1895 German physicist Wilhelm Conrad Röntgen discovered an invisible form of radiation, which he called "x-rays." Röntgen would win the first Nobel Prize for Physics in 1901.

1896 French physicist Antoine-Henri Becquerel found that uranium salts emit an invisible penetrating radiation—the first observation of radioactivity.

1901 Becquerel observed one of the biological effects of radioactivity when he carried some radium in a vest pocket, reddening the skin beneath. In 1903 Becquerel and his French colleagues Pierre and Marie Curie (pictured) would receive the Nobel Prize for Physics. Both Marie Curie and her daughter Irène Joliot-Curie would later die of leukemia, probably caused by their long-term exposure to radioactivity in the laboratory.

ANNUAL CHECKUPS For several decades, doctors and health physicists made annual trips to the Marshall Islands to check the health of islanders accidentally exposed to radioactive fallout during a 1954 U.S. bomb test in the Pacific.

employees at weapons design and production sites, uranium miners, and soldiers present during weapons tests in Nevada. Another effort, stretching from 1947 to 1993, extended prewar studies of instrument-dial painters exposed since 1912 to radium-laced paint. Taken together, these and other epidemiological studies form the core of what we know today of radiation exposure risks—both the risks of long-term, low-level exposure and the dangers of a single high dose. They are likewise the foundation of the laws and standards that protect those who work with radiation every day, as well as the citizen on the street.

Public perception of the risks of radiation continues to cloud the future of nuclear energy in the U.S., but we know

A SUBJECT OF CONCERN

■ Using human beings as experimental subjects in radiation research is no longer countenanced by the federal government. But this has not always been the case. In years past, humans were the subjects of therapeutic studies and of inquiries into how radionuclides get processed and distributed in the body. In fact, rudimentary studies date back at least to 1926, and after the invention of the cyclotron, the pace of such experimentation quickened considerably. In the late thirties, for example, Joseph Hamilton, at the University of California's Radiation Laboratory, conducted a series of human metabolism studies with sodium-24, in hopes of developing a short-lived replacement for the long-lived radium isotopes then used to treat leukemia and other diseases. Then, between 1945 and 1947, in four hospitals around the country, eighteen subjects were injected with plutonium. The aim was to develop a diagnostic tool, based on the amount of the element excreted, that could be used to quantify industrial exposures to plutonium. Despite the studies' laudable goals—namely, to establish protective standards for industrial workers—these experiments were recently the focus of a national controversy. None of the subjects suffered any apparent harm from the plutonium injections, but neither had they been fully informed of what was being done. And many of the scientific results were kept secret for years. ■ When details of these experiments were revealed in 1993, the public was indignant at the appearance of scientific arrogance. Fortunately, times—and ethical standards—have changed. Well before this story hit the press, strong federal regulatory measures were in place to protect subjects of research. Since 1976 DOE regulations have protected human research subjects, and in 1991 the DOE was the first agency to sign the Federal Policy on Protection of Human Research Subjects. Further, following the deliberations of the White House Advisory Committee on Human Radiation Experiments, even greater federal attention is now focused on the need for subjects to be fully informed regarding experimental procedures or treatments. Research using human subjects, including clinical trials to assure the safety and efficacy of new pharmaceuticals, is an important part of modern biology and medicine, but today it is performed openly and in strict accordance with ethical and humanitarian principles. ■