increased our knowledge of the fate of nonradioactive hazardous waste, the metabolism of plants, and many other subjects.

The extremely high detectability of radioactive atoms makes them easy to trace as they move through nature's cycles and migrate from one place to another. Their known decay rates, decay products, and ratios have led to greater understanding of physical, biological, and climatic processes over whole ecosystems and of biological and life processes at the microscopic level. This use of radioactive tracers enabled man to understand the process of photosynthesis vital to plant growth and food production.

In the 1970's health and environmental research in AEC and its successor agencies broadened to support all energy sources and uses. Basic research on toxic substances and cancer-causing agents focused on applying known methods to new substances. New, unique concerns, such as reclaiming of land affected by strip mining, were brought forward to be addressed and solutions identified.

Cell Sorting and Blood Analysis
Two devices for biological analysis widely used in laboratories, hospitals, and clinics are the flow cytometer and the centrifugal fast analyzer. The flow cytometer was developed in 1965 to distinguish cells damaged by radiation from normal cells. Since then, the methods used for cell sorting and their applications have continued to increase. Today the flow cytometer is used routinely for performing complete blood counts (its greatest single application), detecting cancer and monitoring its treatment, detecting genetic abnormalities, and isolating specific chromosomes for analysis of their genetic composition.

The centrifugal fast analyzer also had its beginnings in the search for tools to measure radiation effects in humans. The analyzer, which exploits advances for processing uranium made in centrifuge technology in the 1960's, can handle a large number of samples for automated analysis simultaneously. It is used principally to test blood and other body fluids for diagnostic purposes.

Flow Cytometry The flow cytometer characterizes and sorts individual cells, permitting the measurement of cellular properties and changes in those properties on an individual rather than on a population-average basis. The cells are suspended in a fluid droplet stream flowing past one or more optical or electronic sensors that measure cell characteristics. Typically, for characterization, a cell is stained with a fluorescent dye and passed through a focused laser beam. The fluorescent light emitted from the cell is analyzed and recorded. Cell sorting is a related procedure in which droplets with particular characteristics in the stream are charged electrostatically and then diverted. This separates relatively pure populations of the selected cells from the main sample.

The advantages of flow cytometry and cell sorting over other techniques include:

1. Rapid analysis of single cells and subcellular components (10,000/second versus about 100/minute with a microscope),
2. Statistical analysis of large numbers of individual cells,
3. Rare cell identification (one cell in 10 million can be detected),
4. Greatly enhanced resolution (the 9 percent difference in the DNA content of human male versus female cells can be measured),
5. Simultaneous analysis of many parameters of individual cells, and
6. Sorting of selected cells at rapid rates.

History The first device capable of separating biological cells was developed in 1965 by M. J. Fulwyler at Los Alamos National Laboratory (LLNL) as part of research into the effects of plutonium radiation. The flow cytometer was developed to provide a means of rapidly scanning for and separating cells damaged by radiation. Further developments in the analysis of cell populations were based on optical phenomena such as absorption, light scattering, and fluorescence. The first sorter based on fluorescence analysis was developed in 1972. Almost simultaneously, a multiparameter cell/particle separator was developed. Recent developments in the field of flow cytometry and flow sorting have stressed the use of new or improved sensors for cell physical and chemical properties. Analytical capabilities such as the development of low-resolution morphological information (cell and nuclear size, chromosome length, and location of the chromosome constriction) offer the potential to detect important genetic defects and low-level background mutational events.

Since 1964 at Los Alamos and 1972 at LLNL, flow cytometry R&D has totaled about $6.5 million (1982 dollars).

Four companies currently offer flow cytometry systems at an average cost of about $100,000 per system. The number of instruments in place is estimated at 350. All companies contacted believe that there is a strong growth market for flow cytometers and are investing in new developments.

Benefits The flow cytometer cell sorter, originally intended to separate radiation damaged cells from normal cells, has been used extensively as both a biological and clinical research tool. Its major commercial potential, however, lies in its capability for automated diagnosis and economical population screening in the fields of hematology, immunology, cancer diagnosis, and genetics.

More recently, improvements in the method have permitted the creation of a chromosome-specific DNA library which scientists believe will advance the course of human genetics by a decade; an advance which will certainly be a major step forward in the diagnosis and treatment of genetic diseases.