Appendix C

Federal Funding of Biotechnology Research and Development

Historically, the United States, both in absolute dollar amounts and as a percentage of its research budget, has had the largest commitment to basic research in the biological sciences worldwide. The vast majority of Federal research support in the biological sciences goes to university scientists conducting basic research, whereas applied research and development (R&D) has always been considered the responsibility of industry. This appendix catalogues the extent to which 12 Federal agencies are funding research in biotechnology-related areas.

Basic research is the primary mission of several of these agencies, such as the National Institutes of Health (NIH) and the National Science Foundation (NSF). The National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the National Oceanic and Atmospheric Administration (NOAA) have large technological development programs but are also substantial supporters of basic research, including biotechnology. Other agencies with diverse missions, such as the Department of Defense (DoD) and the U.S. Department of Agriculture (USDA), fund large numbers of R&D projects related to biotechnology. In addition, agencies with substantial regulatory functions, such as the Food and Drug Administration (FDA) and the U.S. Environmental Protection Agency (EPA), fund research relevant to their regulatory and scientific missions. Finally, agencies traditionally viewed as service oriented, such as the Veterans Administration (VA), the National Institute of Standards and Technology (NET), and the Agency for International Development (AID), fund biotechnology research relevant to their service roles.

National Institutes of Health

While the biotechnology industry is rapidly becoming one of the most significant "growth industries" in the United States, its creation and sustained expansion over the recent past is in large part due to the major role in support of basic research and research training played by several Federal agencies, in particular, NIH. The NIH supports research conducted either within its own laboratories, or, through a system of grants, contracts, and training awards at academic institutions, research institutes, and industrial organizations throughout the country.

In the area of biotechnology, NIH-supported research can be divided in two categories. The first is basic research ***directly related to biotechnology,*** which includes recombinant DNA techniques; gene mapping and DNA sequencing; isolation, separation, and detection of DNA; the creation of hybridomas; the production of monoclinal antibodies; protein engineering; production of antibody-tom chimeras (immunotoxins); and the computer analysis of DNA and protein sequences. The second category relates to the ***broad research base underlying biotechnology*** and refers to studies in the fields of genetics, cellular and molecular biology, biological chemistry, biophysics, immunology, virology, macromolecular structure, and pharmacology. For the basic research studies directly related to biotechnology, NIH provided an estimated $1.19 billion in fiscal year 1990. For the broadly based research area, NIH provided an estimated $1.7 billion in fiscal year 1990. Thus, for fiscal year 1990, NIH provided an estimated $2.9 billion for biotechnological research through its research grants and contracts mechanisms and its intramural component.

The basic research discoveries made over the past several years have led to an era of astounding biotechnological progress. These achievements include:

- the elucidation of DNA structure;
- chromosomal sorting methodologies;
- improved techniques for the molecular cloning of large DNA fragments;
- the genetic mapping of human disease genes by the use of restriction fragment length polymorphisms;
- the construction of physical maps of several complex genomes;
- improved DNA sequencing methodologies and microchemical instrumentation;
- enhanced technologies for hybridoma and monoclonal antibody production;
- the discovery of, and highly specific use of, restriction endonucleases;
- methods for amplification of gene expression for site-directed mutagenesis and chemical synthesis of DNA probes;
- new methodologies for the detection, separation and characterization of DNA;
- development of posttranscriptional RNA splicing methods and of synthesis, posttranslational processing, modification, transport, and secretion of proteins;
- protein structure and design;
- elucidation of hormone and cell surface receptor molecules;
- tissue and cell culture methodologies;
- separation technologies; and
- informatics for gene mapping, DNA sequencing, and protein structure.

Advances in basic understanding of biological processes and the development of methodologies for manipulating both biological and chemical processes at the molecular level have created numerous opportunities for

commercial biotechnology companies. The rapid coalescence of basic science knowledge and advanced technologies have decreased the time interval between scientific discoveries and their application to the development of commercially significant products and/or diagnostic tests. New products developed as a result of basic molecular genetic research have enabled biotechnology firms to diagnose human genetic disorders otherwise not detectable by conventional methods. A substantial number of such diagnostic tests are currently available and many others are under investigation.

NIH also supports biotechnology research in several other ways. NIH contributes significant funds to the Small Business Innovation Research (SBIR) Program, which funds industry research. It supports research collaborations with industry, which facilitate the translation of basic research discoveries to the development of commercially significant products. These collaborations, usually in the form of cooperative agreements between NIH scientists and biotechnology companies, have focused on several areas, including: molecular genetics, DNA cloning, genetic-based diagnosis, hybridoma, monoclinal antibody, immunology, and virology research, and the development of therapeutic agents.

NIH provides research resources to university scientists, state-sponsored biotechnology organizations, and biotechnology companies. These resources include the Genetic Sequence Data Bank (GenBank), the Human Genetic Mutant Cell Repository (Cell Bank), the Protein Identification Resource, the American Type culture Collection of Microorganisms and Cell cultures, the Hybridoma Data Bank, the Human DNA Probe Repository, BIONET, large-scale cell production facilities, an Instrumentation Grants program, and a central database of biotechnology databases. In addition, NIH supports research training at both the predoctoral and postdoctoral levels in basic biomedical disciplines that serve to fuel growth in biotechnology. In addition to institutional training programs, NIH funds predoctoral training specifically for biotechnology through the Lawton Chiles Fellowships in Biotechnology program.

As the new biotechnology has emerged, so have new partnerships between the developing industries and universities, the institutional sites for most NIH-funded extramural basic research relevant to biotechnology. These interactions, established between research universities and chemical, agricultural, and pharmaceutical firms, range from informal exchanges of information and consulting arrangements to research contracts, formal partnerships, and the creation of private corporations. There are many university-industry biotechnology research programs encompassing industry sponsored university research; cooperative industry-university research; joint commercial ventures; research consortia; and biotechnology research training centers.

NIH supports the interaction of universities with industry as long as safeguards against conflicts of interest are maintained and government-supported research results are disseminated freely. NIH awards grants to institutions in support of investigators who have meritorious proposals, regardless of whether the research will be done at a university, a private company, some combination of the two, or involves support by another Federal agency. All evidence indicates that this arrangement is working well for both universities and the biotechnology industry whether it is a part of the private sector or is state-sponsored.

There is substantial interest in the nature and scope of collaborative relationships between NIH, its academic grantees, and biotechnology companies. This interest is partly due to the remarkable basic science achievements that have occasioned commercial interests in marketing the products of biotechnology; a desire to enhance the transfer of research findings to commercial applications; and the desire to effectively utilize Federal biomedical research funds not only for basic research but also to support private industry in the translation of such research to the development of products. NIH interacts with industry in diverse ways. NIH grants over $6 billion per year to academic research institutions with the grantee retaining invention rights for licensing to industry. Through these means, the Federal Government transfers knowledge and commercial products to the private sector. Inventions made by government investigators in the course of intramural research are patented and licensed to companies under provisions of the patent law and are transfered to industry with the aid of the Federal Technology Transfer Act of 1986 (FTTA).

The Federal Technology Transfer Act of 1986 (Public Law 99-502), was designed to promote the transfer of government-developed technology into the private sector. The FTTA authorizes the Cooperative Research and Development Agreement (CRADA). Under a CRADA, Federal laboratories and private sector companies conduct research jointly and the collaborating company acquires patent rights at the outset of the collaboration. As an incentive and a reward, the FTTA also provides for the sharing of royalties with government inventors from the licensing of inventions developed under CRADAs and from inventions made through an Agency's intramural research programs. NIH currently has roughly 150 patent license agreements and over 100 CRADAs in effect, and about 100 additional CRADAs in various stages of negotiation.

NIH provides the lion's share of Federal support for the basic research that is critical to the continued vitality and growth of biotechnology in the United States. In addition, NIH promotes the development of productive relationships between scientists in the public and private sectors. All of these efforts will permit the pooling of resources

and expertise under well-defined conditions and thereby facilitate the transfer of basic science findings to commercial research and development activities.

National Science Foundation

The NSF, until 1991, generically described its biotechnology efforts by categorizing research related to biotechnology. This included activities in fundamental genetics, cell physiology, cell culture biology, basic biochemistry and enzymology, and bioprocessing engineering, which are generally regarded as being directly related to the further development of biotechnology. In 1991, an internal task force study was completed that redefined the biotechnology research being done at NSF. NSF's current definition of biotechnology is consistent with that used by the Office of Technology Assessment: a technique that uses living organisms or par&s of organisms to make or modify products, to improve plants or animals, or to develop micro-organisms for specific uses. In addition, it encompasses the development of materials that mimic structure and functions occurring in living systems. NSF's work categorized as research related to biotechnology includes all activities listed in the old definition plus microbial ecology, bimolecular materials, bioelectronics, and bionetworks. Funding figures for fiscal year 1990 reflect the new definition.

NSF's mission is the support of basic research in colleges and universities in the United States. The NSF budget accounted for approximately 7 percent of the fiscal year 1990 Federal nondefense budget for research and development. Approximately 94 percent of the NSF budget goes to basic research, with only 6 percent awarded for applied research.

In addition to Engineering Research Centers, first established in 1985 to facilitate technology transfer and multidisciplinary research, NSF established the Science and Technology Centers program (STC) in 1987 as a mechanism to exploit opportunities in science and engineering requiring complex approaches, to facilitate cooperation among students, faculty, and industry; and to encourage rapid and timely transfer of knowledge. Twenty-five centers have been established-n in fiscal year 1989 and 14 in fiscal year 1991. The central focus of four of those centers is biotechnology-plant resistance to pathogens (University of California, Davis), protein and nucleic acid technology (California Institute of Technology), light microscope imaging (Carnegie Mellon University), and microbial ecology (Michigan State University).

NSF monitors its biotechnology spending by using a data collection system based on review of all new awards for biotechnology relatedness on a subjective scale from none to all, by one-third increments. NSF specifies a category of work as related to biotechnology if it includes research activities related to the following: environmental applications; bioprocessing and bioconservation; bimolecular materials; bioelectronics and bionetworks; agricultural applications; medical applications; and impact of biotechnology.

Biotechnology research is supported by all NSF research directorates: Biological, Behavioral, and Social Sciences; Engineering; Mathematical and Physical Sciences; Computer and Information Science and Engineering; Geosciences; and Scientific, Technological, **and** International Affairs.

The Directorate for Biological, Behavioral, and Social Sciences (BBS) supports basic research that provides the basic underpinnings for biomaintenance, bioremediation, biology-based waste management, environmental diagnostics, bioprocessing and bioconversion, bimolecular materials, bioelectronics, and bionetworks. In addition, within BBS are programs in Ethics and Values Studies, the History of Science, and Social and Economic Sciences, which offer an opportunity for scholarly work on the impact of biotechnology.

The Engineering Directorate's (ENG) largest amount of support for biotechnology is in bioprocessing and bioconversion. The Divisions of Biological and Critical Systems (BCS) and Chemical and Thermal Systems (CTS) support bioseparations for downstream processing. The Bioengineering Program supports research to seek engineering solutions to health-related problems with an emphasis on research leading to new technology or to novel applications of exising technology. The Environmental and Ocean Systems program supports projects using micro-organisms for detoxification of contaminated water sources.

The Directorate for Mathematical and Physical Sciences (MI%) supports basic research that provides the chemical and mathematical underpinning of biotechnology, and that uses the methods of biotechnology in the formulation of new biomolecular materials. Relevant research is conducted in the Division of Materials Research (DMR), the Chemistry Division (CHE), and the Division of Mathematical Sciences (DMS).

The Directorate for Computer and Information Science and Engineering (CISE) supports research in the areas of bioelectronics and bionetworks and medical applications. Bioelectronics projects include work on algorithms and devices for vision/imaging and speech/auditory processes, as well as neuron/silicon circuits and devices. Support is provided for work in computer algorithms, techniques, and software tools pertinent to bimolecular data modeling and management in high-performance, networked computing environments.

The Oceanography Division (OCE) of the Geosciences Directorate (GEO) is involved in marine biotechnology and supports research in: the basic biochemistry and

physiology of organisms from extreme environments; chemically mediated interactions between organisms; development of methods for rapid taxa-specific characterization and identification of marine microbial populations; microbial decomposition and degradative processes; molecular studies of the nitrogenase genes of marine nitrogen-fixing cyanobacteria; and marine viruses.

The Directorate for Scientific, Technological, and International Affairs (STIA) supports biotechnology in three divisions. The Science Resource Studies (SRS) Division studies biotechnology trends and research and development activities in industry, creating a database to be used in monitoring the trends of biotechnology and its industrial applications. The International Division (INT) supports projects in biotechnology through its bilateral agreements with many countries such as Japan and Mexico. The Division of Industrial Science and Technological Innovation (ISTI), through its Small Business Innovation supports research projects in molecular and cell biology, environmental applications, aquiculture, waste management, water treatment, biochemical and bioprocess engineering, biomass processing, and biomedical engineering.

NSF's total support for biotechnology-related research in fiscal year 1990 was $167.9 million. The total is broken down as follows:

- Environmental Applications, $34.93 million;
- Bioprocessing and Bioconversion, $34.02 million;
- Bimolecular Materials, $12.85 million;
- Bioelectronics and Bionetworks, $23.12 million;
- Agricultural Applications, $39.69 million;
- Medical Applications, $20.69 million; and
- Impact of Biotechnology, $2.54 million.

Department of Defense

DOD defines biotechnology to be any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants, or to develop micro-organisms for specific uses. The technologies specifically included in this definition are recombinant DNA, novel bioprocessing techniques, cell fusion technology including hybridomas, and somatic cell genetics.

DOD's efforts in biotechnology are divided between medical and materials efforts. The Army is the principal participant in medical biotechnology, with the Navy contributing to the effort through an extramural contract program. In materials biotechnology, the Navy is the principal participant, with the Army, Air Force, and Defense Advanced Research Projects Agency providing additional support.

Medical biotechnology is primarily directed toward characterization of etiologic agents of disease, development of vaccines, and improved diagnosis of disease and identification of agents. Vaccine development is targeted against militarily relevant diseases that are not of U.S. public health concern, but occur primarily in overseas areas. Examples of this work include vaccine development for dengue, malaria, anthrax, and Rift Valley Fever. Malaria vaccine research is a collaborative effort between DOD and NIH. The diagnostics efforts focus on use of DNA probes and monoclinal antibodies, which are also utilized by DOD for its chemical/biological defense program. The materials biotechnology programs in DOD are diverse. The spectrum of effort includes work on biopolymers, fibers, adhesives, intermediate compounds for synthesis of composites, biosensors, biocorrosion, biofouling control, compliant coatings, and bimolecular electronics.

In fiscal year 1990, DOD's support for both medical and nonmedical biotechnology research and development was about $98 million. The funding was divided about evenly between intramural and extramural programs. Medically related biotechnology R&D accounted for approximately $60 million, nonmedical expenditures totaled $38 million.

Department of Energy

The DOE's total expenditures for biotechnology R&D were approximately $82.2 million in fiscal year 1990. DOE supports both basic and applied research relevant to biotechnology research. DOE has three main programs that fund biotechnology: Basic Energy Sciences and Biological and Environmental Research, which are part of the Office of Energy Research, and Conservation and Renewable Energy.

The Basic Energy Sciences program includes Energy Biosciences and is focused on understanding the fundamental mechanisms of how plants produce biomass, and on the biological transformation of crude, abundant biomass into other usable forms. The program provides the foundation for the broad exploitation of new sophisticated knowledge in molecular genetics. Fiscal year 1990 funding for Energy Biosciences was approximately $20.4 million.

The bulk of DOE's biotechnology funding is from the Office of Energy Research's Biological and Environmental Research program. This program was funded at $54.9 million in fiscal year 1990. The primary biotechnology efforts are the human genome and structural biology programs. These programs are directed at accelerating the mapping of the entire human genome by improving DNA sequencing technology, developing new instrumentation, applying robotics technology, and exploiting unique Departmental facilities to investigate the structure-function relationships of biomolecules. Research is also conducted to investigate cellular processes, such as

growth and protein synthesis, by molecular approaches, and development of monoclinal antibody technologies labeled with radionuclides for diagnostic and therapeutic applications.

The Conservation and Renewable Energy Program funded $6.9 million of biotechnology research in fiscal year 1990. Research in biotechnology is focused on the application of bioprocessing to industrial and municipal wastes to produce fuels. The conversion processes are environmentally benign. The products, such as methane fuel or biodegradable agricultural mulch, are substitutes for fossil liquids and gases.

U.S. Department of Agriculture

Four agencies of USDA fund biotechnology R&D:

. the Agricultural Research Service (ARS);
. the Cooperative State Research Service (CSRS);
• the Forest Service; and
. the Economic Research Service (ERS).

In fiscal year 1990, the four agencies reported combined funding of just under$116 million. A description of each agencies' commitment to biotechnology follows.

Agricultural Research Service

The ARS is the primary research agency within USDA. It funds both intramural research programs and cooperative agreements. ARS conducts research for specific user groups within USDA, including the Animal and Plant Health Inspection Service, Food Safety Inspection Service, and Soil Conservation Review. ARS uses biotechnology to study and understand fundamental biological processes, and to modify and regulate these processes for the solution of agricultural problems.

ARS' biotechnology efforts include projects that use techniques such as gene cloning in micro-organisms, nucleic acid hybridization, biological and biochemical synthesis of nucleic acids and proteins, use of monoclinal antibodies, affinity column separation of antigens, use of immobilized enzymes and cells, protoplast fusion, regeneration of plants from tissue culture, transfer of embryos, gene mapping, and synthesis of peptide neurohormones. In fiscal year 1990, ARS projects using biotechnology totaled about $59.5 million. By the end of 1990, it was estimated that about 400 scientists would be using the tools of molecular biology to address agricultural problems.

Cooperative State Research Service

The CSRS is the USDA's liaison to the State university system for the conduct of agricultural research. Of all the Federal agencies, CSRS handles the most diverse types of research funding, including formula funds, such as the Hatch Act funds, McIntire-Stennis Cooperative Forestry funds, 1890 Colleges and Tuskegee University funds, and the Animal Health and Disease Section 1433 funds. In addition, CSRS provides competitive grants through its Special Research Grants program and the Competitive Research Grants program. The Competitive Research Grants program received funding through fiscal year 1990. A new program, the National Research Initiative, started receiving funds in fiscal year 1991. There are biotechnology programs in all of these funding categories.

According to CSRS, biotechnology refers to the improved or modified organism, microbe, plant, or animal, and "new research techniques' or 'technology" refers to contemporary "tools" available to scientists for the purpose of biotechnology development. CSRS's total funding for biotechnology amounted to $52.2 million in fiscal year 1990. The individual funding figures for 1990, and estimates for 1991, follow:

- Hatch Act: $13.3 million (1990);
- McIntire-Stennis Cooperative Forestry: $617,000 (1990);
- 1890 Colleges and Tuskegee University: $1.0 million (1990);
- Special Research Grants: $10.9 million (1990);
- Competitive Research Grants: $24.9 million (1990);
- National Research Initiative: $0 (1990); and
- Animal Health and Disease Section 1433: $1.5 million (1990).

Forest Service

The Forest Service is the primary forestry research agency within USDA and conducts the largest forestry biotechnology research program in the United States. Current biotechnology research is directed toward developing and testing basic techniques to employ biotechnology in accelerating tree growth and in improving the quality of woody plants. Research is also directed to understanding stress and disease resistance mechanisms; the development of improved natural biological control agents; and the development and testing of new and efficient industrial processes for wood use. The Forest Service's biotechnology research budget was $3.6 million for all phases of the program in fiscal year 1990, and included both matching and cooperative funding. Approximately 90 percent of this funding was allotted to in-house activities and 10 percent to support college and university research.

Economic Research Service

The ERS monitors developments in agricultural technology and assesses their potential economic impacts on farmers, resource use, national and international commodity markets, consumers, and the general economy. ERSs analyses provide information for assessing the social, environmental, and economic tradeoffs for new

technologies. In the area of biotechnologies, research has ranged from assessing the economic conditions under which animal growth hormones are most likely to be adopted, to the potential consumer impacts of biotechnology, to the examination of strategies for regulating the risks of biotechnology. The technology program at ERS includes two research sections and 7 staff-years, plus technology components of programs throughout ERS. In total, technology program expenditures were $500,000 in fiscal year 1990, with about one-half, focused on economic analyses of biotechnology.

Department of Commerce

The National Oceanic and Atmospheric Administration (NOAA) and the National Institute of Standards and Technology (NIST) operate within the Department of Commerce and fund biotechnology research.

National Oceanic and Atmospheric Administration

NOAA defines biotechnology as the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services. For the past several years, the National Sea Grant College Program of NOAA has invested a small but significant share of its budget in the development of fundamental science which will provide the basis for biotechnological development of marine resources. NOAA's biotechnology research falls in four categories: biochemistry and pharmacology, molecular biology, biochemical engineering, and microbiology and phycology.

Research in biochemistry and pharmacology is directed toward the isolation, identification, and biological evaluation of novel marine substances of potential use in medicine or industry. Biochemical engineering research results are also being applied in the commercial sector. For example, estuarine bacteria have been adapted to efficiently metabolize, and thereby detoxify, certain organic substances in industrial effluents that are severely impacting coastal areas. The technology is also being applied to toxic substances. Basic studies in molecular biology are directed to providing the science for genetic engineering of fish and algae and developing diagnostic reagents and vaccines for use in aquaculture. Research in microbiology aims to control biologically mediated corrosion and biofouling.

In fiscal year 1990, there were 47 active projects in these categories. They were supported with $2.0 million in Federal funds and an additional $1.6 million in non-Federal matching funds. The level of Federal support and number of projects are down 11 percent from fiscal year 1989.

National institute of Standards and Technology

NIST's current biotechnology efforts are based on a number of perceived industrial needs including:

- the development of clinical standards for testing new biotechnology products, such as standards used to calibrate scientific instruments and to validate and evaluate data;
- knowledge and measurement methods for understanding protein structure-function, modification, and expression;
- traceability to national standards for key measurement parameters in commercial fermenters (parameters such as cell mass and activity level, product population, glucose and oxygen concentration, and pH);
- measurement methods, databases, and predictive models for effective and efficient separation/purification of bioproducts and for optimizing the design of commercial processes;
- kinetics, thermochemical, and thermophysical properties data for biochemical solutions needed for process design and control; and,
- improved analytical measurement methods, standards, and standard reference materials for use in determining composition of biological solutions.

NIST (formerly the National Bureau of Standards-NBS) funded $4.8 million of biotechnology-related research in 1990.

Agency for International Development (AID)

AID broadly defines biotechnology to be cellular and molecular biology and the new techniques derived from them for improving the genetic makeup and/or management of human and animal health care, crops, livestock and microbes. In accounting for biotechnology research spending, AID also used a narrower definition of biotechnology that refers only to research using genetic engineering or cell fusion.

AID is an agency of the State Department and is the foreign assistance arm of the U.S. Government. It is not, per se, a research agency. The Agency's mandate is to work with developing countries in their efforts to improve economic development and meet basic human needs-to overcome the problems of hunger, illiteracy, disease, and early death. Technology development and transfer, including biotechnology, is one of the basic components in the Agency's strategy to achieve its goal. Given the nature of this goal, the research supported by AID is clearly directed to the development of specific products or systems that will be useful in improving human health conditions, agricultural production, and rural development in developing countries. AID supports projects in the United States and overseas. In general, AID finances

research that is expected to produce usable results within 3 to 5 years.

The overall research portfolio is comprised of projects supported from several offices within AID, and reflect the Agency's organization. AID is divided into central and regional bureaus and independent offices. Regional bureaus focus on the needs of a specific geographic region and serve as the Washington coordinating arm of the field activities conducted by AID missions. Central bureaus address agencywide questions, e.g., private enterprise. The central Bureau for Science and Technology provides technical assistance for the entire agency, and supports and initiates worldwide programs in science and technology. This bureau also coordinates AID's support of the 13 International Agricultural Research Centers. An additional locus of research activity was established in 1980, with the creation of the Office of the Science Adviser. The purpose of this office is specifically to encourage an innovative and collaborative approach to development research, technology transfer, and related capacity building.

The latest available funding information is for fiscal year 1989. In fiscal year 1989, biotechnology funding figures were $24.0 million (broad definition) and $4.7 million (narrow definition).

U.S. Environmental Protection Agency

EPA is primarily a regulatory agency, although it maintains a significant R&D budget for research programs providing a scientific basis for its regulatory activities. Much of the research conducted by EPA deals with biotechnology risk assessment. The research program attempts to develop the capabilities for the regulatory programs within EPA to predict, and thus avoid, unreasonable adverse effects on the environment. The strategy for program development has, as a critical component, the establishment of an in-house, scientific staff to conduct risk assessments. Concurrently, the staff scientists share responsibility for developing a complimentary extramural program, and fostering interactive information exchange with outside scientists. Extramural funding comprises approximately 75 percent of the total resources expended for biotechnology risk assessment research.

Certain micro-organisms fall within the regulatory framework of EPA under the Toxic Substances Control Act (TSCA) and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). For regulatory purposes, EPA is developing procedures to assess the potential risks and benefits of the use of these micro-organisms. As a cooperative adjunct, the Office of Research and Development (ORD) initiated a research program to develop evaluative methodology and gather scientific information that would identify and adequately describe effects on human health or the environment that may result from the introduction of genetically altered micro-organisms into the environment.

With the emphasis of the program on risk assessment, six areas of research were identified as essential:

1. development of methods for the detection and enumeration of novel organisms in complex environmental samples;
2. determination of survival and growth in the environment;
3. assessment of the stability and transfer frequency of introduced genetic material in the intra- and extracellular environment;
4. development of data and predictive models for transport from the point of application or release to other locations;
5. detection of adverse environmental response (e.g., ecological effects, toxicity, host range change) due to introduced organisms; and
6. determination of changes in host range.

The program deals with both recombinant and nonrecombinant bacteria, fungi, and viruses. In all areas, a primary objective is to produce appropriate scientific information for developing protocols. In fiscal year 1991, two additional areas of research will be pursued. One area deals with environmental studies on pollution prevention through the application of bioregulation techniques. The second new area of research will develop testing procedures, cell bioassays and screening methods to elucidate the potential effects of biotechnology products on human health. EPA's total biotechnology funding for fiscal year 1990 was $8.3 million.

Department of Veterans Affairs

The Department of Veterans Affairs adopted the OTA definition of biotechnology-any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or *s, or to develop micro-organisms for specific use-for the purpose of accounting. Specifically, funding data were provided for projects involving cell fusion, gene splicing, monoclinal antibodies, and recombinant DNA.

The VA's expenditures in biotechnology-related research for fiscal year 1990 were $7.5 million.

National Aeronautics and Space Administration

Space biotechnology uses biological materials, such as cells and proteins, to examine how the reduced gravity environment affects these materials, to examine what unique products or factors are produced by cells in reduced gravity, and to use this unique environment to

improve processes already done on Earth, such as protein crystallization and separations of cells or proteins.

Biotechnology research at NASA is conducted principally within the Microgravity Science and Applications Program. The program objectives are:

- improve methods for the crystallization of proteins in space and their complexes with other biological materials.
- utilize the microgravity environment to perform fundamental research on basic biological processes in cells and tissues.
- investigate new separation processes and approaches for purification of biological materials, and
- improve methods for the formation of complex biological systems such as fused cells, liposomes, and biopolymer films and matrices.

Funded at a level of $4.5 million in fiscal year 1990, the program includes nine investigators from universities and three investigators from NASA research centers. The largest and most active laboratory for doing biotechnology in space is at the University of Alabama, Birmingham, where the effort to refine techniques for growing better protein crystals in space is centered.

Of the $4.5 million, NASA spent $2.0 million on research on protein crystal growth and macromolecular crystallography; $1.0 million on separation techniques, theoretical flow analysis, cell culture, and productivity in reduced gravity; and $1.5 million was spent between the Marshall Space Flight Center and the Johnson Space Center to support the above research areas or to develop flight hardware that will support taking these experiments to space.

Food and Drug Administration

FDA is a scientific, regulatory agency responsible for the safety of the Nation's foods, cosmetics, drugs, biologics, medical devices, and radiological products. In this role, FDA monitors and evaluates the manufacturing industry to assure the consumer that the products produced are safe as well as effective. Evaluation of product safety requires, in part, that FDA conduct scientific research focused on developing technology, such as biotechnology. Since biotechnology affects all of FDA's product areas, all products evolving from biotechnology must be evaluated from the appropriate scientific perspective in order to judge their safety and efficacy. FDA's research efforts, including those related to biotechnology, are targeted toward:

- product testing;
- scientific review of new product applications;
- identification of hazards;
- development of new or improved physical, biological, toxicological, or chemical tests;
- determination and establishment of standards, and product compliance with those standards; and
- clarification of mechanisms underlying toxicologic and pharmacologic effects.

Biotechnology is already having a major impact on the development of products that FDA regulates; and the agency's focus is to maintain a research expertise in the field in order to have the knowledge necessary to approve new pharmaceuticals, new food products, and other items regulated by FDA in a minimum of time. In fiscal year 1990, FDA spent approximately $19.4 million on biotechnology research.