INTERNATIONAL DEVELOPMENTS IN BIOTECHNOLOGY AND THEIR POSSIBLE IMPACT ON CERTAIN SECTORS OF THE U.S. CHEMICAL INDUSTRY

Report on Investigation No. 332-174 Under Section 332(b) of the Tariff Act of 1930

USITC PUBLICATION 1589

OCTOBER 1984

United States International Trade Commission / Washington, D.C. 20436

UNITED STATES INTERNATIONAL TRADE COMMISSION

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PREFACE

On January 3, 1984, the United States International Trade Commission, in accordance with the provisions of section 332(b) of the Tariff Act of 1930 (19 U.S.C. 1332 (b)), instituted investigation No. 332-174 on its own motion for the purpose of gathering and presenting information on international developments in biotechnology. 1/ The study assesses the competitiveness of biotechnologically produced chemical products in world markets, the current status of the industry, future trends, and factors which could influence the biotechnology industry and trade.

Biotechnology products are those chemicals derived through the action of microorganisms on feedstock chemicals or materials to produce certain chemical products. Although U.S. popular media coverage of biotechnology has highlighted research in high-technology areas, such as genetic research, much research and development work is also ongoing in the more traditional technologies such as fermentation. This study examines both the advanced methods as well as the traditional production techniques of biotechnology.

Products of the chemicals industry are covered by code number 28 of the Standard Industrial Classification (SIC). This two-digit code covers, among others, pharmaceuticals, other organic chemicals, and agrochemicals. These three product areas have been, and are expected to continue to be, the areas of the heaviest concentration of biotechnology products. It is these areas that are most affected by changes in biotechnology and, thus, were analyzed in this report.

In assessing the possible future impact on trade, estimates of future consumption of certain specified chemicals that may be made using biotechnology were made using linear regression analyses. In addition, information was collected by interviews with interested parties, from U.S. Government agencies, and from research papers.

1/ See Glossary of Terms, app. A, for a definition of this and other technical terms.

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EXECUTIVE SUMMARY

The world biotechnology industry is one of a number of rapidly growing high-technology industries. Although many biotechnology firms are well established, others have only started up within the past 5 years. These newer firms tend to be U.S. based or have U.S. involvement, primarily because of the availability in the United States of the large amounts of capital required for equipment and research.

For the purposes of this study, biotechnology is defined as a process which uses microorganisms to produce chemical products. This definition excludes old processes such as wine and cheesemaking, as well as procedures designed to genetically improve plants and animals.

The products of biotechnology which are covered in this report include some of the most rapidly developing areas of the pharmaceuticals industry. Discrete groups of chemical products within the term certain drugs and related products, as used in this study include antibiotics, biologicals, hormones, and vitamins. Examples of other product areas where biotechnology has had, and will continue to have, an effect are certain organic chemicals, which includes amino acids, enzymes, ethanol, methanol, and certain agricultural chemicals which covers pesticides and fertilizers. The major findings of this investigation are summarized below.

1. Structure of the world biotechnology industry

- <u>The United States is a world leader in production and consumption of biotechnology products</u>.

The United States has more firms actively engaged in biotechnology than any other country in the world. In 1983, there were at least 172 commercial firms as well as 46 other ventures owned by universities, local governments, and private firms dedicated to research in the area of production of such products as enzymes, ethanol, miscellaneous chemicals, and pharmaceuticals. Venture capital and government funding in the form of grants have made major contributions to the startup and rapid growth of many of these domestic firms. The large number of companies supporting biotechnology firms through contract services, laboratory leasing, and custom research chemicals has also helped establish the biotechnology industry. Approximately 5,000 personnel were involved in biotechnology in 1983, with total investment in biotechnology at a level of about $2.5 billion.

Some products which are either natural products or are produced primarily using biotechnology are antibiotics, biologicals, hormones, and vitamins; these constitute the group certain drugs and related products. During 1979-83, domestic shipments of certain drugs and related products increased from $4.8 billion to $7.6 billion. A related product group, enzymes, is almost totally made up of chemicals produced by using biotechnology. Production of enzymes more than doubled from $30 million in 1979 to $69 million in 1983. Over this same period, apparent U.S. consumption of these certain drugs and related products also increased, from $4.0 billion in 1979 to $6.5 billion in 1983. U.S. exports of chemicals produced by biotechnology during 1979-83 accounted for a large percentage of domestic output. For example, U.S. exports were equal to about 20 percent of total domestic shipments of certain drugs and related products in 1983, and exports of enzymes constituted 47 percent of production. Exports of amino acids, produced increasingly by biotechnology methods, accounted for almost 32 percent of domestic production.

- The major European countries involved in biotechnology are West Germany, the United Kingdom, and France.

In 1983, there were a total of 366 commercial firms using biotechnology in Europe. The country with the largest number of commercial firms was the United Kingdom with 65, followed by West Germany with 43, Italy with 38, and the Netherlands with 29.

In terms of value of exports of products of biotechnology, however, West Germany was the leader, followed by the United Kingdom and France. West German exports of certain drugs and related products amounted to $467 million in 1982, and the United Kingdom exported nearly 308 million dollar's worth of these products. France was the largest European exporter of ethanol, with exports of more than $50 million in 1982.

In addition, in 1983, 22 commercial and 10 noncommercial biotechnology firms operated in Denmark. Many of the commercial firms are large, and the world's two largest producers of enzymes are based there. Exports from Denmark of enzymes in 1982 exceeded $127 million, nearly four times the amount exported by the United States in that year.

- There are many biotechnology firms operating in Japan although that country remains a net importer of many of the products of biotechnology.

Many of the commercial firms which operate in Japan are well-established producers, often using older biotechnology concepts for the production of amino acids, enzymes, and certain drugs. As of 1983, there were 92 commercial firms and 6 noncommercial firms operating in Japan.

Although Japanese companes have traditionally been world leaders in fermentation products such as enzymes, amino acids, and certain organic chemicals, the high level of internal consumption of these products by the Japanese manufacturers and the manufacture of finished chemical products by other Japanese producers result in Japanese imports of these products that are higher than exports.

Exports of biotechnology products from Japan in 1982 amounted to about $331 million and consisted of certain drugs and related products, amino acids, enzymes, and ethanol. Imports of these products reached $614 million; about 56 percent of the imports consisted of antibiotics. The next largest import was ethanol, amounting to $80 million in that year.

o Development of biotechnology in other areas of the world has been slower than in the United States, Europe, and Japan.

Although there are many countries such as New Zealand, Kuwait, and Hungary with varying degrees of involvement in biotechnology, these countries are principally concerned with the precommercial development aspects of biotechnology. Of these other countries, in 1983, Canada operated the greatest number of commercial firms (34) followed by Israel (8).

The current small number of commercial ventures in most of these countries compared with the number of firms established elsewhere in the world coupled with the lack of government support available for biotechnology development will probably retard the future establishment of commercial ventures in these areas. Those countries with feedstock advantages, such as excess agricultural products or wastes that can be used to make ethanol, may be the first to develop commercial biotechnology industries.

2. Products and markets for biotechnology

o Biotechnology has meant new ways to make both old and new products for the pharmaceutical industry. The pharmaceutical industry has apparently been the most significantly influenced of all industries affected by biotechnology.

The U.S. pharmaceuticals industry has experienced rapid growth in apparent consumption and trade in antibiotics, biologicals, hormones, and vitamins, nearly all of which are produced using biotechnology processes. Many of the recently developed biotechnology products are in these fields, including the newer, more potent antibiotics and the highly specific clinical materials such as those used in testing for pregnancy and diabetes.

o Apparent U.S. consumption of antibiotics more than doubled during 1979-83, and exports increased by nearly 50 percent.

Apparent U.S. consumption of antibiotics grew from $1.1 billion in 1979 to $2.3 billion in 1983. U.S. exports increased from $526 million in 1979 to $780 million in 1983.

The major export markets for U.S. antibiotics in 1983 were Japan, Canada, and the European countries including France, Belgium, Luxembourg, and West Germany. Both Europe and Japan are traditional markets for antibiotics, and applications of recent innovations in biotechnology should enable the United States to expand, or at least maintain, its market share. U.S. imports of these products have been relatively small and amounted to $189 million in 1983.

o Apparent U.S. consumption of biological products, hormones, and vitamins rose by less than 50 percent during 1979-83, whereas during the same period, the increase in exports was slightly higher.

Apparent U.S. consumption of these products rose from $2.9 billion in 1979 to $4.2 billion in 1983. Exports grew from $509 million in 1979 to $789 million in 1983.

Japan has remained the major market followed by Europe for U.S. exports of all three of these product groups. Other world markets in the top eight U.S. markets for these products include Indonesia, Saudi Arabia, and Brazil. These countries are noted for their recent buildup of health care infrastructure, and could develop into larger markets for U.S. exports in the future. U.S. imports, at $324 million in 1983, accounted for about 8 percent of consumption.

- Apparent U.S. consumption of amino acids increased by about one-third during 1979-83. Exports nearly tripled during 1979-81 but declined during 1982 and 1983.

Apparent U.S. consumption of amino acids increased from $154 million in 1979 to $208 million in 1983.

The value of U.S. exports of amino acids nearly tripled from 1979 to 1981, when they reached a level of $48 million. Although Japan was a developing market during that period, U.S. exports to that country decreased in 1982 and 1983, and were replaced by Japanese production. The current U.S. export market for amino acids is centered in the European nations, and in 1983, Italy accounted for 52 percent of total U.S. exports of amino acids. U.S. exports of amino acids are likely to grow as world demand increases.

U.S. imports of amino acids were larger than exports during 1979-83 and amounted to $126 million in 1983, when they came principally from Japan and France.

- Apparent U.S. consumption of enzymes more than doubled during 1979-83, although export markets have shown a decline since 1981.

Apparent U.S. consumption of enzymes grew steadily from $53 million in 1979 to $129 million in 1983. During this period, U.S. exports of enzymes to traditional markets, such as Europe, fluctuated downward, contributing to the overall decline seen during 1981-83. Exports amounted to $33 million in 1983. Canada has been the leading market for U.S. exports of enzymes since 1979 and received 7.5 million dollar's worth of these exports in 1983, representing an increase of 81 percent from the $4.1 million it received in 1979.

A reason for the decline in U.S. exports of enzymes is increasing competition with world-scale producers of enzymes, particularly Denmark and Japan.

U.S. imports of enzymes were much larger than exports during 1979-83. During that period imports came principally from Denmark and totaled $92 million in 1983.

- Apparent U.S. consumption of ethanol more than doubled during 1979-83, whereas exports decreased. The quantity of U.S. production of ethanol based on biotechnology processes increased during 1979-83.

The quantity of ethanol produced using biotechnology processes as an alternative to synthetic methods is increasing. Domestic production of ethanol increased from 1.7 billion pounds in 1979 to 2.3 billion pounds in 1983. The portion of ethanol produced through biotechnology increased from 18 percent of the 1979 total to 52 percent of the 1983 total. Apparent consumption also increased, from $341 million in 1979 to $787 million in 1983.

U.S. exports of ethanol decreased from $9.5 million in 1979 to $3.8 million in 1983, partly as the result of the availability of fermentation ethanol in foreign countries. U.S. imports of ethanol more than quadrupled in value during this same period and totaled $102 million in 1983. Brazil was the principal source of imports in that year.

- The quantity of methanol made using biotechnology is likely to increase.

Although nearly all methanol is currently produced synthetically from natural gas, more methanol will be produced in the future using biotechnology. It is an important feedstock chemical in biotechnology for the production of single cell protein, an important feed or feed additive for animals and humans. It is possible that biotechnology processes to produce methanol may be commercialized in the next decade or two, particularly in those nations having the necessary biotechnology process feedstocks.

- Future markets for agricultural chemicals are uncertain; however, the primary developing U.S. agricultural chemicals export markets are in the less developed countries.

Nitrogenous fertilizers and pesticides are two agricultural chemicals areas which are, and will be, greatly affected by current and future biotechnological developments. Biological pesticides which are highly specific and relatively nontoxic to animals and humans are currently under development and commercialization. Fertilizers made from farm wastes in some European nations may be important in the next decade. However, the overall future of biotechnology in agricultural chemicals is now clouded, because genetic engineering of plants and animals could decrease the future need for pesticides and/or fertilizers. Research is underway that could dramatically change current requirements for agricultural chemicals by altering the food requirements and/or susceptibility of plants and animals to pests and diseases.

Although U.S. exports of nitrogenous fertilizers in 1983 declined to $231 million compared with $368 million in 1979, developing U.S. export markets in 1983 included the Republic of Korea and China, each of which accounted for $33 million, or 14 percent, of total 1983 U.S. exports. The largest U.S. export market for pesticides in 1983 was Canada, which received $178 million, or 14 percent, of total U.S. pesticides exports ($1.3 billion). Other countries listed in the top eight export markets included Japan and the more traditional U.S. export markets of Brazil, Australia, and several European nations.

3. Factors influencing biotechnology industry trade

- The most common type of reactor vessel used in biotechnology processes in the United States is the stirred tank, to which many foreign improvements have been made since 1978.

Nearly all industrial biotechnology processes use microorganisms which require air. Many recent improvements in the design of reactor vessels have been to distribute air more uniformly throughout the reaction medium. Most of these improvements have been made by foreign firms, which has allowed them to produce some antibiotics, vitamins, and enzymes more economically. Most U.S. firms use a less sophisticated, simple stirred-tank-type reactor. Although this simpler reactor vessel enables the U.S. producer to make a larger number of products, the use of these less efficient, multiproduct reactor vessels instead of the more advanced, specially designed vessels can result in a higher relative cost for the products produced.

- The use of genetic engineering in biotechnology has resulted in a number of products which have heretofore been unavailable or hard to obtain.

The results of genetic engineering experiments have only recently reached commercial status. In 1984, several products have been commercialized, including human insulin, some new vaccines, and diagnostics. Most of the products utilizing genetic engineering techniques are produced by U.S. firms.

- Technology transfer between the United States and other nations is expected to increase as the number of joint ventures and licensing agreements for the development and production of chemicals through biotechnology processes increases.

The United States has benefited from a mutual exchange of technological knowhow in biotechnology with other nations during 1979-83. Because this exchange has been mutual, there has probably been little effect on the balance of trade. Joint ventures and licensing agreements between U.S.-based and foreign firms have resulted in the sharing of many basic research developments. Some foreign subsidiaries have been established in the United States when the foreign firms purchased smaller domestic U.S. firms involved in their own basic research. Still other foreign subsidiaries resulted from foreign companies acquiring U.S. firms that were already using foreign technology obtained through licensing agreements. However, seldom have foreign subsidiaries been formed by the foreign purchase of major U.S. biotechnology companies.

Industry sources expect technology transfer to increase as more foreign and U.S. firms engage in joint ventures for research, development, and commercialization of biotechnological processes. Some sources fear that technology transfer could result in the loss of process or product knowledge vital to a U.S. firm, to the entire U.S. industry, or to national security interests.

o Although U.S. firms currently appear to have a competitive advantage in biotechnology development, as indicated by the number of patents held by U.S. firms, Japanese firms are strongly increasing their competitive position.

The number of U.S. patents related to biotechnology increased from 92 in 1979 to 372 in 1982. U.S. firms were the originators of 56 percent of these patents in areas such as the production of enzymes and genetic engineering, whereas Japanese firms currently hold about 21 percent of these U.S. patents. However, Japanese firms also hold 55 percent of the U.S. patents granted in the biotechnologically oriented processes for the production of amino acids. Utilizing this base, Japanese firms could expand in the U.S. and world amino acids markets and have a competitive advantage for the life of their patents.

o The full-scale commercialization of recently developed products utilizing biotechnology processes will require U.S. investment in plants and equipment.

Large investments are required if many of the smaller U.S. biotechnology firms are to produce commercial quantities of products. For these firms, R&D expenditures are likely to exceed revenues. Thus, with single plants having prices of $10 million of more, these smaller firms may need to seek investment either directly from private sector investors or through some type of public sector program in order to commercialize their products.

Venture capital investment in U.S. biotechnology firms increased from about $84 million in 1980 to about $157 million in 1981, but subsequently decreased to about $70 million in 1983. This is not expected to increase substantially in the near future. This decrease is attributed by some to the fact that many investors had already made financial commitments in biotechnology in the prior years and an increasing amount of research and development (R&D) is being performed in companies already established. For example, the number of equity investments by large multinational companies in smaller biotechnology companies totaled 61 during 1977-82, with the annual dollar investment increasing from about $2 million in 1977 to $119 million in 1982.

o Compared with some foreign countries, the United States is not expected to experience severe shortages of biotechnology-related personnel.

The estimated 5,000 technical personnel performing R&D in biotechnology in 1983 were mostly highly specialized and widely sought by other firms, particularly those in the process of commercializing products. These technical personnel accounted for about 63 percent of the total personnel in the smaller biotechnology firms.

Industry sources have indicated that although the United States may not have a sufficient number of engineers in fields related to biotechnology, significant shortages occur more often in Europe, especially the United

Kingdom and France. 1/ In Europe, because of noncompetitive salaries, many qualified personnel have left and in fact have sought employment in the United States. In Japan, although there are a sufficient number of engineers working in biotechnology, there is a shortage of qualified molecular biologists.

- The National Institutes of Health is the largest source of U.S. Government funding in biotechnology.

The National Institutes of Health funded a total of $1 billion in project research and development in biotechnology during 1979-82. In 1982, the number of projects considered to be in the area of biotechnology reached 3,541, representing an increase of 32 percent from the number in 1981 and over 4 times the number of projects in 1979. Total funding grew from $293 million in 1981 to $380 million in 1982, or by 30 percent.

- The Japanese Government is heavily involved in funding research and development in biotechnology.

In 1982, the Japanese Government, through the Ministry of International Trade and Industry and other agencies, alloted approximately $56 million for research and development in biotechnology. In 1983, this figure increased by 5 percent to $59 million. An additional $128 million over a 10-year period was provided for research in genetic engineering and other innovative biotechnology techniques. It has been suggested that funding to commercialize biotechnology processes from all Japanese Government sources totaled about $200 million annually in recent years. 2/

4. Implications of developments in biotechnology on future U.S. consumption and trade

- Overall U.S. net trade for biotechnologically produced chemicals could decrease by more than 15 percent by the year 2000, but U.S. consumption could increase by 67 percent.

Results from least squares linear regression analysis of historical trade data show that the positive U.S. net trade balance in biotechnologically produced chemicals could decrease from $1.3 billion in 1983 to $1.1 billion in the year 2000; U.S. consumption could increase from $14.7 billion to $24.5 billion. The principal reasons for this decline in net trade are foreign production advantages gained through technology advances and increased production of some chemicals that could be made using biotechnological processes in new, world-scale petrochemical plants in conventional-energy-rich nations. The amount and direction of net trade or domestic consumption changes varies by chemical sector as shown in the following tabulation (in millions of current dollars):

1/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, January 1984.

2/ Office of Science and Technology Policy, Report of a Working Group on the Competitive and Transfer Aspects of Biotechnology, April 1983, vol. II, pp. 45-56.

Sector	1983		2000	
	Apparent consumption	Net trade	Apparent consumption	Net trade
Certain drugs and related products	6,541	1,057	16,852	2,521
Certain organic chemicals	1,602	-241	3,471	-478
Certain agrochemicals	6,555	407	4,218	-947
Total	14,698	1,323	24,541	1,096

- The greatest change in domestic consumption and net trade is expected to be in certain drugs and related products, as new drugs continue to enter the world market.

Of all of the sectors examined, a particularly rapid growth during 1979-83 in trade and apparent U.S. consumption was observed in the sector of certain drugs and related products. In this sector, growth in the domestic consumption of antibiotics and hormones was the most rapid, reaching $2.3 billion and $1.3 billion, respectively, in 1983. As a result of the development of novel antibiotics using biotechnology, as well as biological techniques for the production of hormones, biologicals, and vitamins, apparent U.S. consumption in 2000 could reach $7.2 billion for antibiotics, $3.7 billion for hormones, and $16.8 billion for the entire sector of certain drugs and related products.

Trade in certain drugs and related products also grew rapidly during 1979-83, and net trade exceeded $1.0 billion in 1983. Exports could reach a level of $3.8 billion by the year 2000 and the overall positive trade balance, a level of $2.5 billion.

- Apparent U.S. consumption of certain organic chemicals will probably grow through the year 2000; however, the current negative trade balance could worsen.

The chemicals included in the certain organic chemicals sector, such as amino acids, enzymes, ethanol, and methanol, are widely used industrially as intermediates and in product formulations. Of these chemicals, the apparent consumption of industrial ethanol in 1983 was $815 million and could reach $2.4 billion by the year 2000. Enzyme consumption could reach $451 million by 2000, which would indicate a growth of over 250 percent compared with that in 1983, when consumption totaled $128 million.

However, even though U.S. consumption could increase overall, increases in imports of certain organic chemicals could be primarily responsible for a larger negative trade balance in the year 2000 compared with that in 1983. Advancements in fermentation processes for amino acids production in countries such as Japan could result in increased U.S. amino acid imports. European enzymes production, the largest in the world, could be turned to by the U.S.

market to satisfy an increasing demand. U.S. trade balances in ethanol and methanol, on the other hand, may be affected more by world-scale petrochemical plants, which use natural gas and crude petroleum, coming on stream in the conventional-energy-rich nations, including Saudi Arabia, than by developments in biotechnology.

- Both domestic consumption and net trade in nitrogenous fertilizers and pesticides could decline, depending upon developments in agricultural science as well as changes in biotechnology.

Two product areas, nitrogenous fertilizers and pesticides, within the agrochemicals sector of the chemicals industry were analyzed for possible future impact. Although agrochemicals sector scenarios could result in sector decreases in apparent consumption and net trade by the year 2000, the figures may be distorted by the recent worldwide economic slump, droughts in some areas of the world, and the U.S. payment-in-kind program. More accurate trends, therefore, might be realized through analysis covering a much longer period of time than was used in this report. However, other developments in agricultural science, including genetically engineered plants and animals, may account for some of the indicated future decrease in demand for nitrogenous fertilizers and pesticides. Specially engineered plants could require less fertilizer or may use fertilizer more efficiently, so that overall fertilizer consumption could be less than expected compared with historic trends. Similarly, specially bred animals and engineered plants may be developed that would be more resistant to diseases and natural pests, thus requiring less pesticide usage than historical evidence would indicate.

- Significant trade position changes could develop in the United States by 2000, resulting in employment increases in certain drugs and related products, and decreases in employment in other chemical sectors using biotechnology.

In order to project changes in U.S. industry employment, the U.S. Department of Labor's input/output model was used. 1/ Using the net trade balance figures obtained from linear regression analysis on historical trade data, employment requirements in the certain drugs and related products sector would be expected to increase, possibly rising by 22,122 jobs. Trade changes in this sector would also result in employment increases of 26,594 in the chemicals and allied products industry and 62,612 over the entire U.S. economy.

1/ The estimates of future employment changes contained in this report are based on projected changes in the net U.S. trade position and assume (1) a one-to-one ratio between net changes in U.S. trade and U.S. production changes and (2) constant 1981 employment-output ratios. These estimates do not take into account other factors influencing domestic output and employment which may be be affected by changes in trade levels, such as domestic prices, consumption, exchange rates, and employment-output ratios. The interrelationship between trade and employment is examined in detail in the Commission report on Investigation No. 332-154, U.S. Trade-Related Employment, USITC Pub. 1445, 1983.

Employment requirements could decrease in the certain organic chemicals and certain agrochemicals sectors, with declines of 2,860 and 4,231 in each of these sectors, respectively. Employment decreases in the chemicals and allied products industry as a result of these changes would be expected to be 3,289 and 6,434, respectively, whereas employment decreases over the entire U.S. economy would be 16,603 and 7,343, respectively.

BIOTECHNOLOGY INDUSTRY

Definition

Biotechnology is defined in this study as a process which uses microorganisms to produce chemical products. Since many organizations and countries in the world have had to define biotechnology for the purposes of measurement and planning, several official definitions of biotechnology have resulted. 1/ Some of these organizations are now seeking a common definition so that comparable statistics can be generated. 2/ Because of discrepancies in the various terminologies, one large domestic firm has recently dropped the word "biotechnology" in favor of "biological sciences" in its corporate slogan. 3/

At least one study has made the distinction between "new" and "old" biotechnology. 4/ New biotechnology is referred to as the use of high-technology equipment or processes to modify living organisms, including the use of gene-splicing or recombinant DNA (deoxyribonucleic acid) techniques, and other methods such as recombinant RNA, (ribonucleic acid) in order to impart new qualities to certain microorganisms. Products which have resulted from the new biotechnology include human insulin, monoclonal antibodies, some diagnostic reagents, and vaccines (see app. A, Glossary of Terms).

The old biotechnology refers to established biological processes which predate the use of modified organisms. Such old processes are used in the production of cheese, wine, and, within the last century, antibiotics, amino acids, and enzymes. In many instances, the old biotechnology, as practiced by the U.S. chemical industry uses commonly available or specially bred microorganisms under controlled reaction conditions. These processes have been identified as biotechnology for over 25 years. 5/

This study does not attempt to separate old and new biotechnology. Nearly all industry sources agree that the field of biotechnology includes established fermentation processes, as well as other technologies, including genetic engineering. Most genetically engineered organisms make products already in existence, but cheaper or faster than they are capable of being produced via established chemical processes. Many biotechnology processes already in use in the chemical industry are considered adequate for commercial production (e.g., that for ethanol), and continued use of some of these processes, even without the introduction of genetically modified organisms, could possibly result in increased trade by the year 2000. In addition, the

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1/ J. Coombs, The International Biotechnology Directory (184), 1983, Organization for Economic Cooperation and Development, Biotechnology: International Trends and Perspectives, Paris, 1982; Office of Technology Assessment, Commercial Biotechnology: An International Analysis, January 1984.

2/ Organization for Economic Cooperation and Development, Biotechnology: International Trends and Perspectives, Paris, 1982.

3/ D. Webber, "Biotechnology Moves into the Marketplace," Chemical & Engineering News, Apr. 16, 1984, p. 13.

4/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, January 1984, p. 9.

5/ Elmer L. Gaden, Office of Technology Assessment, Fermentation Technology: An Analysis and Assessment, July 30, 1982, p. 4.

efficiencies of some of these well-known standard biological processes might be enhanced without the need for genetically improved organisms.

History

The history of the development of biotechnology often excludes selective plant or animal breeding, and other processes such as winemaking, brewing, and cheesemaking, all of which are processes considered to be ancient arts. Additional biological processes to serve the chemical industry were developed as early as 1880, and significant improvements continued through the beginning of the 20th century. 1/

Examples of more recent commercial biological processes are those used to produce butanol, acetone, ethanol, and fusel oils. The production of butanol and acetone in the United Kingdom became commercially important during World War I, a time when that country was largely dependent upon its own resources. Although these chemicals could be produced synthetically, feedstocks were generally not available, and synthetic processes were not then considered economically competitive with fermentation processes. 2/

The use of biological processes for production of organic chemicals increased in importance after World War I. Production of a wider variety of more specialized chemicals developed, including citric acid, gluconic acids, and certain vitamins, as well as the newly discovered antibiotic penicillin. 3/

Continued improvements in biotechnology processes were made during 1945-60. 4/ An increase in the variety of available microorganisms led to increased industry capability to produce commercial quantities of antibiotics, enzymes, amino acids, and organic acids. Improved fermentation reactor designs allowed better process control. These changes led to the commercialization of many previously uneconomical small-scale processes. Examples of new chemical products produced during this period include vitamin B_{12}, streptomycin, semisynthetic penicillins, lysine, and single-cell protein. 5/

A new era in biotechnology resulted from the first gene cloning and recombinant DNA experimentation during 1973 and 1974. The development of an ability to selectively recombine DNA fragments made possible the modification of microorganisms, thus providing an alternative to time-consuming, expensive, selective hybridization. As a result, the use of recombinant DNA accelerated the commercialization of biotechnology which otherwise would have taken years to achieve. 6/

1/ M. Grayson, The Kirk-Othmer Encyclopedia of Chemical Technology, 1980, Wiley Interscience, New York, vol. 9, pp. 861-880.

2/ Ibid.

3/ Ibid., vol. 9, p. 864.

4/ Ibid.

5/ Ibid, p. 862.

6/ Organization for Economic Cooperation and Development, Biotechnology: International Trends and Perspectives, Paris, 1982, pp. 31 and 32.

In 1975 a technique was discovered to develop microorganisms that exclusively synthesize single types of antibodies (monoclonal antibodies). Because one type of antibody is specific for one type of antigen, the availability of these antibodies could allow the development of new tests which detect diseases or conditions with a remarkable degree of accuracy. This technique greatly advanced the ability of physicians to diagnose specific diseases rapidly and inexpensively. 1/

The effects of the most recent developments in basic research in biotechnology have yet to be felt by the chemicals industry. Recombinant RNA 2/ may have an even greater impact than that of recombinant DNA on the chemical industry.

World Biotechnology Industry Structure

The leading areas in the world where industrial biotechnology processes are commonly used are the United States, Japan, and Europe. Brazil and some other less developed countries tend to use those biotechnology processes that are well established, rather than those that employ the new biological developments.

In 1983 there were about 672 established firms worldwide producing chemical products using biotechnology processes, as shown in table 1. An estimated 600 to 1,000 other organizations worldwide perform research in biotechnology and produce products on a small scale. 3/

1/ G. Kohler, and C. Milstein, "Continuous Cultures of Fused Cells Secreting Antibody of Predefined Specificity," Nature, Aug. 14, 1975, pp. 495-497.
2/ J. Bishop, "New Technique to Produce Proteins May Alter Biotechnology Industry," The Wall Street Journal, Nov. 10, 1983, p. 31.
3/ J. Coombs, op. cit.

Table 1.-- Firms that perform research in biotechnology and produce products through such research, by areas and by types, 1983

Area	Commercial firms	Noncommercial firms	Support firms
United States	172	46	255
Europe:			
Austria	14	1	12
Belgium	23	10	33
Denmark	22	10	20
Finland	7	2	19
France	28	28	63
West Germany	43	14	71
Greece	10	1	6
Ireland	19	4	16
Italy	38	8	39
Netherlands	29	4	35
Norway	6	1	6
Portugal	12	1	3
Spain	14	1	16
Sweden	11	6	35
Switzerland	25	4	38
United Kingdom	65	13	160
Total	366	108	572
Japan	92	6	55
All other:			
Australia	0	1	4
Canada	34	3	38
Hungary	0	1	0
Israel	8	2	11
Kuwait	0	1	0
New Zealand	0	1	0
Total	42	9	53
Grand total	672	169	935

Source: J. Coombs, Office of Technology Assessment, Impacts of Applied Genetics, April 1981; Office of Science and Technology Policy, Report of a Working Group on Competitive and Transfer Aspects of Biotechnology, April 1983, vol. 1.

Joint ventures are common in the biotechnology field. They are often required when a U.S. firm wishes to do business in a foreign country. In the United States, joint ventures are frequently used by firms to develop a limited range of products. The parent firms often augment each other's technical, financial, and legal resources to service the needs of the joint venture.

Research and development in biotechnology are enhanced by an extensive support system which provides the biotechnology laboratory or plant with state-of-the-art instrumentation and biochemical components such as restriction enzymes and DNA fragments. Originally produced in-house, such materials have more recently been made available by firms which traditionally have supplied chemicals, instrumentation, and laboratory services. In the United States in 1983, for example, there were at least 11 specialty companies that together produced a variety of biochemicals to satisfy industrial and research demand. 1/ According to industry sources, the total synthetic DNA market was valued at approximately $3 million to $4 million in 1983 and is expected to grow at a rate of about 25 to 30 percent per year.

In Europe and Japan there are fewer such firms producing a smaller selection of biochemicals as a service to biotechnology firms. In Japan in 1983 there were three companies producing oligonucleotides, and two companies produced restriction enzymes, valued at about $4.5 million. Some of these enzymes were being exported to the United Kingdom. However, because Japanese production of restriction enzymes and oligonucleotides cannot satisfy demand, some Japanese firms were necessarily importing many of their biochemicals from the United States. In Europe, a similar situation exists (although not to the extent as in Japan); delays of 1 to 2 months in obtaining restriction enzymes and oligonucleotides from outside sources have not been uncommon. One important type of oligonucleotide, known as a DNA probe, which is used to identify specific genes, is not produced in Europe.

Many firms exist worldwide for processing cellulosic waste into methane and fertilizer. Many such plants are located in Europe, with about 50 in France and a larger number in Switzerland. These plants seek to reduce national dependence on foreign sources of nitrogenous fertilizers while assuring the quality of available arable land in Europe.

Other processes using waste materials are currently in the research phase, although some pilot plants do exist for production of chemicals, including ethanol. A $3 million pilot plant, located in Japan, was designed to produce 200 liters per day of ethanol from bagasse, rice husks, and other cellulosic wastes. 2/ An analogous pilot plant is planned in the United States. 3/

United States

The United States is probably the world leader in innovation in biotechnology through genetic engineering and basic research. In 1983, about 46 noncommercial 4/ firms performed research on the production of certain chemicals using biotechnological methods. Of these, 45 firms performed research on production of enzymes, ethanol, and miscellaneous chemicals, and the other firm concentrated on pharmaceuticals. Fifteen of these firms were interested primarily in ethanol, 30 firms had primary research interests in the area of

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1/ J. Coombs, op.cit.

2/ "Japanese Firms to Build Novel Cellulose-to-Ethanol Plant," European Chemical News, May 7, 1984, p. 18.

3/ Ibid.

4/ The terms "commercial" and "noncommercial" are used to describe the current status of biotechnology firms. Commercial firms are those which are currently involved in the production of chemicals using biotechnology, whereas noncommercial firms are not actively producing chemicals but are involved instead with basic or applied research in this area.

anaerobic digestion of locally available wastes to produce methane gas and organic fertilizers.

The commercial U.S. firms which produce commercial quantities of chemicals using biotechnology are generally vertically integrated, and some of the larger firms are also diversified. However, this is not the case for some of the newer and smaller biotechnology firms which utilize genetic engineering methods to produce chemicals. In 1983, about 172 commercial biotechnology firms were involved in producing chemicals, of which some 100 companies were involved primarily in the pharmaceuticals sector; 41 were producers of primarily organic chemical products, 25 firms manufactured primarily enzymes; and 6 firms produced agrochemicals.

In 1983, the United States also had approximately 255 support firms which offered laboratory reagents, biochemicals, and instrumentation, as well as services such as custom laboratory syntheses or fermentation and prepackaged bacterial cultures.

The total number of commercial biotechnology firms in the United States has increased since 1983, because many firms which had engaged only in research have since begun producing chemical products.

Europe

Belgium.--Universities are the major noncommercial organizations in Belgium pursuing research in biotechnology. Some are associated with the Belgian Government. In 1983, about 10 of these organizations were working on developments in the chemicals area, particularly on medicinals and pharmaceutical chemicals; 13 produced pharmaceutical chemicals including vaccines, vitamins, and antibiotics. In addition, six commercial firms were involved with chemicals such as amino acids, enzymes, ethanol, and certain organic acids.

Denmark.--In 1983 there were 10 noncommercial firms in Denmark engaged in the development of biotechnological processes for the production of chemicals. Although one firm was concerned with an industrial-scale synthesis of collagen, the rest were concerned with animal manures and agricultural wastes as feedstocks for generation of methane gas, and the use of digested wastes as substitutes for nitrogenous fertilizers. Because of limited land area and the nation's dedication to dairying and agriculture, increasing attention is being paid to the disposal of agricultural waste.

There were 22 firms engaged in the commercial manufacture of chemicals using biotechnology. Of these firms, 15 produced amino acids, enzymes, and products for the pharmaceuticals industry. The second and third largest producers of insulin in the world are located in Denmark. The second largest firm produces human insulin using recombinant DNA techniques. Other producers of biotechnology-derived chemicals include three producers of gums for food and pharmaceutical preparations and three producers of agricultural pesticides and plant growth hormones.

France.--The noncommercial and commercial biotechnology firms in France operate under a high degree of Government control. Much of the Government-sponsored research is carried out through agencies such as Institut National de la Recherche Agronomiqie (INRA) and Institut National de la Sante et de la Recherche Medicale (INSERM). France is one of Europe's major agricultural producers, and biotechnology could be used to convert waste agricultural products into suitable feedstocks for the manufacture of organic chemicals. Most of the approximately 28 chemicals-related projects now existing have been investigating the use of farm manures or wastes as feedstocks for the production of methane gas.

In 1983 some 28 commercial firms were manufacturing or commercializing processes for the production of biotechnology-derived chemicals. Seventeen of these firms were producing pharmaceutical chemicals, vaccines, and antibiotics. One plant recently began producing human insulin using genetic engineering. About four firms produce amino acids, two were studying production of ethanol from vegetable source feedstocks, and one was researching the production of ethanol, butanol, and acetone through fermentation.

West Germany.--Of the 14 Government and university firms which conducted research and produced chemicals using biotechnology in 1983, 7 explored the production of methane using agricultural waste or algae. Five firms conducted research on the production of organic chemicals, and two were concerned with the production of antibiotics. Like many European countries, West Germany is attempting to use agricultural waste as a chemical feedstock.

There were 43 commercial firms which produced chemicals using biotechnology techniques in 1983. Many of these were widely diversified chemical companies incorporating biotechnological processes in numerous sectors of the chemical industry. About 25 produced pharmaceuticals or intermediates, 8 produced enzymes, and 8 produced other organic chemicals and amino acids.

Italy.--Eight noncommercial firms performed research on the production of chemicals in 1983. Anaerobic digestion of agricultural waste, such as animal manures or plant refuse, to produce methane gas or fertilizers was the most typical endeavor, with four firms involved. Three firms were interested in developing processes to make enzymes from vegetable crops.

There were about 38 commercial firms engaged in the production of biotechnological products in 1983. Twenty-five of these firms produced pharmaceutical chemicals, and two firms produced enzymes. Other firms produced amino acids, organic chemicals, and food additives.

Netherlands.--Of the noncommercial firms in the Netherlands studying processes for the production of chemicals in 1983, four were involved in the production of methane gas, vaccines, and fermentation feedstocks for ethanol.

There were 29 commercial firms producing chemical products using biotechnology. Most of these firms are large, multinational companies which are highly diversified. Sixteen produced products related to the pharmaceutical industry, two produced enzymes, four produced products in the agrochemicals area, and seven were involved in the production of certain organic chemicals.

The Government of the Netherlands, through the Dutch Innovation Program on Biotechnology, encourages research in the areas of basic and applied research. It is expected that the Dutch universities should be able in the future to supply biotechnology expertise to Dutch companies.

Switzerland.--Switzerland, like most other European countries, has been studying the production of methane and alternate fuels using farm waste as feedstocks (biomass). Among the noncommercial firms, four have pursued this type of research. Switzerland has more digesters than any other European country for the production of methane gas and nutrient fertilizers from farm waste. Switzerland also has several of the world's largest commercial firms dedicated solely to biotechnology and genetic engineering. In 1983 there were a total of 25 firms producing chemicals using biotechnology. Of these, 18 produced primarily pharmaceuticals, 5 produced agrochemicals, 3 produced amino acids and related chemicals, and 4 produced organic chemicals.

The four leading Swiss pharmaceutical companies, which account for about 10 percent of world pharmaceutical production, also lead in Swiss production of pharmaceuticals through biotechnological processes. All have foreign subsidiaries where production or proprietary research may be carried out. Government involvement is minimal, and most Swiss biotechnology firms do not collaborate with universities or have Swiss financial backing. 1/

United Kingdom.--In 1983 there were 13 noncommercial organizations in the United Kingdom researching production of chemicals through the use of biotechnological processes. Eight firms were examining the production of methane gas through anaerobic digestion of various wastes, and the other firms were researching production of organic chemicals such as ethanol, butanol, and hydrocarbons. There were about 65 companies involved in biotechnological production of chemicals. Forty of them primarily produced pharmaceuticals; 15 produced primarily organic chemicals; 6 produced agricultural chemicals; and 4 produced amino acids, enzymes, and related chemicals.

Other.--There were eight other European nations in 1983 known to have been involved in research or commercial production of chemicals using biotechnology. These countries are Austria, Finland, Greece, Ireland, Norway, Portugal, Spain, and Sweden. Of these, the greatest number of commercial firms using biotechnology was located in Ireland (19 firms), Austria (14 firms), and Spain (14 firms). Sweden had the largest number of noncommercial firms, 6, followed by Ireland with 4.

Of a total of 93 commercial firms which operated in these 8 countries in 1983, 73 produced pharmaceuticals and enzymes. The rest were involved in production of organic chemicals, including amino acids, ethanol, and some intermediates. The majority of these firms were located in Austria, Ireland, Portugal and Spain.

There are relatively few noncommercial firms operating in these countries as a result of the lack of private capital and low levels of government involvement. Only 17 noncommercial firms had research interests in

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1/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, January 1984, pp. 516-518.

biotechnology in these countries in 1983, with the majority located in Finland (2 firms), Ireland (4 firms), and Sweden (6 firms). Ireland and Sweden combined had seven noncommercial firms investigating production of methane gas, and both noncommercial firms which operated in Finland were investigating production of ethanol.

Japan

Japan has been the second largest producer of chemicals using biotechnology, though few Japanese organizations were involved in developing better production methods. Only six organizations, five universities and one technological institute have investigated production of chemicals through biotechnology. Four were investigating production of ethanol, one was researching production of antibiotics, and another was interested in methane production from agricultural waste.

Of the many commercial biotechnology firms producing chemicals in Japan, most have majority private ownership with some Government involvement. Foreign subsidiaries or joint ventures with non-Japanese chemical companies generally do not produce chemicals in Japan, but rather act as import brokers and distributors. There were 92 firms which produced chemicals through the use of biotechnology in 1983; of these, 38 were engaged primarily in the production of pharmaceuticals, 14 produced enzymes, 6 produced amino acids, 33 produced organic chemicals, and 7 were involved in the production of agrochemicals. Most firms were not devoted entirely to one area of production.

In 1983, there were 55 support firms in Japan providing services to the producers using biotechnology processes. Nearly all of the support firms are wholly Japanese owned, although some joint ventures with U.S. or British firms do exist.

The Japanese Government has become more involved in the commercialization of biotechnology since 1980, helping to form collaborative projects using innovative biological engineering methods of production. All of these projects were sponsored by large, established Japanese companies, which have traditionally been world leaders in fermentation products such as enzymes, amino acids, and certain organic chemicals.

Other countries

Canada.--In 1983 there were three noncommercial organizations in Canada investigating the production of chemicals from waste materials; two were concerned with production of ethanol from vegetable or cellulose sources, and one was researching the production of methane gas from algae.

In 1983, there were 34 commercial firms involved in the production of chemicals using biotechnology, 4 of which were producing ethanol using either wood or grain products as feedstocks. Eighteen of the commercial firms produced pharmaceutical products such as antibiotics, vaccines, diagnostic reagents, and hormones. The remainder produced chemical products related to the food additives industry.

Israel.--Two noncommercial organizations in Israel were studying the production of chemicals using biotechnology in 1983. One was investigating the production of methane and fertilizer using anaerobic digestion.

Eight commercial firms used biotechnological means for production of chemicals in 1983. Four produced pharmaceutical chemicals; one produced organic chemicals; one produced agricultural chemicals; and two produced chemicals for the food industry.

Other.--Countries other than those discussed above have so far displayed only limited interest in developing biotechnology. Hungary, an Eastern bloc country, has one noncommercial State-owned organization which produces vaccines. New Zealand and Australia each have one firm involved in research on ethanol production. In New Zealand, there has been a research effort to use cheese whey as a feedstock, as it is normally an unwanted byproduct from their extremely large dairy industry. A Kuwaiti firm has entered into a joint venture to produce single-cell protein using methanol as a feedstock. The Soviet Union also has entered into production of single-cell protein using methanol feedstock, although it is not expected to compete in the commercial market with this product.

FACTORS INFLUENCING BIOTECHNOLOGY INDUSTRY TRADE

Technology

Fermentation

Fermentation is the action of microorganisms or their chemical components on feedstock nutrients in order to produce a specific product or mixture of products. 1/ Within the scope of this definition, there are two distinctly different types of process microorganisms, as determined by the type of environment required for their survival. Anaerobic processes are those which use microorganisms or cell components, such as enzymes, that need no oxygen in order to survive; whereas aerobic processes use microorganisms which do require oxygen to function. An example of an anaerobic process is the fermentation of sugars by yeast to produce ethanol. Aerobic processes use living cells such as certain types of bacteria for production of such chemical products as amino acids and enzymes.

Because the fermentation process involves living organisms, a suitable medium must be prepared so that the organism can survive; at the same time, the feedstock chemical must be introduced at a rate that will produce the greatest amount of product in the shortest period of time. The nutrient media is generally made up of a mixture provided by materials such as cornsteep liquor, soybean meal, or cottonseed flour. Other chemicals can be added to the nutrient media, such as cobalt salts for the production of vitamin B_{12}. 2/ The fermentation media must be absolutely sterile in order to avoid contamination and resultant low yield.

1/ Office of Technology Assessment, Impact of Applied Genetics, April 1981, p. 49.

2/ M. Grayson, op. cit., pp. 874 and 875.

Most commercial fermentation processes are aerobic in nature, which necessitates the incorporation of oxygen dispersers, or feed tubes, when considering fermenter tank design. Other biotechnology processes, including certain types of enzymatic conversion, use only a tank or a simple flow-through system.

Fermentation tanks, or fermenters, can range in size from a few liters to larger than 1 million liters. Some commercial operations do not use fermenters larger than 200,000 liters because of the increased likelihood of contamination. 1/ Depending upon the process technology, the tank may be fitted with a variety of stirring apparatus, pumps, oxygen dispersers, and sensors to monitor reaction conditions such as temperature, oxygen uptake, pressure, and the concentration of the final product.

Several different types of fermenters have been designed in recent years for industrial use, mainly as the result of foreign technological advances. All were designed for a semicontinuous batch-type process 2/ and are known as stirred tank, bubble column, air lift, and self-priming aerating fermenters. 3/

Stirred tank fermenter.--This is the simplest type of fermenter and can be used to make almost any fermentation product by either aerobic or anaerobic processes. Aerobic systems, however, need the addition of an air injector. The tank is stirred either externally by means of a circulating pump or internally by a mixing propellor. This type of tank is generally used in the production of ethanol. The largest of these fermenters in operation is reported to be about 570,000 liters. 4/

Although there are other designs of fermenters as mentioned above, the use of the stirred tank reactor is still dominant in the chemicals industry. 5/ A reason for this may stem from the fact that many of the commercial chemicals produced by fermentation are already adapted to the stirred tank reactor, and the increase in efficiency provided by changing to another design is not warranted. 6/ In addition, a stirred tank fermenter is considered more adaptable when more than one product is produced with the same system.

Bubble column fermenter.--This type of fermenter is designed to accomodate aerobic fermentation processes. The tank uses pressurized oxygen injected near the bottom of the tank to agitate and aerate the media. An external return loop is added to circulate the media throughout the tank in order to better incorporate the oxygen. This type of fermenter is used to produce organic acids, enzymes, and steroids.

Air lift fermenter.--This type of reactor uses an air injection system similar to that of a bubble column reactor, with the exception that a draft tube is placed in the center of the tank to direct the flow. This allows the

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1/ Organization for Economic Cooperation and Development, Biotechnology: International Trends and Perspectives, Paris, 1982, pp. 34-36.
2/ Ibid., p. 36.
3/ W. Sittig, "Fermentation Reactors," Chemtech, October 1983, pp. 606-613.
4/ M. Grayson, op. cit., pp. 874 and 875.
5/ W. Sittig, op. cit.
6/ M. Grayson, op. cit., pp. 874-878.

fermentation media to circulate with the flow of air, through the draft tube, and down the inside of the tank.

Self-priming aerating fermenter.--This fermenter is similar to the air lift reactor in design, except the tank uses a mechanical stirrer at the bottom of the tank to draw fresh air through the draft tube. The air is dispersed at the bottom of the tank, where it travels upward through the media and out via a vent at the top. This fermenter presents certain advantages when compared with other aerobic fermenters in that a source of compressed air is not needed. This type of fermenter is used commercially in the production of acetic acid, single-cell protein, and other ferments.

Genetic engineering

"Gene splicing" is a term used to describe the process in which selected strands of DNA from one organism are combined and inserted as a gene fragment into another organism. DNA is made up of four essential nucleotide bases: adenine, cytosine, guanine, and thymine. The combinations or arrangements of these four bases form the basis of a genetic code, which contains information necessary for the duplication of living cells. The determination of certain characteristics or traits is controlled by DNA in all living organisms. By splicing those parts of the DNA which encode particular traits, it is possible to transfer these traits from one living organism to another. 1/

Certain criteria must be met before genetic engineering can be used in industrial processes. First, the strands of DNA which determine the desired trait must be located, removed, and reinserted into the desired cell. The completed strand of DNA is then usually duplicated many times using a host cell or bacterium, in order to derive large enough quantities of modified DNA. Second, the desired trait which is coded in the modified strand of DNA must be exhibited when the cell replicates; and third, this trait must be retained over several subsequent generations.

The cell containing the new DNA fragments manifests their coded traits by producing certain amino acids, and then combining these amino acids to form more complex biochemicals, such as proteins and enzymes. For example, one type of host cell used frequently in biological research has been successfully altered to produce the enzyme rennet and human insulin.

The exhibition of these traits during the lifetimes of several generations of the microorganism is probably the most useful feature in commercializing some processes, and recent work has led to increases in the productive lifetimes of recombinant DNA organisms from a normal life of 10 to 20 hours to 50 to 60 hours. 2/ However, reversions of certain strains of microorganisms to earlier, less efficient, forms is a problem with some fermentation processes. 3/ Critics say such serious problems in genetic engineering will have to be overcome for certain commercial processes to be feasible.

1/ Office of Technology Assessment, Impact of Applied Genetics, April 1981, pp. 54 and 55.

2/ "r-DNA breakthrough," Chemical Engineering, Feb. 20, 1984, p. 42.

3/ "There's New Life in Continuous Fermentation," Chemical Week, Feb. 22, 1984, pp. 42-47.

Recombinant RNA is similar to recombinant DNA, although it may have an even greater impact on the chemical industry. Recombinant RNA is a recently developed process which uses spliced RNA fragments which are inserted into particular species of viruses. The viruses are able to copy the RNA strand many times. By mixing the RNA with appropriate starting materials and enzymes, the RNA is able to produce certain desired proteins.

Use of automation and computers

The use of automation is highly desirable in biotechnological processes on an industrial scale because of the large number of reaction conditions that must be controlled. Temperature, time, concentration of starting materials or products, or the concentration of byproduct are examples of such conditions. Monitoring can be performed either by sampling the fermentation medium or by placing sensors in the medium.

The use of sensors provides a means to automate fermentation processes. However, sensors to monitor reaction progress need to be developed which can withstand the stressful conditions in fermenters. Currently, samples must be removed from the fermenter for this monitoring, which causes delay. Industry sources have indicated that the development of biosensors, which would react biologically under certain conditions, could eliminate these delays. 1/

Automation is being applied in the laboratory as well. Although considerable laboratory work must be performed by hand, the recent development of an automated process for synthesizing DNA strands by using "gene machines" allows these strands to be synthesized at a reduced cost and has increased productivity significantly. 2/ There are nine U.S. and three European firms located in West Germany, the United Kingdom, and Sweden that are manufacturing these machines.

Other technologies

In addition to the technologies already discussed, two others are very important to maintaining a competitive posture. These are the technological advances in separation of products from fermentation media, including related techniques of immobilization, and cell fusion.

A basic problem common to most biotechnological methods is that microbial and enzymatic processes must be in an aqueous environment in order to proceed. Separation of the final product from this aqueous environment requires not only removal of water, but also separation from any starting materials, biological nutrients, and the microorganisms used. Conventional separations, such as distillations, are not used, because the products are generally sensitive to heat. As a result, the separation of products that occur in an aqueous environment at low concentrations must be accomplished by other means, such as centrifugation, filtration, or extraction. 3/

1/ Based on conversations with industry analysts.

2/ "After a Slow Start, Gene Machines Approach a Period of Fast Growth and Steady Profits," The Wall Street Journal, Dec. 13, 1983, p. 33.

3/ Organization for Economic Co-Operation and Development, Biotechnology: International Trends and Perspectives, Paris, 1982, pp. 48-50.

Immobilization is one technique which may ease some of the difficulties in the separation step. Through this routine enzymes and cells may be rigidly bound to, or entrapped in, a solid support which can be separated more easily from the fermentation media. The use of entrapment or encapsulation requires that the supporting structure must be semipermeable, so that the products are able to diffuse through the barrier. The support must be reasonably small so as to maximize contact with the fermentation media, and at the same time large enough to be easily separated when the process is complete. Recent research in immobilization has resulted in the development of a continuous process for rapid conversion of glucose to ethanol. 1/

Cell fusion is a technology which is also becoming commercially significant. Probably the best known example of the use of cell fusion is in the production of monoclonal antibodies. Normal antibody-producing cells are fused with cancerous cells, and the resulting hybrid cell produces tremendous quantities of antibodies specific to the cancerous cell originally fused. Other cell fusion methods exist for plant cells and some animal cells, although these processes generally produce agricultural hybrids rather than chemicals. 2/ To date, the most common cell fusion techniques use mammalian cells from mouse spleens; one firm produces more than 70 different types of monoclonal antibodies by this technique. 3/

Products of Biotechnology

As of 1977, about 147 U.S. producers of 184 chemical products were using fermentation processes. 4/ The number of producers and products has grown since that time, and the products now include some complex chemicals, such as human insulin, which were obtained previously in only limited quantities from human or animal sources.

The first products put on the market that were made using innovations in biotechnology were the monoclonal antibody diagnostic kits. 5/ Biotechnology products slated to be commercialized during 1984 and 1985 are all in the category of biologicals and include human growth hormone and alpha-interferon. Shortly thereafter, beta- and gamma-interferon, and hepatitis B vaccine are scheduled to be commercially available. 6/ Industry sources also believe that commercialization prospects are good for certain specialty organic chemicals and food products. 7/

1/ "Ethanol Contract Covers Sugar-Alcohol Process," Chemical Marketing Reporter, Mar. 19, 1984, pp. 7 and 15.

2/ Organization for Economic Cooperation and Development, Biotechnology: International Trends and Perspectives, Paris, 1982, pp. 30 and 31.

3/ Accurate Chemical and Scientific Corp., Monoclonal Antibodies, Spring 1984, pp. 2-4.

4/ M. Grayson, op. cit., pp. 874 and 875.

5/ Chemical Business, Sept. 19, 1983, p. 33.

6/ Ibid.

7/ Currently genetically engineered aspartame, a food sweetener, is being produced commercially using immobilized cells.

Licensing

Many firms involved in biotechnology have come into existence only during the past 2 or 3 years. Marketing segments within companies are now being developed, although many firms are still engaged solely in research. Once a product or process is developed and patented, a firm can either market the process or product itself or allow the process or product to be licensed.

Licensing is the granting of the rights to use certain technological processes which are usually protected by patents or trade secrets. 1/ In the case of biotechnology firms, this definition extends to include the licensing of patented living organisms. 2/ Although most licensing within the United States is controlled by the firm or individual owning the patent or trademark rights, compulsory licensing also exists. 3/ Although it is not frequently implemented, licensing can be compulsory in the United States in certain instances pertaining to patent abuse, public policy, or antitrust violations. 4/

Compulsory licensing laws outside the United States are often more stringent. In most other countries examined in this study, trademark, patent, or technological process rights are granted with the legal expectation that the holder of these rights will use them. The failure to utilize patent rights is considered to be an abuse and may be remedied by compulsory licensing. An exception to this rule is a cooperative agreement which allows a patented process to be used in a cooperating country as long as the domestic demand for the product can be satisfied through that foreign production.

Pharmaceutical products probably have the highest added value of all biotechnological processes and, therefore, were developed first. Thus, licensing activity in biotechnology is largely concentrated in pharmaceutical processes. Worldwide licensing activity in pharmaceuticals during 1979-82 is shown in the following tabulation: 5/

Year	Agreements	Licensors	Products
1979	277	106	180
1980	285	137	204
1981	306	186	236
1982	600	398	500

1/ P. R. Cateora, and J. M. Hess; International Marketing (1975, Richard D. Irwin, Inc., Homewood, IL) p. 7.
2/ Diamond vs. Charkrabarty, 447 U.S. § 303 (1980).
3/ 47 U.S. C. § 2404 (1979).
4/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis. January 1984, p. 460.
5/ "Biotechnology market predicted to grow to $64 bn by 2000," European Chemical News, Mar. 15, 1982, pp. 17-18.

Of 600 agreements listed for 1982, including joint venture agreements, 398 licensors were involved in 500 different product areas. The number of products licensed has nearly tripled since 1979, and the number of licensors of pharmaceutical processes has nearly quadrupled. The number of licensed products using recombinant DNA or genetic engineering in 1982 was 20 percent of the total. At least 40 license agreements involved interferon technology during this period. 1/

In 1982, the United States licensed the greatest share of process technologies. The United States held nearly 200 of these licenses, Japan held 91, and the United Kingdom held 42. Taken together, these countries accounted for more than 66 percent of all licensing and joint venture agreements in pharmaceuticals, and more than 65 percent of the companies originating license or joint venture agreements were based in these countries. 2/

Certain small biotechnology firms both acquire and sell licensing agreements. Much publicity has been given to those firms which license products such as vaccines and insulin. 3/ Increased production of new vaccines or products could result in increased exports of both products and processes.

Historical data indicate a trend toward small U.S. firms acquiring foreign licenses, rather than selling their own technology. A recent study has shown that many smaller U.S. firms involved in the pharmaceuticals sector during 1975-80 became increasingly dependent on such licensing as a source of technology. Nearly 17 percent of the 4 largest domestic firms' new processes were acquired through licensing from foreign sources. Smaller firms acquired 58 percent of their new processes through licensing; slightly more than 36 percent were acquired from foreign sources. 4/

There are many advantages in licensing of biotechnology products, especially for the smaller firms. Many of these firms lack expertise in marketing products and can use licensing in order to gain access to both domestic and international markets without large capital expenses. 5/ Other difficulties incurred by firms trying to market their own technology and products abroad, such as foreign import restrictions, hindrances, or barriers to U.S. ownership in foreign countries, and protection of patents against cancellation for nonuse have encouraged firms to license their products in foreign countries. Licensing may be less profitable than other means of entering foreign markets, but the risks are considerably less than for direct investment or ownership.

Not all aquisition of technology through licensing agreements has been beneficial to U.S. pharmaceutical companies. Small- and medium-sized domestic firms which market products made from licensed technology obtained abroad have

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1/ "Last Year Saw Dramatic Increase in Pharmaceutical Licensing Deals," European Chemical News, Oct. 3, 1983, p. 26.
2/ Ibid.
3/ "Biotechnology comes of age," Business Week, Jan. 23, 1984, pp. 84-94.
4/ National Academy of Sciences, The Competitive Status of the U.S. Pharmaceutical Industry, Washington, D.C., 1983, pp. 41-47.
5/ P. R. Cateora, and J. M. Hess, op. cit.

reduced their level of research and development (R&D), making them especially vulnerable to takeovers by foreign firms. 1/ In the past few years, foreign firms which are mostly based in Europe have used licensing agreements to acquire several of these U.S. pharmaceutical companies.

Investment

Plants and equipment

The commercialization of any biotechnology process often leads to demands for larger space requirements, better control over operating conditions, and sometimes updating existing equipment. Larger, established firms already have in place much of the equipment needed for commercialization of innovative processes. Investment in more advanced equipment is generally not needed, although many established firms are expected to replace or renovate existing equipment during the 1980's. This equipment generally has a life expectancy of 15 to 20 years. 2/

Capital investment is rather extensive for any biotechnology firm conducting research. Many instruments, such as the recently introduced "Gene Machines," were priced at about $35,000, and other machines which identify amino acid sequences in gene fragments or proteins were estimated to cost about $30,000. Industry sources estimate that for every dollar of sales there is about 75 cents invested in plants and equipment. 3/

The desire to commercialize biotechnology processes has led many of the research-based firms to expand, building large-scale production facilities. One firm recently began construction of a 40,000-square-foot production facility projected to have a final cost of $10 million. 4/ Another firm has been building a 72,000-square-foot facility, and at least one other firm is planning a similar project. Recently, the largest planned production site, once used for blending alcoholic beverages, was being renovated to produce the amino acids--phenylalanine and aspartic acid--to be used in the production of the artificial sweetener aspartame.

Personnel training and development

About one-third of the estimated 5,000 technical personnel performing R&D work in biotechnology in 1983 5/ are specialists in genetics (including recombinant DNA, recombinant RNA, and monoclonal antibodies technology); another one-third are specialists in commercialization procedures in microbiological and biochemical engineering. About 63 percent of total

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1/ National Academy of Sciences, The Competitive Status of the U.S. Pharmaceutical Industry, Washington, D.C., 1983, pp. 41-47.
2/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, January 1984, p. 93.
3/ L. W. Borgman & Co., Financial Issues in Biotechnology, May 13, 1983, p. 48.
4/ "Amgen Hires Construction Manager for 40,000 sq. ft. Chicago Plant," Amgen Press Release, May 1984, p. 1.
5/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, January 1984, p. 332.

personnel in smaller firms are technical; 15 percent are managerial; 17 percent are clerical; and 5 percent are involved in production and maintenance. 1/

A survey of biotechnology companies conducted by the Office of Technology Assessment and the National Academy of Sciences in March 1983 revealed that there were sufficient specialists available in most technical fields, but that there were potential shortages of bioprocess engineers, plant molecular biology specialists, and industrial microbiologists. 2/ Industry sources indicated that additional qualified personnel were becoming available in 1984. The United States also suffers from a shortage of bioprocess engineers, in part because of the recent rapid development of commercial interest in fermentation.

Shortages of qualified R&D personnel exist in Europe as well, particularly in France. The United Kingdom has experienced a loss of qualified scientists to other countries in the European Community and to the United States, at least partially because of the noncompetitive salaries offered in the United Kingdom. A shortage of qualified scientists in genetic manipulation exists in Japan because of the lack of support for basic research.

Research and development

Efforts in areas of biotechnology such as recombinant RNA or DNA, cell fusion, and engineering design, are characterized by a high ratio of R&D costs to total expenditures. Unlike other high-technology fields, however, products of genetic engineering have not yet reached full commercialization; total sales amounted to less than $20 million in the United States in 1983 3/ compared with investments, which totaled about $2.5 billion. 4/ According to industry sources, the lack of immediate commercialization prospects is not of concern to either the large, established pharmaceutical or chemical companies or to the universities and public institutions whose R&D is largely Government funded. It is, however, of primary concern to the smaller research-oriented firms, because it is expected that their R&D expenditures will continue to exceed revenues. 5/

A typical estimate for the period required to commercialize pharmaceuticals is 7 to 8 years, of which 2 years are dedicated to research, 2 years are for process development, and 3 to 4 years are for clinical testing. 6/ The typical cost of research is about $2 million, 7/ process development costs about $2 million to $5 million, 7/ and the cost for clinical testing may range from $35 million to $75 million. 8/

1/ Ibid., pp. 331 and 347.
2/ Ibid., p. 335.
3/ Based on conversation with industry analysts.
4/ "Biotech Comes of Age." Business Week, January 23, 1984, pp. 84-94.
5/ "Some Biotech Firms Leave the Red," Chemical Week, Sept. 14, 1983, pp. 52 and 53.
6/ Based on conversations with industry representatives.
7/ Ibid.
8/ B. Tokay, "The New Biotechnology Goes to Market," Chemical Marketing Reporter, Sept. 19, 1983, p. 32.

Since the initial investment in product commercialization is relatively low, many small research-oriented firms can operate successfully through this stage. The high cost of further commercialization, however, has forced some smaller companies to seek financing agreements, such as licensing and joint ventures, with larger and more established firms in order to market their products. Some biotechnology companies have turned to public stock offerings in hoping to acquire sufficient capital, 1/ although some industry analysts have stated that these financing efforts have not enabled them to obtain sufficient capital. 2/

Government Involvement

Direct participation

Although the U.S. Government does not target any private industries, there is considerable Government funding directed toward basic biotechnology research, which has played a major role in accelerating the growth of commercial biotechnology.

The largest outlet for Government funds in basic research is the National Institutes of Health (NIH), which funded nearly $1.0 billion in R&D related to biotechnology during 1979-82. Although the research funded by the NIH is mostly basic in character, it also includes significant semiapplied research, such as clinical testing and efficacy studies that are often performed in close collaboration with industry.

The following tabulation shows the number of projects and funding given by the NIH to biotechnology projects: 3/

	Number of projects	Funding (million dollars)
1979-----	880	105
1980-----	1,611	177
1981-----	2,674	293
1982-----	3,541	380

The total number of NIH projects which dealt with biotechnology in fiscal 1982 increased to 3,541, or by 32 percent from fiscal 1981. The funding of these projects also rose, from a level of $293 million in fiscal 1981 to $380 million in fiscal 1982, or by 30 percent.

The National Science Foundation is the second largest source of U.S. Government funding of biotechnology R&D, which amounted to about $53 million in 1982. Other Government agencies supporting biotechnology R&D include the Department of Agriculture, the Department of Defense, and the Department of Energy.

1/ Mathieu, M. "Test Tube Troubles," Barron's, Feb. 13, 1984, pp. 42 and 43.
2/ Technology, The Wall Street Journal, Mar. 2, 1984, p. 29.
3/ Data are from the National Institutes of Health.

Other participation

The U.S. Government plays an indirect role in supporting the commercialization of biotechnology by providing various incentives for investors, private or public, willing to invest in these companies. U.S. Government laws designed to encourage investments in R&D by providing tax incentives include limited partnership laws, the Economic Recovery Act of 1981, the Small Business Innovation Development Act of 1982, 1/ and the Orphan Drug Act of 1983. 2/

Industry sources have indicated that R&D limited partnership laws have proven to be beneficial to the smaller biotechnology companies in acquiring investment capital. The limited R&D partnership enables an investor to reduce taxes by providing increased tax deductions for R&D equipment and allowing company royalties or equity to be taxed as long-term capital gains. It also permits the investor to convert tax liabilities to multiple write-off investments. 3/ The R&D limited partnerships law also has important benefits for the biotechnology companies, because it enables them to acquire investment capital to finance development without losing control of the company. 4/

Small Business Investment Corporations (SBIC's), authorized by the Small Business Innovation Act of 1982, have also provided funding to biotechnology companies. SBIC's raised 3.4 million dollars' worth of capital for 9 smaller firms in 1982. 5/

The Orphan Drug Act of 1983 is designed to give tax breaks to pharmaceutical companies that develop drugs with a limited market. In early 1984, the Food and Drug Administration (FDA) granted orphan drug status to a pharmaceutical produced by recombinant DNA techniques which will be used to treat a rare form of emphysema. 6/ The pharmaceutical may be available to patients as early as 1985 if clinical tests are favorable.

Concern over the pace of U.S. R&D may result in new legislation to increase incentives to U.S. companies that are innovative. In March 1984, a Senate Task Force recommended that legislation be passed to grant a permanent 25-percent tax credit for R&D expenditures both to universities and to companies that fund research in universities. A bill sponsored in the House of Representatives would establish an Advanced Technology Foundation that would disburse up to $500 million to assist companies and universities in funding commercial development and to develop new manufacturing processes. The bill would also include provisions requiring that research findings be made available to small businesses.

1/ The Washington Post, Washington Business, July 23, 1984, pp. 1 and 19.
2/ Chemical Week, Feb. 29, 1984, p. 28.
3/ S. Woinsky, "The Limited R&D Partnership," Chemtech, March 1984, pp. 162-164.
4/ Ibid.
5/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, January 1984, p. 280.
6/ Chemical Week, Feb. 29, 1984, p. 28.

For the research-oriented biotechnology companies that are publicly owned, public stock offerings can be a major source of R&D financing. Demand for biotechnology stocks have fluctuated with changes in the economy as well with the changes in the public's perception of the prospects for commercialization of biotechnology processes.

Prices of stocks of biotechnology companies have been very volatile, reflecting the shifting attitudes of the public to biotechnology. Between April 1982 and August 1982, the average stock price for a select group of biotechnology companies declined by about 10 percent. However, the price doubled between the first week of August 1982 and March 1983. 1/

In Japan, R&D in biotechnology is conducted mostly by the larger established companies which rely on debt financing (including personal loans) to support their commercialization programs. Because of low equity levels, venture capital and public stock offerings are relatively unimportant.

The Japanese Government, through the Ministry for International Trade and Industry (MITI) and several other agencies, provided approximately $56 million in 1982 and $59 million in 1983 for R&D work in biotechnology. The MITI has allocated $128 million to be funded during a 10-year period for biotechnology, including research on mass cell culture techniques and recombinant DNA. The research program will be administered by a consortium of chemical and pharmaceutical firms. 2/ Other Japanese Government agencies that are funding biotechnology R&D are the Ministry of Health and Welfare; the Ministry of Education; and the Ministry of Agriculture, Forestry, and Fisheries, which supports biotechnology R&D in agriculture and food processing. A U.S. Government study estimated that the Japanese Goverment has been spending about $200 million per year to commercialize biotechnology. 3/ In contrast to U.S. Government funding policy, which emphasizes basic research and development, a significant portion of Japanese Government funding was used for applied research in biotechnology.

Because only limited venture capital is available in the United Kingdom, most R&D in biotechnology is conducted by established companies, although several new smaller research firms have also appeared. The Science and Engineering Research Council and the University Grants Committee of the Education Department provide funds to universities to support teaching and research and to improve links between the universities and private industry. 4/

The British Government has also funded joint ventures between universities and private firms and spent about $100 million on research in biotechnology during 1982 and 1983. 5/ The Department of Industry plans to

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1/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, January 1984, p. 281.

2/ Office of Science and Technology Policy, Report of a Working Group on the Competitive and Transfer Aspects of Biotechnology, April 1983, vol. II, pp. 45 and 46.

3/ Ibid.

4/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, January 1984, p. 513.

5/ Ibid., p. 317.

spend $32 million during 1984-87 to support basic research and set up pilot plants, including a center for applied microbiology and research. 1/

Because there is no significant venture capital market in West Germany, nearly all the private R&D work in biotechnology is conducted by established companies. Financing for this work is largely provided by the commercial banks. In addition, the Society of Biotechnology Research (GBF), funded by the West German Government, is one of the leading research institutions in the world. The West German Government and its research institutes annually spend about $40 million in biotechnology R&D, and private industry spends about $90 million. 2/

According to industry observers, biotechnology R&D in France lags behind that in the United Kingdom and West Germany. The Institut Pasteur, which receives about one-half of its income from the French Government, is mostly involved in basic biotechnology research. Estimates of French Government funding for biotechnology R&D range from $35 million to $60 million per year.

All of the countries discussed provide tax incentives to firms doing R&D work, including firms doing work in biotechnology. According to a U.S. Government study, the United States has the most favorable tax incentive program for small firms trying to raise capital for R&D, whereas the United Kingdom, which taxes income from patents at corporation tax rates and which has a relatively high long-term capital gains tax rate, has the least favorable tax incentives program of the countries discussed. 3/

Rules and regulations

The possible consequences of unregulated R&D in genetic engineering caused concern in Congress in the mid-1970's. However, as a result of self-regulating guidelines that were established by scientists under the auspices of the NIH in 1976, Congress agreed to forgo enacting mandatory regulations for controlling recombinant DNA R&D. Because no serious problems arose from genetic engineering experiments, these guidelines were later eased. Increased experience and further experiments indicated that the original risk may have been overstated. 4/

Another important responsibility of the NIH has been to monitor experiments involving the release of genetically engineered microorganisms to the environment. This was challenged in a suit brought by several environmental organizations to prevent the first environmental release experiments from taking place. The environmentalists charged that the NIH did

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1/ Office of Science and Technology Policy, Report of a Working Group on the Competitive and Transfer Aspects on Biotechnology, April 1983, Vol. 11, p. 53.

2/ Ibid., p. 57.

3/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, January 1984, pp. 300.

4/ Office of Science and Technology Policy, Report of a Working Group on the Competitive and Transfer Aspects of Biotechnology, April 1983, Vol. II, p. 93.

not take into account all of the possible consequences to the environment and thus did not comply with the National Environmental Policy Act. In May 1984, a U.S. district court upheld the position of the environmentalists and ordered a halt to these environmental release experiments, 1/ although some other experiments have been tentatively approved.

Part of the controversy about environmental release experiments may be jurisdictional in nature, as the Environmental Protection Agency (EPA) does not currently have any role, other than advisory, in NIH deliberations on environmental release. 2/ The EPA will play a far more important role in regulating the approval of environmental release experiments in the future, since organisms produced by the methods of recombinant DNA technology are subject to EPA jurisdiction, because they are considered chemical substances as defined in the Toxic Substances Control Act (TSCA). The EPA is currently drafting guidelines on environmental control of biotechnology products, and expects to publish them in final form in late 1985 or 1986. 3/

In addition to the special arrangement for monitoring genetic engineering R&D by the NIH, the products of R&D in biotechnology are regulated by other Federal agencies including the Food and Drug Administration (FDA), the Department of Agriculture (USDA), and the Occupational Safety and Health Administration (OSHA).

The FDA has taken the position that pharmaceutical or biological products of recombinant DNA would be considered a "new" drug or biologic, even if it appears identical to a product produced by traditional methods, and would therefore require new clinical testing. 4/ The FDA may agree, however, to consider, on a case-by-case basis, reducing the data that a firm would have to furnish in order to meet FDA approval. The net result is that a pharmaceutical produced by recombinant DNA methods is considered a new drug. This significantly increases the cost of the drug, since the FDA's drug approval process is one of the most rigorous in the world. In contrast to pharmaceuticals produced for human consumption, the regulation of veterinary medicines is controlled by two Federal agencies, the FDA and the USDA.

In addition to its domestic responsibility, the FDA has approval authority over imports and exports of certain pharmaceuticals and biologics. Industry sources have indicated that trade has been affected by FDA export regulations that limit pharmaceutical exports to those items which have received FDA approval in the United States. 5/ Several U.S. pharmaceutical companies have built production facilities outside the United States in order to supply demands of foreign markets.

1/ P. Hilts, "U.S. Judge Halts Experiments in Gene Altering," Washington Post, May 17, 1984, p. A1.

2/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, p. 550.

3/ P. Hilts, "Guidelines for Biotechnology are Drafted by EPA," The Washington Post, June 27, 1984, p. A13.

4/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, p. 360.

5/ Ibid, p. 364.

The FDA position concerning clinical testing outside the United States was also cited by industry sources as an impediment to biotechnology companies, because the results from the foreign tests would not be accepted by the FDA. According to one source, the FDA nonacceptance of clinical test data collected outside the United States forced one company to delay commercialization of a product by at least 1 year.

U.S. exports of products of biotechnology are monitored by the U.S. Department of Commerce under the authority of the Export Administration Act of 1979 (EAA). All goods exported that are on the commodity control list of the EAA require a license, although license applications can be withheld for validation if the Commerce Department feels this is necessary. License approval may also involve the Department of State, the Department of Defense, the Department of Energy, and the Central Intelligence Agency. Although the EAA expired on September 30, 1983, the provisions of the bill remain in effect until superseded by a new law as specified in Executive Order 12444 of October 14, 1983 and Executive Order 12451 of December 20, 1983. As such, the Commerce Department may ban exports because of various specific considerations such as national security and foreign policy issues.

There are two areas of export controls which specifically relate to products of biotechnology. The first is that all microorganisms which are exported to countries other than Canada must have validated export licenses, unless they have been rendered weak or harmless. The second area involves fermentation products. According to Interpretation No. 24 of the EEA, all fermentation products exported to Soviet bloc countries require a validated license, with the exception of certain protein substances, prepared culture media, and drugs that are to be used by humans or animals. A validated license is also required for most articles that are exported to Libya, the People's Democratic Republic of Korea, Vietnam, Cambodia, and Cuba.

The United States has been the leader in instituting regulatory standards for biotechnology. This leadership role has led to regulations in Europe and Japan that reflect the U.S. regulations, though in some cases, foreign laws regulating biotechnology differ substantially from those in the United States.

In Western Europe, the approval time for new pharmaceuticals may be considerably shorter than in the United States. In both the United Kingdom and Switzerland, for example, the approval time for old drugs produced by new methods takes less time than in the United States because less documentation is required. 1/ Laws governing the exports of pharmaceuticals from the United Kingdom are less restrictive than in the United States; for example, drugs that are intended for export from the United Kingdom are reviewed only for quality, not for safety and efficacy as is done in the United States. 2/

U.S. regulations governing biotechnology and related fields are substantially less restrictive than corresponding laws in Japan. Although Japanese regulations of biotechnology have eased considerably, the Japanese Government's Science and Technology Center has kept tight control on large-

1/ A. Fox, J. Sciortino, and D. Smith, International Health and Safety Regulations of Biotechnology, July 1983.

2/ Ibid.

scale work involving recombinant DNA products. In 1982 and 1983 the Japanese Government approved only one application for the use of a commercial-scale bioreactor vessel 1/ in making a product of recombinant DNA. These restrictions could, however, be lifted in the near future. 2/

Transportation

Transportation is an important factor in many segments of the chemical industry. This is particularly true among many of the commodity petrochemicals, where profitability has been dampened by rising feedstock costs, as well as other costs involved in production. The decreased profitability and increased competition have resulted in certain advantages for commodity chemical plants located near available truck, rail, and river transportation facilities.

The costs of transportation among high-value-added products, which include most biotechnology products, contribute small shares to the overall costs of production. The current production of biotechnology items is represented mainly by the pharmaceuticals industry, in which antibiotics, biologicals, and hormones have traditionally had high unit values.

In the pharmaceutical industry, safety and efficacy of treatment is the primary concern. Research and development costs, including production of the complex chemicals, testing and clinical trials, packaging, promotion, prescribing, and dispensing, far exceed costs associated with transportation of most drugs and related products. With the possible exception of some antibiotics and vitamins added to animal feeds, transportation costs have a limited effect on competiveness in drugs and related products.

Shipment of products such as amino acids and enzymes is generally in small volume containers, transported by air, truck, or rail, depending upon the distance and the urgency of need, as these products are generally considered high-value-added products. For commodity chemicals, such as ethanol and methanol, transportation is limited to cost-effective methods such as rail tank car or tank truck. For very large, continuous use of ethanol or methanol, delivery by pipeline is used.

Transportation is of major significance in the nitrogenous fertilizer industry. Roughly 33 million tons of nitrogenous fertilizers were domestically consumed in 1983. Although perhaps 15 million tons were consumed captively in the production of other fertilizers, the annual distribution of fertilizers to the final domestic consumers is a major logistical accomplishment.

Virtually all forms of transportation, except air, are used to move nitrogenous fertilizers to markets. For example, a 1,700-mile pipeline system carries liquid anhydrous ammonia from Louisiana to Iowa, Nebraska, Illinois, Indiana, Missouri, and other Midwestern consuming areas. Another long-distance ammonia pipeline stretches for more than 700 miles, from Borger, TX, to points in Kansas, Nebraska, and Iowa.

1/ J. Choy "Biotechnology in Japan," Japan Economic Institute, Feb. 24, 1984.

2/ Biotechnology Newswatch, July 18, 1983, p. 2.

In addition to pipelines, large tonnages of nitrogenous fertilizers move by barges up the Mississippi river and along other inland waterways. The Mississippi river is also the gateway for large tonnages of imported fertilizers to move into the domestic distribution system. Also, ocean freighters have easy access to other coastal markets.

Rail lines and trucks are also important transportation modes for nitrogenous fertilizers. Railroads are the principal bulk movers of nitrogenous fertilizers in markets isolated from the pipeline or waterway systems, and trucks are usually the final means of transportation used to move nitrogenous fertilizers from distribution centers and retail outlets to the final purchaser.

Any new technology that alters the way nitrogenous fertilizers are produced will also affect the product is transported. If biotechnology ultimately results in greater in situ production of nitrogenous fertilizers on or near farms through developments in plant genetics, then there could be less movement of nitrogenous fertilizers in domestic and world markets. However, there is little evidence at present that such developments are imminent.

Pesticides are marketed through many of the same distribution centers and retail outlets and to the same consumers that purchase nitrogenous fertilizers. Pesticides, however, are distributed in much smaller quantities and are sold at much higher unit values than nitrogenous fertilizers, so large, bulk shipments of pesticides are less common than for fertilizers. There is more selectivity by the consumer in purchasing pesticides to control a particular pest under specified conditions. Thus, transportation cost becomes less significant as the specificity and unit cost of the pesticide increases. In many instances, there are a limited number of pesticides suitable for a particular application, thus making transportation cost a secondary or even a minor consideration.

Competitiveness

Patents

A study by the U.S. Patent Office compared the number of U.S. patents in 6 areas of biotechnological processes or products by the countries of origin, providing a useful representation of the relative progress achieved by countries doing R&D work in biotechnology. Of a total of 1,011 selected U.S. patents related to biotechnology issued during 1979-82, 54 percent were of U.S. origin compared with 46 percent that were of foreign origin, as shown in the following tabulation: 1/

1/ Derived from official statistics of the U.S. Department of Commerce.

Origin	1979	1980	1981	1982
United States	45	119	172	211
Japan	19	52	64	70
United Kingdom	5	14	8	25
France	4	6	7	12
West Germany	7	18	23	17
All other	12	25	39	37
Total	92	234	313	372

In 1982, 19 percent of these U.S. patents originated in Japan compared with 7 percent from the United Kingdom, 3 percent from France, and 5 percent from West Germany. About 10 percent of these patents originated in other Western European countries.

Almost 56 percent of the U.S. patents in 1982 which were related to amino acids originated in Japan, as shown in the following tabulation: 1/

Origin	1979	1980	1981	1982
Japan	2	10	5	10
United States	0	3	6	4
Italy	0	0	1	2
France	1	1	0	1
West Germany	0	1	3	0
All other	0	2	3	1
Total	3	17	18	18

The Japanese are the world's largest producers of amino acids by biotechnological processes and have conducted intensive R&D efforts to maintain their competitive advantage in that area. Japan also holds a number of patents in the areas of enzymes, genetic engineering, and cell culture, as shown in table 2.

1/ Derived from official statistics of the U.S. Department of Commerce.

Table 2.--Biotechnology patents held worldwide, by countries and by types, 1979-82

Country/patent	1979	1980	1981	1982
United States:				
Enzymes	36	84	117	104
Mutation and genetic engineering	2	6	24	75
Tissue culture	7	26	25	28
Japan:				
Enzymes	16	38	54	39
Mutation and genetic engineering	0	0	5	17
Tissue culture	1	4	0	4
United Kingdom:				
Enzymes	4	10	7	16
Mutation and genetic engineering	0	1	0	6
Tissue culture	1	2	1	3
West Germany:				
Enzymes	6	15	16	12
Mutation and genetic engineering	0	1	2	5
Tissue culture	1	1	2	0
France:				
Enzymes	2	5	6	3
Mutation and genetic engineering	1	0	1	7
Tissue culture	0	0	0	1
All other:				
Enzymes	9	19	28	18
Mutation and genetic engineering	1	2	6	12
Tissue culture	2	3	1	4
Total	89	217	295	354

Source: Compiled from official statistics of the U.S Department of Commerce.

According to another study of U.S. patents related to biotechnology, out of 641 such U.S patents of U.S. origin related to biotechnology that were issued in 1982, 420 patents were assigned to U.S. corporations. 1/ Most of these patents went to large, established pharmaceutical firms. Only 12 of these patents were assigned to the smaller research-oriented firms. In addition to U.S. companies, 32 universities acquired 76 patents in 1982 related to biotechnology, and 81 biotechnology patents went to independent inventors, individuals, or groups. 2/

Although the number of patents related to biotechnology issued to universities (76) in 1982 has been much smaller than the number of patents issued to U.S. corporations (420), biotechnology-related patents issued to universities included some of the more noteworthy biotechnological developments. Perhaps the most important of these patents was the Cohen-Boyer

1/ Derived from official statistics of the U.S. Department of Commerce.
2/ Oscar Zaborsky, "Biotechnology Patents of 1983: An International Perspective," Biotechnology, March 1983.

patent, which described the general cloning of genes. Approximately 68 companies agreed to be licensed under this patent. 1/

An examination of U.S. patent laws and a comparison of these laws with patent laws in foreign countries is an important consideration in evaluating the impact of patents on the U.S. competitive position in biotechnology. In the United States an invention is patentable if it meets the following requirements. 2/

- o The invention must be capable of being described as a process, machine, manufacture, or composition of matter.
- o The invention must be new, useful, and nonobvious.
- o The invention and the process of making the invention must be described in such a way that an expert (i.e., one skilled in the same technology as the inventor) should be capable of reproducing the invention. The inventor must also describe the best mode possible for carrying out his invention.

Developments in biotechnology have raised a number of issues related to the above definitions of what makes an invention patentable. In Diamond v. Chakrabarty (1980) the Supreme Court ruled that a live microorganism (specifically produced through genetic engineering) is patentable under 35 U.S.C. section 101. The Patent Office in the Manual of Patent Examining Procedures interpreted the Supreme Court decision to encompass microorganisms that are not produced through genetic engineering techniques as well as those which are so produced and interpreted the terms "manufacture" and "composition of matter" in a very broad manner. 3/

Another important development in patent law related to biotechnology arose from the Supreme Court's interpretation of the statutory requirement that an inventor applying for a patent must describe how the invention was made. For inventions involving the use of microorganisms which are either not generally available or unknown (i.e., microorganisms obtained from soil), the Court of Customs and Patent Appeals (CCPA) approved the use of a despository for cultures of these micoorganisms which the inventor must make available to the public upon the issuing of a patent. The inventor must deposit the culture on or before the date of filing the patent application. The inventor must also identify the culture by deposit number, name and address of the depository, and by a taxonomic description wherever possible. 4/

Foreign patent laws often differ from U.S. patent laws in several important aspects:

1/ "Genetic Engineering Patent Approval Likely," Chemical and Engineering News, Feb. 20, 1984, p. 7.

2/ Adopted from 35 U.S.C.§ 101 and based on contacts with industry representatives and from various books and publications.

3/ U.S. Department of Commerce, Patent and Trademark Office. Patent Profiles in Biotechnology: 1982 Update, 1983, pp. 9-11.

4/ Ibid., p. 11.

o In the United States, a patent application is held in secrecy until the patent issues; in Western Europe, 1/ public inspection of a patent is allowed (usually for 18 months) after filing regardless of whether a patent is granted or not. 2/ Because most countries require deposits of a microorganism by the filing date, a competitor may be able to acquire a microorganism from the depositor even before a patent is granted.

o In the United States, a written description of the invention may be made publicly available up to 1 year before the filing of a patent application; in Japan, the grace period is 6 months; in Europe there is no grace period.

o In the United States, if there are several separate applicants (each of whom must be the inventor) for the same invention, priority for the patent goes to the applicant who was the first to invent. 3/ In Western Europe and Japan, the applicant does not have to be the inventor. Priority for the patent goes to the applicant who was the first to file for a patent application. 4/

o In contrast to the patent policy of the United States which appears to allow inclusion of plants and animal types and biological methods for producing them the European Patent Convention (EPC) excludes new plants and animal types from being considered for patents. 5/ The EPC also excludes surgical or therapeutic methods which involve the direct treatment of the human or animal body. 6/ Japan is similar to the EPC in excluding inventions from patent consideration that involve unclear processes or methods.

o The United States, in contrast to the EPC countries and Japan, does not define as patent infringement the using of a process which is patented in the United States outside of the United States by a competitor to the patentee. The product produced by this patented process can then be imported into the

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1/ West Germany, the United Kingdom, France, Switzerland, and seven other Western European countries are members of the European Patent Convention (EPC). Even though a patent application is filed with a single office, separate patents are issued in the various European States designated by the inventor. Patent litigation is under the authority of national courts, however.

2/ Office of Science and Technology Policy, The Report of a Working Group on The Competitive and Transfer Aspects of Biotechnology, April 1983, vol. 2, p. 89.

3/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, January 1984, p. 394.

4/ Ibid., p. 394.

5/ The Economist Intelligence Unit Limited, Biotechnology: Can Europe Stay in the Race? (Spencer House, London, 1983) p. 75.

6/ Ibid., p. 75.

United States. The patentee does, however, have the option to petition the U.S. International Trade Commission that the imports constitute patent violations by foreign producers and, therefore, are an unfair trade practice.

The United States provides a number of incentives for encouraging inventors to file for a patent application that are not provided in Western Europe and Japan. These include the 1-year grace period, secrecy for the invention until a patent is granted (which also permits the inventor to retain his culture microorganism unavailable to the public until after a patent is granted), and a very broad intrepretation of what is patentable. The United States appears to offer a competitive advantage over Europe and Japan in encouraging inventors to file for patents rather than to keep the invention a trade secret.

In spite of these incentives, many U.S. biotechnology representatives are very concerned about the viability of U.S. biotechnology patents. Because many patents in biotechnology cover similar subject matter and appear to claim very similar material, a shakeout of U.S. patents in biotechnology could occur as a result of extensive and expensive patent litigation.

Conversely, because of the proliferation of U.S. patents in biotechnology, an inventor could be very reluctant to do research in an area that could be construed to infringe on an issued patent. An inventor would, for example, be hesitant to do research on an organism which is covered by a product patent.

Production costs

In each of the three sectors of the chemical industry covered in this study, two different situations exist with respect to production costs. Organic chemicals and agrochemicals produced using biotechnology are often designed as replacements for existing products made by synthetic means. In these areas, lower costs of production using biotechnology could result in competitive advantages. In certain drugs and related products, however, the products are available only by fermentation or other biotechnological processes. Significant competititive advantages are then not necessarily related to lower production costs, as such products have no identical counterparts made by other technologies.

The costs of production of chemicals using biotechnology processes incorporate the same factors as production of chemicals using conventional synthetic means. These include raw-material costs, operating cost, and capital cost, as illustrated in the following tabulation (in percent): 1/

1/ Charles L. Cooney, "Bioreactors: Design and Operations," Science, Feb. 11, 1983, p. 729.

Category	Penicillin	Ethanol 1/
Raw materials cost	35	62
Operating costs:		
Utilities	15	2/ 26
Labor	4	
Maintenance	11	
Plant and overhead	8	
Capital costs	3/ 27	3/ 12
Total	100	100

1/ Using corn as raw material.
2/ A precise breakdown is not available; however, total operating costs are believed to be about 26 percent.
3/ Includes depreciation, property taxes, and insurance.

In 1983, raw-material cost for the production of penicillin was 35 percent, and for ethanol (using biotechnology processes) it was 62 percent. In contrast, ethylene as a raw material for production of synthetic ethanol may make up as much as 70 percent of total cost. 1/

Although other costs enter into total production costs, apparent competitive advantages could exist for firms which are able to use the lowest cost raw materials or feedstocks in a biotechnology process, particularly with materials such as biomass. The advantages of lowering costs can be extended from capturing a larger market share from competing biotechnology companies to the ability to replace competing synthetic products. Some industry sources have stated that fermentation-derived organic chemicals such as ethanol cannot compete successfully on the basis of cost of production, although the use of cellulosic biomass as feedstock materials might eventually lessen feedstock costs. As an example, production of ethanol by fermentation could use cellulosic biomass at a price of $20 to $30 per dry ton, whereas the corn currently used as a raw material might be $110 per ton.

Finance and joint ventures

Because smaller biotechnology companies often lack necessary funds or technology for the commercialization of biotechnology, many are involved in complex relations with venture capitalists and with larger established companies to obtain equity. Biotechnology companies have taken advantage of domestic venture capital, 2/ which increased from a total of about $1.0 billion in 1979 to an estimated $2.8 billion for 1983. The percentage of total domestic venture capital invested in genetic engineering increased from

1/ Based on conversations with representatives of Venture Capital Journal.
2/ Venture capital is provided by R&D limited partnerships, by venture capital funds, by corporations, and by small business investment corporations.

7.6 percent in 1980 to 11.2 percent in 1981, and then decreased to 3 percent in 1982 and 1983. 1/ The relative share decreased in 1982 and in 1983, because most potential investors in biotechnology had previously committed themselves and because the investor community may have grown somewhat skeptical about the near-term commercialization prospects of biotechnology.

The relationship between smaller biotechnology companies and larger, established companies in the late 1970's and early 1980's has been a result of two key factors: the failure of many of the larger established companies to initially appreciate the potential of genetic engineering and other innovative methods in biotechnology, and the inability of biotechnology companies which have acquired experience in genetic engineering and other technological advances in biotechnology to afford to commercialize and market their products. According to industry sources, joint company ventures in biotechnology are expected to decrease as the larger, established, multinational companies build up their in-house expertise in biotechnology and as the smaller companies either fold, are acquired, or become large companies themselves. Industry sources have estimated that only about 5 to 20 small biotechnology firms have the potential to become very large (more than $1.0 billion in sales).

Between 1978 and 1982 there were at least 60 equity investments in the smaller biotechnology firms by the larger U.S. companies. These equity investments, many in the form of joint ventures, which amounted to only $2 million in 1977, increased to $78 million in 1981, $119 million in 1982, and appear to have declined significantly in 1983 as a result of increased in-house R&D in biotechnology and continued agreements in previous years. 2/

Although the smaller companies have often left marketing of products to larger established firms, industry sources have indicated that, in most cases, smaller firms retain the rights to patents and obtain royalties on sales which may be used to establish independence from their partners. Thus, the smaller biotechnology companies have eventually been able to market their own products. By 1983, many smaller firms had established their own sales forces, as the marketing of products became more important to them. 3/

In addition to establishing joint ventures with larger domestic companies, smaller biotechnology companies have been involved in a host of licensing agreements and joint ventures with foreign companies and Governments, particularly in Western Europe and Japan. In most cases, licensing agreements between the smaller U.S. biotechnology firms and foreign firms give the foreign firm the right to market only one product or type of product in a specified geographical region; however, in some instances these licensing agreements have given the foreign firm the right to market a broad spectrum of products throughout the world, including the United States.

Concern has been expressed by industry about the potential loss of technology from the United States as a result of these agreements. Although the larger, established U.S. companies have been licensing their products,

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1/ Based on conversations with representatives of Venture Capital Journal.

2/ Office of Technology Assessment, Commercial Biotechnology: An International Analysis, January 1984, p. 101.

3/ Based on contacts with industry representatives.

e.g., pharmaceuticals, to foreign companies for years, less concern has been expressed about these agreements. The larger U.S. companies are believed to be secure financially, so that these agreements would not allow foreign firms to reduce the ability of the domestic firms to compete internationally.

Technology transfer

Transfer of technology between the United States and other countries is the transfer of skills, knowledge, or know-how, and occurs through a variety of communicative processes. These include the reading of patents, publications, dissemination of scientific information, and other means, including expansion of domestic firms outside of the home country.

According to a recent study, licensing agreements between U.S. and foreign firms tend to involve a higher degree of technology transfer than actions such as the establishment of joint ventures or wholly owned subsidiaries in foreign countries. 1/ It appears that the exportation of domestic products involves minor transfer of technology.

Many research-oriented firms license self-originated technology to an established company, because they do not have sufficient capital to produce and market the products. Certain domestic companies may prefer to license their technology to foreign firms rather than to U.S.-based firms in order to retain the home market for themselves. 2/

Some concern has been expressed that technology transfer could result in a weakening of the competitive position of the United States in biotechnology. According to industry sources, the effect of technology transfer from the United States should be analyzed in terms of its effects on capital, employment, and the ability of the foreign recipient of the technology to compete successfully with U.S. firms. The establishment of subsidiaries in countries with higher technology capabilities can result in a loss of domestic employment, reduced trade, and reduced competitiveness in the domestic market.

Sources have indicated, however, that historical perspectives show that two-way technology transfer has benefited the United States in the acquisition and dissemination of technology. Institutions such as the Pasteur Institute in Paris and the Medical Research Council in the United Kingdom were instrumental in the development of molecular genetics and enzymology, and the United States has benefited from the knowledge acquired in these countries. Hybridoma technology was discovered in the United Kingdom by an Argentine researcher and then commercialized in the United States; the first human interferon was synthesized by a Japanese scientist in a Swiss laboratory; and the technique for sequence determination of DNA was developed through independent efforts by scientists in the United Kingdom and the United States. 3/

1/ N. Newell, AAAS Conference on Biotechnology: International Trade Considerations, May 27, 1984, New York, NY.

2/ Ibid.

3/ Glick, J.L., Statement Before the Committee on Science and Technology, U.S. House of Representatives, May 24, 1984.

More recently, however, industry sources have expressed concern that Japan, with one of the most advanced fermentation industries worldwide, could continue to apply innovative biotechnological techniques to existing production processes in order to compete even more effectively in the world market.

Preliminary data show that the United States and Japan negotiated at least 48 agreements concerning pharmaceuticals, most of which were related to biotechnology, during 1980-82. Nineteen of these agreements licensed U.S. technology to Japanese firms, and nine involved licensing of Japanese technology to U.S. firms. 1/ There were approximately 20 agreements made for the joint development and/or production of biotechnological products.

Market access

The United States possesses certain competitive advantages in the ability to access world markets for recently developed biotechnological products. These include distributorships, license agreements, and patents.

In the United States, the most recently developed products are the higher-value-added products such as antibiotics, hormones, and biologicals such as diagnostics and vaccines. More slowly developed, lower-value-added products of biotechnology are certain organic chemicals and agrochemicals, although some biological pesticides can be considered as high-value-added products. The U.S. market potential for diagnostics or vaccines was, until recently, unexplored, but as products were commercialized, biotechnology firms apparently pursued these areas intensively.

Examples of biotechnology products recently appearing or due to appear in the domestic market are recombinant DNA human insulin, a veterinary scours vaccine, and diagnostics for human pregnancy, Acquired Immune Deficiency Syndrome (AIDS), and hepatitis B. Diabetes and pregnancy tests are estimated to account for the major portion of the U.S. diagnostics market. 2/ In 1980 and 1981, there were about 5.7 million diabetics in the United States. 3/ Data for later years are not available. There were more than 3.6 million pregnancies in the United States in 1980. 4/

U.S. markets for diagnostics and vaccines for AIDS and hepatitis B are currently being pursued to some extent by foreign firms. A diagnostic for AIDS has been developed and tested by a Swedish firm and a British firm. 5/ A vaccine for hepatitis B is slated to be produced by a French firm.

1/ H. Fusfeld, Technology Exchanges between American and Japanese Companies (Preliminary Survey) Center for Science Technology and Policy, New York University, 1984.

2/ "Medical Diagnostics," Chemical Week, Feb. 29, 1984, pp. 30-35.

3/ U.S. Department of Commerce, Statistical Abstract of the United States 1983, p. 122.

4/ Ibid., 1984, p. 124.

5/ "Pharmacia Develops Diagonostic to Detect AIDS in Early Stages, European Chemical News, Feb. 6, 1984, p. 21.

The international markets for products such as biologicals, antibiotics, and hormones are generally pursued through U.S. subsidiaries of biotechnology firms engaged in joint ventures, agreements, or licensing, or through international health-care firms established in foreign countries. Larger U.S. firms market products produced in the United States through their foreign subsidiaries, and research-oriented firms may tend to utilize joint ventures or licensing agreements. According to a recent study, the most rapidly emerging markets of health care and health care products have been in the Middle East, the Far East, Central America, and South America. 1/

CURRENT WORLD MARKET STATUS IN BIOTECHNOLOGY

Certain Drugs and Related Products

Certain drugs and related products encompass four major pharmaceutical subgroups--antibiotics, biologicals, hormones, and vitamins--that are either naturally occurring chemicals or have biological steps in their production processes. These product groups are likely to be affected by biotechnology, and the reasons why are discussed under the individual group subheadings.

Collectively, apparent consumption of these certain drugs and related products is estimated to have increased by 61 percent during 1979-83, from $4.1 billion in 1979 to $6.5 billion in 1983. The ratio of imports to consumption varied in a narrow range, from a minimum of 7.6 percent in 1982 to a maximum of 9.1 percent in 1981 (app. A, table C-1). The changes in consumption of the four pharmacological groups that make up the total for drugs and related products, and the reasons for changes in consumption, are discussed in detail below.

Domestic shipments of certain drugs and related products are estimated to have increased by 60 percent during 1979-83, from $4.8 billion in 1979 to $7.6 billion in 1983 (table C-1).

Imports of certain drugs and related products increased by 53 percent during 1979-83, from $334 million in 1979 to $512 million in 1983. Principal sources of U.S. imports of certain drugs and related products in 1983 were Japan ($103 million), West Germany ($80 million), and the United Kingdom ($66 million) (table C-2).

U.S. exports of certain drugs and related products increased by 52 percent during 1979-83, from $1.0 billion in 1979 to $1.6 billion in 1983. Principal U.S. export markets in 1983 were Japan (24 percent) and France (8.5 percent) (table C-3).

1/ The Relationship of Exports in Selected U.S. Service Industries to U.S. Merchandise Exports: Report of Investigation No. 332-132. . ., USITC Publication 1290, September 1982, pp. 231-264.

Antibiotics

Antibiotics are chemical compounds derived from, or produced by, a living organism. Antibiotics are capable, in small concentrations, of inhibiting the life processes of microorganisms. 1/

Penicillin was the first, and probably most familiar, antibiotic to be isolated and developed for commercial use. After penicillin, the development of other antibiotics and chemical modifications of natural antibiotics proceeded rapidly and continues at the present time. The various antibiotics differ from one another in their antibacterial activity, their physical properties, their mechanisms of action, and/or their chemical properties or structure. Many of the antibiotics are classified as broad spectrum, in that they are effective against a wide range of pathogenic microorganisms, but some antibiotics are effective only against specific microorganisms.

Most microorganisms have the ability to develop resistance upon repeated exposure to most antibiotics, and, thus, there is a continuing need to develop new antibiotics to treat infections caused by pathogenic microorganisms resistant to the more common antibiotics.

Apparent U.S. consumption of antibiotics is estimated to have increased by 106 percent during 1979-83, from $1.1 billion in 1979 to $2.3 billion in 1983. The apparent consumption of antibiotics increased rapidly during this period, most likely because of the introduction of a significant number of new, and more costly, antibiotics such as the cephalosporins during 1979-83. The ratio of imports to consumption varied erratically during this period, ranging from a high of 11.6 percent in 1982 to an estimated low of 8.3 percent in 1983 (table C-4).

Domestic shipments of antibiotics are estimated to have increased by 89 percent during 1979-83, from $1.5 billion in 1979 to $2.9 in 1983 (table C-4). Part of the increase in value is accounted for by the introduction of newer and more costly antibiotics which have replaced, to some extent, some of the older antibiotics. This is especially true for antibiotics used in the treatment of humans and, to a lesser extent, for antibiotics use in veterinary practice and in animal feed supplements.

Imports of antibiotics into the United States increased by 63 percent during 1979-83, from $116 million in 1979 to $189 million in 1983 (table C-5). Principal sources of U.S. imports of antibiotics in 1983 were Italy ($42 million), West Germany ($36 million), Japan ($31 million), and the United Kingdom ($30 million).

U.S. exports of antibiotics increased by 48 percent during 1979-83, from $526 million in 1979 to $780 million in 1983. Principal U.S. export markets in 1983 were Japan (22 percent) and France (12 percent) (table C-6). U.S. exports of antibiotics were about four times U.S. imports in 1983, and exports accounted for 27 percent of estimated U.S. shipments.

1/ C. Wilson, O. Grisvold, and R. Doerge, A Textbook of Organic Medicinal and Pharmaceutical Chemistry, seventh edition, 1977, J. B. Lippincott Co., Philadelphia, PA, p. 269.

United Nations (U.N.) data are available only for international trade of antibiotics in bulk form, which is the form of the pure drug prior to packaging in dosage forms suitable for unit dispensing or retail sale. Thus, while the U.N. statistics will not agree with official U.S. Department of Commerce Statistics for U.S. Trade, the U.N. data should be internally consistent for specified countries and should be a useful indicator of trends in multinational trade. Tables of trade in antibiotics compiled from the U.N. data are included in appendix C for the United Kingdom (table C-7), Canada (table C-8), France (table C-9), Italy (table C-10), Japan (table C-11), Switzerland (table C-12), and West Germany (table C-13). Of these countries, Japan was the largest importer of antibiotics during 1979-82. Japanese imports of antibiotics increased 31 percent, from $263 million in 1979 to $345 million in 1982. The United States was the principal supplier of antibiotics to Japan during this period and accounted for 47 percent of Japanese imports of antibiotics in 1982 (table C-11). Other major importers of antibiotics were France, with $207 million imported in 1982, $98 million of which was supplied by the United States (table C-9); West Germany, with $164 million imported in 1982, $27 million of which was supplied by the United States (table C-13); and Italy, with $153 million imported in 1982, $42 million of which was supplied by the United States (table C-10).

As is the situation for imports, U.N. data are available only for certain international exports of antibiotics in bulk form. Data are included for British, Canadian, French, Italian, Japanese, Swiss, and West German exports in tables 7 through 13, respectively. Italy is a major exporter of antibiotics with exports of $269 million in 1982. The United Kingdom is also a major exporter of antibiotics, with exports having increased by 32 percent, from $160 million in 1979 to $211 million in 1982.

Biologicals

Biological products, as defined as an industry, include a wide range of natural products that are articles of commerce and used in the prevention, diagnosis, treatment, or cure of diseases or injuries of man and animals (mostly domesticated animals). Included among these products are therapeutic serums, vaccines, toxins, antitoxins, antivenins, human blood and fractions of human blood, human skin and bone grafts, and other anatomical parts of the human body prepared for diagnostic or therapeutic purposes.

A large number of different articles of commerce fall under the above-mentioned broad descriptions. Examples of vaccines include pertussis (whooping cough) vaccine and typhoid vaccine, which are bacterial vaccines. Toxoids include diphtheria and tetanus toxoids. Viral vaccines include those for influenza, polio, rubella (German measles), and smallpox. Antivenins are therapeutic agents used to counteract the poison from bites by venomous snakes and insects. The antivenins are usually obtained from the serum of horses immunized against the venom of insects and snakes.

Biologicals also include human whole blood and blood components. Blood components that are articles of commerce include red blood cells, platelet concentrate, and frozen or liquid plasma. Other blood derivatives include some blood-typing and blood-grouping serums, immune globulins, and immune serums. Human skin, bone, and organs for grafts and transplants are usually characterized as biologicals.

Apparent U.S. consumption of biological products is estimated to have increased by 65 percent during 1979-83, from $930 million in 1979 to $1.5 billion in 1983 (table C-3). The ratio of imports to consumption increased from 1.0 percent in 1979 to 3.1 percent in 1983. The ratio of imports to consumption was low during 1979-83, probably because of the specialized nature of the biologicals and the strong position of the United States in this market. However, the ratio of imports to consumption increased rapidly from year to year during 1979-83 and could be viewed by the domestic industry as cause for some concern on a long-term basis.

Domestic shipments of biologicals are estimated to have increased by 61 percent during 1979-83, from $1.2 billion in 1979 to $1.9 billion in 1983 (table C-14). New products in this group are nearing the commercial market stage; consequently, the growth rate of this group is likely to accelerate.

U.S. imports of biologicals increased by over 400 percent during 1979-83, from $9 million in 1979 to $48 million in 1983 (table C-15). Principal sources of U.S. imports of biologicals in 1983 were Switzerland ($8.0 million), Canada ($7.2 million), the United Kingdom ($6.3 million), and Sweden ($5.5 million).

The United States is a major, and probably the largest, exporter of biologicals in the world, with exports of $430 million in 1983, 56 percent more than the $275 million in exports of biologicals in 1979. Unfortunately, there are major discrepancies in U.N. data for this product group when compared with official U.S. statistics. Most of the differences are accounted for by human blood and its derivatives. Under U.S. classification systems, human blood and its derivatives are considered to be biologicals. In the Standard International Trade Classification used by the U.N., human blood and its derivatives are included, for the most part, within the large general classification for "medicaments."

Principal U.S. markets for biologicals in 1983 were Japan (33 percent) and West Germany (12 percent) (table C-16). Exports of biologicals, mostly human blood and its derivatives, to Japan increased by 127 percent during 1979-83.

U.N. trade statistics for biologicals are tabulated for the United Kingdom (table C-17), Canada (table C-18), France (table C-19), Italy (table C-20), Japan (table C-21), Switzerland (table C-22), and West Germany (table C-23). Of these countries, West Germany was the largest importer of biologicals, with imports valued at $23 million in 1982. Trade in biologicals was less than in the other types of drugs and related products included in this study.

Within the previously discussed limitations, U.N. data show that France exported $59 million in biologicals in 1982, followed by Canada, with exports of $35 million, and the United Kingdom, with exports of $34 million. In contrast, exports of biologicals from Japan in 1982 totaled $3.1 million.

Hormones

Hormones are secreted by various animal endocrine glands and function as physiological process regulators. Certain hormones regulate the metabolic processes, growth, reproduction, pigmentation, fluid balance, and so forth. Hormones produced by one species of animal usually show similar, if not identical, action in other species. Many hormones are now produced by chemical synthesis, and others are extracted from endocrine glands of domestic animals.

The hormones have diverse and often complex chemical structures which usually preclude simple chemical classifications. Therefore, most discussions and classifications focus on the glands in which the various hormones are produced.

For example, the adrenal glands secrete over 50 different hormones, the most important of which are aldosterone and hydrocortisone. Therapeutically, the adrenocortical hormones, most of which are now produced synthetically, are used for their anti-inflammatory and antiallergic effects. In addition, these hormones are sometimes used as immunosuppresive agents.

Perhaps one of the most familiar hormones to most individuals is insulin. Insulin is a hormone secreted by the pancreas and is essential for carbohydrate metabolism. Insulin is used in the treatment of diabetes. Until recently, all insulin was obtained commercially by extraction from pork or beef pancreas. Although most insulin is still produced in this manner, human insulin is now being produced by biotechnological procedures. Also, insulin that has the same chemical structure as human insulin is now being produced by chemical modification of animal insulin.

The thyroid gland produces the hormones thyroxine and triiodothyroxine. These hormones regulate a number of metabolic functions and also affect growth. Some of the thyroid hormones are extracted from animal thyroid glands, and others can be produced synthetically. Thyroid hormones are used in the treatment of certain conditions or diseases of the thyroid glands. In addition, some antithyroid drugs inhibit thyroxine synthesis for treatment of overactive thyroid conditions.

The posterior pituitary gland produces polypeptide hormones including vasopressin and oxytocin, both of which have also been produced by chemical synthesis. Vasopressin has a significant effect on kidney function, and the hormone acts as an antidiuretic. Oxytocin has a number of metabolic effects, most of which seem to be related to the reproductive system of the female. Oxytocin preparations are used primarily to induce labor in pregnant women.

The anterior pituitary gland produces several hormones. The functions of some of these hormones are reasonably well established, and the functions of others are not clearly known.

The ovary produces the female sex hormones, estrogens and progesterone. (Progesterone is one of a group of steroids that are called progestins.) These hormones regulate the female reproductive cycle. The principal use of estrogen-progestin drugs is as contraceptive agents for women. In addition, the estrogens and progestins are used for a wide variety of physiological and disease conditions. A large number of drugs that act as estrogens or progestins have been produced by chemical synthesis.

The testis and, to a small extent, the ovary and adrenal cortex, produce the male sex hormones, androgens. The principal effects of the androgens are their masculinizing and muscle-building effects. The usual therapeutic use of these hormones is in replacement therapy in men. Most of the androgens are produced commercially by chemical synthesis.

Apparent U.S. consumption of hormones is estimated to have increased by 69 percent during 1979-83, from $792 million in 1979 to $1.3 billion in 1983 (table C-24). The ratio of imports to consumption was almost constant during 1979-83, ranging from 6.6 to 7.6 percent.

Domestic shipments of hormones are estimated to have increased by 62 percent during 1979-83, from $907 million in 1979 to $1.5 billion in 1983 (table C-24). There were few new hormones marketed during this period. However, the decision by the FDA which allowed marketing of hydrocortisone in over-the-counter pharmaceutical preparations bolstered hormone shipments.

Imports of hormones into the United States increased by 64 percent during 1979-83, from $54 million in 1979 to $88 million in 1983 (table C-25). Principal sources of U.S. imports of hormones in 1983 were the United Kingdom ($21 million), France ($16 million), and the Bahamas ($13 million).

Domestic exports of hormones increased by 29 percent during 1979-83, from $169 million in 1979 to $218 million in 1983 (table C-26). Principal U.S. export markets in 1983 were Japan ($32 million), France ($32 million), the United Kingdom ($26 million), and Belgium and Luxembourg ($21 million).

U.N. trade statistics for hormones are shown for the United Kingdom (table C-27), Canada (table C-28), France (table C-29), Italy (table C-30), Japan (table C-31), Switzerland (table C-32), and West Germany (table C-33). Of the U.N. data examined for major trading countries, France was the largest importer of hormones in 1982 ($68 million), followed by Italy ($59 million), and Japan ($52 million). Imports of hormones by the various countries shown in U.N. statistics are somewhat lower than exports to those countries, as shown in official U.S. statistics, because hormones in dosage form or packaged for retail sale are not included in the U.N. data. According to the U.N. data, the United States was the principal supplier of hormones to the United Kingdom (48 percent), Canada (54 percent), and Japan (41 percent) during 1979-82.

According to U.N. statistics, West Germany was a major exporter of hormones during 1979-82, with exports ranging from $94 million to $104 million during 1979-82. Other major exporters of hormones in 1982 were France ($38 million), Italy ($32 million), and Switzerland ($30 million).

Vitamins

Vitamins are organic chemicals required for normal growth and maintenance of life of humans and animals. In general, humans and animals must obtain vitamins in their diets, although some species of animals produce certain vitamins in vivo. In the absence of one or more of the essential vitamins, recognizable disease conditions develop. However, if promptly treated, these deficiency diseases can usually be reversed by diet supplementation with the missing vitamin or vitamins.

The different vitamin groups are unrelated in chemical structures or functions, but are required for the maintenance of normal body structure and normal metabolic functions. Several chemicals within vitamin groups which, in the ultimate of simplicity of chemical nomenclature, are designated as A, B, C, D, E, and K, have activity within the specified group. There are, for example, a number of chemicals with vitamin A activity, but these chemicals do not have vitamin B activity and vice versa.

Vitamin deficiencies are rare in humans who have nutritionally balanced diets, because the essential vitamins are widely present in various foods. In animal nutrition, however, the situation is different than for humans. Many animal feeds are naturally deficient in one or more vitamins, and vitamins are routinely added to animal feed in the large-scale production of domesticated animals such as poultry and swine.

Apparent U.S. consumption of vitamins is estimated to have increased by 13 percent during 1979-83, from $1.2 billion in 1979 to $1.4 billion in 1983 (table C-34). The ratio of imports to consumption varied over a narrow range, from 11.4 to 13.5 percent, during 1979-83.

Domestic shipments of vitamins are estimated to have increased by 17 percent during 1979-83, from $1.1 billion in 1979 to $1.3 billion in 1983 (table C-34). Of all the major pharmacologically active drugs, vitamins are the only group for which essentially all of the products are available without prescription. Vitamins are, therefore, widely used for self-medication, are routinely added to some large-volume consumer foods (such as some milk and most infant formulas and many other products such as breakfast cereals), and vitamins are also consumed in large amounts as additives in animal feeds.

Imports of vitamins into the United States increased by 21 percent during 1979-83, from $155 million in 1979 to $188 million in 1983 (table C-35). Principal sources of U.S. imports of vitamins in 1983 were Japan ($69 million), West Germany ($37 million), Switzerland ($22 million), and France ($20 million).

Domestic exports of vitamins increased by 117 percent during 1979-83, from $65 million in 1979 to $141 million in 1983 (table C-36). Principal U.S. export markets in 1983 were Japan ($40 million) and Canada ($26 million). U.S. exports of vitamins were less than imports during 1979-83, and in 1983, exports accounted for 11 percent of estimated domestic shipments (table C-34).

U.N. trade statistics for vitamins are tabulated for the United Kingdom (table C-37), Canada (table C-38), France (table C-39), Italy (table C-40), Japan (table C-41), Switzerland (table C-42), and West Germany (table C-43).

Of the countries examined, U.N. data show that France was the largest importer of vitamins ($83 million), followed by West Germany ($66 million), Switzerland ($53 million), and Japan ($48 million).

West Germany was a major exporter of vitamins during 1979-82, with exports of $253 million in 1982. Of the selected major trading countries, Switzerland was the second largest exporter of vitamins during 1979-82, with exports of vitamins valued at $185 million in 1982, down 14 percent from 1979 exports of $214. Japan was also a major exporter of vitamins, with exports of $126 million in 1982.

Certain Organic Chemicals

A number of industrial organic chemicals have been produced commercially by fermentation processes, although most large-volume chemicals are also produced by chemical synthesis from petroleum-based feedstocks. Some of the major industrial organic chemicals of these types are the amino acids, enzymes, ethanol, and methanol. A number of industrial chemicals could be significantly affected by advances in biotechnology, and more detailed discussions are presented under the following subheadings.

Amino acids

Most, if not all, of the commercially important amino acids are chemicals that occur naturally in plant or animal tissue. Approximately 20 to 25 amino acids are protein constituents. About 8 to 10 of these amino acids cannot be synthesized within the living body and must be present in foods consumed by humans and by animals. Proteins found in eggs, beef, milk, and other foods are sources of amino acids consumed in human diets. Humans with well-balanced diets under normal conditions obtain all of the essential amino acids required to maintain life and health.

Rations for domesticated animals, however, are often naturally deficient in one or more amino acids. Methionine, for example, is one of the essential amino acids routinely added to poultry and swine feeds to provide optimum animal nutrition. Methionine is produced in large quantities, primarily to be used in animal feeds. Lysine is another commercially important amino acid that is sometimes added to animal feeds. Some lysine is made synthetically, but most is made by biochemical fermentation.

Another important amino acid produced by fermentation is glutamic acid. The sodium salt of glutamic acid, monosodium glutamate, is employed in human foods as a flavor enhancer. Most of the other commercially important amino acids are made by fermentation processes.

Apparent U.S. consumption of amino acids is estimated to have increased 27 percent in quantity and 35 percent in value during 1979-83, from 124 million pounds, valued at $154 million, in 1979 to 157 million pounds, valued at $208 million, in 1983 (table C-44). The ratio of imports to consumption varied in a narrow range during 1979-83, from 41 to 49 percent on the basis of quantity and from 55 to 66 percent on the basis of value. The quantity of amino acids consumed during 1979-83 is believed to have followed trends in the poultry and swine industries, because these are the principal end-use markets for the large-volume amino acids.

Domestic production of amino acids was variable during 1979-83, ranging from 74 million pounds, valued at $85 million, in 1979 to 96 million pounds, valued at $120 million, during 1983 (table 44). Decreased production in 1982 was more than offset by increased imports, resulting in an increase in apparent consumption during that year.

U.S. imports of amino acids increased by 25 percent in quantity and by 46 percent in value during 1979-83, from 57 million pounds, valued at $86 million, in 1979 to 71 million pounds, valued at $126 million, in 1983 (table C-45). Principal sources of imports of amino acids in 1983 were Japan ($50 million) and France ($45 million).

U.S. exports of amino acids increased by 148 percent in quantity and by 191 percent in value during 1979-81, from 6 million pounds, valued at $17 million, in 1979 to 15 million pounds, valued at $48 million, in 1981 (table C-46). U.S. exports declined by 34 percent in quantity and by 22 percent in value during 1981-83, to 10 million pounds, valued at $38 million. The principal U.S. export market, on the basis of value, for amino acids during 1979-83 was Italy. The high unit value, which ranged from $26 to $32 per pound, of U.S. exports to Italy indicate that the amino acids were high-value medicinal-grade products rather than animal-feed-grade amino acids.

Foreign trade statistics for amino acids are shown for the Netherlands (table C-47), Japan (table C-48), Switzerland (table C-49), and West Germany (table C-50). The largest importer of amino acids in 1982 of these countries was Switzerland. Swiss imports reached $47 million in 1982, representing a 7-percent decrease from the level in 1979. Switzerland, also the largest exporter of amino acids, had exports valued at $198 million in 1982. Exports from West Germany increased from $28 million in 1979 to $32 million in 1982, or by 16 percent. The United States was the principal supplier of amino acids to the Netherlands (34 percent) and Japan (64 percent) in 1982.

<u>Enzymes</u>

Enzymes are nonliving proteins, generated by all living cells, that serve as biological catalysts necessary for the chemical reactions that sustain cell life. Industry experts estimate that as many as 25,000 different enzymes occur in nature, and about 100 or so have important industrial applications. The natural processes that turn milk into cheese, fruit into wine, and sugar into alcohol are dependent on reactions promoted by enzymes. The enzymes are quite specific in their actions, and each enzyme reacts in just one way and produces a specific chemical output.

The pharmacological actions of many drugs depend on drug-enzyme interactions, but at present, enzyme preparations per se are of limited use in therapeutics. Industrially, enzymes are used to produce cheese, wine, alcohol, bakery products, precooked baby foods, some drugs, meat tenderizer, detergents, animal feed supplements, high-fructose corn syrup, and many other useful products, including some amino acids.

Most enzymes are produced by extraction from animal or plant sources, although increasing numbers are produced by means of microbial fermentation. For example, rennet is usually produced from dried calf stomach to manufacture cheese; however, rennet shortages using this production method have encouraged microbial production of rennet.

Apparent U.S. consumption of enzymes is estimated to have increased by 142 percent during 1979-83, from $53 million in 1979 to $129 million in 1983 (table C-51). The ratio of imports to consumption dropped from 100 percent in 1979 to 71 percent in 1983.

U.S. production of enzymes is estimated to have increased by 128 percent during 1979-83, from $30 million in 1979 to $69 million in 1983 (table C-51). The conversion of starch into high-fructose corn syrup by using enzymes may be one reason for the increased production of enzymes during 1979-83. High-fructose corn syrup has been used recently to replace sucrose in some soft drinks.

U.S. imports of enzymes were 19 million pounds, valued at $53 million, in 1979 and increased by 72 percent in value to 27 million pounds, valued at $92 million, in 1983 (table C-52). The value of the enzymes reflects the changes in imports more accurately than the quantity, because the value is determined by the specific activity of the enzyme rather than weight. Principal sources of U.S. imports of enzymes in 1983 were Denmark ($44 million), followed by West Germany ($10 million), and Japan ($7.6 million).

U.S. exports of enzymes totaled 4.6 million pounds, valued at $33 million, in 1983, after increasing by 6 percent in terms of value from 4.0 million pounds, valued at $31 million, in 1979 (table C-53). The principal U.S. export market for enzymes in 1983 was Canada ($7.5 million).

U.N. trade data were examined for the United Kingdom (table C-54), Canada (table C-55), Denmark (table C-56), the Netherlands (table C-57), France (table C-58), Japan (table C-59), Switzerland (table C-60), and West Germany (table C-61). In 1982, the largest importer of enzymes was Japan ($53 million), followed by West Germany ($33 million), France ($30 million), Great Britain ($14 million), Switzerland ($8 million), and the Netherlands ($6 million). The United States was the major source of enyzmes imports for Canada in 1982, accounting for nearly 78 percent of total Canadian enzymes imports.

The United States was the largest market for Danish exports of enzymes, accounting for 31 percent of total Danish exports, which were $127 million (table C-56). The United States was also a major market for enzymes from the United Kingdom (26 percent) (table C-54), Canada (34 percent) (table C-55), the Netherlands (43 percent) (table C-56), Japan (31 percent) (table C-59), and West Germany (15 percent) (table C-61), according to U.N. data.

Ethanol

Ethanol is a clear, water-white liquid classified chemically as a monohydric alcohol. Because it is hydrophilic, the commercial grades usually contain water. The ethanol produced by fermentation processes is usually 95 percent pure with 5 percent water and impurities.

Ethanol is synthetically produced by the hydration of the petrochemical ethylene. However, competitive fermentation processes for ethanol have expanded recently, mostly with corn as the raw material, but also including the fermentation of sulfite liquor from pulp mills, 1/ and production from wood waste and sugar cane. 2/

Apparent U.S. consumption of ethanol was erratic during 1979-83, ranging from a high of 3.0 billion pounds, valued at $787 million, in 1983 to a low of 1.6 billion pounds, valued at $445 million, in 1981 (table C-62). It is quite likely that actual consumption was less erratic than apparent consumption, but data are not available so that inventory adjustments could be taken into account. However, some of the fluctuations in apparent consumption are accounted for by changes in production and in imports as discussed below. The ratio of imports to consumption annually ranged from 11 to 29 percent on the basis of quantity and from 6 to 13 percent on the basis of value during 1979-83.

Production of ethanol using synthetic methods decreased from 1.4 billion pounds in 1979 to 1.0 billion pounds in 1982, or by 38 percent. Fermentation ethanol, which accounted for 18 percent of total ethanol production in 1979, increased from 301 million pounds in that year to 1.26 billion pounds, or 52 percent of total production, in 1983. Based on official statistics of the U.S. International Trade Commission and the U.S. Department of Treasury, the following tabulation shows U.S. production of ethanol, by processes (in thousands of pounds):

Year	Synthetic	Fermentation	Total
1979	1,408,464	301,380	1,709,844
1980	1,450,769	518,884	1,969,653
1981	1,317,185	193,555	1,510,740
1982	1,023,287	939,537	1,962,824
1983	1/ 1,103,885	1,194,728	2,298,613

1/ Preliminary figure.

Total U.S. production of ethanol from all sources fluctuated during 1979-83, but reached a level of 2.3 billion pounds, valued at $689 million in 1983, an increase of more than 34 percent in quantity from 1.7 billion pounds, valued at $325 million, in 1979.

U.S. imports of ethanol increased to 672 million pounds, valued at $102 million, in 1983 from 184 million pounds, valued at $25 million, in 1979

1/ Biotechnology in Industry, (1983, Ann Arbor Science, Ann Arbor, MI) p. 37.
2/ "Biochemical Processes, Metals and Minerals, and Synfuels Show Strong Interest," Chemical Engineering, Aug. 23, 1982, pp. 95-105; "Brazil Drives to Fuel Up With Alcohol," Chemical Week, May 11, 1983, pp. 32-34.

(table C-63). The principal source of U.S. imports in 1983 was Brazil ($71 million). Brazil, which has large quantities of arable land, initiated programs to use sugarcane crops to produce ethanol for fuel. World-scale plants, low-cost labor, and inexpensive agricultural resources have resulted in the production of competitively priced ethanol.

U.S. exports increased from 59 million pounds, valued at $9.5 million, in 1979 to 68 million pounds, valued at $15 million, in 1981 but decreased to 16 million pounds, valued at $3.8 million, in 1983 (table C-64). This represents a decrease of 76 percent in quantity since 1981 and a 73-percent decrease in quantity since 1979. These decreases are the results of the availability of fermentation ethanol in foreign nations, coupled with the inability of the United States to compete effectively with European capacity increases. 1/

Data for international trade in ethanol were examined for Brazil (table C-65), Canada (table C-66), France (table C-67), the Netherlands (table C-68), Switzerland (table C-69), Japan (table C-70), West Germany (table C-71), and the United Kingdom (table C-72). Brazil was by far the largest exporter of ethanol, with exports reaching $82 million in 1982, followed by France ($50 million) and the United Kingdom ($48 million). The United States was the major source of imports of ethanol by Canada (98 percent), although total trade value was small.

Brazil instituted a program to substitute domestically produced chemicals for imports. These efforts to balance trade and the switch to fermentation ethanol as an alternate fuel for motor vehicles resulted in little or no Brazilian imports of ethanol in recent years. Exports of ethanol are mainly surplus fuel stocks, and reached $82 million in 1982 compared with $26 million in 1979. The major markets for Brazilian exports of ethanol in 1982 were the United States, Japan, and the Netherlands, which together accounted for more than 95 percent of the exports (table C-65).

Methanol

Methanol is also a clear, water-white liquid classified chemically as a monohydric alcohol. It is hygroscopic, and commercial grades contain about 3 percent water. The principal uses of methanol are as a chemical intermediate used to produce other organic chemicals, as a solvent, and as a fuel.

Methanol is produced primarily from natural gas. Biotechnology has begun to make some inroads, however, into the production of methanol using extractive processes 2/ as well as using methanol as a feedstock for the production of single-cell protein.

Apparent consumption of methanol was erratic during 1979-83, reaching a peak of 7.9 billion pounds, valued at $716 million, in 1983 before declining to 6.7 billion pounds, valued at $478 million, in 1983 (table C-73). The

1/ "Mouton Cadet," The Economist, Mar. 3, 1984, pp. 68-70.
2/ "Canadian Methanol Plans $200 m. Methanol Plant," European Chemical News, June 27, 1983, p. 22.

ratio of imports to consumption was also erratic during 1979-83, ranging from a low of 2 percent in 1981 to a high of 10 percent in 1983, on the basis of quantity. The recent economic recession was probably the principal reason for the drop in consumption of methanol during 1981-83.

U.S. production of methanol totaled 6.6 billion pounds, valued at $482 million, in 1983, representing a decrease of 12 percent in quantity from that in 1982 and an overall decrease of 10 percent in quantity from that in 1979 (table C-73).

U.S. imports of methanol totaled 687 million pounds, valued at $41 million, in 1983, nearly doubling from 376 million pounds, valued at $28 million, in 1979 (table C-74). Imports of methanol from Canada accounted for 95 percent of the quantity and 94 percent of the value of U.S. imports of methanol in 1983. Most synthetic methanol is made by using natural gas as the principal feedstock. Canadian producers of methanol have lower priced natural gas feedstocks than some, if not most, U.S. methanol producers. Therefore, feedstock cost advantages coupled with the proximity of Canadian producers to major U.S. methanol consumer markets probably account for the increased imports of methanol from Canada in 1982 and 1983.

U.S. exports of methanol increased from 370 million pounds, valued at $23 million, in 1979 to 1.1 billion pounds, valued at $89 million, in 1982, or by nearly 200 percent. However, they decreased to 653 million pounds, valued at $45 million, in 1983 (table C-75).

New plants going on stream and some old plants in Europe changing from naphtha to cheaper natural gas raw material produced nearly all of the shifts in world trade in 1983. Japan, for example, which produced methanol from petroleum-based feedstocks such as naphtha or refinery gas, began importing methanol from a new Saudi Arabian plant that it partially owns, which uses natural gas.

The countries for which trade in methanol was examined were the United Kingdom (table C-76), Canada (table C-77), the Netherlands (table C-78), France (table C-79), Japan (table C-80), Switzerland (table C-81), and West Germany (table C-82). In 1982, the largest methanol importer was West Germany, reaching a level of $126 million. The next largest importer was Japan, with imports valued at $96 million in 1982. Exports of methanol were largest from Canada and the Netherlands, which reached $85 million and $80 million, respectively. Exports of methanol from the United Kingdom were $60 million in 1982.

Certain Agrochemicals

Certain agrochemicals are limited to nitrogenous fertilizers and pesticides, because these chemicals seem to be the agrochemicals for which developments in biotechnology have the greatest potential impact. Animal drugs and vaccines are not classified as agrochemicals but were included in the previous discussion of certain drugs and related products.

Nitrogenous fertilizers

The nitrogenous fertilizers are chemical compounds or mixtures of chemical compounds that contain only the primary plant nutrient nitrogen. Although air is about 78 percent nitrogen, most crops cannot utilize nitrogen directly from air and must obtain nitrogen from chemicals in which the nitrogen is converted to water-soluble derivatives. Many different chemicals can be used as nitrogenous fertilizers, but only a few are of commercial significance in the United States and in international trade. Agronomics, economics, logistics, and customer preference usually determine the particular nitrogenous fertilizer or fertilizers that are used.

Anhydrous ammonia is the key chemical of the nitrogenous fertilizer industry, and almost all of the other nitrogenous fertilizers are derived from it. Minor exceptions are natural sodium nitrate, which is produced from mineral deposits in Chile, and ammonium sulfate, some of which is recovered as a byproduct from coke-oven gas. Other than ammonia, major nitrogenous fertilizers include urea and ammonium nitrate, both of which are made from anhydrous ammonia. Ammonium phosphates, though incorporating two major plant nutrients, are also major sources of fertilizer nitrogen. Nitrogenous fertilizers of less commercial significance than the major ones are ammonium sulfate, calcium cyanamide, calcium nitrate, and sodium nitrate.

Domestic consumption of nitrogenous fertilizers increased by 6 percent, on the basis of quantity, from 37 million tons in 1979 to 39 million tons in 1980, before dropping by 15 percent to 33 million tons in 1983 (table C-83). On the basis of value, domestic consumption increased 37 percent, from $4.4 billion in 1979 to $6.0 billion in 1981, and then dropped 38 percent to $3.8 billion in 1983. A number of reasons have been cited for the drop in quantities of nitrogenous fertilizers consumed during 1980-83, including low net farm incomes in 1981 and 1982 because of low crop prices, high interest rates, crop surpluses, weak export markets for grain, and a worldwide recession affecting most industries. 1/ In 1983, nitrogenous fertilizer consumption was further reduced as a result of the U.S. Department of Agriculture crop reduction programs for 1983 2/ and by severe drought in major corn-producing States. The ratio of imports to consumption in terms of quantity varied during 1979-83, from a low of 10.6 percent in 1981 to a high of 17.5 percent in 1983 (table C-83).

Most nitrogenous fertilizers are consumed or shipped to local distributors shortly after the fertilizers are produced. Production is "demand driven" to a greater extent than that for potassic and phosphatic fertilizers, because nitrogenous fertilizers in general, and especially anhydrous ammonia, are expensive to store. Thus, when demand dropped, as it did during 1981-83, production was adjusted accordingly. On the basis of quantity, domestic production of nitrogenous fertilizers fell by 24.3 percent during 1980-83, from 38.8 million tons in 1980 to 29.3 million tons in 1983

1/ "Fertilizer Experts Predict Slump In World Markets Will Persist; '84 Tagged as Recovery Year," Chemical Marketing Reporter, Nov. 1, 1982, pp. 5 and 40.

2/ "A relief Plan For Farmers will Hurt Agrichemicals," Chemical Week, Jan. 26, 1983, pp. 12 and 13.

(table C-83). The principal reasons for the drop in production were the reductions in demand, decreased exports, and, in 1983, increased imports.

Imports increased erratically during 1979-83, from 4.0 million tons, valued at $380 million, in 1979 to 5.7 million tons, valued at $703 million, in 1983 (table C-84). Canada was the principal source of imports of nitrogenous fertilizers during 1979-83. Imports from Canada accounted for 37 percent of the quantity and 41 percent of the value of imports in 1983. The U.S.S.R. was the second largest source of nitrogenous fertilizer imports during 1979-83. Imports from the U.S.S.R. accounted for 18 percent of the quantity and value of imports of nitrogenous fertilizers in 1983.

Domestic exports of nitrogenous fertilizers increased by 14.0 percent in quantity and by 58.1 percent in value during 1979 and 1980, from 3.9 million tons, valued at $368 million, in 1979 to 4.5 million tons, valued at $581 million, in 1980 (table C-85). Exports then dropped by 48.0 percent in quantity and by 60.3 percent in value during 1980-83, from 4.5 million tons, valued at $581 million, in 1980 to 2.3 million tons, valued at $231 million, in 1983.

With the exception of Brazil, the United States did not have many large markets for nitrogenous fertilizers during 1979-83. The export market is mostly composed of numerous small shipments to many countries which, in the aggregate, constitute a large total market. Many of the countries that make up the export market for nitrogenous fertilizers are developing countries or other countries that are not highly industrialized. Many of these countries were severely affected by the recent worldwide economic recession and were simply unable to purchase their usual requirements of nitrogenous fertilizers. For example, exports to Brazil sank by 77 percent in quantity and by 81 percent in value during 1979-83, from 1.2 million tons, valued at $94 million, in 1979 to 279,000 tons, valued at $17.6 million, in 1983. These adverse economic conditions in usual export markets were probably the principal reasons for reduced exports of nitrogenous fertilizers during 1980-83.

The U.N. publishes annual fertilizer yearbooks. However, the U.N. data are in tons of nitrogen content, and anhydrous ammonia is not classified as a fertilizer in the Brussels Tariff Nomenclature system used by most countries; thus, the U.N. fertilizer statistics do not include trade in ammonia. In addition, trade data for some major producers of nitrogenous fertilizers are either not included in U.N. statistics or are outdated. Since the available U.N. data are of limited utility within the context of this study, no international statistical data have been included for nitrogenous fertilizers.

For the previously noted reasons with, respect to U.N. import data on nitrogenous fertilizers, no U.N. export data for nitrogenous fertilizers are included in this study.

Pesticides

The term "pesticides" means products such as insecticides, insect attractants and repellants, rodenticides, fungicides, herbicides, fumigants, and seed disinfectants, chiefly used to destroy animal or plant life.

"Pesticide" is a generic term for a wide variety of chemicals used to restrict or destroy specific animals or plants.

Most pesticides are synthetic organic chemicals rather than natural products. The first major synthetic insecticides were chlorinated hydrocarbons. These chemicals found widespread use in agriculture because of their unusual persistance and toxicity to a wide variety of insects. However, most chlorinated hydrocarbon insecticides were found to have undesirable environmental effects that led to restrictions or bans on their use, at least in the United States.

Organophosphorus insecticides have largely replaced the chlorinated hydrocarbons, because the organophosphorus insecticides decompose more rapidly. Disadvantages of the organophosphorus insecticides are that they are, on direct contact, more toxic to humans and are more expensive than the chlorinated pesticides.

As a result of environmental regulations, several pesticide firms have been engaged in research on synthetic pyrethroids, a class of insecticides similar to the active compounds found in natural pyrethrum. Pyrethrum is highly toxic to insects but has low toxicity to mammals, which is a desirable characteristic for insecticides.

Herbicides, which account for roughly one-half of total pesticide production, are used to destroy or control a wide variety of weeds and other plants. A large number of different kinds of chemicals are used as herbicides. Other pesticides include chemicals that promote, alter, or depress plant growth; funigicides; rodenticides; fumigants; and insect sex attractants and growth regulators.

Domestic consumption of pesticides and related products is estimated to have increased by 17 percent in quantity and by 47 percent in value during 1979-81, from 889 million pounds, valued at $2.9 billion, in 1979 to 1.0 billion pounds, valued at $4.3 billion, in 1982 (table C-86). Consumption then dropped by 34.7 percent in quantity and by 33.6 percent in value during 1981-83, from 1.0 billion pounds, valued at $4.3 billion, in 1981 to 677 million pounds, valued at $2.8 billion, in 1983. The fall in pesticide consumption during 1981-83 was for the same reasons discussed with respect to nitrogenous fertilizers. The ratio of imports to consumption, on the basis of quantity, increased from 12.3 percent in 1979 to 25.5 percent in 1983.

Domestic production of pesticides and related products is estimated to have decreased 31 percent in quantity during 1980-83, from 1.4 billion pounds in 1980 to 1.0 billion pounds in 1983, after increasing slightly (2.7 percent) from 1979 to 1980 (table C-86). The value of pesticide production is estimated to have increased 36 percent during 1979-81, from $3.8 billion in 1979 to $5.2 billion in 1981. The value of production then declined by 26 percent during 1981-83, from $5.2 billion in 1981 to $3.8 billion in 1983. The principal reasons for the drop in pesticide production were the reductions in demand, decreased exports, and increased imports.

U.S. imports of pesticides and related products increased by 57 percent in quantity during 1979-83, from 110 million pounds in 1979 to 173 million pounds in 1983 (table C-87). The value of pesticide imports increased by 39 percent, from $241 million in 1979 to $335 million in 1981. Then imports decreased by 9.7 percent in value to $302 million in 1983. The two largest sources of U.S. imports in 1983, on the basis of value, were Switzerland ($63 million) and West Germany ($56 million). The unit value of pesticide imports fell by 36 percent during 1980-83, from $2.72 per pound in 1980 to $1.75 per pound in 1983.

Domestic exports of pesticides and related products declined by 23 percent in quantity but increased by 15 percent in value during 1979-83, from 650 million pounds, valued at $1.1 billion, to 502 million pounds, valued at $1.3 billion (table C-88). In contrast to the unit value of imports, the unit value of exported pesticides increased from $1.71 per pound in 1979 to $2.55 per pound in 1983. Principal U.S. markets in 1983 were Canada (14 percent), Japan (8.3 percent), and Switzerland (8.0 percent).

U.N. trade statistics for pesticides are shown for the United Kingdom (table C-89), Canada (table C-90), France (table C-91), Italy (table C-92), Japan (table C-93), Switzerland (table C-94), and West Germany (table C-95). According to U.N. statistics for these selected countries, France was the largest importer of pesticides during 1979-82, with 1982 imports valued at $432 million. Other large importers of pesticides in 1982 were Canada ($199 million), West Germany ($178 million), the United Kingdom ($175 million), and Italy ($120 million). Major pesticide exporting countries in 1982 were West Germany ($741 million), the United Kingdom ($479 million), France ($367 million), and Switzerland ($314 million).

POSSIBLE IMPLICATIONS OF FUTURE BIOTECHNOLOGY DEVELOPMENTS ON U.S. CONSUMPTION AND TRADE

Recent biotechnological developments in the production of chemicals could affect trade in biotechnologically produced goods. For the purposes of this study, apparent U.S. consumption, exports, and imports were projected to the year 2000 using standard linear regression analysis on historical data for 1979-83 to project possible future trends. The regression analysis does not take into account any changes in Government policy which could affect the biotechnology industry. It should be noted that the value of such projections is to provide a benchmark for policymakers. Results of the linear regression are good predicators of possible future effects only if relationships which existed during 1979-83 hold true in the future. The results should be interpreted as indicating the direction and magnitude, but not the precise size of changes in consumption and trade.

Certain Drugs and Related Products

Table 3 shows the results of linear regression analysis for the certain drugs and related products sector.

Table 3.--Certain drugs and related products: Results of linear regression analysis 1/ of apparent U.S. consumption, exports, and imports, by types, 1983 and 2000

(In millions of 1984 dollars)

Product	Apparent consumption		Exports		Imports	
	1983	2000	1983	2000	1983	2000
Antibiotics	2,275	7,218	780	1,817	189	508
Biologicals	1,537	3,997	430	1,073	48	208
Hormones	1,342	3,699	218	427	88	251
Vitamins	1,387	1,938	141	454	187	283
Total	6,541	16,852	1,569	3,771	512	1,250

1/ The method of least squares was used, which is shown in S. M. Selby, Standard Mathematical Tables, 1974, Cleveland, p. 576.

Source: Compiled by the staff of the U.S. International Trade Commission.

The certain drugs and related products sector shows increases of more than 100 percent in consumption, exports, and imports from 1983 to 2000, primarily because of new developments expected in the industry.

Antibiotics

The industry producing antibiotics could be affected in several different ways by new developments in biotechnology. It is likely that genetic improvements could be made to increase the productivity of the microorganisms currently used to produce the large-volume antibiotics such as the penicillins and tetracyclines. It is possible that methods will be developed for altering the genetic structure of antibiotic-producing microorganisms to facilitate the production of new and improved antibiotics. In addition, it may be possible to develop biological processes for the direct fermentation production of antibiotics now made by synthetic chemical modifications of the natural fermentation products. 1/ These developments could result in an accelerated rate in the production of antibiotics; this is because new developments are likely to add to existing production rather than displace older antibiotics, because most, if not all, of the existing commercial antibiotics are still therapeutically useful for certain patient populations and disease conditions and veterinary medicine.

Lower cost production of existing antibiotics through genetic improvements in the microorganisms producing these antibiotics could make these drugs available for more widespread uses, including increased utilization in veterinary medicine. However, a factor that might tend to reduce the consumption of antibiotics would be the development of vaccines

1/ John N. Vournakis and Richard P. Elander, "Genetic Manipulation of Antibiotics-Producing Microorganisms," Science, vol. 219, Feb. 11, 1983, pp. 703-708.

effective against bacterial diseases. Most current effort in vaccines has been directed toward viral diseases, and the vaccines will be further discussed in the section of this study dealing with biologicals.

The domestic market for antibiotics could increase from $2.3 billion in 1983 to $7.2 billion in the year 2000. Industry projections fall within the range between $7.2 billion and $26.6 billion, which reflect the continuation of the 15.6-percent growth rate experienced during 1979-83.

Because the United States is a substantial exporter of antibiotics, future developments in the international markets could have a significant impact on U.S. imports and exports and thereby affect domestic production and employment. Imports of antibiotics could reach $508 million by the year 2000, and exports could increase to $1.8 billion. Thus, if current trends were to prevail, the United States could have a large and highly competitive industry supplying antibiotics to the world market.

Biologicals

As would be expected, developments in biotechnology are likely to have a profound affect on the industry producing medical therapeutic and diagnostic products which are classified as biologicals, because several new biologicals are either now or soon likely to be on the market. Domestic consumption could reach $4 billion by the year 2000. Industry estimates are also about $4 billion.

A group of biological products that has been marketed recently include monoclonal antibody diagnostic test kits. Antibodies are serum proteins, i.e., immunoglobulin molecules, produced by living tissues as reaction products to foreign biological materials, including pathogenic microorganisms. Production of antibodies is one of the basic foundations of immunology, at least to the extent the process is understood. Antibodies are of critical importance in the ability of humans and animals to develop immunity to certain diseases. 1/ These antibodies also provide methods for the diagnosis of infectious diseases and other immune responses. Through developments in biotechnology, it is now possible to create virtually immortal cloned cell lines that reproducibly produce unique antibody molecules. The monoclonal antibodies are proving to be useful for very specific and rapid diagnosis of many infections. 2/ In addition, the monoclonal antibodies can be used in pregnancy tests, to monitor blood levels of certain drugs, to test for certain cancers, to evaluate white blood cells, to test donated blood for infectious diseases, and to measure numerous other immune system responses. 3/ Monoclonal antibodies can also be used as diagnostic agents in veterinary medicine and may be especially useful in this field, as many animal diseases are difficult to diagnose.

1/ Gilbert L. Zink, "Principles of Immunology," Remington's Pharmaceutical Sciences, 16th ed., Mack Publishing Co., Easton, PA, 1980, pp. 1,315-1,340.
2/ Robert C. Nowinski, et al., "Monoclonal Antibodies for Diagnosis of Infectious Diseases in Humans," Science, vol. 219, Feb. 11, 1983, pp. 637-644.
3/ "A Medical Marvel Goes to Market," Business Week, Apr. 11, 1983, pp. 56-58.

Biotechnology is also having a significant effect on the development of vaccines, another product group that is within the biologicals classification. A number of different approaches are being used in developmental work on new vaccines. Recent advances have made it possible to grow certain pathogens, including hepatitis viruses and the malaria parasite, in quantities large enough for research and development work. This work could ultimately result in vaccines that are effective against these disease-causing organisms.

Biotechnological techniques are being used to develop safer attenuated vaccines. Some live vaccines now in use can potentially, although rarely, cause the disease they are intended to prevent. Newer vaccines under development may use harmless components of the pathogenic microorganism to elicit an immune response, thus precluding infection by the microorganism.

One difficulty in preventing some diseases by vaccination is that there are often numerous strains of the microorganisms that cause diseases such as influenza and pneumonia. Newer vaccines will reportedly be marketed that will be more effective against multistrain, pathogenic microorganisms. Thus, major research efforts are likely to yield vaccines that may be more effective in the prevention of human diseases such as meningitis, pneumonia, malaria, typhoid, hepatitis, herpes, chlamydia infections, gonorrhea, and other diseases. 1/

In addition to vaccines for humans, a great deal of work is being done on animal vaccines. The market for animal vaccines is potentially very profitable, because the need for many animal vaccines is recurring with each generation of animals. In the United States, for example, scours is estimated to kill 10 percent of all calves and piglets. 2/ A number of vaccines are available for the prevention of scours, and others are under development. 3/ One of the major commercial animal vaccines is the rabies vaccine. Its sales volume is large, because most municipal governments require owners to have pets immunized periodically for rabies.

Probably the world's largest exporter of biologicals, the United States should be in a favorable position to market internationally the new biological products. Often, however, a single establishment or two can supply most of the world's requirements for a particular vaccine or other product. As discussed under the section on competitive advantages, numerous considerations can influence a multinational corporation's selection of a site for its research and development and manufacturing facilities.

U.S. imports of biologicals could total $208 million by the year 2000, and exports of biologicals could amount to about $1.1 billion. The United States should continue to have a large, positive trade balance in biologicals.

1/ Joseph Alper, "Vaccine Research Gets New Boost," High Technology, April 1983, pp. 58-64.
2/ Ibid, p. 62.
3/ "Common Sense Trips Save More Calves," Progressive Farmer, May 1984, pp. 39 and 40.

In the international markets, there are a number of diseases that are not prevalent in the United States, especially tropical diseases, 1/ that may become susceptible to better treatment by biologicals. Animal diseases, such as foot-and-mouth disease, that are not problems in the United States serve as the basis for additional potential international markets for biologicals produced by U.S. firms. 2/

Hormones

All of the hormones are produced within the normal living human or animal by in vivo biosynthesis. Therefore, the hormones are logical candidates for commercial production by biotechnological processes. In fact, the first major commercial product of the recent developments in biotechnology was human insulin. 3/ Another feature of hormones that makes them attractive chemicals to produce by biosynthetic processes is that, for the most part, the hormones are required in small quantities and are high-value products. For example, in 1982, the average unit value of hormones sold in bulk form was $750.86 per pound. 4/ Other types of hormones, or hormonelike substances, are under development by using biotechnological procedures and include growth hormones, fertility drugs, and birth control products. 5/ New commercial products may ensue as a more complete understanding of the functions of hormones is developed. 6/

The possible future domestic market for hormones could be $3.7 billion by the year 2000. Consumption, according to industry estimates, could be about $3 billion. The markets for the special hormones that may be produced in commercial quantities by new biotechnological processes may not add greatly to the consumption rate, because some of the markets, such as the market for human growth hormone, may be small. There is potentially a sizable market for growth hormones in livestock and poultry production, provided the use of such products proves safe for these applications.

U.S. imports could increase to about $251 million by the year 2000, and exports, to about $427 million. One consideration that should be kept in mind about the international markets for hormones is that total world markets for hormones are smaller in quantity than the markets for many other therapeutic classes of drugs. Thus, total world requirements for a particular hormone can often be supplied by a few manufacturing facilities. Therefore, future production locations could significantly alter existing international trade patterns.

1/ "Combating the Resurgence of Tropical Diseases," Business Week, Apr. 16, 1984, pp. 168-173.

2/ "Genentech Buys Back Rights of Its FMD Vaccine From IMC," European Chemical News, Apr. 4, 1983, p. 18.

3/ "Rushing With Synthetic Insulins," Chemical Week, Mar. 2, 1983, pp. 13 and 14.

4/ Synthetic Organic Chemicals, United States Production and Sales, 1982, USITC Publication 1422, 1983, p. 164.

5/ "The New Peptide Drugs. Big Growth Ahead as They Zero In On a Host of Human Ills," Chemical Week, Sept. 28, 1983, pp. 40-48.

6/ Julius Axelrod and Terry D. Reisine, "Stress Hormones: Their Interaction and Regulation," Science, vol. 224, May 4, 1984, pp. 452-459.

Vitamins

Vitamins are organic chemicals that occur in nature, although synthetic processes have been developed to produce many of them on a large scale for commercial markets. Nevertheless, some major vitamins, such as vitamin B_{12} and vitamin C, 1/ are produced by fermentation or use some intermediate chemicals that are produced by fermentation or biosynthesis. In addition, it is possible to separate optical isomers of certain vitamins by using biochemical techniques. Separation of optical isomers is frequently desirable, because often there is only one physiologically active isomer in the complex mixtures that result from total chemical synthesis.

Thus, some of the vitamins are subject to the same type of microbiological efficiency enhancements that were discussed in the previous part of this study dealing with antibiotics. However, some vitamins are produced totally, or in large part, by very cost-efficient chemical processes. These synthetic processes allow marketing of vitamins at low prices. As a group, the unit value of sales of vitamins in bulk form, which is the pure vitamin not diluted with extenders or inert diluents and not put up in dosage form, is low when compared with unit values of many other drugs in bulk form. For example, in 1982, the average unit value of sales of bulk vitamins was $9.57 per pound. 2/

Domestic consumption could reach $1.9 billion by the year 2000. Some industry estimates are more conservative, indicating about $1.3 billion by 2000. U.S. imports could increase to $283 million by the year 2000, and exports could reach $454 million.

Some significant information can be obtained from an analysis of recent trends. For example, the domestic market for vitamins is not growing rapidly, nor are imports. Exports, on the other hand, have exhibited a recent rapid rate of growth, and the domestic industry may become increasingly dependent on foreign markets for further growth of this segment of the pharmaceutical industry. It may be difficult to maintain the current growth rate in vitamin exports, because the U.S. producers face formidable competition in international markets, especially from West Germany, Switzerland, and Japan. None of the major vitamins are proprietary products, so price becomes the most significant competitive factor in many markets. Therefore, lowering of production costs of vitamins through new biotechnological developments could affect competitive conditions in international markets.

Certain Organic Chemicals

Results of linear regression analysis on statistical data for certain organic chemicals are shown in table 4:

1/ C. Wilson, C. Grisvold, and R. Doerge, Textbook of Organic Medicinal and Pharmaceutical Chemistry, J. B. Lippincott Co., 1977, pp. 924 and 931.
2/ Synthetic Organic Chemicals, United States Production and Sales, 1982, (Investigation No. 332-135), USITC Publication 1422, 1983, p. 104.

Table 4.--Certain organic chemicals: Results of linear regression analysis 1/ of apparent U.S. consumption, exports and imports, by types, 1983 and 2000

(In millions of 1984 dollars)

Product	Apparent consumption		Exports		Imports	
	1983	2000	1983	2000	1983	2000
Amino acids-----	208	378	38	120	126	290
Enzymes---------	129	451	33	36	92	239
Ethanol---------	787	2,406	4	0	102	278
Methanol--------	478	236	45	250	41	85
Total-------	1,602	3,471	120	406	361	892

1/ The method of least squares was used, which is shown in S. M. Selby, Standard Mathematical Tables, 1974, Cleveland, p. 576.

Source: Compiled by the staff of the U.S. International Trade Commission.

Amino acids

Each amino acid can exist as one of two optically active isomers, or in mixtures of the two isomers. The optical isomers differ from one another in the way the atoms, or groups of atoms, of the chemical molecule are arranged in space. 1/

An extremely important characteristic of the different isomers is that frequently one is physiologically active while the other is not. One major advantage of most, if not all, fermentation processes is that the biological processes yield only one isomer, usually the physiologically active one, but processes that use chemical syntheses yield racemic mixtures.

A specific example is the amino acid methionine. Methionine occurs in nature in the form of L-methionine and, in fact, all of the amino acids that occur naturally in food proteins are present as the optically active L-isomers. Methionine, however, is produced commercially by chemical synthesis from acrolein and methyl mercaptan. The reaction product of the methionine chemical synthesis process is DL-methionine or, in a variation of the process, the calcium salt of the DL-methionine hydroxy analog. The DL-methionine must be further processed in order to produce synthetic L-methionine. A number of chemical or physical methods have been used to separate L-methionine from

1/ The molecular formulas and molecular weights of the isomers are identical, but there is a simple test to distinguish the isomers from one another. When polarized light is passed through a medium containing one type of isomer, the plane of polarization is rotated. If the isomer rotates the polarized light to the right, it is called dextrorotatory (D), and if the polarized light is rotated to the left, the isomer is called levorotatary (L). If the D and the L isomers are mixed in equal portions, then the mixture is not optically active, does not rotate polarized light, and is called a racemic mixture (DL).

DL-methionine, and the principal method is through enzymatic decomposition of various chemical derivatives of DL-methionine, which leads to the isolation of L-methionine. This isolation adds substantially to its cost, and is the major reason that L-methionine is too costly for use in the animal feed market at this time. 1/

Other than for methionine, fermentation processes are the predominant commercial processes used to produce other amino acids. These fermentation processes have the inherent advantage that they produce the L-amino acids which are the preferable isomers for use in nutritional products for humans. Advancements in biotechnology will most likely produce more efficient microorganisms to be used in these fermentation processes. In addition, the development of microorganisms to produce amino acids from substrates that are less expensive than those now used is a possible future development.

World demand for animal protein is likely to grow with increasing populations, so there will probably be a concurrent increase in world demand for amino acids for animal feed supplements. In addition, amino acid products added to human foods, such as monosodium glutamate, also appear likely to increase. Most industry sources contend that Japan is the world leader in amino acid fermentation technology, although in 1982, Switzerland exported amino acids valued at about twice the value of Japanese exports of amino acids.

The results of linear regression analysis of statistical data for amino acids indicate that apparent U.S. consumption could reach $378 million by the year 2000. Industry estimates range from $473 million to $800 million. U.S. imports of amino acids could reach $290 million, and exports could reach $120 million by the year 2000. Most of the increase in imports could come from Japan because of their advancements in fermentation processes.

Enyzmes

Enzymes are products of living cells and are, therefore, highly likely to be affected by new developments in biotechnology. It is currently impractical to produce, on a commercial scale, the complicated enzyme molecules by chemical synthesis. Thus, enzymes for commercial use are either extracted from animal or plant tissue or are produced by fermentation. Fermentation enhancement techniques, such as those discussed for antibiotics, can also be applied to microorganisms used to produce enzymes.

In the past, almost all enzyme reactions were carried out in an aqueous solution at moderate temperatures. Recently, however, researchers carried out an enzyme reaction in an organic medium at a temperature of 100 degrees Celsius. 2/ This could lead to new synthesis processes for industrial organic chemicals. Another major development in the use of enzymes as biochemical catalysts is in immobilization technology. Most fermentation processes and

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1/ Synthetic L-Methionine from Japan, Determination of the Commission in Investigation No. 751-TA-4 . . ., USITC Publication 1167, July 1981, pp. A-2-A-9.

2/ "Enzyme Active in Hot Organic Media," Chemical and Engineering News, July 2, 1984, p. 23.

processes using enzymes to promote other reactions are batch processes which are more labor intensive, slower, and more costly than continuous processes. Thus, immobilizing enzymes by physically binding them to some neutral medium so that enzymes can ultimately be used in continuous chemical processes has a lot of practical economic attraction. To quote from a paper on enzymes, "Long known for their role in the manufacture of cheese and wine, enzymes have become the workhorses of genetic engineering - able to do anything from feeding the world's hungry to rivaling petroleum as a source of organic chemicals. Now enzymes can be immobilized for continuous production, a feat that may transform industry." 1/

U.S. consumption of enzymes could reach about $451 million by the year 2000 if historical growth trends continue. Industry sources estimate that consumption would reach only about $270 million by the year 2000. U.S. imports of enzymes could increase to $36 million by the year 2000, and exports may reach $120 million.

Ethanol

As previously noted, ethanol is produced in commercial quantities by chemical synthesis or by fermentation. Fermentation processes now use sugar or starch substrates for the microorganisms to change to alcohol, so the cost of production varies with the price of the substrate. Abundant and inexpensive supplies of sugar or starch are, therefore, required for fermentation ethanol to be price competitive for industrial uses with ethanol produced by chemical synthesis from petroleum-related feedstocks. Through advancements in biotechnology, it may become possible to produce commercial quantities of ethanol at competitive prices by fermentation processes that use cellulose or other wood polymers for feedstock. 2/

U.S. consumption of ethanol could reach $2.4 billion by the year 2000, according to linear regression analysis. Industry sources, however, believe that ethanol consumption of about $500 million to $800 million by the year 2000 may be more likely.

U.S. imports of ethanol could reach $102 million if conventional-energy-rich nations (CERN's) such as Saudi Arabia begin exporting to the United States in the future. U.S. exports of ethanol could decrease to zero by the year 2000 as the result of world-scale petrochemical plants coming on-stream in the CERN's.

1/ Stephen Kindel, "Enzymes, The Bioindustrial Revolution," Technology, November/December 1981, pp. 62-73.

2/ Douglas E. Eveleigh, "The Microbiological Production of Industrial Chemicals," Scientific American, vol. 245, No. 3, September 1981, pp. 160-170.

Methanol

U.S. consumption of methanol could decrease to $236 million by the year 2000. Industry sources estimate methanol consumption then to be about $280 million. U.S. imports of methanol could increase slightly to about $85 million by the year 2000 as petrochemical plants come on-stream in the CERN's. U.S. exports could increase to $250 million by the year 2000; however, this projection is unrealistic in light of the petrochemical production capacity, which is expected to startup in the late 1980's and 1990's in the CERN's.

Certain Agrochemicals

A linear regression analysis of 1979-83 data projected to the year 2000 is presented in table 5.

Table 5.--Certain agrochemicals: Results of linear regression analysis 1/ of apparent U.S. consumption, exports and imports, by types, 1983 and 2000

(In millions of 1984 dollars)

Product	Apparent consumption		Exports		Imports	
	1983	2000	1983	2000	1983	2000
Nitrogenous fertilizers	3,709	1,130	231	38	703	1,941
Pesticides	2,846	3,088	1,281	1,938	301	551
Total	6,555	4,218	1,512	1,976	1,004	2,492

1/ The method of least squares was used, which is shown in S. M. Selby, Standard Mathematical Tables, 1974, Cleveland, p. 576.

Source: Compiled by the staff of the U.S. International Trade Commission.

However, unlike the other categories analyzed, trends in trade and apparent U.S. consumption for agrochemicals during 1979-83 was affected by several unusual circumstances such as the U.S. Department of Agriculture crop reduction programs, crop surpluses, and a worldwide recession in many industries. All of these instances have led to reduced worldwide demand in these chemicals. Results of linear regression analyses including these expectedly nonrecurring trends, therefore, are considered to be uncharacteristic because of the unusual ciscumstances that reduced domestic consumption of both categories during 1981-83. These and other circumstances are discussed in previous sections of this report.

There are certain possible developments in agricultural science, however, that could account for decreases in demand for nitrogenous fertilizers and pesticides. Specially engineered plants could require less fertilizer or may use fertilizer more efficiently, resulting in lower fertilizer consumption than would be expected. Also, specially bred animals and engineered plants may be developed that would be more resistant to diseases and natural pests, thus requiring less pesticide usage than historical evidence would indicate.

Nitrogenous fertilizers

It has been known for many years that certain types of bacteria are capable of producing fixed nitrogen directly from elemental nitrogen. The mechanisms of bacterial nitrogen fixation have intrigued scientists for many years, and for good reason. The biological nitrogen fixation takes place at atmospheric pressure and mild temperatures, but the present synthetic processes take place at high temperatures and pressures and require large amounts of energy.

There is a symbiotic relationship between certain bacteria and leguminous plants. Some of the most familiar of the legumes include alfafas, clovers, peas, beans, lupines, soybeans, and cowpeas. Nitrogen-fixing bacteria are found, for the most part, in nodules on the roots of the leguminous plants. Botanists estimate that there are 10,000 to 12,000 species of leguminous plants, most of which are found in the tropics. About 200 species of leguminous plants are cultivated by man, and about 50 species are grown commercially in the United States. 1/

It is, therefore, theoretically possible to produce nitrogenous fertilizers by biosynthesis. Whether or not it will become economically feasible to do so is another question. 2/ Current ammonia synthesis processes are very efficient and produce fixed nitrogen that sells for 12 cents a pound or less. Therefore, there would have to be major new developments in biotechnology to produce nitrogenous fertilizers by biosynthesis at a lower cost.

What seems more likely to happen are genetic modifications of certain plants so that crop production would require less fertilizers, especially nitrogenous fertilizers. 3/ There have been forecasts that such developments will reduce fertilizer consumption by the year 2000. 4/

Most of the so-called agrochemical developments in biotechnology, as they relate to fertilizers, seem to actually be developments in plant genetics 5/ and are largely outside the scope of this study except for possible indirect effects on the fertilizer industry.

1/ J. R. Postgate, The Chemistry and Biochemistry of Nitrogen Fixation, Plenum Press, New York, 1971, p. 326.

2/ Alan Sherman Michaels, "The Impact of Genetic Engineering," Chemical Engineering Progress, April 1984, pp. 9-15.

3/ Federal Reserve Bank of Atlanta," The Advent of Biotechnology: Implications for Southeastern Agriculture," Economic Review, March 1984, pp. 42-50.

4/ "Bioengineering to Cut Fertilizer Demand," Chemical and Engineering News, Dec. 12, 1983, p. 6.

5/ James H. Mannon, "Britain Biotech Thrust Into Agrochemicals," Chemical Marketing Reporter, Apr. 4, 1983, pp. 28-34.

In recent years, the U.S. nitrogenous fertilizer industry has experienced some major competitive changes related to the cost and availability of hydrocarbon feedstock used to produce anhydrous ammonia. These developments have been evaluated and discussed in a previous Commission study. 1/

In addition, there are indications of possible restructuring of the world's fertilizer industry which may have an impact, or is likely to affect, the domestic industry. Given the size of the U.S. fertilizer industry and its importance in the domestic economy, and given the complexity of the international issues (including the relationships of the fertilizer industry and transportation industry), it may become appropriate to analyze the world's fertilizer industry under a separate investigation. The domestic fertilizer industry may be affected by more immediate changes than those likely to result from biotechnology.

Pesticides

Insect sex attractants and growth regulators are two new types of chemicals now being used to control insects. Insect sex attractants are chemicals used to confuse specific male insects, making it difficult for them to locate females for mating. Insect growth regulators, such as juvenile hormones, are synthetic compounds similar to the biological chemicals which regulate the growth of a specific insect. Both types of chemicals have attracted a great deal of interest because of their ability to control insects resistant to conventional methods. 2/ Such compounds seem likely to become products of new developments in biotechnology in addition to such agents as bacteria, viruses, and fungi that can be used as biological insecticides. 3/ These developments in biotechnology can also be applied to herbicides 4/ and other pesticides.

Input/Output Model

The U.S. Department of Labor input/output model can be used to calculate the change in U.S. industry employment resulting from any given hypothetical change in final demand for a domestically produced commodity. The model is based on the input/output relations existing in the U.S. economy in 1977 and the 1981 productivity factor (employment-output ratios). 5/

1/ The Probable Impact on the U.S. Petrochemical Industry of the Expanding Petrochemical Industries In the Conventional-Energy-Rich Nations: Final Report on Investigation No. 332-137 . . ., USITC Publication 1370, April 1983, p. 196.

2/ Summary of Trade and Tariff Information on Synthetic Organic Pesticides, USITC Publication 841, Control No. 4-1,2-4, April 1981, pp. 1-5.

3/ "Biotech Insecticide: New Plan of Attack," Industrial Chemical News, February 1984, p. 9.

4/ "New Fungal Sprays: The "Natural" Way to Kill Weeds," Progressive Farmer, May 1984, pp. 18 and 19.

5/ It should be noted that to the extent that the input/output relationships have changed since 1977, the model results will not reflect the current situation. Also, the scenarios presented previously relate to the 1983-2000 period, and the actual input/output relations and labor productivity in the year 2000 will most likely differ from those in the model.

The estimates of the effect on production of net trade can vary with different assumptions about the elasticities of demand and supply. For this study a 1-to-1 ratio is assumed between net trade changes and production changes. This assumption implies an infinite supply elasticity or a zero demand elasticity, or that any increase in imports replaces domestic production; domestic prices, consumption, exchange rates, and other variables are assumed to be unaffected by changes in imports and export.

Changes in industry employment provided by the input/output model are upper limits. A decrease in demand will be reflected by the model as a decrease in employment. An increase or decrease in labor is a result of the projection of total demand and does not take into consideration the possibility of shifting from conventional production methods to biotechnological processes, which could result in offsetting losses in employment in those other industries.

Drugs and related products

The input/output model indicates that for each hypothetical increase of $1 billion in final demand for biotechnologically produced products, this sector of the chemicals industry would experience an increase in employment of 8,775 jobs. An increase of $1 billion could result in an increase of 10,549 jobs in the chemicals and allied products industry and 24,836 more jobs in the entire U.S. economy.

Using the net trade figures obtained from the linear extrapolation of historical trends of $2.5 billion as input, an increase of 22,122 jobs is indicated for this sector. Employment would increase by 26,594 in the chemicals and allied products industry, and an increase of 62,612 over the entire U.S. economy would be possible.

Certain organic chemicals

A hypothetical increase of $1 billion in final demand for biologically produced certain organic chemicals indicates an increase in employment of 5,984 jobs, an increase of 6,881 jobs in the chemicals and allied products industry, and employment increases of 15,362 jobs in the entire U.S. economy.

According to the resulting hypothetical trade decreases of $478 million, the model indicates a decrease in employment requirements of 2,860 for this sector. For the chemicals and allied products industry, decreases in employment requirements of 3,289 would be indicated, and the entire economic would experience a decrease in employment of 7,343.

Certain agrochemicals

In the agricultural chemicals sector, an increase of 4,468 jobs could result from each hypothetical increase of $1 billion in final demand. The chemicals and allied products industry could experience an increase of 6,794 jobs, and the entire U.S. economy could show employment increases of 17,532 jobs. On the basis of a net trade balance decrease of $947 million as input, the model indicates a decrease in employment requirements of 4,231 in the agricultural chemicals sector. Employment requirements would decrease by 6,434 in the chemicals and allied products industry, and an overall U.S. economy decrease in employment of 16,603 would be indicated.

APPENDIX A

GLOSSARY OF TERMS

Amino acids.--A carboxylic acid with an amine functional group attached elsewhere in the molecule. Amino acids are the building blocks of proteins, with about 20 amino acids considered common in biological processes.

Amino acid sequencer.--A machine which determines the linear order of amino acids in a protein.

Anaerobic.--Living or acting in the absence of oxygen.

Anaerobic digester.--A device which uses microorganisms in order to break down cellulosic and other farm wastes, producing a nutritive fertilizer and methane gas. The nutritive fertilizer is generally used on-site, although the methane produced may be further processed to be used as a fuel.

Antibiotic.--A specific chemical substance used to fight infections.

Antibody.--A complex chemical protein produced by humans or higher animals in response to a specific foreign substance in the body.

Bacillus thuringiensis.--A bacteria which acts as a pesticide. The bacteria is naturally occuring and acts against only certain insects.

Batch processing.--In terms of biotechnology, a method in which a fermentation reactor or tank is loaded with raw materials and microorganisms, and the process run to completion.

Biologicals.--Complex organic chemicals isolated from organisms. This group includes vaccines, monoclonal antibodies, and insulin.

Biomass.--In general, usually plant or vegetable matter having a high cellulose content, which can be processed or broken down to yield fermentable sugars.

Biotechnology.--For the purpose of this study, any process using living cells or a product of those cells, such as enzymes, to transform some starting material into the desired product. This does not include processes such as cheese processing or winemaking.

Clone.--A group of genetically identical cells or organisms produced asexually from a common ancestor.

Conventional organism.--An organism, in this case a bacteria, plant or fungal microorganism which is found in nature and used as it exists in biotechnology processes.

Cross-licensing.--A licensing agreement which involves the exchange of technology or certain rights by both parties to the agreement, such as trade secrets, patent rights, and geographic marketing rights.

Diagnostic reagents.--In terms of biological diagnostics, any biological product which indicates the presence of disease or other biological condition and is used for such diagnoses.

Deoxyribonucleic acid.--A linear polymer made up of four essential nucleotide base units, arranged so as to carry genetic information necessary for inherited characteristics of the organism.

DNA.--See Deoxyribonucleic acid.

Enzymes.--Chemical proteins formed in the cells of plants, animals, and some bacteria which are necessary catalysts for the chemical reactions of biological processes. Enzymes are usually very specific for a particular chemical reaction.

Expression.--The mechanism whereby the genetic code is processed by an organism to give final products. Such products are usually proteins.

Fermentation.--The process by which chemical feedstocks or starting materials are transformed into the desired product, using a living microorganism.

Gene machine.--A labor-saving laboratory device which uses the four nucleotide bases to automatically synthesize strands of DNA. Originally, such work was performed manually and was very tedious.

Gene splicing.--Although a nonexact term, it is the process by which gene fragments are inserted, or 'spliced,' into another gene fragment, usually a large DNA fragment. The main purpose of gene splicing is experimental, whereby gene fragments which transfer certain characteristics in one organism are inserted into the DNA fragment of another organism to determine if those characteristics can be transferred to the new organism and thus produce higher quality or quantity of product.

Genetic engineering.--Includes the term gene splicing, but additionally includes any technique related to manipulation of genetic material, such as recombinant RNA and monoclonal antibodies.

Growth hormone.--A hormone used to stimulate allover growth. In humans, human growth hormone has been used to treat dwarfism, and bovine growth hormone has been suggested as a feed additive for producing more robust cattle.

Hormones.--Complex organic compounds which are formed by one organ and which act in a specific manner on another organ or organs.

Human insulin.--A hormone which promotes the utilization of sugar in human beings. Although insulin derived from animals has been used in the past to treat deficiencies in diabetics, some persons develop side reactions because animal insulin is of a different chemical structure. Human insulin is produced both enzymatically by altering animal insulin and by using recombinant DNA technology.

Hybridoma.--A product of fusion between tumorous antibody-producing cells and normal antibody-producing cells. Hybridomas produce only antibodies of one type, which are called monoclonal antibodies.

Immobilized cells or immobilized enzymes.--Cells or enzymes which are rigidly attached or encapsulated to enable easier separation from the final product.

Interferon.--A biological product which is thought to inhibit viral infections. Many different types of interferon have been produced using biotechnology, including alpha, beta, and gamma human interferons, as well as bovine interferons.

Interleukin.--A biological product which is thought to be potentially useful against some tumors and immune deficiency diseases. Several types of interleukin are known.

In vivo pharmaceutical.--A pharmaceutical to be used inside the body.

Joint venture.--A form of association of separate business entities which falls short of a formal merger but unites certain agreed-on resources of each entity for a limited purpose. Joint ventures are sometimes looked on as partnerships.

Licensing.--The exchange of information such as proprietary or trade secrets, patent rights, and specific marketing rights for payment or exchange of other information by two parties in a contractual agreement.

Microorganism.--Microscopic living entities, which can be viruses, bacteria, plants, or fungi.

Monoclonal antibodies.--Antibodies derived from hybridomas that have a very high specificity for certain chemical proteins and are very useful in clinical applications to diagnose diseases and biological conditions.

Mutated organism.--A microorganism which has been specially bred for maximum production of product. Mutated organism are in use in the production of antibiotics such as penicillin.

Nucleotide base.--A structural chemical unit of DNA or RNA. Four nucleotide bases exist in DNA: Adenine, Cytosine, Guanine, and Thymine. They are essentially cyclic chemical structures containing nitrogen or oxygen within the ring to form a purine or pyrimidine system.

Oligonucleotides.--In commercial biotechnology, short segments of RNA or DNA.

Pesticide.--A descriptive term used to encompass all materials used for the control of animal or plant pests. These include insecticides, fungicides, herbicides and rodenticides.

Plasmid.--A self-replicating piece of DNA located within the cell away from the genetic strands of DNA in the nucleus. Plasmids are used to "clone" or produce multiple copies of DNA by attaching or inserting the DNA fragment of interest and allowing the plasmid to replicate, producing copies of the desired DNA fragment.

Recombinant DNA.--The hybrid DNA produced by joining pieces of DNA from different organisms.

Recombinant RNA.--The hybrid RNA produced by joining pieces of RNA from different organisms, one of which is a piece of virus RNA. The hybrid RNA structure is then used under appropriate conditions to produce proteins. It is believed that recombinant RNA could be more efficient in processes for production of some products such as interferon rather than using processes involving recombinant DNA.

Restriction enzyme.--Enzymes which have the ability to break chemical bonds between nucleotide bases in DNA.

Ribonucleic acid.--A polymer similar to DNA, made up of four nucleotide bases. Only one nucleotide base is different in the makeup of DNA.

Single-cell protein.--Cells, or protein extracts, or microorganisms grown in large quantities for use as human or animal protein supplements.

Vitamins.--Relatively complex organic compounds present in small and variable amounts in natural products, and essential in small amounts in the diet for life and growth.

Source: The Condensed Chemical Dictionary 10th Edition, Van Nostrand Reinhold Co., New York, NY, 1981; Dictionary of Scientific and Technical Terms, McGraw-Hill Book Co., New York, NY, 1974, and Commercial Biotechnology: An International Analysis, Office of Technology Assessment, January 1984.

APPENDIX B

COMMISSION'S NOTICE OF INVESTIGATION

[Inv. No. 332-174]

International Developments in Biotechnology and Their Possible Impact on Certain Sectors of the U.S. Chemical Industry

AGENCY: United States International Trade Commission.

ACTION: In accordance with the provisions of section 332(b) of the Tariff Act of 1930 (19 U.S.C. 1332(b)), the Commission has instituted on its own motion investigation No. 332-174 for the purpose of gathering and presenting information on international developments in biotechnology. The information will be used in assessing the competitiveness of biotechnologically produced products in world markets, the current status of the industry, future trends, and certain other areas relevant to the investigation. The possible future impact of biotechnology on U.S. chemical trade will be analyzed.

Background

Biotechnology is a rapidly growing field of expertise which is on the leading edge of the high technology industries. The exchange and licensing of developed fermentation and other biologically oriented processes is growing. The potential exists that products produced by biotechnological processes will impact future trade, particularly in chemicals. Certain drugs and related products, enzymes, ferments, amino acids, biologicals, and alcohols, that are already large items of trade, may in the future be made by new biotechnological processes more expensively, purer, or both, which could alter current trade patterns.

EFFECTIVE DATE: January 3, 1984.

FOR FURTHER INFORMATION CONTACT: Mr. David G. Michels or Mr. Jack Greenblatt, Energy and Chemicals Division, U.S. International Trade Commission, Washington, D.C. 20436 (telephone 202-523-0293, 202-523-1212 respectively).

Written Submissions

While there is no public hearing scheduled for this study, written submissions from interested parties are invited. Commercial or financial information which a party desires the Commission to treat as confidential must be submitted on separate sheets of paper, each clearly marked "Confidential Business Information" at the top. All submissions requesting confidential treatment must conform with the requirements of § 201.6 of the Commission's *Rules of Practice and Procedure* (19 CFR 201.6). All written submissions, except for confidential business information, will be made available for inspection by interested parties. To be ensured of consideration by the Commission, written statements should be received by the close of business on April 30, 1984. All submissions should be addressed to the Secretary at the Commission's office in Washington, D.C.

Issued: January 4, 1984.

By order of the Commission.

Kenneth R. Mason,

Secretary.

[FR Doc. 84-716 Filed 1-10-84; 8:45 am]

BILLING CODE 7020-02-M

APPENDIX C

STATISTICAL TABLES

Table C-1.--Certain drugs and related products: U.S. shipments, exports of domestic merchandise, imports for consumption, and apparent consumption, 1979-83

Year	Shipments	Exports	Imports	Apparent consumption	Ratio of imports to consumption
	1,000 dollars				Percent
1979	4,757,682	1,034,777	334,079	4,056,984	8.2
1980	5,543,577	1,265,631	358,323	4,636,269	7.7
1981	6,101,265	1,379,582	475,480	5,197,163	9.1
1982	6,814,604	1,474,879	438,006	5,777,731	7.6
1983	7,598,000	1,568,660	511,958	6,541,298	7.8

Source: Shipments, estimated by the staff of the U.S. International Trade Commission; imports and exports, compiled from official statistics of the U.S. Department of Commerce.

Table C-2.--Certain drugs and related products: U.S. imports for consumption, by principal sources, 1979-83

(In thousands of dollars)

Source	1979	1980	1981	1982	1983
Japan	68,313	74,358	93,376	78,633	102,669
West Germany	51,141	44,023	63,802	54,569	80,449
United Kingdom	44,273	31,327	41,598	33,255	65,803
France	22,599	25,779	34,527	32,129	44,827
Italy	32,991	37,769	65,198	67,441	44,452
Switzerland	21,417	24,482	30,971	37,601	35,775
Netherlands	9,884	9,583	15,023	11,230	14,026
Bahamas	7,135	13,031	13,580	13,037	13,440
All other	76,325	97,970	117,404	110,112	110,517
Total	334,079	358,323	475,480	438,006	511,958

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-3.--Certain drugs and related products: U.S. exports of domestic merchandise, by principal markets, 1979-83

(In thousands of dollars)

Market	1979	1980	1981	1982	1983
Japan	187,446	249,581	314,341	370,318	383,156
France	99,758	116,789	130,766	127,917	132,630
Belgium and Luxembourg	95,300	122,676	108,003	103,935	103,954
Canada	69,090	82,194	81,623	94,859	103,659
West Germany	60,915	94,072	87,902	93,621	91,222
United Kingdom	47,722	52,943	59,470	65,396	81,592
Italy	60,014	64,046	83,504	66,980	78,933
Switzerland	31,850	42,496	43,781	46,264	76,691
All other	382,684	440,835	470,194	505,591	516,824
Total	1,034,777	1,265,631	1,379,582	1,474,879	1,568,660

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-4.--Antibiotics: U.S. shipments, exports of domestic merchandise, imports for consumption, and apparent consumption, 1979-83

Year	Shipments	Exports	Imports	Apparent consumption	Ratio of imports to consumption
	1,000 dollars				Percent
1979	1,514,109	525,865	115,571	1,103,815	10.5
1980	1,846,425	635,838	122,281	1,332,868	9.2
1981	2,091,145	713,197	181,114	1,559,062	11.6
1982	2,492,590	728,757	162,354	1,926,187	8.4
1983	2,866,000	779,607	188,741	2,275,134	8.3

Source: Shipments, estimated by the staff of the U.S. International Trade Commission; imports and exports, compiled from official statistics of the U.S. Department of Commerce.

Table C-5.--Antibiotics: U.S. imports for consumption, by principal sources, 1979-83

(In thousands of dollars)

Source	1979	1980	1981	1982	1983
Italy	30,955	35,718	62,680	65,111	41,616
West Germany	5,046	6,076	21,374	22,394	36,393
Japan	9,299	11,025	15,949	17,890	31,236
United Kingdom	27,485	16,648	23,967	13,151	30,362
Portugal	3,964	2,628	2,207	4,361	4,996
Switzerland	1,959	4,336	4,548	5,438	4,571
France	1,079	1,404	4,080	3,187	4,136
Brazil	3,243	4,596	3,969	3,147	3,918
All other	32,540	39,851	42,340	27,675	31,514
Total	115,571	122,281	181,114	162,354	188,741

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-6.--Antibiotics: U.S. exports of domestic merchandise, by principal markets, 1979-83

(In thousands of dollars)

Market	1979	1980	1981	1982	1983
Japan	100,277	122,761	150,235	157,455	169,575
France	72,080	84,674	91,323	101,890	94,341
Belgium and Luxembourg	37,492	54,742	54,095	47,500	50,627
Italy	40,859	43,000	56,227	37,011	49,441
United Kingdom	23,812	25,717	32,368	33,729	40,095
Canada	28,638	35,996	35,395	38,070	38,423
Switzerland	12,670	23,732	25,099	26,111	38,075
West Germany	12,733	20,642	23,641	29,227	28,839
All other	197,303	224,575	244,906	257,764	270,192
Total	525,865	635,838	713,197	728,757	779,607

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-7.--Antibiotics: British imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	28,690	26,987	33,301	29,077
France	2,609	4,913	23,485	25,846
Switzerland	1,427	911	2,941	4,767
Italy	1,950	3,507	2,747	4,402
Denmark	1,055	1,012	2,275	3,480
Netherlands	2,844	2,315	2,438	2,862
West Germany	4,688	1,545	3,069	2,558
Japan	795	106	113	1,606
All other	13,872	11,982	9,743	6,613
Total	57,930	53,278	80,112	81,211
	Exports			
United States	21,774	19,020	17,060	44,993
Italy	27,630	27,169	35,079	24,103
Japan	5,918	6,112	9,707	23,828
France	7,947	8,274	14,395	15,026
Switzerland	809	1,947	2,187	8,682
Belgium and Luxembourg	6,396	13,410	7,083	7,687
West Germany	18,852	21,401	11,251	6,237
Mexico	5,425	7,447	5,454	5,185
All other	65,026	82,772	79,915	75,446
Total	159,777	187,552	182,131	211,187

Source: Compiled from official statistics of the United Nations.

Table C-8.--Antibiotics: Canadian imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	30,850	29,887	26,593	27,350
United Kingdom	5,477	4,875	5,056	5,225
Italy	3,048	4,133	3,034	2,779
Japan	380	527	786	869
China	325	768	716	781
Spain	121	418	739	779
West Germany	1,358	966	1,282	698
Switzerland	72	145	55	554
All other	4,122	4,909	5,207	3,551
Total	45,753	46,628	43,468	42,586
	Exports			
Belgium and Luxembourg	-	69	167	285
Taiwan	-	-	-	223
United States	113	109	354	163
Venezuela	8	-	-	31
Australia	-	-	196	13
Mexico	48	-	-	10
All other	13	121	154	4
Total	182	299	871	729

Source: Compiled from official statistics of the United Nations.

Table C-9.--Antibiotics: French imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	79,922	93,217	93,616	98,083
Italy	49,632	53,169	48,015	32,798
Japan	8,269	10,773	16,781	15,135
Belgium and Luxembourg	17,463	18,129	17,980	14,068
United Kingdom	8,604	7,085	10,635	8,071
West Germany	4,533	2,974	8,652	7,571
Ireland	382	41	2,886	7,342
Austria	7,212	7,380	2,274	4,224
All other	14,025	17,859	18,214	20,049
Total	190,042	210,627	219,053	207,341
	Exports			
United Kingdom	1,962	2,271	14,404	28,183
Italy	10,197	11,238	20,518	16,258
United States	1,194	1,214	3,935	11,553
West Germany	3,301	4,653	9,930	8,047
Japan	1,572	317	291	4,905
Spain	2,749	4,942	2,694	4,436
Switzerland	457	1,135	6,370	4,355
Morocco	4,027	3,787	3,224	3,302
All other	30,640	31,501	31,565	21,687
Total	56,099	61,058	92,931	102,726

Source: Compiled from official statistics of the United Nations.

Table C-10.--Antibiotics: Italian imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	41,888	52,413	59,726	41,767
United Kingdom	27,641	36,392	41,358	34,577
West Germany	4,605	10,981	16,814	19,980
France	11,574	14,567	20,219	17,274
Japan	5,949	4,948	4,042	7,720
Sweden	51	5,318	7,850	5,582
Switzerland	12,015	8,950	7,123	4,733
Belgium and Luxembourg	1,284	2,613	1,724	3,425
All other	13,745	13,445	12,537	18,221
Total	118,752	149,627	171,393	153,279
	Exports			
Switzerland	51,019	50,993	46,106	38,878
France	43,895	48,192	40,573	32,017
Japan	18,772	25,315	20,875	21,008
West Germany	22,418	24,963	19,244	20,576
Spain	11,289	10,667	17,346	16,722
United States	21,011	22,148	20,099	11,486
Greece	7,424	9,501	7,814	8,138
Indonesia	3,409	5,132	6,244	7,759
All Other	82,723	97,604	104,774	111,958
Total	261,960	294,515	283,075	268,542

Source: Compiled from official statistics of the United Nations.

Table C-11.--Antibiotics: Japanese imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	105,731	122,405	141,311	163,309
Singapore	53,347	67,723	60,430	61,930
Italy	38,106	48,626	35,206	34,513
Ireland	15,925	14,481	18,259	19,521
Spain	10,198	14,876	21,021	14,766
Thailand	9,470	9,241	9,763	7,683
Sweden	29	43	36	5,500
Switzerland	12,111	10,604	5,613	3,216
All other	18,499	18,376	21,886	34,497
Total	263,416	306,375	313,525	344,935
	Exports			
France	5,916	10,091	13,642	13,733
Republic of Korea	6,834	4,806	6,537	10,031
Italy	1,749	1,989	2,008	6,426
United States	2,867	3,334	5,566	5,266
Belgium and Luxembourg	6,053	4,888	7,414	4,919
West Germany	2,948	7,416	3,199	3,674
Tiawan	2,383	2,262	2,042	2,938
Indonesia	1,142	1,894	2,143	2,806
All other	24,900	27,401	29,731	25,840
Total	54,792	64,081	72,282	75,633

Source: Compiled from official statistics of the United Nations.

Table C-12.--Antibiotics: Swiss imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Italy	19,790	31,752	36,499	31,811
United States	6,124	9,090	10,054	9,709
United Kingdom	502	1,257	394	7,229
Austria	163	159	525	2,603
West Germany	2,775	8,444	11,545	2,048
Japan	465	1,251	3,067	1,896
China	1,622	2,890	2,409	1,513
France	331	541	2,110	726
All other	2,922	4,172	2,686	2,326
Total	34,694	59,556	69,289	59,861
	Exports			
Italy	10,739	10,136	7,301	12,757
West Germany	12,389	16,990	13,126	7,279
United States	3,370	5,029	5,502	3,621
Japan	11,439	9,776	5,841	2,700
Pakistan	-	2,039	3,507	2,591
India	50	1,452	2,725	2,232
Philippines	494	829	1,967	1,653
Taiwan	1,952	2,882	2,403	1,581
All Other	11,226	15,700	21,187	13,375
Total	51,659	64,833	63,559	47,789

Source: Compiled from official statistics of the United Nations.

Table C-13.--Antibiotics: West German imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
France	5,041	10,771	50,690	46,599
Netherlands	37,065	43,615	38,127	29,732
United States	12,476	21,605	20,471	26,921
Italy	21,248	26,976	20,770	12,181
United Kingdom	18,147	19,346	10,877	8,948
China	2,339	10,973	6,565	8,101
Switzerland	14,394	17,379	12,382	7,322
Japan	3,181	4,317	6,199	6,684
All other	26,808	10,305	17,966	17,902
Total	140,699	165,287	184,047	164,390
	Exports			
Italy	3,635	11,036	16,881	19,062
France	4,857	3,823	6,298	9,884
United States	1,659	3,919	5,532	7,296
Austria	4,731	7,114	3,911	4,483
Indonesia	2,061	3,585	2,214	3,758
Spain	687	1,592	3,383	3,439
Netherlands	3,148	2,408	2,708	2,949
Ireland	744	255	360	2,831
All other	35,552	56,714	46,321	35,333
Total	57,074	90,446	87,608	89,035

Source: Compiled from official statistics of the United Nations.

Table C-14.--Biological products: U.S. shipments, exports of domestic merchandise, imports for consumption, and apparent consumption, 1979-83

Year	Shipments	Exports	Imports	Apparent consumption	Ratio of imports to consumption
	1,000 dollars				Percent
1979	1,196,000	275,278	9,332	930,054	1.0
1980	1,425,000	366,187	15,292	1,074,105	1.4
1981	1,545,000	359,294	28,838	1,214,544	2.4
1982	1/ 1,715,000	425,700	33,881	1,323,181	2.6
1983	1/ 1,920,000	430,286	47,649	1,537,363	3.1

1/ Estimated.

Source: Compiled from official statistics of the U.S. Department of Commerce, except as noted.

Table C-15.--Biological products: U.S. imports for consumption, by principal sources, 1979-83

(In thousands of dollars)

Source	1979	1980	1981	1982	1983
Switzerland	4,046	4,450	7,851	11,714	7,965
Canada	2,480	3,821	4,104	7,115	7,237
United Kingdom	185	1,233	3,957	4,388	6,336
Sweden	40	899	1,996	1,545	5,534
France	702	1,644	2,092	2,466	3,997
Austria	249	75	227	61	3,001
Ireland	-	15	14	8	2,372
West Germany	635	942	1,543	735	2,370
All other	996	2,214	7,054	5,848	8,837
Total	9,332	15,292	28,838	33,881	47,649

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-16.--Biological products: U.S. exports of domestic merchandise, by principal markets, 1979-83

(In thousands of dollars)

Market	1979	1980	1981	1982	1983
Japan	62,444	97,886	127,280	163,363	141,918
West Germany	38,180	58,600	53,478	53,575	53,173
Switzerland	14,514	13,541	12,156	12,550	32,526
Belgium and Luxembourg	36,606	43,294	31,900	33,939	30,227
Canada	16,635	20,438	17,494	26,732	27,616
Austria	18,825	22,055	16,629	24,554	25,052
Italy	12,531	13,574	17,463	19,468	21,050
United Kingdom	6,001	6,945	8,414	9,276	11,405
All other	69,541	89,853	74,480	82,243	87,320
Total	275,278	366,187	359,294	425,700	430,286

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-17.--Biologicals: British imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Netherlands	4,083	4,511	7,699	6,895
United States	1,970	2,231	3,304	3,347
Belgium and Luxembourg	1,012	2,427	2,787	1,864
New Zealand	1,370	3,519	1,727	1,708
France	1,322	2,485	2,864	1,451
West Germany	2,103	3,010	1,619	1,151
Denmark	196	237	239	299
Israel	146	209	278	275
All Other	744	1,536	2,008	560
Total	12,946	20,165	22,525	17,550
	Exports			
West Germany	2,187	4,106	2,884	2,892
Netherlands	3,493	4,541	3,824	2,762
Ireland	3,935	3,277	2,648	2,124
Belgium and Luxembourg	2,454	4,419	2,160	1,871
Switzerland	1,314	2,183	2,253	1,478
France	639	1,710	1,628	1,645
Saudi Arabia	997	432	433	1,278
Italy	660	682	845	1,129
All Other	17,990	23,139	18,767	19,141
Total	33,669	44,489	35,442	34,320

Source: Compiled from official statistics of the United Nations.

Table C-18.--Biologicals: Canadian imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	12,279	15,168	13,313	14,559
Switzerland	6	17	23	1,069
United Kingdom	443	491	816	683
New Zealand	47	45	50	148
Sweden	36	89	7	52
Spain	-	14	167	38
Japan	-	-	4	20
Netherlands	8	12	1	10
All other	1,343	2,170	2,915	2,010
Total	14,162	18,006	17,296	18,589
	Exports			
Japan	2,386	7,114	7,763	8,182
France	4,553	3,307	6,101	7,118
United States	4,831	5,065	4,061	5,243
Spain	1,893	4,377	4,507	1,662
Taiwan	173	440	765	1,096
Switzerland	198	107	360	991
Italy	1,580	1,546	1,581	832
Hong Kong	339	316	392	714
All other	7,466	7,625	9,349	8,986
Total	23,419	29,897	34,879	34,824

Source: Compiled from official statistics of the United Nations.

Table C-19.--Biologicals: French imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Netherlands	2,531	3,063	2,678	2,734
United States	1,437	2,458	866	1,959
West Germany	873	739	1,532	1,164
United Kingdom	801	1,083	1,194	798
Denmark	270	361	410	625
Belgium and Luxembourg	402	462	414	547
Sweden	680	558	573	515
Italy	167	163	199	353
All other	1,340	937	1,178	1,272
Total	8,501	9,824	9,044	9,967
	Exports			
West Germany	4,819	6,976	7,564	7,841
Belgium and Luxembourg	2,595	3,992	1,843	3,276
Switzerland	2,484	2,701	2,186	2,443
Sandi Arabia	1,992	3,954	2,670	2,262
United States	982	1,402	2,344	2,191
Morocco	2,178	3,123	1,698	1,775
Republic of Korea	53	135	1,452	1,679
Ivory Coast	1,893	2,816	1,756	1,650
All Other	35,430	42,179	47,338	36,019
Total	52,426	67,278	68,851	59,136

Source: Compiled from official statistics of the United Nations.

Table C-20.--Biologicals: Italian imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	4,379	3,663	3,651	5,285
Switzerland	4,778	3,156	4,507	4,085
Netherlands	1,223	1,401	996	1,123
France	562	1,023	1,575	929
West Germany	130	795	604	748
United Kingdom	327	335	587	484
Austria	1,031	1,337	1,197	443
Belgium and Luxembourg	3	-	3	245
All other	435	579	433	311
Total	12,868	12,289	13,553	13,653
	Exports			
United States	335	332	429	648
Switzerland	194	144	211	541
Argentina	-	68	177	381
Spain	495	393	447	341
Egypt	21	98	58	287
Chile	-	14	99	280
Israel	218	164	61	275
France	295	288	217	274
All Other	2,929	3,773	4,154	3,846
Total	4,487	5,274	5,853	6,873

Source: Compiled from official statistics of the United Nations.

Table C-21.--Biologicals: Japanese imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	1,290	1,740	3,203	13,753
West Germany	2,097	2,246	2,675	3,046
United Kingdom	110	30	136	2,696
Taiwan	2	6	57	872
Netherlands	789	822	737	495
India	-	-	21	394
France	99	225	48	342
Denmark	258	262	240	336
All other	646	633	1,031	1,036
Total	5,291	5,964	8,148	22,970
	Exports			
Saudi Arabia	51	59	321	493
Republic of South Africa	293	314	543	483
Republic of Korea	170	180	210	369
Taiwan	367	354	321	347
Egypt	101	198	119	219
Pakistan	110	102	46	161
Philippines	29	78	90	145
Burma	48	84	66	123
All other	1,679	1,729	1,959	745
Total	2,848	3,098	3,675	3,085

Source: Compiled from official statistics of the United Nations.

Table C-22.--Biologicals: Swiss imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	5,714	3,996	4,963	4,807
France	2,114	3,148	2,781	3,527
West Germany	2,080	2,025	1,743	1,709
Netherlands	298	433	450	1,651
United Kingdom	900	1,191	886	808
Italy	204	158	212	736
Republic of South Africa	755	1,034	74	666
Canada	200	220	324	567
All other	875	989	1,131	867
Total	13,140	13,194	12,564	15,338
	Exports			
Italy	5,983	8,434	5,148	4,120
Portugal	2,224	2,669	2,669	3,234
Saudi Arabia	1,133	2,192	1,522	1,864
Greece	1,526	1,546	1,654	1,524
Venezuela	1,129	1,269	1,206	1,149
West Germany	652	1,690	852	1,111
Spain	1,664	933	655	866
United States	287	911	1,021	795
All other	10,720	9,838	15,672	10,899
Total	25,318	29,482	30,399	25,562

Source: Compiled from official statistics of the United Nations.

Table C-23.--Biologicals: West German imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	5,392	9,420	8,127	7,811
France	3,189	5,637	3,916	3,655
Austria	4,840	2,983	2,682	3,261
United Kingdom	866	1,952	1,812	2,601
Netherlands	1,862	1,763	1,847	2,370
Switzerland	585	1,647	1,722	1,210
Japan	728	691	850	720
Denmark	385	476	430	567
All Other	1,875	2,160	1,787	1,002
Total	19,722	26,729	23,173	23,197
	Exports			
Italy	4,110	2,881	2,162	2,398
France	3,128	1,762	2,261	2,181
Greece	2,156	2,223	2,126	1,935
Belgium and Luxembourg	2,288	1,880	1,419	1,796
Algeria	847	2,204	2,093	1,718
Austria	2,483	2,003	1,592	1,337
Switzerland	2,020	1,860	1,484	1,327
Spain	940	748	1,130	1,236
All other	20,023	18,612	14,460	12,099
Total	37,995	34,173	28,727	26,027

Source: Compiled from official statistics of the United Nations.

Table C-24.--Hormones: U.S. shipments, exports of domestic merchandise, imports for consumption, and apparent consumption, 1979-83

Year	Shipments	Exports	Imports	Apparent consumption	Ratio of imports to consumption
	1,000 dollars				Percent
1979	906,843	168,639	53,776	791,980	6.8
1980	977,635	188,860	59,568	848,333	7.0
1981	1,120,840	213,240	74,345	981,945	7.6
1982	1,279,968	209,405	85,294	1,155,857	7.4
1983	1,472,000	217,952	88,049	1,342,097	6.6

Source: Shipments, estimated by the staff of the U.S. International Trade Commission; imports and exports, compiled from official statistics of the U.S. Department of Commerce.

Table C-25.--Hormones: U.S. imports for consumption, by principal sources, 1979-83

(In thousands of dollars)

Source	1979	1980	1981	1982	1983
United Kingdom	7,751	4,967	6,472	10,644	21,135
France	8,560	9,765	12,485	10,920	16,434
Bahamas	7,135	13,031	13,579	13,037	13,435
Mexico	1,958	2,264	6,054	9,790	9,982
Netherlands	5,136	4,525	7,369	6,879	8,129
West Germany	3,701	3,113	5,135	3,295	5,024
Sweden	1,083	1,271	1,034	2,560	2,944
Denmark	8,923	9,311	13,504	16,197	2,029
All other	9,529	11,321	8,714	11,973	8,938
Total	53,776	59,568	74,345	85,294	88,049

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-26.--Hormones: U.S. exports of domestic merchandise, by principal markets, 1979-83

(In thousands of dollars)

Market	1979	1980	1981	1982	1983
Japan	22,596	26,138	31,263	34,976	31,766
France	17,352	18,568	31,672	18,556	31,553
United Kingdom	14,653	16,030	12,422	18,248	26,154
Belgium and Luxembourg	18,622	22,211	19,514	18,790	20,751
Indonesia	8,124	9,363	11,195	11,954	12,324
Canada	8,360	9,519	9,844	9,528	11,396
Italy	5,220	6,479	8,946	10,015	8,114
West Germany	7,694	8,725	9,386	9,105	7,080
All other	66,018	71,836	78,996	78,235	68,813
Total	168,639	188,870	213,240	209,405	217,952

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-27.--Hormones: British imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	18,189	19,692	9,526	16,896
France	3,075	6,584	6,442	4,460
Netherlands	4,051	1,962	4,628	3,902
Belgium and Luxembourg	3,238	2,739	3,467	3,703
Switzerland	2,097	2,136	4,049	2,642
Bahamas	193	445	1,785	1,110
West Germany	437	379	671	1,035
Italy	237	1,129	407	527
All other	5,629	1,535	866	583
Total	37,146	36,601	31,841	34,858
	Exports			
Japan	6,662	11,485	9,070	6,206
France	5,550	8,734	6,330	4,897
Italy	3,745	9,358	5,003	1,147
Canada	1,013	927	858	1,083
Republic of South Africa	552	891	1,196	1,074
Brazil	545	1,068	605	1,066
Portugal	394	851	1,494	947
Switzerland	5,028	2,965	522	849
All other	8,946	11,675	12,446	5,909
Total	32,435	47,954	37,524	23,178

Source: Compiled from official statistics of the United Nations.

Table C-28.--Hormones: Canadian imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	4,853	5,310	5,746	5,176
Bahamas	2,132	1,393	1,495	1,371
United Kingdom	1,227	1,179	1,400	1,164
Switzerland	407	374	442	459
France	624	496	405	261
West Germany	102	241	286	248
China	-	-	64	185
Argentina	-	-	-	117
All other	836	637	695	572
Total	10,181	9,630	10,533	9,553
	Exports			
United States	363	229	303	375
Belgium and Luxembourg	-	-	76	187
West Germany	243	168	239	72
Mexico	-	-	-	29
Italy	-	-	85	10
All other	56	-	90	6
Total	662	397	793	679

Source: Compiled from official statistics of the United Nations.

Table C-29.--Hormones: French imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Denmark	7,841	9,546	12,081	17,654
United States	6,999	12,602	15,845	15,130
Netherlands	8,758	7,713	10,501	11,840
United Kingdom	5,754	8,174	6,221	4,866
Switzerland	4,977	6,309	3,669	4,324
Bahamas	2,821	2,708	2,320	2,275
Italy	1,585	2,178	2,129	851
Spain	-	-	-	337
All other	10,955	11,663	10,812	10,929
Total	49,690	60,893	63,578	68,206
	Exports			
Belgium and Luxembourg	3,742	5,502	7,635	7,915
Netherlands	4,640	5,513	6,585	6,599
United States	2,131	5,042	6,630	5,879
West Germany	9,563	6,687	6,908	5,769
Italy	3,126	2,824	1,985	2,823
Spain	1,418	1,301	1,272	1,068
Japan	976	1,066	1,388	983
Brazil	906	1,533	739	796
All other	9,675	7,392	9,373	6,650
Total	36,177	36,860	42,515	38,482

Source: Compiled from official statistics of the United Nations.

Table C-30.--Hormones: Italian imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
West Germany	21,693	25,145	19,929	23,913
United States	5,796	5,998	7,141	7,156
Switzerland	5,006	6,422	5,906	6,410
France	10,317	8,075	6,468	6,131
Netherlands	8,145	5,082	4,365	5,597
Belgium and Luxembourg	3,879	1,636	2,656	3,915
United Kingdom	5,209	3,145	2,500	1,893
Republic of Korea	93	1,089	983	1,395
All other	3,526	3,884	1,573	2,362
Total	63,664	60,476	51,521	58,772
	Exports			
Switzerland	13,770	3,906	3,655	8,284
West Germany	3,853	3,268	3,179	4,987
Poland	1,799	2,092	557	1,406
United States	1,983	1,087	1,147	1,276
France	1,412	1,842	1,440	1,243
Argentina	1,131	817	1,103	1,242
United Kingdom	324	717	1,114	1,088
India	773	716	597	911
All other	11,537	10,178	10,737	11,731
Total	36,582	24,623	23,529	32,168

Source: Compiled from official statistics of the United Nations.

Table C-31.--Hormones: Japanese imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	15,947	17,203	18,827	21,584
Bahamas	15,546	14,371	12,711	10,023
United Kingdom	6,305	6,101	5,171	4,826
Netherlands	6,792	6,394	4,636	4,380
France	2,750	2,891	2,903	3,074
Italy	1,665	1,541	1,952	2,690
China	452	1,825	1,952	1,094
Portugal	1,742	1,493	1,104	1,078
All other	3,747	4,437	3,713	2,978
Total	54,946	56,256	52,969	51,727
	Exports			
United States	582	817	721	453
Spain	3	68	69	172
West Germany	30	29	1	170
Hungary	233	612	434	168
Netherlands	212	-	11	93
Thailand	38	41	28	83
Ireland	226	246	91	82
Mexico	-	20	258	61
All other	835	590	359	165
Total	2,159	2,423	1,972	1,447

Source: Compiled from official statistics of the United Nations.

Table C-32.--Hormones: Swiss imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Italy	3,292	3,325	2,786	5,134
West Germany	1,343	2,983	2,924	3,583
Israel	10	11	1,127	1,486
Ireland	109	1	193	1,025
Netherlands	788	1,147	686	803
France	511	512	662	791
China	695	137	514	737
Spain	20	-	12	510
All other	3,160	2,915	2,238	1,524
Total	9,928	11,031	11,142	15,593
	Exports			
Italy	4,814	9,121	8,619	10,927
Belgium and Luxembourg	1,979	1,953	1,960	1,850
Brazil	3,530	2,702	2,284	1,681
Spain	1,912	2,181	1,649	1,574
United States	600	766	926	1,312
Japan	189	315	935	1,265
France	1,842	1,935	1,509	1,173
Yugoslavia	1,311	1,357	1,920	992
All other	12,128	12,508	10,250	9,590
Total	28,305	32,838	30,052	30,364

Source: Compiled from official statistics of the United Nations.

Table C-34.--Vitamins: U.S. shipments, exports of domestic merchandise, imports for consumption, and apparent consumption, 1979-83

Year	Shipments	Exports	Imports	Apparent consumption	Ratio of imports to consumption
	1,000 dollars				Percent
1979	1,140,730	64,994	155,400	1,231,136	12.6
1980	1,294,517	74,736	161,182	1,380,963	11.7
1981	1,344,280	93,851	191,182	1,441,611	13.3
1982	1,327,046	111,017	156,478	1,372,507	11.4
1983	1,340,000	140,815	187,518	1,386,703	13.5

Source: Shipments, estimated by the staff of the U.S. International Trade Commission; imports and exports, compiled from official statistics of the U.S. Department of Commerce.

Table C-35.--Vitamins: U.S. imports for consumption, by principal sources, 1979-83

(In thousands of dollars)

Source	1979	1980	1981	1982	1983
Japan	57,881	61,781	75,394	58,814	69,059
West Germany	41,760	33,892	35,751	28,145	36,662
Switzerland	14,731	15,224	18,298	19,920	22,355
France	12,258	12,967	15,870	15,555	20,260
China	-	2,715	8,548	7,254	10,535
United Kingdom	8,852	8,479	7,202	5,072	7,970
Denmark	9,793	13,349	16,481	8,973	6,338
Yugoslavia	452	1,123	2,352	3,936	3,645
All other	9,674	11,651	11,286	8,808	10,695
Total	155,400	161,182	191,182	156,478	187,518

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-33.--Hormones: West German imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
France	16,013	16,139	10,714	8,790
United States	6,187	5,063	6,241	7,055
Italy	3,623	3,373	2,037	5,039
Mexico	938	1,621	5,255	2,935
Bahamas	3,616	5,133	3,035	2,896
Argentina	651	147	3,996	2,829
Netherlands	4,681	2,536	1,907	1,817
Switzerland	2,566	1,604	1,923	786
All other	3,402	3,874	2,997	4,369
Total	41,677	39,490	38,105	36,516
	Exports			
Italy	21,159	20,779	19,175	19,535
Spain	13,736	12,350	12,017	11,712
France	6,004	9,959	9,082	8,838
Switzerland	1,900	2,916	3,250	5,890
Egypt	904	2,441	2,925	4,816
Indonesia	1,790	2,445	2,092	3,737
Brazil	8,518	6,016	4,282	3,705
United States	4,086	2,734	2,656	2,943
All other	38,953	44,845	38,473	38,067
Total	97,051	104,485	93,952	99,243

Source: Compiled from official statistics of the United Nations.

Table C-37.--Vitamins: British imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Switzerland	14,667	12,324	12,413	14,636
West Germany	9,045	7,481	8,942	7,434
Denmark	3,892	3,272	2,803	4,645
France	1,919	1,560	2,968	2,551
Netherlands	1,154	1,464	768	1,668
United States	1,555	2,337	2,216	1,332
Japan	1,934	1,295	1,335	1,280
Ireland	441	461	321	969
All other	1,871	2,781	1,483	1,746
Total	36,478	32,975	33,249	36,261
	Exports			
Switzerland	5,178	8,036	7,322	5,886
Japan	3,440	2,287	3,268	4,897
United States	6,272	7,316	5,848	4,593
France	6,808	7,696	4,565	4,444
Italy	3,500	2,220	3,243	2,751
West Germany	3,733	2,014	2,787	2,017
Brazil	1,918	2,036	1,569	1,998
Sweden	140	163	153	1,259
All other	18,204	13,218	10,766	11,405
Total	49,193	44,986	39,521	39,250

Source: Compiled from official statistics of the United Nations.

Table C-36.--Vitamins: U.S. exports of domestic merchandise, by principal markets, 1979-83

(In thousands of dollars)

Market	1979	1980	1981	1982	1983
Japan	2,128	2,796	5,563	14,524	39,896
Canada	15,456	16,240	18,890	20,529	26,223
Australia	2,842	3,390	4,048	5,626	8,406
Switzerland	2,027	2,615	3,110	3,646	4,121
Brazil	943	626	1,389	3,166	4,039
United Kingdom	3,255	4,251	6,264	4,144	3,939
Saudi Arabia	4,234	4,070	8,569	13,768	3,819
Netherlands	3,154	2,362	3,706	3,555	3,557
All other	30,955	38,386	42,312	42,059	46,815
Total	64,994	74,736	93,851	111,017	140,815

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-38.--Vitamins: Canadian imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	9,838	11,483	12,607	10,608
Switzerland	6,125	4,084	6,397	7,181
West Germany	2,040	1,368	1,324	2,904
Japan	2,343	4,141	4,174	2,050
France	975	787	418	402
China	254	352	177	397
Denmark	1,634	1,987	1,136	342
United Kingdom	243	679	253	241
All other	549	160	761	612
Total	24,001	25,041	27,247	24,737
	Exports			
United States	561	810	1,162	1,107
Jamaica	22	2	-	72
West Germany	47	91	16	41
Portugal	11	19	-	35
Italy	-	-	-	24
All other	119	55	86	18
Total	760	977	1,264	1,297

Source: Compiled from official statistics of the United Nations.

Table C-39.--Vitamins: French imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Switzerland	36,297	38,797	34,283	36,207
West Germany	28,361	26,957	25,211	25,751
United Kingdom	5,102	6,065	4,687	4,817
Japan	4,302	4,430	3,717	4,356
Denmark	4,340	4,397	4,288	4,355
China	205	2,081	841	1,573
United States	1,204	1,798	1,181	1,551
Netherlands	1,527	1,780	1,555	1,004
All other	2,784	3,847	2,423	2,937
Total	84,122	90,152	78,186	82,551
	Exports			
Switzerland	13,340	14,965	15,693	15,591
United States	4,503	6,427	6,796	9,445
Italy	6,530	7,604	6,242	7,675
Japan	5,876	6,358	6,134	6,097
West Germany	4,901	5,559	6,166	5,157
United Kingdom	1,897	1,801	3,054	3,368
Spain	2,649	3,117	2,840	2,775
Netherlands	3,184	3,934	2,280	2,752
All other	22,475	27,226	27,984	26,757
Total	65,355	76,991	77,189	79,617

Source: Compiled from official statistics of the United Nations.

Table C-40.--Vitamins: Italian imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
France	11,227	14,416	7,144	7,633
West Germany	12,927	13,663	7,149	7,034
Denmark	4,189	5,628	3,976	3,397
Switzerland	9,490	7,905	3,525	2,743
United Kingdom	3,558	1,846	1,545	1,601
Netherlands	1,582	2,092	1,237	1,383
Japan	2,655	2,902	1,994	1,317
Spain	757	881	670	487
All other	2,493	2,361	2,083	1,128
Total	48,878	51,694	29,323	26,723
	Exports			
West Germany	593	588	741	787
Republic of South Africa	1,272	1,016	1,091	537
Argentina	253	495	320	528
Japan	348	298	723	499
Switzerland	248	244	205	352
France	496	431	555	297
Egypt	32	29	287	278
Greece	232	177	190	271
All other	2,361	3,104	3,959	2,147
Total	5,835	6,382	8,071	5,696

Source: Compiled from official statistics of the United Nations.

Table C-41.--Vitamins: Japanese imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
West Germany	11,258	11,155	11,868	15,730
United States	786	1,197	3,073	10,037
France	9,267	8,657	8,668	8,123
Switzerland	9,230	8,685	8,266	7,455
United Kingdom	3,357	2,639	3,156	5,274
Italy	643	370	679	609
Netherlands	316	130	235	207
Spain	245	263	270	186
All other	539	592	341	315
Total	35,641	33,688	36,556	47,936
	Exports			
United States	50,975	59,159	77,936	58,300
West Germany	13,787	16,164	14,587	12,996
Denmark	267	3,535	7,466	9,748
Switzerland	9,102	5,416	2,662	5,844
Indonesia	1,904	3,244	2,522	3,167
Australia	4,427	4,306	2,656	2,583
India	1,630	521	1,293	2,445
Brazil	4,128	5,096	3,941	2,182
All other	43,994	37,535	29,133	28,556
Total	130,214	134,976	142,196	125,821

Source: Compiled from official statistics of the United Nations.

Table C-42.--Vitamins: Swiss imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
West Germany	11,031	14,030	14,777	14,197
France	13,879	12,090	11,654	13,701
United Kingdom	4,936	7,506	11,475	12,439
Japan	10,554	10,701	4,586	8,723
United States	699	757	1,251	1,441
Netherlands	1,477	1,577	1,736	1,173
Denmark	446	149	373	310
Italy	115	164	189	211
All other	596	1,409	1,104	802
Total	43,733	48,383	47,145	52,997
	Exports			
France	34,079	33,253	27,955	28,335
West Germany	22,091	17,691	21,299	18,740
United States	12,835	14,338	16,024	16,551
Italy	12,085	10,831	13,722	13,405
Japan	13,987	11,415	11,125	9,304
United Kingdom	10,890	8,817	7,960	8,033
Hong Kong	6,168	7,238	6,802	6,924
Canada	4,490	3,705	4,609	5,924
All other	97,368	82,843	80,832	77,521
Total	213,993	190,131	190,328	184,737

Source: Compiled from official statistics of the United Nations.

Table C-43.--Vitamins: West German imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Switzerland	23,893	24,249	24,379	24,032
Japan	10,097	14,088	11,845	11,289
Denmark	12,493	9,344	8,553	8,464
France	6,860	6,414	6,836	5,671
China	767	5,325	2,915	4,832
United Kingdom	3,655	2,998	2,853	2,423
Netherlands	1,958	2,343	1,501	2,211
Yugoslavia	1,903	2,481	1,293	2,099
All other	4,515	3,985	5,047	5,333
Total	66,141	71,227	65,222	66,354
	Exports			
France	31,822	32,002	30,296	31,497
United States	35,077	35,941	40,048	28,198
Switzerland	17,588	21,027	19,666	17,272
Japan	15,472	13,449	13,787	16,993
Denmark	18,221	19,668	17,287	16,365
Italy	14,847	16,216	15,045	15,296
Belgium and Luxembourg	7,236	8,523	14,599	12,960
Spain	9,881	9,814	10,082	10,756
All other	112,330	116,592	109,364	103,398
Total	262,474	273,232	270,174	252,735

Source: Compiled from official statistics of the United Nations.

Table C-44.--Amino acids: U.S. production, exports of domestic merchandise, imports for consumption, and apparent consumption, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per pound)

Year	U.S. production 1/	Exports	Imports	Apparent consumption	Ratio (percent) of imports to consumption
	Quantity				
1979	74,223	6,175	55,953	124,001	45
1980	77,602	11,432	48,434	114,604	42
1981	86,946	15,310	54,125	125,761	43
1982	78,860	12,579	63,087	129,368	49
1983	95,641	10,053	71,355	156,938	45
	Value				
1979	84,615	16,548	86,093	154,160	56
1980	111,747	38,476	87,722	160,993	55
1981	116,508	48,172	100,722	169,058	60
1982	96,210	40,320	107,332	163,222	66
1983	119,551	37,793	125,783	207,541	61
	Unit value				
1979	$1.14	$2.68	$1.54	-	-
1980	1.44	3.37	1.81	-	-
1981	1.34	3.15	1.86	-	-
1982	1.22	3.21	1.70	-	-
1983	1.25	3.76	1.76	-	-

1/ Estimated by the staff of the U.S. International Trade Commission.

Source: Compiled from official statistics of the U.S. Department of Commerce, except as noted.

Table C-45.--Amino acids: U.S. imports for consumption, by principal sources, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per pound)

Source	1979	1980	1981	1982	1983
	Quantity				
Japan	15,128	11,152	19,577	22,380	25,187
France	31,859	29,361	26,065	31,252	33,434
Republic of Korea	5,969	6,181	7,199	8,283	9,088
Ireland	1	3	10	32	61
West Germany	159	238	506	562	1,434
Taiwan	300	493	121	169	1,093
Netherlands	450	334	78	88	115
Singapore	-	1/	-	-	27
All other	2,107	671	568	321	916
Total	55,973	48,434	54,125	63,087	71,355
	Value				
Japan	36,196	30,297	45,935	45,251	50,368
France	36,091	38,225	37,476	40,984	45,198
Republic of Korea	8,610	8,623	10,372	10,135	11,583
Ireland	14	5,997	2,484	5,263	10,031
West Germany	1,201	1,879	2,630	3,800	4,647
Taiwan	299	566	187	238	923
Netherlands	479	424	151	161	833
Singapore	-	7	-	-	404
All other	3,206	1,704	1,488	1,500	1,798
Total	86,093	87,722	100,722	107,332	125,783
	Unit value				
Japan	$2.39	$2.72	$2.35	$2.02	$2.00
France	1.13	1.30	1.44	1.31	1.35
Republic of Korea	1.44	1.39	1.44	1.22	1.27
Ireland	26.90	2,074.50	252.83	163.29	163.29
West Germany	7.56	7.88	5.19	6.76	3.24
Taiwan	1.00	1.15	1.54	1.40	0.84
Netherlands	1.06	1.27	1.94	1.82	7.24
Singapore	-	16.13	-	-	14.97
All other	1.52	1.81	1.86	1.70	1.76
Average	1.54	1.81	1.86	1.70	1.76

1/ Less than 500 pounds.

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-46.--Amino acids: U.S. exports of domestic merchandise, by principal markets, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per pound)

Market	1979	1980	1981	1982	1983
	Quantity				
Italy	288	345	434	568	609
Belgium and Luxembourg	1,064	5,184	4,575	3,434	3,577
West Germany	5	187	271	74	222
Japan	1,291	1,353	2,179	887	192
Hong Kong	-	-	163	869	1,685
Philippines	3	1	-	134	172
Canada	179	1,038	1,447	781	977
Mexico	1,233	745	764	790	396
All other	2,113	2,579	5,476	5,041	2,228
Total	6,175	11,432	15,310	12,579	10,058
	Value				
Italy	7,618	10,099	12,516	14,861	19,584
Belgium and Luxembourg	1,077	6,244	6,359	4,430	4,573
West Germany	57	771	984	1,230	2,676
Japan	2,073	11,024	12,478	5,747	1,866
Hong Kong	-	-	210	658	1,467
Philippines	9	2	-	140	1,276
Canada	166	944	1,926	1,805	1,115
Mexico	689	1,249	1,362	1,582	925
All other	4,859	8,143	12,338	9,867	4,311
Total	16,548	38,476	48,172	40,320	37,793
	Unit value				
Italy	$26.45	$29.25	$28.84	$26.17	$32.14
Belgium and Luxembourg	1.01	1.20	1.39	1.29	1.28
West Germany	1.89	4.21	3.63	16.62	12.04
Japan	1.61	8.14	5.73	6.48	9.71
Hong Kong	-	-	-	1.29	.67
Philippines	3.01	1.80	-	1.04	7.42
Canada	.93	.91	1.33	2.31	1.14
Mexico	.56	1.67	1.78	2.00	2.34
All other	2.30	3.16	2.25	1.96	1.93
Average	2.68	3.37	3.15	3.20	3.76

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-47.--Amino acids: Dutch imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	1,567	3,070	7,932	8,837
France	254	3,629	5,846	6,189
Switzerland	-	-	1,328	3,378
West Germany	2,667	2,311	1,980	2,491
Spain	619	719	693	1,731
Japan	1,100	1,220	1,492	1,365
United Kingdom	1,572	647	1,019	802
Italy	151	54	217	522
All other	4,231	2,258	2,461	452
Total	12,161	13,908	22,968	25,767
	Exports			
France	6,222	9,124	14,177	14,448
United Kingdom	13,005	7,316	8,754	9,764
West Germany	3,793	3,373	2,957	5,590
Spain	1,585	2,771	2,666	4,619
Italy	3,697	4,097	2,981	3,937
United States	4,308	2,666	4,285	3,363
Czechoslovakia	1,973	2,427	1,520	2,157
Belgium and Luxembourg	782	1,470	1,516	1,890
All other	21,202	16,414	17,135	17,236
Total	56,567	49,658	55,991	63,004

Source: Compiled from official statistics of the Government of the Netherlands.

Table C-48.--Amino acids: Japanese imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Puerto Rico	5,469	7,634	9,482	5,722
Taiwan	2,167	3,086	3,306	1,970
United States	2,410	797	2,122	3,099
Singapore	-	38	72	724
France	308	294	686	576
Hungary	576	1,359	675	516
Italy	165	66	427	445
West Germany	399	421	777	287
All other	946	515	232	447
Total	12,439	14,210	17,779	13,786
	Exports			
United States	23,677	21,442	35,140	39,921
West Germany	9,812	7,471	6,550	4,919
Switzerland	4,523	3,883	5,973	4,048
Taiwan	2,043	2,361	3,462	3,756
United Kingdom	2,699	3,541	4,165	3,055
Thailand	949	2,475	2,686	3,033
France	1,684	2,135	3,114	2,853
Spain	2,746	3,063	3,361	2,706
All other	34,809	42,800	40,553	36,126
Total	82,942	89,171	105,004	100,417

Source: Compiled from official statistics of the Government of Japan.

Table C-49.--Amino acids: Swiss imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
West Germany	21,489	21,817	12,799	15,624
Japan	-	8,744	1,747	11,749
France	8,305	9,341	7,383	5,844
Italy	2,345	2,871	1,745	3,315
United Kingdom	955	2,343	5,168	2,802
United States	5,472	5,177	4,013	2,613
Netherlands	644	383	12,835	1,687
Poland	804	990	1,200	661
All other	10,781	2,488	25,815	2,769
Total	50,795	54,154	72,705	47,064
	Exports			
France	29,002	38,626	7,875	43,010
Italy	14,517	22,920	2,707	38,265
West Germany	25,864	30,946	6,570	22,559
Japan	277	12,803	1,644	17,438
United Kingdom	24,724	21,298	4,350	15,666
United States	9,546	3,966	1,568	10,091
Yugoslavia	3,931	4,766	357	6,056
Spain	4,489	5,720	1,888	5,636
All other	51,068	35,134	9,206	39,495
Total	163,418	176,179	36,165	198,216

Source: Compiled from official statistics of the Government of Switzerland.

Table C-50.--Amino acids: West German imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
France	6,259	7,940	7,141	7,916
Netherlands	3,710	3,331	2,436	4,840
United Kingdom	1,399	2,386	1,258	2,525
Italy	1,069	578	1,439	909
United States	420	482	486	838
Switzerland	406	568	344	708
Japan	556	660	1,514	612
U.S.S.R	-	-	414	360
All other	840	736	1,876	705
Total	14,659	16,681	16,908	19,413
	Exports			
France	3,924	3,569	4,346	4,894
Italy	2,930	3,390	3,063	4,834
United Kingdom	2,422	1,731	1,832	2,078
Spain	1,662	1,481	1,752	1,976
Switzerland	1,496	1,485	1,762	1,907
Sweden	861	1,402	1,067	1,770
Japan	1,740	1,568	1,654	1,643
Netherlands	3,491	3,281	2,055	1,526
All other	9,282	9,366	11,013	11,528
Total	27,808	27,273	28,544	32,156

Source: Compiled from official statistics of the Government of West Germany.

Table C-51.--Enzymes: U.S. production, exports of domestic merchandise, imports for consumption, and apparent consumption, 1979-83

Year	U.S. production	Exports	Imports	Apparent consumption	Ratio of imports to consumption
	1,000 dollars				Percent
1979	30,430	30,686	53,410	53,154	100
1980	39,544	34,231	70,372	75,685	93
1981	45,768	37,548	83,388	91,608	91
1982	1/ 66,000	32,008	78,969	112,961	70
1983	1/ 69,300	32,599	92,080	128,781	72

1/ Estimated by the staff of the U.S. International Trade Commission.

Source: Production, Synthetic Organic Chemicals, United States Production and Sales, U.S. International Trade Commission, except as noted; imports and exports, compiled from official statistics of the U.S. Department of Commerce.

Table C-52.--Enzymes: U.S. imports for consumption, by principal sources, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per pound)

Source	1979	1980	1981	1982	1983
	Quantity				
Denmark	13,355	14,172	17,007	14,419	17,220
West Germany	2,420	4,762	3,764	1,947	1,770
Japan	458	433	483	587	697
Netherlands	618	185	477	1,508	2,052
Ireland	50	36	1,301	43	63
Belgium and Luxembourg	927	1,710	1,649	1,560	3,233
United Kingdom	66	229	156	379	257
Sweden	3	20	70	46	7
All other	1,015	1,196	1,343	1,213	1,600
Total	18,915	22,743	26,250	21,701	26,899
	Value				
Denmark	24,447	31,446	42,958	42,107	44,494
West Germany	8,811	14,909	11,032	8,622	10,228
Japan	4,926	5,086	6,897	7,264	7,606
Netherlands	1,727	672	806	3,390	5,279
Ireland	321	217	2,424	3,140	4,985
Belgium and Luxembourg	2,659	5,490	4,451	2,151	4,429
United Kingdom	2,998	3,410	4,574	4,247	3,386
Sweden	90	248	400	116	1,778
All other	7,431	8,894	9,845	7,032	9,894
Total	53,410	70,372	83,388	78,969	92,080
	Unit value				
Denmark	$1.83	$2.22	$2.53	$2.92	$2.58
West Germany	3.64	3.13	2.93	4.43	5.78
Japan	10.75	11.76	14.29	12.38	10.90
Netherlands	2.80	3.62	1.69	2.25	2.57
Ireland	6.38	6.08	1.86	72.43	79.41
Belgium and Luxembourg	2.87	3.21	2.70	1.38	1.37
United Kingdom	45.34	14.90	29.33	11.22	13.18
Sweden	35.03	12.18	5.69	2.54	241.37
All other	7.32	7.44	7.33	6.54	6.19
Average	2.82	3.09	3.18	3.64	3.42

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-53.--Enzymes: U.S. exports of domestic merchandise, by principal markets, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per pound)

Market	1979	1980	1981	1982	1983
	Quantity				
Canada	1,603	751	1,415	951	1,367
Netherlands	63	295	243	93	283
Japan	157	103	73	99	106
Italy	53	101	85	74	100
West Germany	81	93	199	147	149
France	260	140	200	1,333	225
Belgium and Luxembourg	131	205	111	534	754
United Kingdom	217	262	146	77	88
All other	1,435	1,781	1,498	1,349	1,509
Total	4,000	3,730	3,971	4,656	4,581
	Value				
Canada	4,127	3,957	7,591	6,077	7,480
Netherlands	204	2,865	2,370	946	3,403
Japan	2,034	1,801	2,115	1,899	3,167
Italy	1,654	2,159	2,426	2,312	2,548
West Germany	1,228	2,617	2,898	2,145	2,342
France	3,242	2,976	4,245	5,568	2,026
Belgium and Luxembourg	783	1,346	728	1,339	1,655
United Kingdom	2,380	2,181	1,931	1,326	1,480
All other	15,033	14,329	13,244	10,397	8,497
Total	30,686	34,231	37,548	32,008	32,599
	Unit value				
Canada	$2.57	$5.27	$5.37	$6.39	$5.47
Netherlands	3.23	9.71	9.75	10.19	12.01
Japan	12.93	17.54	28.90	19.27	29.99
Italy	30.93	21.44	28.41	31.40	25.53
West Germany	15.20	27.99	14.56	14.60	15.75
France	12.45	21.24	21.21	4.18	9.01
Belgium and Luxembourg	6.00	6.56	6.53	2.51	2.19
United Kingdom	10.97	8.34	13.26	17.25	16.84
All other	10.48	8.05	8.84	7.71	5.63
Total	7.67	9.18	9.46	6.87	7.12

Source: Compiled from official Statistics of the U.S. Department of Commerce.

Table C-54.--Enzymes: British imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Denmark	5,341	5,694	5,165	6,687
United States	2,949	3,467	2,864	2,643
Ireland	676	838	914	1,845
West Germany	437	729	790	811
Japan	276	233	227	496
India	78	167	338	443
France	793	764	625	352
Netherlands	183	343	146	129
All other	673	663	806	436
Total	11,406	12,898	11,875	13,842
	Exports			
United States	3,478	5,161	4,807	3,467
Ireland	1,413	1,661	2,091	1,306
France	908	913	513	985
West Germany	774	1,444	986	888
Italy	209	577	494	882
Pakistan	785	1,013	877	603
Netherlands	271	289	914	466
Denmark	289	390	615	380
All other	3,420	4,587	7,765	4,080
Total	11,547	16,035	19,062	13,057

Source: Compiled from official statistics of the United Nations.

Table C-55.--Enzymes: Canadian imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	3,624	3,714	5,476	4,906
Denmark	1,353	1,509	1,604	1,046
Republic of South Africa	171	76	27	157
Switzerland	113	155	151	111
Yugoslavia	11	31	22	17
Netherlands	56	-	23	15
West Germany	15	47	21	15
United Kingdom	221	1	-	12
All other	194	257	153	12
Total	5,758	5,790	7,477	6,291
	Exports 1/			
Japan	692	1,079	619	937
United States	572	748	1,240	602
Italy	-	-	-	37
Ireland	1	1	-	20
United Kingdom	1	2	2	7
Jamaica	108	26	34	-
Spain	-	14	29	2/ -
Republic of Korea	15	15	10	2/ -
All other	83	252	171	186
Total	1,471	2,137	2,105	2/ 1,789

1/ Figures were derived from corresponding imports by partner countries.
2/ Estimated.

Source: Compiled from official statistics of the United Nations.

Table C-56.--Enzymes: Danish imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
France	1,013	2,520	2,992	1,804
West Germany	663	766	791	1,338
United Kingdom	325	486	621	422
Italy	153	320	196	264
New Zealand	602	355	541	236
United States	102	87	94	135
Brazil	6	17	30	51
Argentina	282	661	834	44
All other	230	216	177	128
Total	3,376	5,428	6,276	4,422
	Exports			
United States	25,091	32,544	41,725	39,398
Japan	6,395	9,753	11,182	13,014
West Germany	14,497	17,402	13,654	10,812
France	4,601	5,756	7,062	7,886
Italy	6,948	7,483	7,002	7,823
Spain	6,692	8,204	7,625	7,607
United Kingdom	5,205	5,122	5,005	5,204
Republic of Korea	810	991	1,854	2,507
All other	35,559	34,500	35,228	32,949
Total	105,798	121,755	130,337	127,200

Source: Compiled from official statistics of the United Nations.

Table C-57.--Enzymes: Dutch imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Belgium and Luxembourg	1,985	2,135	2,844	2,163
Denmark	823	1,323	1,862	1,638
West Germany	1,598	1,625	993	875
France	452	767	463	719
United Kingdom	220	323	341	476
United States	291	324	407	283
Japan	320	233	377	154
Brazil	-	-	13	111
All other	90	243	18	38
Total	5,779	6,973	7,318	6,457
	Exports			
United States	1,586	2,208	2,770	3,624
Japan	951	835	1,172	1,053
France	539	1,490	1,032	699
Hungary	535	587	300	346
West Germany	786	1,097	626	280
Romania	194	1,178	277	268
Argentina	227	287	448	263
Switzerland	69	280	217	252
All other	2,237	2,360	1,040	1,614
Total	7,124	10,322	7,882	8,399

Source: Compiled from official statistics of the United Nations.

Table C-58.--Enzymes: French imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Denmark	1,423	2,216	3,503	6,270
Belgium and Luxembourg	4,276	6,112	5,924	5,590
United States	3,513	3,994	4,121	5,468
West Germany	2,311	2,770	2,713	2,838
Italy	2,273	2,530	2,597	2,365
Japan	1,125	2,236	2,516	2,267
Ireland	1,273	2,030	1,597	1,168
Argentina	784	715	1,096	871
All other	3,012	1,832	1,830	3,087
Total	19,990	24,435	25,897	29,924
	Exports			
West Germany	4,552	3,137	2,604	4,139
Denmark	1,230	2,635	2,948	1,848
Italy	1,309	1,386	1,962	1,524
Belgium and Luxembourg	3,290	2,487	1,651	1,409
Spain	1,367	1,028	963	1,212
United States	1,214	830	1,916	1,208
Switzerland	644	881	724	1,046
Netherlands	496	839	506	822
All other	4,697	5,648	6,581	6,322
Total	18,799	18,871	19,855	19,530

Source: Compiled from official statistics of the United Nations.

Table C-59.--Enzymes: Japanese imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Denmark	5,065	10,000	12,287	13,915
Republic of Korea	10,580	10,882	9,987	8,138
Mexico	3,440	4,643	4,729	6,353
Italy	2,976	3,245	3,678	4,428
United States	4,528	4,471	4,670	3,849
West Germany	2,171	3,026	2,958	2,846
Taiwan	2,132	2,283	2,527	2,840
Switzerland	1,497	1,399	1,729	1,838
All other	4,306	5,122	6,168	8,585
Total	36,695	45,071	48,733	52,792
	Exports			
United States	4,823	5,844	6,213	7,553
West Germany	2,327	2,878	3,449	4,209
Republic of Korea	1,524	1,413	1,374	2,190
France	1,178	2,018	2,417	1,935
Italy	455	474	315	1,409
Spain	315	817	433	767
Ireland	769	528	910	673
Taiwan	461	427	561	587
All other	4,576	4,747	4,993	5,018
Total	16,428	19,146	20,665	24,341

Source: Compiled from official statistics of the United Nations.

Table C-60.--Enzymes: Swiss imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Denmark	1,828	2,080	2,021	1,949
Italy	1,057	1,617	1,100	1,768
West Germany	814	984	896	1,070
United States	772	734	1,007	785
Belgium and Luxembourg	222	367	378	777
France	491	697	594	750
United Kingdom	155	265	341	285
Japan	366	206	32	95
All other	317	914	741	377
Total	6,022	7,864	7,110	7,856
	Exports			
Italy	980	841	3,066	2,663
West Germany	2,677	1,320	623	2,250
Spain	641	1,026	871	1,220
United States	847	781	1,571	560
Austria	295	209	358	535
France	751	650	554	453
Republic of South Africa	386	482	394	406
Portugal	231	216	204	356
All other	3,190	3,717	2,735	2,699
Total	9,998	9,248	10,376	11,142

Source: Compiled from official statistics of the United Nations.

Table C-61.--Enzymes: West German imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Denmark	7,301	7,288	6,359	6,224
Japan	2,214	3,274	3,661	4,484
United States	1,696	2,412	3,542	3,765
France	4,250	3,458	2,482	3,654
Belgium and Luxembourg	1,053	1,193	1,359	2,422
Switzerland	3,509	4,298	2,854	2,410
Spain	3,553	4,045	2,311	1,780
Netherlands Antilles	957	812	834	1,747
All other	7,050	8,362	6,522	6,813
Total	31,583	35,142	29,924	33,299
	Exports			
United States	9,989	14,564	10,106	6,325
Belgium and Luxembourg	4,651	5,588	5,504	6,093
Italy	3,459	4,492	4,872	4,931
France	2,649	2,591	2,997	3,826
India	1,204	2,817	2,485	2,644
Hong Kong	258	383	1,051	1,488
Switzerland	1,451	1,415	1,181	1,365
Republic of Korea	1,316	1,664	6,522	1,309
All other	14,196	16,079	9,715	14,834
Total	39,173	49,593	44,433	42,815

Source: Compiled from official statistics of the United Nations.

Table C-62.--Ethyl alcohol: U.S. production, exports of domestic merchandise, imports for consumption, and apparent consumption, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value in cents per pound)

Year	U.S. production 1/	Exports	Imports	Apparent consumption	Ratio (percent) of imports to consumption
	Quantity				
1979	1,709,844	59,065	184,173	1,834,952	10
1980	1,969,653	63,688	396,900	2,302,865	17
1981	1,510,740	67,698	188,789	1,631,831	12
1982	1,962,824	50,771	232,936	2,144,989	11
1983	2/ 2,298,613	16,009	672,326	2,954,930	23
	Value				
1979	324,870	9,474	25,190	340,586	7
1980	531,806	13,143	74,623	593,286	13
1981	423,007	14,882	36,469	444,594	8
1982	588,847	13,498	39,025	614,374	6
1983	689,584	3,808	101,584	787,360	13
	Unit value				
1979	19	16	14	-	-
1980	27	21	19	-	-
1981	28	22	19	-	-
1982	30	27	17	-	-
1983	30	24	15	-	-

1/ Production values estimated by applying unit value of sales to production quantities.
2/ Preliminary.

Source: Production, Synthetic Organic Chemicals, United States Production and Sales, U.S. International Trade Commission, and the U.S. Treasury Department, except as noted; imports and exports, compiled from official statistics of the U.S. Department of Commerce.

Table C-63.--Ethyl alcohol: U.S. imports for consumption, by principal sources, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per pound)

Source	1979	1980	1981	1982	1983
	Quantity				
Brazil	16,249	267,544	55,628	116,457	478,663
Canada	62,730	56,212	56,794	34,183	92,811
Argentina	61,314	73,111	47,215	30,056	36,211
United Kingdom	249	1/	2	45,570	33,817
France	-	20	1/	-	10,575
Republic of South Africa	-	-	-	-	9,387
Belgium and Luxembourg	-	-	-	-	4,343
Spain	0474	-	-	-	6,055
All other	10,786	13	12	6,673	466
Total	184,172	396,900	159,662	232,939	672,328
	Value				
Brazil	2,430	50,829	17,013	18,717	71,240
Canada	9,737	12,300	12,033	5,018	12,984
Argentina	6,538	11,468	7,302	5,790	6,336
United Kingdom	5,559	2	10	8,568	6,336
France	202	2	1	-	1,870
Republic of South Africa	-	-	-	-	1,744
Belgium and Luxembourg	-	-	-	-	762
Spain	-	-	-	-	596
All other	724	21	112	932	132
Total	25,190	74,623	36,469	39,025	101,584
	Unit value				
Brazil	$0.15	$0.19	$0.20	$0.16	$0.15
Canada	.15	.22	.21	.15	.14
Argentina	.11	.16	.15	.19	.17
United Kingdom	.17	-	4.46	.19	.17
France	.81	.10	-	-	.18
Republic of South Africa	-	-	-	-	.19
Belgium and Luxembourg	-	-	-	-	.18
Spain	-	-	-	-	.10
All other	.07	1.61	9.33	.14	.28
Average	.14	.19	.19	.17	.15

1/ Less than 500 pounds.

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-64.--Ethyl alcohol: U.S. exports of domestic merchandise, by principal markets, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value in cents per pound)

Market	1979	1980	1981	1982	1983
			Quantity		
Belgium and Luxembourg	37,090	30,839	23,714	13,284	4,244
Republic of Korea	236	682	328	597	2,578
Canada	4,093	5,779	7,124	4,369	6,225
Netherlands	1,135	794	1,063	715	479
Trinidad and Tobago	223	295	230	394	289
Ivory Coast	236	197	105	112	367
Mexico	505	866	800	531	499
British Virgin Islands	-	-	112	59	105
All other	15,548	24,232	34,223	30,707	1,220
Total	59,066	63,684	67,699	50,768	16,006
			Value		
Belgium and Luxembourg	5,153	4,699	4,475	3,480	1,112
Republic of Korea	76	287	169	221	822
Canada	373	482	666	447	674
Netherlands	305	293	329	242	183
Trinidad and Tobago	65	116	95	173	135
Ivory Coast	62	60	37	33	116
Mexico	49	78	101	72	86
British Virgin Islands	-	-	32	13	81
All other	3,391	7,127	8,978	8,817	600
Total	9,474	13,143	14,882	13,498	3,808
			Unit value		
Belgium and Luxembourg	14	15	19	26	26
Republic of Korea	32	42	52	37	32
Canada	09	08	09	10	11
Netherlands	27	37	31	34	38
Trinidad and Tobago	29	39	41	44	47
Ivory Coast	26	30	35	29	32
Mexico	10	09	13	14	17
British Virgin Islands	-	-	29	22	77
All other	22	29	26	29	49
Average	16	21	22	27	24

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-65.--Ethyl alcohol: Brazilian imports and exports, by sources and by principal markets, 1979-82 1/

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
West Germany	1/	2	2	1
Total	1/	2	2	1
	Exports			
United States	2,228	52,738	14,053	61,961
Japan	7,452	44,117	37,438	12,315
Netherlands	6,389	20,758	9,544	4,387
West Germany	-	-	-	1,661
Chile	351	1,250	1,534	769
United Kingdom	-	5,204	-	581
Netherlands Antilles	-	-	-	489
Israel	-	-	301	126
All other	9,593	9,378	6,548	107
Total	26,013	133,445	69,418	82,396

1/ Not available.

Source: Compiled from official statistics of the United Nations.

Table C-66.--Ethyl alcohol: Canadian imports and exports, by sources and by markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	82	158	335	199
United Kingdom	3	2	4	4
Switzerland	-	4	-	-
West Germany	25	-	-	-
Total	110	164	339	203
	Exports 1/			
United States	10,289	12,559	12,251	5,171
Switzerland	-	-	715	227
Jordan	-	-	-	7
France	507	-	-	-
Japan	-	10	-	-
Malaysia	2	1	-	2/-
Portugal	402	-	-	-
Total	11,200	12,570	12,966	2/ 5,405

1/ Export figures were derived from corresponding imports by partner countries.

2/ Estimated by the staff of the U.S. International Trade Commission.

Source: Compiled from official statistics of the United Nations, except as noted.

Table C-67.--Ethyl alcohol: French imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United Kingdom	43	476	4,514	8,897
Belgium and Luxembourg	8	14	1	327
West Germany	133	99	106	139
Netherlands	1	-	1	1
Spain	-	-	-	1
Switzerland	-	226	885	-
Brazil	6,991	2,732	34	-
India	1,438	75	-	-
All other	592	33	-	-
Total	9,206	3,655	5,541	9,365
	Exports			
West Germany	6,300	7,293	12,544	16,870
United Kingdom	3,731	10,452	11,046	9,614
Netherlands	3,782	3,249	15,482	5,311
Belgium and Luxembourg	2,800	6,665	5,584	4,937
Italy	7,587	5,741	4,133	2,939
Japan	2,826	2,220	2,042	1,976
Algeria	4	858	17	1,813
Greece	1,390	2,688	1,035	1,731
All other	30,312	7,505	26,875	5,115
Total	58,732	46,671	78,758	50,306

Source: Compiled from official statistics of the United Nations.

Table C-68.--Ethyl alcohol: Dutch imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
France	3,373	3,598	5,573	4,216
Belgium and Luxembourg	2,366	1,042	1,896	2,905
United States	2,134	2,527	1,266	1,135
Italy	868	878	850	910
West Germany	83	1,054	2,145	668
Brazil	2,065	2,092	539	613
Argentina	2,942	260	175	392
Republic of South Africa	206	-	-	193
All other	2,727	172	647	244
Total	16,764	11,623	13,091	11,276
	Exports			
West Germany	904	1,948	2,808	2,804
United Kingdom	1,013	1,639	2,048	1,467
Belgium and Luxembourg	501	1,301	1,710	830
Israel	-	-	271	533
Ghana	74	141	601	439
Liberia	124	61	198	238
Cameroon	98	58	275	187
Niger	133	66	179	156
All other	1,546	1,410	754	331
Total	4,393	6,624	8,844	6,983

Source: Compiled from official statistics of the United Nations.

Table C-69.--Ethyl alcohol: Swiss imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Hungary	-	589	594	1,866
United States	794	1,327	2,253	1,811
Brazil	924	3,982	5,326	1,501
United Kingdom	588	2,411	-	967
Norway	-	-	-	903
South Africa	-	427	-	513
Canada	-	-	715	227
West Germany	115	142	119	123
All other	631	797	1,446	11
Total	3,052	9,675	10,453	7,922
	Exports			
Saudi Arabia	3	1	12	9
Iraq	17	8	7	8
Italy	1	5	8	5
Egypt	-	1	1	4
France	1	2	1	3
Japan	1	1	-	3
Greece	-	-	-	2
Kuwait	1	-	3	2
All other	35	55	33	23
Total	59	73	65	59

Source: Compiled from official statistics of the United Nations.

Table C-70.--Ethyl alcohol: Japanese imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Brazil	13,731	47,171	54,697	17,218
Argentina	16,425	19,072	21,735	16,064
Australia	11,701	13,024	13,736	10,309
Thailand	4,355	3,655	5,937	7,334
Philippines	3,013	4,455	5,088	7,328
United States	1,076	2,269	6,078	5,699
Pakistan	1,964	4,196	2,057	4,999
Indonesia	2,902	4,498	4,328	4,922
All other	6,332	12,413	1,819	6,252
Total	61,499	108,753	115,475	80,125
	Exports			
Republic of Korea	102	137	86	50
North Korea	48	6	20	18
Singapore	-	1	7	7
Pacific Islands Territory	5	6	5	6
Indonesia	-	1	5	3
People's Republic of China	-	2	1	2
Burma	2	5	6	1
Guam	-	-	9	1
All other	20	16	28	5
Total	177	174	167	93

Source: Compiled from official statistics of the United Nations.

Table C-71.--Ethyl alcohol: West German imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
France	6,319	7,017	12,164	16,860
Netherlands	911	1,947	3,007	2,669
United States	1,735	1,642	1,522	1,283
Brazil	104	1,378	1,747	511
Hungary	-	-	-	348
Italy	36	637	1,837	267
Switzerland	-	1	609	111
Yugoslavia	-	67	52	31
All other	637	255	463	378
Total	9,742	12,944	21,401	22,458
	Exports			
Belgium and Luxembourg	1,289	3,803	7,441	6,597
Netherlands	234	1,356	3,209	3,208
Denmark	825	2,199	911	1,357
Iraq	28	131	194	264
Israel	44	181	167	188
Sweden	4	8	12	170
Italy	145	235	198	162
France	118	118	122	154
All other	1,138	1,531	1,626	1,343
Total	3,825	9,562	13,880	13,443

Source: Compiled from official statistics of the United Nations.

Table C-72.--Ethyl alcohol: British imports and exports, 1/ by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
France	3,731	10,452	11,046	9,614
Netherlands	1,013	1,639	2,048	1,130
Brazil	-	5,204	-	581
Ireland	620	1,648	856	104
United States	8	1,085	12	12
West Germany	22	15	7	3
Argentina	4,090	1,258	-	2/ -
Belgium and Luxembourg	1,354	-	-	-
All other	1	72	3	-
Total	10,839	21,303	13,[illegible]72	2/ 11,444
	Exports			
Belgium and Luxembourg	4,642	5,902	7,064	10,052
France	43	476	4,514	8,897
United States	6,046	3	11	8,748
Italy	2,722	4,416	3,008	6,022
Denmark	7,309	7,189	7,023	5,455
Jordan	-	-	85	4,143
Ireland	2,773	3,552	3,269	3,416
Switzerland	588	2,411	-	967
All other	5,625	3,067	2,120	519
Total	29,748	27,016	27,094	48,219

1/ Trade figures were derived from corresponding trade with partner countries.
2/ Estimated.

Source: Compiled from official statistics of the United Nations.

Table C-73.--Methyl alcohol: U.S. production, exports of domestic merchandise, imports for consumption, and apparent consumption, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value in cents per pound)

Year	U.S. production 1/	Exports	Imports	Apparent consumption	Ratio (percent) of imports to consumption
	Quantity				
1979-------	7,367,404	370,249	386,448	7,383,603	5
1980-------	7,152,974	323,304	234,139	7,063,809	3
1981-------	8,576,597	831,055	174,546	7,920,088	2
1982-------	7,554,588	1,110,199	353,993	6,798,382	5
1983-------	2/ 6,623,686	653,490	687,219	6,657,415	10
	Value				
1979-------	515,718	22,991	28,147	520,874	5
1980-------	643,768	28,944	16,454	631,278	3
1981-------	771,894	69,115	13,622	716,401	2
1982-------	604,367	89,272	23,365	538,460	4
1983-------	2/ 482,204	45,176	40,600	477,628	9
	Unit value				
1979-------	7	6	7	-	-
1980-------	9	9	7	-	-
1981-------	9	8	8	-	-
1982-------	8	8	7	-	-
1983-------	3/ 7	7	6	-	-

1/ Production values estimated by applying unit value of sales to production quantities.
2/ Preliminary
3/ Estimated from industry sources.

Source: Production, Synthetic Organic Chemicals, United States Production and Sales, U.S. International Trade Commission, except as noted; imports and exports, compiled from official statistics of the U.S. Department of Commerce.

Table C-74.--Methyl alcohol: U.S. imports for consumption, by principal sources, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per pound)

Market	1979	1980	1981	1982	1983
			Quantity		
Canada	229,010	140,559	76,796	325,838	651,931
Mexico	101,810	57,295	43,127	9,774	35,215
West Germany	-	1/	1	21	59
Japan	1/	-	1/	15	11
India	-	-	-	-	1/
Italy	-	-	-	-	1/
Netherlands	-	-	13,641	1	2
Libya	13,667	27,535	27,367	18,342	-
All other	41,961	8,750	13,614	2	1
Total	386,448	234,139	174,546	353,993	687,219
			Value		
Canada	13,265	8,864	5,975	21,349	38,006
Mexico	11,499	4,694	3,430	668	2,560
West Germany	-	2	8	15	25
Japan	1	-	1/	23	7
India	-	-	-	-	1
Italy	-	-	-	-	1/
Netherlands	-	-	998	2	1/
Libya	1,038	2,238	2,129	1,299	-
All other	2,345	657	1,082	9	-
Total	28,147	16,454	13,622	23,365	40,600
			Unit value		
Canada	$0.06	$0.06	$0.08	$0.06	$0.06
Mexico	.11	.08	.08	.07	.07
West Germany	-	-	-	.75	.42
Japan	-	-	-	1.77	.54
India	-	-	-	-	-
Italy	-	-	-	-	-
Netherlands	-	-	.07	-	-
Libya	.08	.08	.08	.07	-
All other	.06	.08	.08	4.50	-
Average	.07	.07	.08	.06	.06

1/ Less than $500.

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-75.--Methyl alcohol: U.S. exports of domestic merchandise, by principal markets, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per pound)

Market	1979	1980	1981	1982	1983
	Quantity				
Netherlands	59,084	48,542	212,872	295,937	290,392
Spain	6	2	53,115	21,617	66,904
Japan	67,284	56,033	194,221	346,881	52,480
West Germany	37	100	5,489	5,255	46,950
Turkey	-	-	15,416	-	39,789
Republic of South Africa	15,953	13,136	25,267	62,715	26,087
United Kingdom	14	17	32	13	26,331
Australia	17,722	19,942	23,468	36,053	22,648
All other	210,149	185,532	301,175	341,728	81,909
Total	370,249	323,304	831,055	1,110,199	653,490
	Value				
Netherlands	3,211	2,567	14,377	27,243	18,479
Spain	1	1	3,765	1,535	5,969
Japan	2,691	5,746	14,948	24,073	3,270
West Germany	4	26	358	366	2,783
Turkey	-	-	1,113	-	2,477
Republic of South Africa	1,729	1,266	2,090	8,566	1,795
United Kingdom	28	3	11	2	1,670
Australia	1,227	1,732	1,845	2,475	1,583
All other	14,100	17,604	30,608	25,013	7,148
Total	22,991	28,944	69,115	89,272	45,176
	Unit value				
Netherlands	$0.05	$0.05	$0.07	$0.09	$0.06
Spain	.17	.50	.07	.07	.09
Japan	.04	.10	.08	.07	.06
West Germany	.11	.26	.07	.07	.06
Turkey	-	-	.07	-	.06
Republic of South Africa	.11	.10	.08	.14	.07
United Kingdom	2.00	.18	.34	.15	.06
Australia	.07	.09	.08	.07	.07
All other	.07	.09	.10	.07	.09
Average	.06	.09	.08	.08	.07

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-76.--Methyl alcohol: British imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Netherlands	2,971	3,216	2,119	3,648
Libya	-	1,688	926	1,458
Switzerland	-	1	16	70
Ireland	2	33	1	38
Belgium and Luxembourg	236	-	-	23
France	-	-	1	16
United States	21	44	29	8
West Germany	26	9	13	2
All other	958	13	586	3
Total	4,214	5,004	3,691	5,266
	Exports			
Netherlands	22,986	39,222	37,697	38,279
Italy	8	22	5,673	7,756
West Germany	3,053	3,248	5,078	4,642
France	12	1,657	1,307	3,181
Denmark	376	1,750	2,075	3,097
Ireland	1,375	2,029	1,401	1,232
Portugal	554	1,093	434	431
Australia	3,022	5,247	2,488	362
All other	5,679	11,041	6,326	1,222
Total	37,065	65,309	62,479	60,202

Source: Compiled from official statistics of the United Nations.

Table C-77.--Methyl alcohol: Canadian imports and exports, by sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	86	139	170	58
Netherlands	-	-	3	-
Total	86	139	173	58
	Exports 1/			
Japan	8,420	28,205	38,813	48,617
United States	15,487	10,669	6,651	24,433
Singapore	1,315	1,187	1,101	3,840
West Germany	3	5	5	3,343
Indonesia	-	-	625	2,204
Malaysia	644	151	1,654	2/ 1,700
Thailand	-	-	-	838
France	-	-	-	547
All other	1,472	1,496	316	854
Total	27,341	41,713	49,165	2/ 86,376

1/ Export figures were derived from corresponding imports by partner countries.

2/ Estimated by the staff of the U.S. International Trade Commission.

Source: Compiled from official statistics of the United Nations.

Table C-78.--Methyl alcohol: Dutch imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	3,372	4,062	6,423	11,088
United Kingdom	483	3,478	6,094	5,532
Libya	7,596	21,510	4,251	4,841
Canada	-	-	-	3,279
Algeria	645	-	-	696
West Germany	342	275	178	468
Soviet Union	2,358	1,896	1,896	394
Belgium and Luxembourg	208	1,253	147	169
All other	1,046	1,204	88	-
Total	16,050	33,678	19,077	26,467
	Exports			
West Germany	43,487	62,653	54,496	50,404
France	3,767	4,544	3,851	6,833
Belgium and Luxembourg	4,813	4,366	5,347	5,404
Finland	3,876	5,375	4,812	4,251
United Kingdom	2,498	2,895	1,726	3,399
Sweden	10,855	-	-	3,240
Norway	5,393	-	-	2,143
Austria	17	11	-	2,050
All other	5,595	24,749	17,738	1,978
Total	80,301	104,593	87,970	79,702

Source: Compiled from official statistics of the United Nations.

Table C-79.--Methyl alcohol: French imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Netherlands	4,061	4,222	4,392	7,725
United Kingdom	1,194	1,947	1,417	5,243
Libya	182	591	685	2,248
United States	21	104	407	988
West Germany	974	408	762	837
Canada	-	-	-	547
Belgium and Luxembourg	11	703	804	464
Soviet Union	-	-	579	332
All other	325	319	26	367
Total	6,768	8,294	9,072	18,751
	Exports			
Belgium and Luxembourg	4,705	5,250	4,513	4,133
West Germany	1,392	3,000	2,443	2,093
Switzerland	2,012	1,651	1,241	1,718
Nigeria	-	-	-	75
Italy	22	265	25	71
Spain	208	174	36	46
Portugal	55	2	2	33
Austria	78	39	88	27
All other	276	379	357	170
Total	8,748	10,760	8,705	8,366

Source: Compiled from official statistics of the United Nations.

Table C-80.--Methyl alcohol: Japanese imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Canada	8,420	28,205	38,813	48,617
United States	4,282	8,880	19,322	32,116
Libya	6,916	4,241	1,210	5,453
China	1,439	7,018	5,036	5,435
Republic of Korea	35,352	36,148	22,935	4,382
Taiwan	-	1,168	410	-
Indonesia	497	-	-	-
Australia	-	11	-	-
All other	108	-	1	-
Total	57,014	85,671	87,727	96,003
	Exports			
Indonesia	360	1,020	149	259
Philippines	155	174	414	109
Republic of Korea	81	125	141	84
Iraq	21	1	2	37
Malaysia	340	74	118	21
Taiwan	974	12	11	5
China	2,311	6	2	3
Singapore	563	145	162	3
All other	180	316	37	5
Total	4,985	1,873	1,036	526

Source: Compiled from official statistics of the United Nations.

Table C-81.--Methyl alcohol: Swiss imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
West Germany	3,034	4,203	3,429	3,201
France	2,009	1,738	1,312	1,554
Netherlands	1,033	1,476	663	580
Libya	-	-	19	409
United States	1	78	21	209
Czechoslovakia	-	624	242	183
Canada	-	-	-	174
United Kingdom	19	76	18	13
All other	4	10	5	15
Total	6,100	8,205	5,709	6,338
	Exports			
West Germany	1,333	1,595	1,734	1,565
Italy	13	28	60	49
Belgium and Luxembourg	6	15	21	28
Austria	22	21	6	14
Bulgaria	1	1	5	6
France	1	2	2	4
Netherlands	-	-	6	4
Saudi Arabia	1	1	3	4
All other	18	33	39	36
Total	1,395	1,696	1,876	1,710

Source: Compiled from official statistics of the United Nations.

Table C-82.--Methyl alcohol: West German imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Netherlands	38,673	58,896	64,117	61,263
United Kingdom	32,038	39,857	43,126	40,406
United States	3,830	2,349	6,855	6,680
Libya	11,986	9,193	7,323	4,738
Canada	3	5	5	3,343
France	1,605	3,617	3,674	2,054
Italy	615	1,790	1,527	1,799
Algeria	1,471	-	-	1,592
All other	11,812	10,554	10,952	4,724
Total	102,033	126,261	137,579	126,599
	Exports			
Switzerland	2,958	3,777	3,068	2,979
Belgium and Luxembourg	1,362	1,157	818	1,324
Austria	106	197	164	1,248
France	746	384	801	794
Netherlands	169	376	193	253
Italy	137	175	154	130
Sweden	68	160	99	109
Iran	20	48	59	9
All other	706	1,001	1,048	1,039
Total	6,272	7,275	6,404	7,885

Source: Compiled from official statistics of the United Nations.

Table C-83.--Nitrogenous fertilizers: U.S. production, exports of domestic merchandise, imports for consumption, and apparent consumption, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per short ton)

Year	U.S. production	Exports	Imports	Apparent consumption	Ratio (percent) of imports to consumption
	Quantity				
1979	36,490	3,902	4,008	36,596	11.0
1980	38,761	4,450	4,424	38,735	11.4
1981	37,852	3,411	4,083	38,524	10.6
1982	32,917	3,350	4,235	33,802	12.5
1983	29,340	2,316	5,733	32,757	17.5
	Value				
1979	4,386,759	367,805	380,286	4,399,240	8.6
1980	5,492,273	581,495	478,837	5,389,615	8.9
1981	6,017,161	488,507	495,834	6,024,488	8.2
1982	4,654,310	427,973	577,881	4,804,218	12.0
1983	3,237,032	230,872	702,917	3,709,077	19.0
	Unit value				
1979	$120.22	$94.26	$94.87	-	-
1980	141.70	130.67	108.23	-	-
1981	158.97	143.22	121.43	-	-
1982	141.40	127.74	136.45	-	-
1983	110.33	99.67	122.61	-	-

Source: Production, estimated by the staff of the U.S. International Trade Commission; imports and exports, compiled from official statistics of the U.S. Department of Commerce.

Table C-84.--Nitrogenous fertilizers: U.S. imports for consumption, by principal sources, 1979-83

(Quantity in thousands of short tons; value in thousands of dollars; unit value per short ton)

Source	1979	1980	1981	1982	1983
	Quantity				
Canada	1,850	1,666	1,717	1,758	2,131
U.S.S.R	777	1,103	796	702	1,029
Mexico	309	378	434	585	653
Trinidad and Tobago	376	384	364	324	547
Netherlands	346	373	177	311	346
Norway	162	173	189	204	214
Venezuela	-	3	7	34	173
Romania	-	33	16	-	222
All other	189	312	383	318	419
Total	4,008	4,424	4,083	4,235	5,733
	Value				
Canada	178,406	184,100	211,326	239,065	288,963
U.S.S.R	56,466	94,796	78,414	99,199	124,636
Mexico	25,523	42,323	57,136	73,771	76,974
Trinidad and Tobago	38,023	43,915	47,837	43,450	67,245
Netherlands	50,812	61,682	36,961	60,628	43,145
Norway	11,325	14,293	15,840	19,045	19,826
Venezuela	-	584	1,240	4,641	17,835
Romania	-	5,268	2,893	-	16,388
All other	19,733	31,878	44,189	38,082	47,905
Total	380,286	478,837	495,834	577,881	702,917
	Unit value				
Canada	$96.42	$110.50	$123.06	$135.96	$135.63
U.S.S.R	72.66	85.98	98.47	141.41	121.07
Mexico	82.68	112.10	131.56	126.19	117.96
Trinidad and Tobago	101.17	114.37	131.41	134.18	122.98
Netherlands	146.97	165.49	209.02	194.84	124.86
Norway	70.01	82.49	83.92	93.38	92.76
Venezuela	-	168.73	185.65	138.33	103.01
Romania	-	160.37	181.44	-	73.76
All other	104.42	102.21	115.32	119.72	114.34
Total	94.87	108.23	121.43	136.45	122.61

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-85.--Nitrogenous fertilizers: U.S. exports of domestic merchandise, by principal markets, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per short ton)

Market	1979	1980	1981	1982	1983
	Quantity				
Canada	226	187	228	211	260
Republic of Korea	1/	1	24	125	272
China	249	231	122	363	313
Brazil	1,190	1,061	610	525	279
Singapore	1/	24	23	24	101
Philippines	21	92	174	96	99
Taiwan	1/	40	48	1/	72
Dominican Republic	129	160	144	121	110
All other	2,087	2,654	2,039	1,886	809
Total	3,902	4,450	3,411	3,350	2,316
	Value				
Canada	23,868	28,089	35,118	30,981	37,308
Republic of Korea	2	148	3,162	17,627	33,353
China	27,179	35,037	18,955	55,035	32,706
Brazil	94,434	114,245	70,935	51,808	17,568
Singapore	1	3,446	3,866	2,776	11,851
Philippines	2,227	14,476	30,190	12,316	9,333
Taiwan	8	7,197	8,316	8	7,798
Dominican Republic	10,600	16,787	12,244	10,234	7,215
All other	209,486	362,070	305,722	247,188	73,740
Total	367,805	581,495	488,507	427,973	230,872
	Unit value				
Canada	$105.76	$150.38	$153.82	$146.71	$143.67
Republic of Korea	351.71	155.27	133.38	141.23	122.49
China	109.32	151.51	155.65	151.57	104.36
Brazil	97.34	107.64	116.33	98.73	62.89
Singapore	36.83	145.40	170.00	117.93	117.32
Philippines	104.12	156.89	173.14	128.53	93.85
Taiwan	87.48	179.61	174.59	77.72	107.67
Dominican Republic	82.03	104.87	85.00	84.47	65.56
All other	100.38	136.44	149.97	131.07	91.19
Total	94.26	130.67	143.22	127.74	99.67

1/ Less than 500 pounds.

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-86.--Pesticides and related products: U.S. production, exports of domestic merchandise, imports for consumption, and apparent consumption, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per pound)

Year	U.S. production	Exports	Imports	Apparent consumption	Ratio (percent) of imports to consumption
	Quantity				
1979-------	1,429,408	650,445	109,586	888,549	12.3
1980-------	1,468,202	649,936	114,319	932,585	12.3
1981-------	1,430,075	532,333	139,256	1,036,998	13.4
1982-------	1,112,798	516,130	166,030	762,698	21.8
1983-------	1,006,504	501,281	172,551	677,774	25.5
	Value				
1979-------	3,790,703	1,113,285	241,096	2,918,514	8.3
1980-------	4,257,960	1,210,282	311,431	3,359,109	9.3
1981-------	5,155,000	1,204,369	335,031	4,285,662	7.8
1982-------	4,300,452	1,256,903	319,707	3,363,256	9.5
1983-------	3,824	1,280,716	302,410	2,846,411	10.6
	Unit value				
1979-------	$2.65	$1.71	$2.20	-	-
1980-------	2.90	1.86	2.72	-	-
1981-------	3.60	2.26	2.40	-	-
1982-------	3.82	2.44	1.93	-	-
1983-------	3.80	2.55	1.75	-	-

Source: Production, Synthetic Organic Chemicals, United States Production and Sales, U.S. International Trade Commission; imports and exports, compiled from official statistics of the U.S. Department of Commerce.

Table C-87.--Pesticides: U.S. imports for consumption, by principal sources, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per pound)

Source	1979	1980	1981	1982	1983
	Quantity				
Switzerland	33,236	40,938	51,567	52,030	40,563
West Germany	21,158	19,286	14,051	19,388	16,844
United Kingdom	10,334	9,876	12,402	10,881	12,241
Japan	3,790	3,390	10,720	11,519	7,906
Italy	10,042	8,103	9,181	10,761	14,333
Netherlands	4,964	4,231	7,512	7,110	12,600
Brazil	78	187	1,274	7,511	19,044
Israel	2,411	3,158	3,766	4,720	4,954
All other	23,571	25,151	28,784	42,110	44,066
Total	109,586	114,319	139,256	166,030	172,551
	Value				
Switzerland	48,157	65,943	79,546	82,361	63,173
West Germany	69,475	82,670	69,623	66,016	56,154
United Kingdom	17,634	35,706	36,252	25,838	30,728
Japan	27,500	32,862	48,754	28,116	25,933
Italy	14,323	14,326	15,914	18,275	20,279
Netherlands	8,099	12,005	14,997	11,835	17,096
Brazil	56	995	3,325	7,139	15,671
Israel	5,025	5,963	8,949	9,176	10,624
All other	50,829	60,960	57,673	70,951	62,751
Total	241,096	311,431	335,031	319,707	302,410
	Unit value				
Switzerland	$1.45	$1.61	$1.54	$1.58	$1.56
West Germany	3.28	4.29	4.96	3.41	3.33
United Kingdom	1.71	3.62	2.92	2.37	2.51
Japan	7.26	9.69	4.55	2.44	3.28
Italy	1.43	1.77	1.73	1.70	1.41
Netherlands	1.63	2.84	2.00	1.66	1.36
Brazil	.71	5.31	2.61	.95	.82
Israel	2.08	1.89	2.38	1.94	2.14
All other	2.16	2.42	2.00	1.68	1.42
Total	2.20	2.72	2.41	1.93	1.75

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-88.--Pesticides: U.S. exports of domestic merchandise, by principal markets, 1979-83

(Quantity in thousands of pounds; value in thousands of dollars; unit value per pound)

Market	1979	1980	1981	1982	1983
	Quantity				
Canada	148,678	148,283	93,998	106,905	106,162
Japan	26,493	32,775	26,941	27,784	29,860
Switzerland	38,034	45,950	39,650	52,474	47,448
Belgium and Luxembourg	42,614	39,120	40,494	27,608	28,492
Brazil	35,742	31,136	23,084	18,937	16,490
Netherlands	16,013	12,179	12,411	11,651	16,993
Australia	13,042	8,423	7,494	7,369	10,787
West Germany	16,804	13,196	11,921	20,020	15,293
All other	313,024	318,874	276,340	243,383	229,755
Total	650,445	649,936	532,333	516,130	501,281
	Value				
Canada	123,665	143,537	140,355	162,563	178,362
Japan	82,325	95,308	100,489	103,451	106,352
Switzerland	62,019	89,763	92,063	117,076	101,968
Belgium and Luxembourg	132,184	116,456	87,570	95,057	80,663
Brazil	91,173	101,801	69,954	58,923	70,914
Netherlands	29,489	27,295	34,261	39,312	58,100
Australia	31,945	28,167	25,851	32,808	51,512
West Germany	34,987	36,919	45,573	74,396	45,021
All other	525,498	571,035	608,255	573,318	587,824
Total	1,113,285	1,210,282	1,204,369	1,256,903	1,280,716
	Unit value				
Canada	$0.83	$0.97	$1.49	$1.52	$1.68
Japan	3.11	2.91	3.73	3.72	3.56
Switzerland	1.63	1.95	2.32	2.23	2.15
Belgium and Luxembourg	3.10	2.98	2.16	3.44	2.83
Brazil	2.55	3.27	3.03	3.11	4.30
Netherlands	1.84	2.24	2.76	3.37	3.42
Australia	2.45	3.34	3.45	4.45	4.78
West Germany	2.08	2.80	3.82	3.72	2.94
All other	1.68	1.79	2.20	2.36	2.56
Total	1.71	1.86	2.26	2.44	2.55

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table C-89.--Pesticides: British imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
Switzerland	44,950	23,320	35,546	43,397
West Germany	78,154	50,649	39,973	42,153
France	40,963	54,431	58,400	38,287
Belgium and Luxembourg	51,663	71,998	19,651	14,426
Netherlands	14,979	17,829	10,490	13,218
Italy	3,771	9,733	6,365	7,281
United States	8,952	5,304	3,993	5,084
Ireland	2,366	3,256	3,636	2,784
All other	6,639	6,473	7,731	8,642
Total	252,437	242,993	185,785	175,272
	Exports			
France	32,036	40,027	71,458	56,616
Egypt	27,053	21,519	21,227	32,619
Saudi Arabia	22,214	20,578	27,944	27,485
West Germany	23,353	21,123	23,413	26,540
Nigeria	16,399	39,421	24,205	23,300
Ireland	17,713	20,716	17,072	21,946
Belgium and Luxembourg	13,001	13,987	24,707	21,713
Canada	13,090	14,360	15,965	20,749
All other	260,249	299,238	281,888	247,857
Total	425,108	490,969	507,879	478,825

Source: Compiled from official statistics of the United Nations.

Table C-90.--Pesticides: Canadian imports, by principal sources, 1979-82

(In thousands of U.S. dollars)

Source	1979	1980	1981	1982
United States	126,286	141,501	124,848	157,136
United Kingdom	11,145	13,898	12,292	17,366
Japan	936	667	639	7,698
Belgium and Luxembourg	6,745	5,548	609	5,985
West Germany	3,537	5,864	4,494	5,258
Switzerland	3,912	11,211	5,838	1,906
Netherlands	2,289	926	78	1,281
Israel	112	95	63	1,241
All other	3,208	2,374	3,429	1,571
Total	158,170	182,084	152,290	199,442

Source: Compiled from official statistics of the United Nations.

Note.--Export data are not available.

Table C-91.--Pesticides: French imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
West Germany	196,014	231,230	235,499	217,285
Belgium and Luxembourg	22,030	58,048	49,377	59,336
United Kingdom	27,300	27,979	58,758	48,270
United States	47,452	36,685	16,640	31,730
Netherlands	18,566	14,735	15,505	20,690
Italy	11,161	16,448	16,527	16,440
Switzerland	7,601	6,376	10,342	12,443
Spain	1,423	6,786	8,716	9,399
All other	5,525	8,307	11,458	16,751
Total	337,072	406,594	422,822	432,344
	Exports			
West Germany	65,420	67,392	65,651	57,942
United Kingdom	36,467	33,317	36,103	30,136
Belgium and Luxembourg	25,070	31,757	24,274	26,354
Sudan	11,041	10,926	25,101	24,889
U.S.S.R	13,723	25,274	23,221	21,040
Italy	25,112	28,637	22,944	19,178
Switzerland	38,113	30,109	13,646	13,079
Netherlands	10,882	11,512	12,882	13,058
All other	168,456	180,088	181,117	161,245
Total	394,284	419,012	404,939	366,921

Source: Compiled from official statistics of the United Nations.

Table C-92.--Pesticides: Italian imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
West Germany	49,432	55,480	42,958	42,125
France	26,509	31,892	21,462	22,792
Switzerland	19,342	18,902	11,020	16,589
Belgium and Luxembourg	8,479	9,146	12,680	13,361
Netherlands	10,443	13,972	11,078	9,732
United Kingdom	7,129	13,419	7,975	7,312
United States	6,767	9,222	4,205	4,674
Israel	2,063	1,669	1,252	625
All other	2,761	3,864	2,685	2,574
Total	132,925	157,566	115,315	119,784
	Exports			
France	9,948	17,242	15,775	14,897
Iran	3,166	2,369	2,615	7,200
Egypt	2,932	4,313	4,901	6,910
United Kingdom	2,581	7,595	4,948	6,529
West Germany	5,603	6,854	7,304	5,802
United States	3,225	5,743	4,315	5,252
Spain	3,282	3,324	3,965	4,409
Belgium and Luxembourg	2,428	3,343	1,750	4,256
All other	55,513	69,178	62,817	58,501
Total	88,678	119,961	108,390	113,756

Source: Compiled from official statistics of the United Nations.

Table C-93.--Pesticides: Japanese imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
United States	36,905	43,903	42,251	36,936
United Kingdom	8,872	9,311	11,782	9,018
West Germany	10,201	11,117	10,836	8,972
France	4,852	13,105	8,448	4,053
Switzerland	9,008	7,174	1,551	1,275
Taiwan	322	522	718	1,241
Netherlands	938	2,518	1,035	524
Republic of Korea	412	609	225	281
All other	1,720	2,426	1,245	211
Total	73,230	90,685	78,091	62,511
	Exports			
United States	4,597	23,828	29,716	31,180
China	15,748	7,061	11,974	24,748
U.S.S.R	5,682	11,294	6,379	13,158
Democratic People's Republic of Korea	9,621	13,429	12,930	10,736
West Germany	8,810	8,486	6,581	8,803
Pakistan	265	4,889	3,183	6,995
Egypt	5,794	2,802	3,457	5,099
Canada	361	371	777	4,955
All other	69,897	68,087	75,470	80,767
Total	120,775	140,247	150,467	186,441

Source: Compiled from official statistics of the United Nations.

Table C-94.--Pesticides: Swiss imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
West Germany	13,575	15,022	13,849	13,242
France	6,282	5,930	6,426	6,654
United States	3,710	4,591	3,867	4,364
Netherlands	2,660	2,753	3,420	2,836
United Kingdom	2,683	2,647	2,787	2,815
Italy	2,273	2,175	2,136	2,418
Brazil	3,894	2,592	3,013	2,373
Ireland	18	182	360	350
All other	6,485	4,794	3,026	1,518
Total	41,580	40,686	38,884	36,570
	Exports			
United Kingdom	34,847	15,437	33,969	44,703
West Germany	17,683	38,416	33,161	38,624
Italy	11,752	16,804	9,783	16,523
Cuba	21,601	22,156	26,031	13,192
France	7,121	5,582	9,838	12,510
Cameroon	10,246	9,494	3,815	10,985
U.S.S.R	23,975	30,151	16,042	10,946
Democratic People's Republic of Korea	8,543	6,908	4,688	10,083
All other	138,591	171,657	168,091	156,435
Total	274,359	316,605	305,418	314,001

Source: Compiled from official statistics of the United Nations.

Table C-95.--Pesticides: West German imports and exports, by principal sources and by principal markets, 1979-82

(In thousands of U.S. dollars)

Source or market	1979	1980	1981	1982
	Imports			
France	66,999	79,161	67,190	57,453
Switzerland	25,626	37,326	34,325	36,356
United Kingdom	23,785	24,287	27,480	24,581
United States	24,306	30,413	17,565	15,266
Netherlands	10,806	11,468	9,424	10,509
Japan	8,365	10,492	5,695	10,102
Belgium and Luxembourg	7,441	9,005	10,713	8,198
Italy	4,895	8,451	3,993	4,955
All other	12,021	13,362	11,643	10,885
Total	184,244	223,965	188,028	178,305
	Exports			
France	175,883	205,649	228,835	226,561
United Kingdom	70,542	48,490	44,097	42,694
Netherlands	40,968	39,284	37,144	36,847
Italy	48,136	60,425	42,888	34,314
Iran	23,193	25,404	29,652	25,669
Belgium and Luxembourg	24,909	24,470	23,746	22,234
United States	22,003	20,358	14,860	20,902
Denmark	21,920	20,327	17,114	19,638
All other	316,250	350,253	325,516	312,579
Total	743,804	794,660	763,852	741,438

Source: Compiled from official statistics of the United Nations.