed DOE to submit a separate appropriations request for 1987 should it decide to go forward on the