BRIE

WP29

not online 4/07

BRIE Working Paper

THE JAPANESE CHALLENGE IN BIOTECHNOLOGY:
Industrial Policy

Akihiro Yoshikawa
BRIE
University of California, Berkeley

September 1987

BRIE Working Paper #29

Berkeley Roundtable on the International Economy
University of California, Berkeley

BRIE

The Berkeley Roundtable on the International Economy (BRIE), a research group at the University of California, Berkeley, specializes in policy-oriented studies of the interaction of high-technology development and the international economy. BRIE Working Papers is a series designed to make in-progress research available in timely, low-cost editions. It is made possible in part by a grant from the German Marshall Fund of the United States.

For further information or to order (titles listed below and on back cover), call (415) 642-3067, FAX: (415) 643-6617, or write: BRIE - IIS, 2234 Piedmont Avenue, University of California, Berkeley, CA 94720. Please make checks payable to the Regents of the University of California.

BRIE Working Papers

___1. Countertrade, Offsets, Barter and Buybacks: A Crisis in the Making, Cohen and Zysman, 11/84. 20pp. $4.00.

___2. U.S. and Japanese Trade and Industrial Policies, Zysman, Tyson et al., 3/84. 135pp. $10.50.

___3. How Government Policies Shape High Technology Trade, Borrus, Tyson and Zysman, 10/84. 100pp. $8.50.

___4. Institutions, Policies, and Industrial Policy in France, Cohen, Halimi and Zysman, 10/84. 40pp. $5.00.

___5. Assessing the Impact of the VHSIC (Very High Speed Integrated Circuit) Program, Brueckner and Borrus, 11/84. 95pp. $8.50.

___6. Responses to the Japanese Challenge in High Technology: Innovation, Maturity, and U.S.-Japanese Competition in Microelectronics, Borrus, Millstein and Zysman, 7/83. 165pp. $12.50.

___7. The New Media, Telecommunications, and Development: The Choices for the United States and Japan, Borrus and Zysman, 8/84. 40pp. $5.00.

THE JAPANESE CHALLENGE IN BIOTECHNOLOGY:
Industrial Policy

Akihiro Yoshikawa
BRIE
University of California, Berkeley

September 1987

BRIE Working Paper #29

ABSTRACT

The Japanese Challenge in Biotechnology: Industrial Policy

Berkeley Roundtable on the International Economy
University of California, Berkeley

Akihiro Yoshikawa, Ph.D.

The biotechnology-related market in Japan is expected to be worth as much as $100 billion by the year 2000. Rather than being an industry in and of itself, biotechnology will affect many economic sectors, and may soon become crucial for maintaining a competitive edge in those sectors. In the immediate term, biotechnology will affect industries such as pharmaceuticals, agriculture, and food processing; further on, and with far greater uncertainty, waste disposal, electronics, and materials.

This report provides a preliminary analysis of Japan's industrial policies to promote biotechnology, one of the three technologies the Japanese government has identified as essential to Japan's future competitiveness. The government has introduced various mechanisms, both old-fashioned and experimental, to foster Japanese success in biotechnology. American firms and policy makers need to understand Japanese efforts in biotechnology, just as they have had to understand Japanese efforts in advanced electronics. An early start is well advised.

Although Japan today may be second to the U.S. in biotechnology development, it is not a distant second. With both governmental long-term strategic policies and private firms' efforts to become more innovative, Japan may rapidly catch up to the U.S.

The Japanese Challenge in Biotechnology:

Industrial Policy

University of California, Berkeley

Berkeley Roundtable on the International Economy (BRIE)

Akihiro Yoshikawa, Ph.D.

* This study was made possible in part by grants from the Carnegie Corporation and California Policy Seminar.

Preface

The Japanese Challenge in Biotechnology: Industrial Policy, is the first working paper in the BRIE Biotechnology series.

This is a discussion paper in the sense that we are hoping to receive feedback and responses from readers. Those responses will be incorporated into subsequent studies. We hope that such an interaction with readers will stimulate better understanding of the issues surrounding biotechnology.

Two other working papers are in preparation:

1. Japanese Biotechnology: Development of New Drugs.

2. In Search of the "Ultimate Map" of the Human Genome: The Japanese Challenge (originally prepared for the Office of Technology Assessment, U.S. Congress; release of the study is pending approval from the OTA).

All responses and inquiries concerning the BRIE biotechnology project and these working papers should be addressed to:

BRIE/BIO PROJECT
2234 Piedmont Ave.
University of California
Berkeley, CA 94720

---

* I would like to thank Dr. Stephen Cohen and Dr. John Zysman, Co-Directors of BRIE, for sponsoring this study and providing me with helpful guidance. Dr. Chalmers Johnson encouraged me and gave the incentive to write this working paper. Dr. Ed Blakely and Dr. Suzanne Scotchmer, with whom I am conducting a biotechnology policy research program for California Policy Seminar, gave me useful comments. I would like to acknowledge Mr. Brian Sway, the Executive Director of the California Industrial Biotechnology Association, for providing useful intellectual insights. I also thank Moya Melody and Jay Tharp for editing and helping me throughout this paper.

* Akihiro Yoshikawa, Ph.D., is an industrial economist at Berkeley Roundtable on the International Economy (BRIE), University of California, Berkeley. BRIE is a university-based research institute that conducts specialized analyses of issues related to high technology.

I. INTRODUCTION

The emerging field of biotechnology is affecting various industries in a profound way. A report by the U.S. Office of Technology Assessment defines biotechnology as a "technology using biological phenomena for copying and manufacturing various kinds of useful substances."[1] Some biotechnology-based products are genuinely new, but many of them are in fact improvements on existing products. By utilizing biotechnology, for example, we can produce valuable proteins, such as human insulin and growth hormone, more cheaply and more efficiently. Amino acids can be manufactured by using either biotechnology or conventional chemical methods.

The technological impacts of biotechnology are therefore not limited to a single industrial group. By utilizing biotechnology, traditional agriculture may be transformed into a manufacturing industry. Today in Japan, traditional manufacturers of sake and other manufacturers in food processing are trying to transform themselves into high-technology companies. Combining biological functions with microelectronic technologies may also establish a new field of bioelectronics.

Therefore, through its integration with existing products, this emerging biotechnology may fundamentally transform existing businesses. Because it can affect so many sectors in a national economy, biotechnology becomes a crucial factor for maintaining a competitive

---

[1] U.S. Office of Technology Assessment (OTA), Commercial Biotechnology: An International Analysis (1984), Washington, D.C., p. 503.

edge in those sectors.[2]

Although American entrepreneurial start-up companies have been the leading innovators in biotechnology, the U.S. may be unable to maintain such competitiveness. The 1984 OTA Report states:

> Japan is likely to be the leading competitor of the United States for two reasons. First, Japanese companies in a broad range of industrial sectors have extensive experience in bioprocess technology. Japan does not have superior bioprocess technology, but it does have relatively more industrial experience using old biotechnology, more established bioprocessing plants, and more bioprocess engineers than the United States. Second, the Japanese government has targeted biotechnology as a key technology of the future, is funding its commercial development, and is coordinating interactions among representatives from industry, universities, and government.[3]

Today some important questions are whether Japanese industrial policy can realize the same success in promoting biotechnology as it has in its semiconductor industry, and whether Japan can realize a competitive edge in biotechnology. This report analyzes the Japanese government's efforts to promote biotechnology.

---

[2] Gerd Junne also argued that this wide applicability of biotechnology qualified it as a strategic sector: "Since it is not only a new area of growth, but since it has fundamental implications for almost <u>all</u> sectors of the economy, biotechnology can be regarded as a 'strategic sector'--not in the military sense but in the economic sense of being decisive for the future international competitiveness of national economies." Gerd Junne, "International Interaction Between National Policies: The Case of Biotechnology," paper presented at the World Congress of the International Political Science Association, Paris, July 15-20, 1985.

[3] OTA, <u>Commercial Biotechnology</u>, p. 8.

II. BACKGROUND

The biotechnology industry originated in American universities and research institutions, where the techniques of recombinant DNA (rDNA) and hybridoma, or cell fusion, were developed and refined. Developed in the mid-1970s, these were revolutionary techniques, for they allowed the recombination of genetic material from different organisms to form commercially useful living organisms. It was well after the invention of rDNA in 1973 that commercial possibilities for this technology were explored.

In the U.S., biotechnology began to emerge from the academic world in about 1976, when small start-up firms, often called new biotechnology firms (NBFs), began to emerge. There are approximately 200 NBFs in the U.S. today. After a slow start, the number of NBFs entering the market increased greatly in 1980-81, and since then has begun to decline (see Table 1).

Table 1. Number of NBFs Entering by Year

year	number of entrants
1976	1
1977	3
1978	4
1979	6
1980	26
1981	43
1982	22
1983	3

Source: Peter Daly, The Biotechnology Business, Frances Pinter, London (1985), p. 40.

Many of these firms were established by entrepreneurial university scientists. One of the founders of Genentech, Dr. Herbert Boyer, was a professor at University of California, San Francisco, and Dr. Ronald Glaser of Cetus, a Nobel lauraute, was at the University of California, Berkeley. Similarly, Genetics Institute Inc. was established in 1980 by Dr. Mark Ptashne, who was then Chairman of the Department of Biochemistry and Molecular Biology at Harvard, and by Dr. Thomas Maniatis, who later became chairman of the department. More than 50% of biotechnology companies established between 1971 and 1980 were founded by academic scientists.[4]

These companies are R&D-intensive, judging both by the number of research scientists on staff, and the R&D expenditures as a percentage of total assets (see Table 2).

Table 2. R&D Intensity of Selected NBFs

company	% of employees engaged in R&D	R&D spending as a % of total assets
1. California Biotechnology, Inc.	74.11	30.95
2. Genentech	47.14	27.20
3. Immunex	86.49	51.04
4. Monoclonal Antibodies	25.00	9.26

Source: 1985 annual reports and SEC forms 10-K.

NBFs are responsible for most of the technical innovations in biotechnology in the U.S., for example using rDNA to produce therapeutic proteins and applying hybridoma technology to diagnostics.

[4] However, there has been a decline in numbers of academic founders in the 1980s. Between 1981 and 1986, the majority of biotechnology companies were founded by people from industry: Mark Dibner, "Commercial Biotech's Founding Fathers," Bio/Technology, June 1987, p. 571.

While small firms were the dominant force in the initial development of the biotechnology industry, larger firms joined the market in the early 1980s and contributed to further development in many ways. One way was by establishing licensing and marketing arrangements with NBFs. Licensing arrangements led to the commercial production of many of the biotechnology products now on the market. These arrangements are not surprising since small, research-oriented firms don't often have the resources or desire to mass-produce commercial products. They also lack the marketing skills and established reputation that larger firms enjoy. For example, Schering-Plough's alpha interferon resulted from the licensing of technology from Biogen, while Eli-Lilly's human insulin resulted from technology obtained from Genentech.

Larger companies also invest in biotechnology by acquiring NBFs. Although some major companies acquired small start-up companies in the 1970s, acquisitions have become more common in the past few years. Pharmaceutical and chemical companies have been particularly aggressive in acquiring NBFs.

The recent increase in acquisitions can be explained by the fact that more and more NBFs are moving from a stage where competition is based on the quality of R&D, to a stage where product differentiation and advertising may be more important--capabilities the NBFs lack. In the commercialization of pharmaceuticals, larger companies have the advantage of large financial resources and experience with requirements for lengthy clinical testing and with the regulatory process.[5]

Table 3. Equity Purchased in Biotechnology Firms

large firm	biotechnology firm	year
Abbott	Amgen	1980
Baxter Travenol	Genetics Institute	1982
Becton Dickenson	Applied Biosystems	1984
Bristol-Myers	Genetic Systems *	1985
Charles River Lab.	Atlantic Antibodies *	na
Damon Biotech	Biotherapy Systems *	na
Dow	Collaborative Research	1981
Du Pont	New England Nuclear *	1981
Fluor	Genentech	1981
Hybridoma Sciences	ICL Scientific *	na
J.G. Boswell	Phytogen *	na
Johnson & Johnson	Enzo Biochem	1982
Lederle	Molecular Genetics	1981
Lederle	Cytogen	1983
Lilly	Synergen	1984
Lilly	Hybritech *	1985
Lubrizol	Agrigenetics *	na
Martin Marietta	Molecular Genetics	1982
Monsanto	Biogen	1980
Monsanto	Collagen Corporation	1980
Schering-Plough	Biogen	1982
Schering-Plough	DNAZ Ltd. *	1982
SmithKline	Beckman *	1982
Syntex	Genetic Systems	1982
Ventrex	Bioclinical *	na
Ventrex	Immuno Modulators Lab. *	na
W.R. Grace	Amicon *	1983
W.R. Grace	Cetus Madison *	na

* Acquisition.
Sources: Mark Dibner, "Biotechnology in the American Pharmaceutical Industry: The Japanese Challenge," in Daniel Koshland, ed., Biotechnology: The Renewable Frontier (1986) and Peter Daly, The Biotechnology Business (1985).

---

[5] The development of monoclonal antibodies for use in diagnostics is illustrative. In the first stage of development, the key to success was to create biotechnology-based diagnostic kits that were cheaper than, and just as accurate as, conventional diagnostics. At this stage, good research and development were the keys to success. Today, the products have been refined, and many companies produce diagnostics that are essentially identical. Therefore, the key to success is product differentiation and marketing, as evidenced by the prevalent advertising for pregnancy test kits.

Many NBFs are acquired just as they begin seriously to market their products. For example, Hybritech, an NBF acquired by Eli-Lilly in 1985, started making net profits at the end of 1983, and profits rose throughout 1984. Their 1984 annual report stated,

> "Hybritech has now clearly made the transition from a research oriented start-up to a fully capable health-care company. We are developing, manufacturing, and selling medical products..."

In summary, small firms have played a major role in biotechnology innovation in the U.S. in the past decade. Even though larger companies are entering the industry through licensing agreements and acquisition, these larger companies continue to rely on the smaller NBFs for innovative technology.[6]

In Japan, there are no NBFs. This may be due both to a lack of entrepreneurship and to a lack of venture capital in Japan. A rigid labor market characterized by Japan's life-long employment system, also discourages possible spin-offs from established companies and universities. Because it is unlikely that a young, able scientist would

---

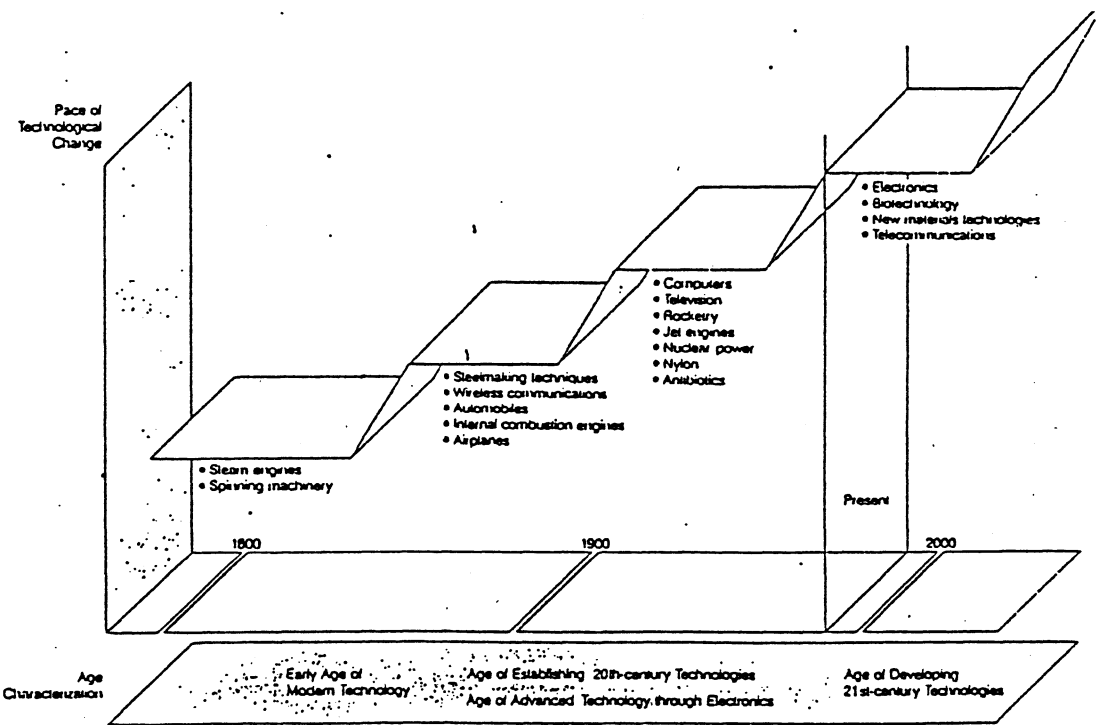
[6] Although it is tempting to conclude that small firms will always be the source of innovation in this industry, this may not be so. Raphael Kaplinsky (1982) studied the Computer Aided Design (CAD) industry, and concluded that in different stages of industry development, innovations came from firms of different sizes. The initial technology was discovered in large firms. Next, software writers began to emerge from these large firms to form their own small companies, which applied the technology to the electronics industry. In the third stage, concentration occurred, and innovations came from medium-sized companies. Finally, these medium-sized firms grew to large firms, and small firms began to spin off from the large firms. If the biotechnology industry develops in a similar manner, innovation may soon emerge from medium- to large-sized firms. See Raphael Kaplinsky, "Firm Size and Technical Change in a Dynamic Context," in The Journal of Industrial Economics (Sept. 1983).

start his/her own company, the majority of Japanese firms working in biotechnology are large established firms with backgrounds in the pharmaceutical or chemical industry, although some are from the food industry.

III. ECONOMIC IMPACTS IN JAPAN

The government of Japan has specified three technologies as "Basic Technologies for Future Industries." They are new materials, microelectronics, and biotechnology. The government has introduced various policies to promote these three areas.

FIGURE 1: Past, Present, and Future Technologies



Source: Technological Progress as it Relates to Society and the Economy, by NIRA (National Institute for Research Advancement)

What is the potential economic benefit from the commercialization of biotechnology products? We can easily guess the future market size, but cannot know whether such an estimate is correct. However, a look at various estimates of market size will convince us of the potential economic importance of biotechnology in the 21st century. According to one industry source, the worldwide market for biotechnology products may reach $40 to 60 billion in the year 2000.[7] For the Japanese market alone, the government estimated a market of between $28 to 45 billion.[8] A more optimistic estimate by the Japanese Bioindustry Development Center (BIDEC) maintained that the future biotechnology-related market will reach approximately $100 billion (15 trillion yen) in Japan alone (see Table 4).

These estimates should be considered carefully because the numbers depend on various assumptions, such as the rate of future market growth,

---

[7] Genex forecasts the worldwide market for rDNA products as $40 billion in the year 2000. Leslie Glick, "The Industrial Impact of the Biological Revolution," in Biotechnology in Society, Joseph Perpich, ed., Pergamon Press (1986). T.A. Sheets & Co. maintained that the market, which is currently about $25 million, will be $64.8 billion by the year 2000 (European Chemical NEWS). The Japanese Agency of Industrial Science and Technology estimated the worldwide biotechnology market in the year 2000 as 5 to 8 trillion yen, or about $33 to 53 billion. (Ministry of International Trade and Industry (MITI), 21 seki o kizuku Baio Indasutorii (Biotechnology as a Foundation of the 21st Century), 1984).

[8] This estimate was given by the Agency of Industrial Science and Technology in its technology assessment study (1980). The original figure was 4.2-6.8 trillion yen, dollar value calculated according to the current exchange rate of one dollar equalling 150 yen. Using a broader definition, BIDEC estimated it as high as 15 trillion yen. Japan Economic Journal presented an estimate of 5.7 trillion yen, based on its recent survey of biotechnology companies. These estimates of the future biotechnology market in Japan encouraged both domestic firms' investments in newly developed biotechnology and foreign firms' direct investment in Japan.

the rate of industrial application in each market, and most importantly the definition of biotechnology. Thus these estimates are not free from the accusation that they are simply "facile and stupid."[9]

Can biotechnology generate as much economic expansion as did the development of microelectronics? Although its impacts on medical science and the economy are expected to be significant, the economic impacts may be limited compared with those generated by developments in microelectronics.[10] Employment opportunities created by the development of biotechnology are also limited because the technology is capital- and knowledge-intensive, not labor-intensive.

Table 4 shows that biotechnology will affect a wide range of industries. Industries such as food processing, chemical manufacture, and agriculture will experience some fundamental changes in market definition.[11] Although still in the distant future, development of biological applications in electronics, i.e. the biochip, may create another microelectronics revolution.

---

[9] John Elkington, The Gene Factory: Inside the Genetic and Biotechnology Business Revolution (New York: Carroll & Graf Publishers, Inc., 1985), p. 44.

[10] Compared to the other two, the size of the economic impact of biotechnology is smaller. The total economic value created by the development of microelectronics is estimated at 163.2 trillion yen, and new materials at 57.9, whereas the estimated market size for biotechnology is only 6.6 trillion yen.

[11] For example, today we can observe a mixing of agriculture and manufacturing through the use of genetic engineering.

Table 4: Impact of Biotechnology in Japanese Market

Year 2000 in Japan (billion yen)

industry	industrial application rate (%)	market size of biotech. based prod.	share (%)
agriculture	12	1,401.4	9.3
livestock	24	475.7	3.2
forestry	1	8.5	0.0
fisheries	3	118.1	0.8
food	23	4,247.4	28.3
pulp	5	89.9	0.6
chemical	13-16	2,598.3	17.3
pharmaceutical	40	3,151.4	21.0
pesticide	30	141.6	0.9
energy	2	462.8	3.1
utility	23	1,370.2	9.1
electronics	3	603.5	4.0
TOTAL	12	15,003.2	100.0

Based on estimates by the Bioindustry Development Center in BIDEC, Seireki 2000 nen ni Okeru Baiotekunorogii no sangyo kozo ni Oyobosu Inpakuto (Impacts of Biotechnology on Industrial Structure in the Year 2000), 1985. The value of the market is based on 1980 prices.

According to BIDEC, biotechnology will have the greatest impact on the pharmaceutical and food industries in the Japanese economy. In the year 2000, 21% of the total biotechnology-related market of 15 trillion yen is expected to be in pharmaceuticals, and 28% in food. The BIDEC estimate shows that the application rate of biotechnology in pharmaceuticals is more than 40%, and the value of biotechnology-based pharmaceutical products accounts for more than 20% of the biotechnology-based market. The Agency of Industrial Science and Technology estimated an even higher proportion of pharmaceutical applications, up to 50% of the biotechnology-related market in the year 2000.[12]

The changing age structure in Japan helps explain the Japanese preoccupation with pharmaceutical development. The proportion of people in Japan over the age of 65 is expected to rise from 10.1% in 1985 to 17.1% of the total population by the year 2000. It is expected to be more than 20% by the year 2010. As Japan's population ages, diseases associated with aging will increase as well. Such diseases include Alzheimer's disease, diabetes, deficiencies in enzyme and hormone production, osteoporosis, and thrombosis.

In the U.S., one-quarter of the Caucasian women over 65 years old are believed to suffer from osteoporosis, or the weakening of bones, and the number of patients is about 15 million today.[13] Annually more than 337,000 people in the U.S. are diagnosed with Alzheimer's.[14] It is expected that approximately one million people will suffer from Alzheimer's in Japan by the year 2000.

In Japan, studies on new drugs for diseases related to aging are active, as are cancer-related studies. Along with the many firms conducting R&D in diseases of aging, Japan's government is conducting various research projects on the mechanism and regulation of aging. For

---

[12] This high expectation for the pharmaceutical application of biotechnology may be criticised as overly optimistic. More recently, a U.S. consultant predicted that the economic impact of biotechnology would be much more modest, and would contribute just over 5% of total sales in the therapeutic and diagnostic market. The estimate was given by Henry Weinert, President of Boston Biomedical Consultants, Bio/Technology, Vol. 5, January 1987, p. 27.

[13] Elkington, The Gene Factory, p. 103.

[14] "Alzheimer's Costs Billions, Study Finds," in San Fransisco Chronicle, 8/27/87.

example, the Science and Technology Agency is conducting multidisciplinary studies on the aging process at the Institute of Physical and Chemical Research.[15]

Table 4 shows that, on the other hand, energy (2%) and electronics (3%) have low rates of industrial application. By the year 2000, the application of biotechnology to these fields probably will still be limited. Applications of biotechnology in areas such as energy and electronics are a long-shot target.

In addition to direct applications, it is expected that in the year 2000 there will be a market of 300 to 600 billion yen (approximately $2 to 4 billion) for industries that supply biotechnology research. Some researchers have predicted that these supporting industries might be the true winners of the heated biotechnology race, just as those who made money out of the Gold Rush were not "those who rushed in to find gold: instead, they were the people who sold picks, shovels, and tents to those who were digging for gold."[16]

According to a market analyst, the supporting industries are expected to grow at an annual rate of 13% throughout the 1990s and at a slightly lower rate until 2000.[17] The following table is based on the same assumption.

---

[15] These are themes studied under a new long-term reserch project entitled the "Frontier Research Program."

[16] Elkington, The Gene Factory, p. 56.

[17] An assumption used by Business Communication Co., Elkington, ibid., p. 56.

Table 5: Research-Supporting Industries
(billion dollars)

year	Japan	U.S.
1983	0.5	1.6
2000	3.0	7.0

Such a development of equipment and facilities is important to realizing efficient R&D in biotechnology. Four key automating instruments necessary to realize the "revolution" in molecular biology research are said to be the protein sequenator, DNA systhesizer, protein synthesizer, and DNA sequenator.

IV. CHARACTERISTICS OF BIOTECHNOLOGY

Some specific characteristics of biotechnology must be understood before analyzing Japanese policies to promote biotechnology.

First, one must understand that biotechnology is a "technology," not a "product." Biotechnology can be applied to various products in many different industries. As shown in Table 4, its impacts are not limited to a single product or industrial classification. The potential applications of biotechnology range from agricultural to pharmaceuticals.

The conditions for commercial success are different in each market. Similarly, the environment suitable to promote R&D is also different in each application. Therefore, both corporate strategies to realize commercial success and government policy to promote industrial applications of biotechnology differ according to market area. For example, policy measures taken to promote agricultural biotechnology are necessarily different from policies to promote development of the next generation of biotechnology-based pharmaceutical products.

Additionally, the product markets for biotechnology-based products are highly diversified, and each may be limited in size. For example, although pharmaceutical applications of biotechnology in Japan are estimated to reach 3 trillion yen in the year 2000, the market varies according to the type of drugs.

Another issue is that many of the products manufactured by utilizing the new biotechnology have "substitutes" produced by conventional technologies. Similar substitutability was observed in the initial development of the integrated circuit (IC) with respect to the then-conventional transistor, but due to its nature the issue is more complicated for biotechnology. Whereas the development of the IC created a new but well-defined market, there is no such "biotechnology industry." In many cases, biotechnology is merely one of many technologies that can be used to produce goods.

Especially in industrial biotechnology, i.e., manufacturing amino acids, the issue of substitution is important. For example, amino acids can also be manufactured by more conventional technologies, such as chemical synthesis. Final products are essentially the same in quality. The choice of technology thus depends on relative cost-performance.

Often the economic and social impacts of biotechnology will be realized more significantly when it is integrated with conventional technologies and experiences. To make a new biotechnology-based drug, clinical and diagnostic experience are essential. Traditional expertise in "old biotechnology," for example the knowledge of fermentation involved in manufacturing sake and soy sauce, may also be useful in manufacturing new pharmaceutical products. Similarly, in order to apply the new biotechnology to agriculture, a fundamental and traditional understanding of plants and cultivation may be essential. Thus many conventional areas of expertise may be extremely useful in utilizing biotechnology and in developing products based on it. In this manner, biotechnology may be able to transform some "old" industries into high-technology industries, and it may change the nature of an industry profoundly. The traditional agricultural sector may be transformed into a more engineering-based industry. Thus policy measures may be introduced to promote integration of old and new technologies and encourage smooth transformation of existing companies.

Biotechnology is also characterized by its great uncertainty. For example, although many firms are using biotechnology to try to develop an anti-cancer drug, there is much commercial risk involved in such a pursuit. Often the commercial introduction of a new pharmaceutical takes about 10 years of R&D and testing and $100 million. When making the initial investment, it is difficult to know what will be the most appropriate product in 10 years. Although this is particularly serious in pharmaceutical applications of biotechnology, it is also true of other areas. This uncertainty creates further difficulties in the formation of long-term corporate strategy and government policy.

Lastly, one should realize that in biotechnology, the distinction between basic and applied science is extremely ambiguous. A basic scientific breakthrough itself may be patentable and is therefore directly associated with commercialization. Thus "fundamental" studies in biotechnology, although they cannot be simply characterized as "basic" science, are as important as "applied" R&D to improve process technologies. Needless to say, the environment suited to promoting scientific breakthroughs is different from the one suited to promoting applied research.

V. REVIEW OF JAPANESE BIOTECHNOLOGY POLICIES

The Japanese government has introduced various policies to promote biotechnology. Because biotechnology will affect a wide range of industries, several ministries have introduced seperate, but often overlapping, policies.

In 1984, the Ministry of Agriculture, Forestry, and Fishery organized a basic research group on cell fusion, and 14 firms joined the group.[18] The ministry is trying to develop biotechnology-based crops in cooperation with private firms.[19] It has also been trying to promote biotechnology development in local areas. A similar policy to promote

---

[18] It included Ajinomoto, Asahi Chemical, Kyowa Hakko, Kirin, Suntory, Mitsui Toatsu, Mitsubishi Chemical. It is interesting to note that no traditional nursery or seed company was involved in the joint effort.

[19] Many members also participated in PCC Technologies, a joint research company established with funds made available by the Key Technology Center.

regional biotechnology has been attempted through the Ministry of International Trade and Industry's (MITI) Technopolis project.

In 1986, the Ministry of Health and Welfare (MHW) established the Human Science Foundation (HSF) to promote the cooperation of private companies, universities, and government in the development of new pharmaceuticals.[20] With the HSF as an organizational body, member firms with government research institutes and/or university laboratories formed various groups to pursue different themes in biotechnology application for next-generation pharmaceutical products. Although many firms joined the HSF, it contributed only 860 million yen, to which the Ministry added 600 million; the rest was contributed by member companies. The MHW also introduced a measure to promote biotechnology more directly.[21] In 1987 the MHW established a mechanism to finance private firms' R&D activities in pharmaceutical products and sophisticated medical equipment, such as nuclear magnetic imaging.[22]

The Ministry of International Trade and Industry (MITI) is the champion of Japanese industrial policy. The MITI has overseen various efforts to carry out basic and applied research in biotechnology.[23]

---

[20] Well over 100 firms, including some foreign-owned firms, joined the HSF. Not only established pharmaceutical firms, such as Takeda and Sankyo, joined, but traditionally non-pharmaceutical firms joined, such as Kirin and Asahi, both breweries of beer.

[21] <u>Shakai Hosho</u>, No. 1438 (6/22/1987), No. 1421 (2/21/1987).

[22] MHW modified the Relief Fund for Adverse Reaction to a Medicine in 1987 so that it also can administer special funds to promote pharmaceutical development. This is the first financial support by the MHW for commercialization of products.

[23] One should, however, realize that such cooperative efforts in biotechnology are also being conducted in European countries. Under coordination of the Biotechnology Directorate of the Science and

There are two mechanisms for promoting joint research under the ministry. One is to join a non-profit research association established under the Research and Development Project on Basic Technologies for Future Industries (hence Next Generation Project). The other type of joint research effort is an R&D corporation established by the Key Technology Center.

The Next Generation Project was established in 1981 to promote the three "key" technologies for the future: next-generation microelectronics, new materials, and biotechnology (see Table 6). Twelve themes of study under the project were specified, among which were three under biotechnology. They were: (1) bioreactor, (2) mass cell culture, and (3) rDNA application.

Engineering Research Council and Department of Trade and Industry, British pharmaceutical companies and universities are conducting cooperative efforts in biotechnology. "More Collaborations in British Biotech," in Bio/Technology (February 1987), p. 112. The U.K.'s Medical Research Council set up Celltech, and research conducted at the Agricultural Genetics Company was funded by the Agricultural and Food Research Council. Elkington, The Gene Factory, p. 193.

Table 6.
Themes of R&D Projects on Basic
Technologies for Next Industries

	project area	1984 buget (¥ million)
1.	Fine ceramics	863
2.	Synthetic membranes for new separation technology	527
3.	Synthetic metals	340
4.	High-performance plastics	301
5.	Advanced alloys with controlled crystalline structures	568
6.	Advanced composite metals	658
------	New materials subtotal:	3,257
7.	Bioreactors	453
8.	Large-scale cell cultivation	383
9.	rDNA application	365
------	Biotechnology subtotal:	1,201
10.	Superlattice devices	430
11.	Three-dimensional ICs	737
12.	Fortified ICs for extreme conditions	311
------	New electron devices subtotal:	1,478
TOTAL		5,936

To study these three areas, the Biotechnology Research Association was established and subdivided into three groups. Each group's research was designed to be conducted by cooperating closely with government research institutions, such as the Fermentation Research Institute, Research Institute for Polymer and Textiles, and National Chemical Laboratory. Table 7 lists the 14 firms that joined the joint research association.

Table 7: Biotechnology Joint Research Association

company	industry	project
Sumitomo Chemical	chemical	rDNA application
Mitusi Toatsu Chemical	chemical	rDNA application
Mitsubioshi Chemical*	chemical	rDNA application
Takeda Chemical	pharmaceutical	mass cell culture
Toyojuzo	food	mass cell culture
Kyowa Hakko	chemical	mass cell culture
Ajinomoto	food	mass cell culture
Asahi Chemical	textile	mass cell culture
Mitusbishi Chemical	chemical	bioreactor
Mitsubishi Gas Chemical	chemical	bioreactor
Daicel Chemical	chemical	bioreactor
Kao Corp.	chemical	bioreactor
Denki Kagaku Kogyo	chemical	bioreactor
Mitsui Petrochemical	chemical	bioreactor

* Mitsubishi Kasei Institute of Life Science, a wholly owned subsidiary of Mitsubishi Chemical.

Table 7 supports several interesting observations. It shows that many of the firms involved in the joint research association are chemical companies. The chemical industry in Japan is often characterized as a "declining" industry. We see an interesting mix of industrial policies to promote next-generation industries (the sunrise industries) and to reinvigorate declining industries (the sunset industries). This policy mixture may imply a strong governmental commitment to transform the declining chemical industry into a sunrise industry once again. With these forms of government support, the chemical companies are likely to make substantial investments in biotechnology. The most likely areas of application will be 1) agricultural biotechnology, where they have experience manufacturing herbicides and pesticides; 2) industrial biotechnology (amino acids, etc.), where they can utilize their experience in enzyme reaction technologies; and 3) pharmaceutical biotechnology, where the potential pay-off is high.[24] Although the chemical companies have been suffering from adverse conditions in their primary business, they still enjoy large size and financial "deep pockets." With pressure to diversify, these chemical companies may become the most aggressive competitors to other biotechnology companies both in Japan and abroad.[25]

One such company is Mitsubhishi Chemical, the largest integrated chemical company in Japan. Its Mitsubishi Kasei Institute of Life Sciences was established in 1971. Considering that one of the earliest biotechnology companies, Cetus, was established in 1971, and Genentech was established in 1976, Mitsubishi Kasei was genuinely one of the earliest entrants to biotechnology.

Two food-processing companies and one textile company belong to the association. Toyojuzo manufactures sake and other alcohols and recently

---

[24] A scientist at Mitsui Toatsu Chemical stated that biotechnology was in fact within the domain of chemical technologies, and chemical comapnies had useful experiences throughout their chemical business. According to Nobuyasu Noguchi, Chief Project Coordinator of the Life Science Department at Mitusi Toatsu Chemicals, "Biotechnology can be interpreted as substance conversion technology based on life science, and therefore can be included in the category of chemical technology. To put it concretely, enzymes and cells correspond to chemical catalysts, while cell culture and bioreactor correspond to chemical reaction. Recombinant DNA and cell fusion technologies are catalyst technology." Business Japan, September 1986, p. 53.

[25] With their declining business, they may try to break into any potential market. Even if such markets are relatively small, fierce competition may force them to enter in order to preempt the market, which may cause severe price-cutting and dumping where cost factors are important, i.e., industrial biotechnology.

diversified into pharmaceutical market.[26] The company belongs to Asahi Chemical Industry.[27] Ajinomo is the largest integrated food-processing company and the world's leading manufacturer of amino acids. The company is one of the leading Japanese firms in biotechnology. Many Japanese food-processing companies have traditional expertise in the "old" biotechnology of fermentation, and are trying to utilize this background in their pursuit of biotechnology.

Although pharmaceutical applications are said to be the primary focus of the Japanese effort in biotechnology, only one pharmaceutical company, Takeda, was involved in MITI's joint research association.[28]

One should also realize that all the companies involved in the association are large, established companies; no new companies are specializing in biotechnology.

There are difficulties in these government-led cooperation efforts in R&D, especially when companies are competing against each other. Participants who have more knowledge and experience than other members tend to be unwilling to share such expertise. To avoid such problems in government-led joint research efforts, MITI introduced a new framework in cooperative R&D. (See also Section IX.)

The Key Technology Center was established in 1985 with the Ministry of Post and Telecommunication (MPT) by utilizing a fund made available

---

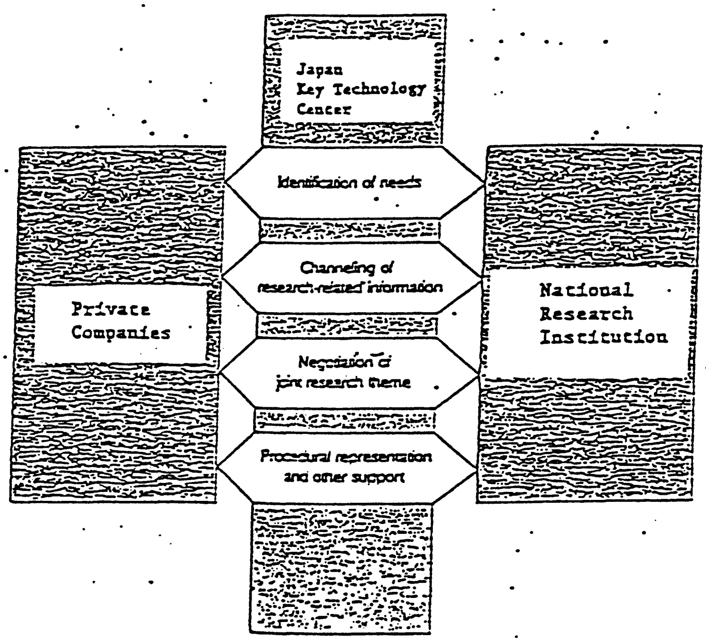
[26] In 1986, 36% of its sales were from sake, and 49% from pharmaceuticals.

[27] Asahi Chemical is the leading manufacturer of synthetic fibers and is also known for its aggressive diversification policy. It recently diversified into the semiconductor industry as well as biotechnology.

[28] Takeda is the largest pharmaceutical company in Japan.

from the sale of NTT (Nippon Telephone and Telegraph) stock.[29] The center was designed to utilize the energy and dynamism of the private sector in research and development.[30] Under the Key Technology Center scheme, two or more firms with their own initiative can jointly establish an R&D company and conduct research. R&D companies are established by joint investment of the Key Technology Center and by member firms. The Key Technology Center provides up to 70% of the investment necessary for the joint venture.

FIGURE 2: Mediation Service of Key Technology Center



Source: Japan Key Technology Center

---

[29] It was established by the 1985 law entitled "Law for the Facilitation of Research in Fundamental Technologies."

[30] Some Japanese executives, however, maintained that it was simply an excuse for the government to use private money for a national project. The tremendous government deficit imposes a serious limit on the amount the government can spend to finance their projects.

Four companies related to biotechnology were established with financial support from the Key Technology Center. In 1985, the Protein Engineering Research Institute (PERI) and M.D. Research were incorporated. Five private firms: Toray, Mitsubishi Chemical, Kyowa Hakko, Takeda Chemical, and Toa Nenryo Kagaku, jointly established PERI to conduct research in protein engineering.[31] The MITI and MPT financed 70% of the capital, and the remainder was shared by the five firms. The PERI is also trying to construct a data base necessary for research into the structure of protein. It is said that the study of protein structure is essential to promoting the next generation of pharmaceutical products. The total investment in the PERI is expected to be 17,000 million yen (about $115 million) in 10 years.

Although Japan doesn't have a Jeremy Rifkin devoted to opposing biotechnology, local residents opposed the establishment of the Protein Research Engineering Center out of fear of its unleashing possible new diseases.

In 1986, two other R&D companies were established. One was PCC Technology, which was jointly created by Kyowa Hakko, Mitsui Petrochemical, Kirin Brewery, etc. The company was incorporated to conduct research on plant biotechnology. The second one, the Foundation of Biomaterial Research Institute (BRI), was created by Toray, Sumitomo Bakelite, and Sumitomo Electric. BPI was established to develop bioactive materials by hybridizing synthetic materials and living cells

---

31 Toa Nenryo Kagaku is a subsidiary of Esso and Mobile. The opportunities offered by the Key Technology Center are not limited to Japanese firms. Nine additional companies (Kirin Beer, Suntory, Nippon DEC, Nippon Roche, etc.) later joined the PERI.

to produce artificial organs and biochips.

Money provided to these R&D companies by the Key Technology Center is public money made available from the sale of NTT stock. Since this money represents an "investment" of public funds rather than a government subsidy from governmental budgets, a question is whether the Key Technology Center can realize a profit or at least recover the money invested. An overwhelming majority believe that it is unlikely that a joint R&D company established by the Key Technology Center can be a successful "corporation" in terms of its own balance sheet. However, it was originally intended to provide Japanese companies with the necessary financial support to develop next-generation technologies, and was not intended to be financially lucrative itself. It is a bureaucratic achievement in that it promotes Japanese high technologies within a context of seriously limited government funding.

The Science and Technology Agency (STA) is the foremost governing body of Japanese science and technology policy. The primary function of the agency is to promote basic scientific studies in Japan. It also coordinates the use of various funds designed to promote science. One such account, the Special Coordination Fund for the Promotion of Science and Technology, was established in 1981. The fund was designed to provide an incentive for basic R&D for new technologies. The fund is controlled by the Policy Committee of the Council for Science and Technology, which defines the long-term goals of Japan's science and technology policy. The Policy Subcommittee members include top executives from large Japanese corporations.

Recently, however, STA became more involved in the commercialization of technologies. The growing interest of STA in commercial development may be due partly to its jurisdictional competition with MITI over Japan's technology-based industries. Since the distinction between basic science studies and applied research for commercialization is becoming less and less clear, and at the same time fundamental knowledge of science is increasingly important for the development of new technologies related to areas such as superconductivity and biotechnology, MITI is introducing its own policies to promote basic R&D. STA regards such activities as a threat to its authority.

STA established the Research Development Corporation to actively promote the commercial use of government-owned technologies.[32] It was designed to support commercial development of technologies that probably would not be developed by the private sector alone. It provides private companies with scientific findings from public (university and government) research laboratories.[33] The Research Development Corporation also coordinates a joint research group to pursue commercialization of technologies. It selects private firms to conduct research with public research institutes. The Research Development

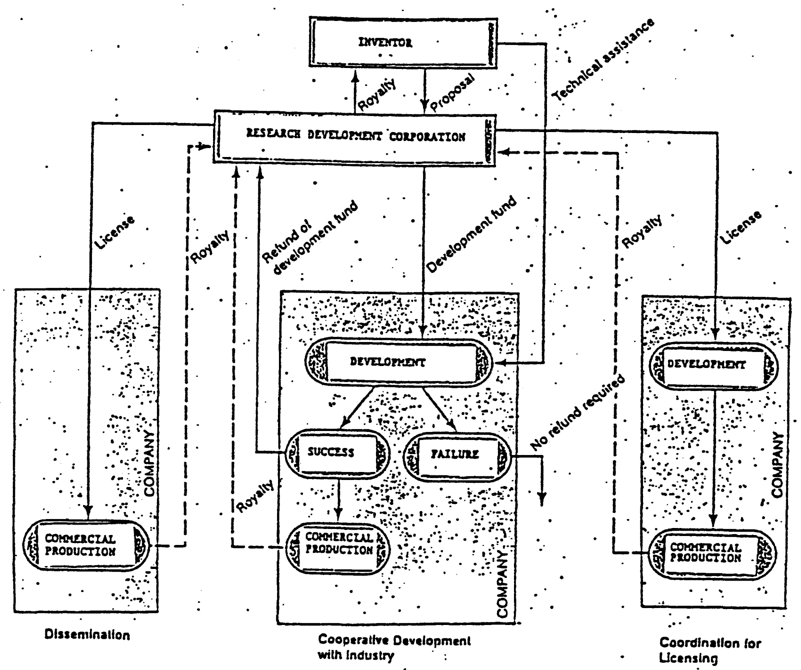
---

[32] Whereas Special Coordination funds provide an incentive for basic research for new technologies, the Research Development Corporation plays an active role in the commercial development of technologies. It is a government-funded public corporation.

[33] In the U.S., the Center for the Utilization of Federal Technology was established in 1983 by the Steven-Wydler Technology Innovation Act of 1980. It was designed to promote private-sector utilization of federally owned patents and other technical know-how (i.e., at the National Institutes of Health and the National Bureau of Standards). See Thomas Maugh II, "Spreading the Government's Technological Wealth," in High Technology, August 1985, p. 80.

Corporation has conducted several studies in biotechnology. For example, it has supported projects concerning the development of interferon at Green Cross and Toray.

FIGURE 3:SERVICES OFFERRED BY THE RDC



Source: Research Development Corporation

VI. FINANCIAL SUPPORT FOR BIOTECHNOLOGY

In 1986, MITI, the champion of Japanese industrial policy, spent about 5.5 billion yen on biotechnology. The MITI's biotechnology-related budget increased 17% between fiscal years 1985 and 1986. This figure, however, doesn't include the amount spent by the Key Technology Center. The STA spent about 10 billion yen. Although the STA funding was mainly for basic research, as mentioned above, some of its money was spent to promote commercialization of technologies. The

Ministry of Education spent about 13.3 billion yen, primarily for university and government research institutes to conduct basic research, including cancer research. The MAFF (Ministry of Agriculture, Forestry and Fisheries) and MHW (Ministry of Health and Welfare) each spent roughly 2 billion yen.

Therefore, total government spending for biotechnology in 1986 was approximately 35 billion yen, or $235 million based on a recent exchange rate. One should note that this amount is substantially larger than the estimate presented by other reports on Japanese biotechnology.[34] We may be over-estimating the total governmental spending for biotechnology because the budget for biotechnology is not clearly seperable from other expenditures and because various government ministries in competition to secure their budgets use biotechnology as an excuse to gain approval from the Ministry of Finance.

Table 8 summarizes the biotechnology-related budgets of various ministries, and Table 10 itemizes MITI spendings.

---

[34] The total governmental assistance for biotechnology research in 1986 in Japan was $65 million, according to the Nomura Research Institute. According to the same report, in 1986, government assistance for biotechnology research was $550 million in the U.S. See Bio/Technology (May 1987), p. 431. Similarly, Saxonhouse estimated it to be 9,903 million yen (about $66 million) in 1984. Gary Saxonhouse, "Industrial Policy and Factor Markets in Japan and the United States," in Hugh Patrick (ed.), Japan's High Technology Industries (Seattle: University of Washington Press, 1986).

Table 8. Biotechnology-Related Budget (1986)
(billion yen)

Ministry of Agriculture, Forestry and Fisheries	2.5[35]
Ministry of Construction	0.1
Ministry of Education	13.4
Ministry of Health and Welfare	2.2
Ministry of International Trade and Industry	5.5
Environmental Agency	0.1
Science and Technology Agency	10.3
Total	34.1

Source: BIDEC News, No. 43 (January 1987).

Table 9 compares government funding of biotechnology in advanced countries. Careful interpretation is required because countries use different definitions of biotechnology. Data for European countries are also relatively old. It should be noted that the expenditure by the U.S. government is much larger than that by the Japanese government. The table shows that U.S. funding in 1982 was more than twice Japanese funding in 1986. In 1988 the U.S. National Institute of Health (NIH) alone will probably spend more than $700 million on research closely related to biotech. By using a broader definition of biotechnology research, NIH funding may reach $1200 million in 1988. The share of government funding for health-related R&D is also larger in the U.S. (see Figure 4). Whereas government funding comprised about 50% of available financing in Japan in 1983, in the U.S. in the same year approximately two-thirds of funds came from the federal government.

[35] Additionally, 3.8 billion yen was spent under Seibutsukei Tokuteisangyo Gijutsukenkyu Suishin Kiko for various biotechnology-related studies.

Table 9: Biotechnology-Related Budget
($ million)

U.S.	522.3	(1982/83)
Japan	235.2	(1986)
West Germany	117.5	(1982/83)
France	74.8	(1982/83)
United Kingdom	52.5	(1982/83)
European Community (EC)	316.1	(1982/83)

Sources
Japan: BIDEC News No. 43 (January 1987).
U.S.: Saxonhouse, "Industrial Policy and Factor Markets".
Others: Junne, "International Interaction".

FIGURE 4: Sources of Health R&D

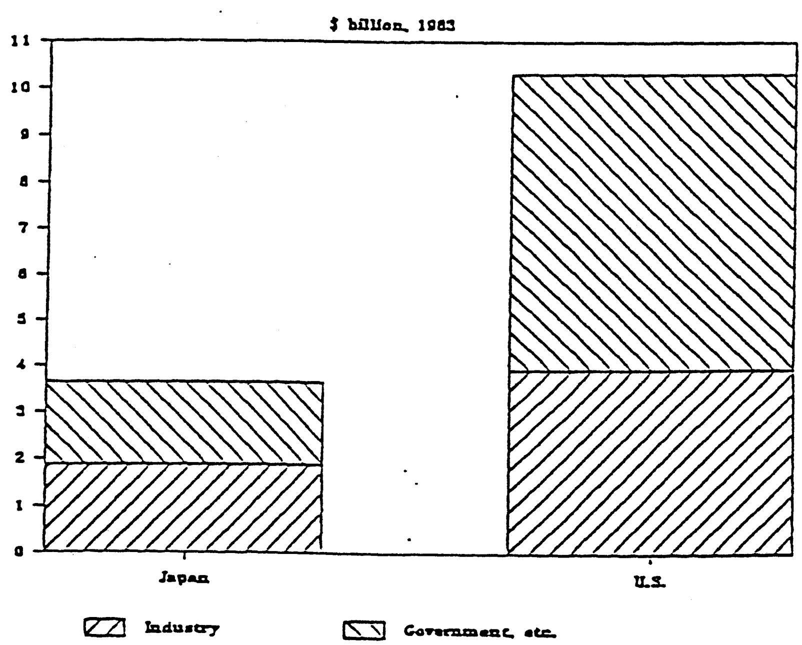


Table 10. MITI's Biotechnology-Related Budget
(million yen)

Item	FY1985	FY1986
1. Establishment of plans to assist biotechnology industry	100	115
2. Promotion of technological development		
(a) Biotechnology relating to the R&D in Basic Technology for Future Industries	1,252	1,280
(b) Technology development relating to biomass	1,247	1,312
(c) Special credit for the Agency of Industrial Science and Technology relating to biotechnology	283	249
(d) Grant-in-aid for R&D on technology to activate industries relating to biotechnology	621	480
(e) Survey on biological technology for waste water treatment	60	53
(f) Total water re-utilization system ("AQUA Renaissance'90") in the large-scale industrial technology R&D system	20	1,072
3. Providing the base for technological development		
(a) Expansion and reinforcement of the operation for Patent Microorganism Depository	276	511
(b) Construction of a laboratory for experiments utilizing plant and animal cells	209	196
(c) Biotechnology activities relating to the provision and promotion of data bases and information supply	0	76
4. Promotion of international cooperative research for the manufacture of physiologically active substances	148	172
TOTAL	4,216	5,517

Source: Ministry of International Trade and Industry, "Policy for Bioindustry" (brochure printed October 1986).

Various authors have stated that the relatively low government funding in Japan compared with the U.S. is misleading because the U.S. government primarily finances basic research, which could benefit foreign researchers, instead of commercially oriented research.[36] Japan has been criticized as being a free-rider on the U.S. effort in science and technology. Whereas the U.S. government funds approximately half of the nation's total R&D expenditure, the Japanese government funds less than 20%. For example, 35% of the entire budget for medical research in the U.S. was provided by the National Institute of Health (NIH) alone. At NIH various basic studies are conducted to find, for example, a cure for AIDS. However, in 1986 there were 327 Japanese researchers at NIH, and only a small fraction of them were paid by a Japanese source. American support of Japanese research became an issue when it was pointed out by White House science officials.[37]

Tax Incentives

Japan's government offers tax incentives and conditional loans to encourage the purchase of equipment and facilities (depreciatable assets) necessary for R&D, and hence to promote R&D in the private sector. Tax incentives and credits may be the most direct way to promote private R&D.[38]

---

[36] See for example, Saxonhouse, "Industrial Policy and Factor Markets," p. 107.

[37] Marjorie Sun, "Strains in U.S.-Japan Exchange," Science, July 31, 1987, pp. 476-478.

[38] The 1984 OTA report, Commercial Biotechnology, also states that the tax incentive program may be an effective public option to promote private biotechnology R&D.

A firm can deduct from its corporate tax 20% of any R&D spending that exceeds the maximum level of the past. Additionally, a firm can deduct certain assets (equipment, facilities) used for high-technology research. As of the spring of 1987, there were more than 200 such deductable items, of which 114 were in fields related to new materials and 27 in biotechnology.

Table 11. Facilities Eligible for Tax Deductions

technology	number of facilities
New Materials	114
Biotechnology	27
Advanced electronics	40
Robotics & advanced production/ processing technologies	23
Technologies for extreme environment	30
Innovative processing technologies	9
Technologies related to space development	9
TOTAL	217

Source: Masaharu Higuchi, "Current Status of New Materials Industry and the Tasks of the Future." (February 1987)

VII. RESEARCH AND DEVELOPMENT

Technology Transfer

It was said that in the early 1980s, Japan was at least four years behind the U.S. in biotechnology. The year 1982 is said to have been "the year Japan's biotechnology industry was born."[39] Since then Japan has engaged in aggressive efforts to catch up with the U.S. in the new technology.

Many such efforts involved technology transfer from the U.S. to Japan. The table below shows examples of technology transfer in terms of joint venture, licensing, and acquisition. So far in biotechnology, technology transfer from the U.S. to Japan is far more common than from Japan to the U.S.[40] The smaller biotechnology firms are the source of technology transfer to the Japanese. Japanese companies aggressively tried to transfer technologies from these smaller start-up companies.

---

[39] Industry Review of Japan (Tokyo: Nihonkeizai Shimbun, 1983).

[40] Although few in number, some technology transfers from Japan to the U.S. have occured recently. Examples are technology transfers from Suntory to Schening-Plough (interferon, 1983), from Ajinomoto to Hoffmann-LaRoche (interleukein-2, 1984), and from Kyowa Hakko to Ciba-Geigy (interferon, 1985). Existence of these transfers may suggest that Japan has caught up to the U.S. in biotechnology quickly.

Table 12: U.S.-Japan Relationships in Biotechnology

	Japanese firms	size		U.S. firms	size
1	Ajinomoto	5612	--	Charles River Labs	65
2	Chemo-Sero-Therapeutic Research Institute	876	--	Hybritech	500
3	Kyowa Hakko	5388	--	Genentech	900
4	Kirin Brewery	7769	--	Genetics Institutes	250
5			--	AMGen	195
6			--	Plant Genetics	100
7	Suntory Limited	4830	--	Biogen	400
8	Shionogi & Co.	6465	--	Biogen	400
9			--	Molecular Genetics	120
10	Shinetsu Chemical	3020	--	Syntro Corporation	50
11	Sumitomo Pharmaceutical	1800	--	Biogen	400
12	Chugai Pharmaceutical	3374	--	Genetics Institute	250
13	Teijin Limited	6968	--	Hybritech	500
14			--	Biogen	400
15	Toyo Soda Mfg.	4000	--	Hybritech	500
16			--	Unigene Laboratories	35
17	Toyobo	10600	--	Integrated Genetics	140
18	Toray	12633	--	Genentech	900
19	Japan Scientific Inst.	266	--	Applied Biosystems	300
20	Fujisawa Pharmaceutical	5738	--	Biogen	400
21			--	Genentech	900
22	Fuji Rebio	697	--	Biotech Research Lab.	101
23			--	Hana Biologicals	80
24			--	Centocor	150
25			--	Integrated Genetics	140
26	Mitsui Toatsu Chem.	5435	--	Genex	250
27	Mitsubishi Chemical	8118	--	Genentech	900
28	Mitsubishi Corporation	8900	--	Biovec Technology	NA
29			--	Sungene Technology	45
30	The Green Cross Corp.	2689	--	Genex	250
31			--	Biogen	400
32			--	Collaborate Research	NA
33	Meiji Seika	5662	--	Enzo Biochem	60
34	Yamanouch Pharm.	2903	--	Biogen	400
35			--	Genex	250
36			--	Genetics Institute	250
	Average size	5166	--	Average size	323

* Size is the number of employees in 1985.
* This table includes joint agreements between firms on R&D and marketing, equity purchases, establishment of joint venture companies, and acquisitions.
* This table was created by the author based on data in Sekai no Baio Kigyo 500-sha ("World's 500 Biotechnology Firms") (Tokyo: Nikkei McGraw-Hill, 1986).

Large Japanese companies could transfer technologies from abroad relatively easily because many smaller firms, with no "deep pockets," had to sell technologies in order to finance their operation and R&D costs. New biotechnology firms (NBFs) also couldn't sustain lengthy and money-consuming product development, especially in pharmaceutical applications. These small NBFs thus essentially functioned as an industrial laboratory to large companies.[41]

The management of Biogen stated:

> Because many of these companies have substantially larger financial, marketing and human resources and greater experience in clinical trials, production and marketing than Biogen and because of Biogen's more limited resources, Biogen continues to pursue a strategy of licensing many of its products to such companies.[42]

Through joint venture partnerships with NBFs, large Japanese companies also gained access to basic research conducted in foreign universities, because many of these NBFs were founded by entrepreneurial university scientists.

Bioreactor

Although Japan clearly has been the second-runner behind the U.S. in biotechnology, Japan has one unique strength in the basic and

---

[41] Although most NBFs have tried to grow by rapidly generating innovation and selling technologies to other companies, a few of these smaller companies tried to become full-blown pharmaceutical companies. Some of examples of the latter group are Cetus and Genentech. However, in its early days, Cetus also conducted most of its work for a subsidiary of a large established firm, Schering-Plough. Elkington, The Gene Factory, p. 46.

[42] Biogen, Form 10-K (1986), p.6.

potentially very important fermentation technology. Among the many useful process technologies developed in Japan, the bioreactor, an outgrowth of amino acids manufacturing, is the most well known. Bioreactors are vessels in which a bioprocess takes place--in this process a raw material substrate is converted into a product using microbial fermentation or enzymes. Japanese firms developed very efficient bioprocess systems that greatly decreased production costs. A bioreactor can eliminate some steps in the traditional production process and lower the total production time and cost. Bioreactor technology will be one of the keys to mass production of enzymes, amino acids, and some pharmaceutical products. Utilizing advanced skills and knowledge in these markets, Japanese firms may be able to overwhelm their U.S. rivals. In the amino acids markets, Japanese firms are already dominant, and Japanese experience in fermentation may well discourage any potential entrants. In short, Japanese firms may well capture all the benefits brought by new biotechnology in this field.[43]

The bioreactor is one of the three areas studied by a major government-sponsored R&D cooperative, Biotechnology Research Association. The government also organized four joint-study groups, composed of firms from various industrial backgrounds, to develop bioreactor technology.

---

[43] It should be noted that such a cost advantage may not guarantee Japanese success in other areas of biotechnology. For example, the production cost for a high value added pharmaceutical is only a small fraction of its price. For such a product, the key factor in commercial success is a firm's innovative ability.

Trends in R&D

Expenditures for rDNA technology research in the industrial and academic sectors doubled by 1984.[44] The number of researchers engaged in the rDNA field was more than 3,300 in 1985, an increase of about 20% over the previous year.[45] The total number of researchers engaged in life sciences in Japan is well over 70,000.[46] There has been a dramatic rise in the number of biotechnology-related patents applied for, about half of which come from abroad. In 1983, Japanese patent applications for the first time exceeded the number of applications from abroad.[47]

As mentioned above, Japanese companies in the food, chemical, and even textile industry have been aggressive in utilizing biotechnology developed for pharmaceutical applications. Although the R&D level among Japanese pharmaceutical firms is sluggish, R&D is increasing in firms having backgrounda in areas other than pharmaceuticals, and such increases are due largely to their growing efforts in biotechnology.

---

44 Often R&D and commercialization of biotechnology products are characterized as a long-distance marathon. Over-all performance of a company, i.e. its financial health, is extremely important. Big companies in general have larger financial resources, a "deeper pocket", than smaller firms. Most Japanese firms in biotechnology today are very big. Additionally, some Japanese companies enjoy a close relationship with a large city bank. These large Japanese companies are also well diversified, whereas many U.S. firms are biotechnology-specific. Japanese firms with profitable lines of operations can cross-subsidize money-losing basic R&D. The advantages of Japanese big business were observed in the experiences of the semiconductor industry.

45 MITI, Biotechnology as a Foundation.

46 MITI, Ibid.

47 MITI, Ibid.

Table 13: R&D Intensity in Japanese Industries

R&D category	pharmaceutical	chemical	food
TRD Intensity	9.38	14.77	1.86
	(63.51)	(100.00)	(12.59)
BIOR&D Intensity	1.35	1.43	0.42
	(94.40)	(100.00)	(29.34)
RDFOCUS	7.33	7.32	40.21
	(100.27)	(100.00)	(550.07)

The numbers in brackets refer to the value weighted at chemical = 100.
TRD Intensity: total R&D expenditure divided by sales.
BIOR&D Intensity: biotechnology-specific R&D expenditure divided by sales.
RDFOCUS: biotechnology specific R&D expenditure divided by total R&D expenditure.
Source: Nancy Knappenberger & Akihiro Yoshikawa, "Corporate R&D Strategy in Biotechnology: Japanese Challenge," a paper presented at the Strategic Management Society Seventh Annual Conference, Boston, October 1987.

The emerging biotechnology market is characterized by aggressive corporate attitudes toward using the technology to diversity into new fields.[48] Many firms are trying to develop new rDNA pharmaceutical products, and most of the top-ranking biotechnology firms are non-pharmaceutical. Between 1982 and 1984, only one pharmaceutical firm was in the top 10 in biotechnology-related pharmaceutical patent registrations.[49] Among the the top 10 firms that registered such patents, only the eighth, Takeda, is a traditional pharmaceutical firm. Ajinomoto (food) registered 54 patents, and Toray (textile) registered

[48] In the U.S. various industries are also diversifying into biotechnology. However, the extent of such diversification is much more limited in the U.S. Japanese food-processing and textile firms were among the first group of firms trying to develop interferons.

[49] The ranking was given in Bio21 Group, Baio Kakumei (Tokyo: PHP Kenkyu-jo, 1984), p. 221.

14 patents during the period (see Table 15).

Toray, a textile firm, was the first to develop beta interferon through domestic technology instead of technology transferred from abroad.[50] It was the first drug produced by a textile firm.[51] As this example shows, many Japanese companies in the textile, food, and chemical industries are trying to capture opportunities opened up by the emergence of the new biotechnology.

Table 14: Top Japanese Biotechnology Firms

Kyowa Hakko (chemical)
Ajinomoto (food)
Meiji Seika (food)
Takeda (pharmaceutical)

Based on a survey taken among Japanese biochemists.

Table 15: Number of Biotechnology-related Pharmaceutical Patents (1982-1984)

company	number of patents	industry
Ajinomoto	54	food
Mitsubishi Chemical	16	chemical
Toray	14	textile
Kyowa Hakko	13	chemical
Mitsui Petrochemical	13	chemical
Asahi Chemical	12	textile
Sumitomo Chemical	11	chemical
Nippon Oil	11	chemical
Takeda	9	pharmaceutical
Unitica	7	textile

Source: Trigger (May 1985)
Industrial Classification is according Japan Company Handbook, Toyo Keizai Shinposha (1986).

---

50 Japan Economic Almanac 1986 (Tokyo: The Japan Economic Journal, April 1985), p. 175.

51 Toray is the leading manufacturer of synthetic fibers as well as artificial leather and polyester.

VIII. NEW CHALLENGES IN BIOTECHNOLOGY RESEARCH

Although Japan has been praised for successfully developing superior process technology, it has been argued that the country has proven to be neither original nor innovative. It is widely believed that Japan is good at improving or modifying existing technologies rather than creating new technologies. Chalmers Johnson characterized the Japanese emphasis on improvement of process technology in R&D as the "engineering R&D," whereas he characterized the more purely scientific attitude in the U.S. as "Nobel Prize R&D."[52]

Similarly, the Japanese education system was not designed to develop unique talents and skills, rather it was designed to attain a higher prevalence of average sills.[53] Of course, unique talents and independent minds played an essential role in the biotechnology business revolution in the U.S. Many founders of biotechnology companies were scientists with unique and independent minds.

One such example is Dr. Walter Gilbert, a Nobel Prize winner at Harvard, who helped to found, and later became the CEO of, Biogen. The widespread public perception of Professor Gilbert was "dominant, strong willed, powerful, egotistic, driven, impatient, most of all arrogant".[54] One of his former graduate students, Allan Maxam, who together with

---

[52] Johnson, Chalmers, "The Industrial Foundation of Japanese Industrial Policy," in Claude Barfield and William Schambra (eds.), The Politics of Industrial Policy (Washington: American Enterprise Institute for Public Policy Research, 1986).

[53] Science, July 18, 1987, p. 267.

[54] I must stress that this assessment comes from Stephen Hall, "Biologist in the Boardroom," Science 85, February 1985, p. 44. I did not have the same impression of Professor Gilbert.

Gilbert developed one of the standard DNA sequencing methods, stated that "the arrogance, the strong mindedness, having original ideas...these are the same things that make him brilliant and give him the intense self-discipline to be correct".[55] Gilbert himself admits that he "was no shrinking violet."[56]

Today in biotechnology, where a potential scientific breakthrough itself may be protected by patents, and inventors can exclude others from the market, innovative minds and fundamental breakthroughs are more important than in traditional industries.

Desire to be More Independent

The Japanese government has expressed the concern that unless Japan develops its own mechanism to promote innovative ability, it will be unable to maintain its competitive strength in the next century. Japanese officials, especially at the Ministry of International Trade and Industry (MITI), believe that Japan should be less reliant on technologies transferred from abroad, and better able to fulfil its own technological needs. Faced with a serious trade imbalance with the U.S. and European countries, and the rise of protectionism, Japan expects technology transfer to be more difficult in the future. Today many U.S. firms are cautious about sharing technologies with Japanese companies, as they fear possible future competition.

Major legal decisions concerning patents in the U.S. have strengthened these Japanese concerns. One example is the 1980 decision,

---

[55] Hall, "Biologists in the Boardroom," p. 44.

[56] Hall, Ibid.

called the Cohen-Boyer patent, which granted a key patent in genetic engineering to the University of California and Stanford University. The Japanese feared that the patent was so fundamental as to cover all biotechnological products,[57] although it has not been applied that way.

Importance of Multidisciplinary Approach

It is also important to note that the Japanese government's efforts to promote joint research may also be designed to promote more interdisciplinary interactions among Japanese scientists. Lack of mobility of scientists due to the life-long employment system creates a static research environment. Dynamic interactions, especially among scientists having various backgrounds, are regarded as important for the incubation of new ideas and innovations.[58]

It is argued that scientific breakthroughs in the field of high technology are often pursued by a group of scientists from varied backgrounds. For example, the transistor was invented jointly by physicists, chemists, and metallurgists; the scientific breakthrough leading to the discovery of DNA was made by integrating the work of chemists, biologists, biochemists, and crystallographers.[59] Today it is

---

[57] Soichiro Tahara, Idenshi Sangyo Kakumei, (Tokyo: Bungeishunju, 1986), p. 150.

[58] Bell Labs has been applauded as the source of many important inventions, and it adapted a policy to encourage interactions among scientists from various disciplines. Due to Japan's rigidity of labor market, there is little infusion of new scientists to a company, and companies cannot provide the same level of multi-disciplinary interaction.

[59] Nathan Rosenberg, Inside the Black Box: Technology and Economics (Cambridge University Press, 1982), p. 290.

said that the next-generation semiconductor will be a "biochip." Development of such a product will require close cooperation between biologists, biochemists, electrical engineers, and computer scientists. An OTA study of biotechnology emphasized its multidisciplinary nature:

> Biotechnology is unusual among most technologies in that it spans an array of scientific disciplines. Individuals seeking to be well versed in applications of biotechnology must have interdisciplinary training. Bioprocess engineers, for example, need some knowledge of biochemistry and microbiology as well as knowledge of engineering design so that the most efficient combination of micro-organism and bioreactor can be determined. Similarly, plant molecular biologists need to know both physiology and molecular genetics. People working in microbial enhanced oil recovery need training in microbiology as applied to a specific geological environment.[60]

The OTA Report also suggests the importance of a framework to promote such an interdisciplinary effort:

> The multidisciplinary nature of biotechnology has extensive implications for educational and industrial structures. To excel in biotechnology, universities will need to draw on the resources of several departments. Diversified companies may have an inherent advantage over other companies, because technologies perfected for the production of one product (e.g., a pharmaceutical product) can be modified and used for the production of another (e.g., a food additive).[61]

In contrast to MITI, STA has emphasized basic scientific research rather than research directly related to commercialization. Although less known outside Japan than the infamous MITI, STA has been the primary governmental body administering Japan's science and technology policies. By coordinating and administering the use of the Special

---

60 OTA, Commercial Biotechnology, pp. 25-26.

61 OTA, Ibid.

Coordination Fund, STA has played the leading role in Japanese science policy. Realizing the importance of the active integration of scientists from various backgrounds, STA introduced new projects emphasizing interdisciplinary approaches to science: Exploratory Research for Advance Technology (ERATO) and the Frontier Research Program. The Agency also established the Research Development Corporation to promote the commercial development of technologies.

Exploratory Research for Advanced Technology (ERATO)

The Exploratory Research for Advanced Technology (ERATO) program was established in 1981. It was inaugurated by the Research and Development Corporation. Nine exploratory projects are being conducted (see Table 16).

Table 16. ERATO Program

name of ERATO project (year)	project members
1. Ultra-fine Particle Project (1981-1986)	Meijo University Stanley Electric ULVAC Corp.
2. Amorphous & Intercalation Compounds Project (1981-1986)	Research Institute of Electric & Magnetic Alloys Gakushuin University Otsuka Chemical Furukawa Electric
3. Fine Polymer Project (1981-1986)	Sophia University Mitsubishi Chemical Matsushita Research Inst.
4. Perfect Crystal Project (1981-1986)	Semiconductor Research Institute (Sendai) Mitsubishi Electric Corp. Mitsubishi Metal Hamamatsu Photonics
5. Bioholonics Project (1982-1987)	Teikyo University Nissho Bldg.
6. Bioinformation Transfer Project (1983-1988)	Osaka Medical College Nippon Shinyaku
7. Superbugs Project (1984-1989)	Riken Hamamatsu Photonics
8. Nano-Mechanism Project (1985-1990)	Tsukuba Research Consort. Nippon Kagaku
9. Solid Surface Project (1985-1990)	Tsukuba Research Consort. Toray Research Center

In 1986 three more projects were added; Molecular Dynamics Assembly Project (biophysics), Biophoton Project (biophysics), and Quantum Magneto Flux Project (information science).

Each ERATO project is conducted under a project director who is appointed by the Research and Development Corporation. The director selects both academic and corporate members of a project team. Each team includes members from government research institutes, private corporations, and universities.[62] The ERATO program promotes the participation of young scholars having various technical backgrounds. All results from ERATO projects are the common property of Research Development Corporation and the members of the project. Patent rights are to be shared by Research Development Corporation and members directly associated with the invention. Members' patent rights can be transferred to their parent institutions after the end of the project.

Although the emphasis is on the study of basic science rather than the commercialization of technologies, there may be valuable spin-offs from these projects. Some of the goals of ERATO projects are in fact closely related to potential commercial interests. For example, whereas the primary goal of the Perfect Crystal Project was to develop a new generation of semiconductors by combining perfect crystal formation technology and static induction control technology, the Quantum Magneto Flux Logic Project explores the possibility of creating an ultra-fast computer using magnetic quantra as units of operation. The Superbugs

[62] Since the Research and Development Corporation doesn't have its own research facilities, ERATO research projects are conducted in various industrial and academic institutions involved in the program.

Project attempts to establish next-generation biotechnology by studying microorganisms isolated from extreme environments. The Nano-Mechanism Project studies new precision engineering (measuring and processing) methods and hopes to establish new techniques useful in a wide range of scientific research, such as semiconductors and biotechnology.

Frontier Research Program

The Frontier Research Program was established in 1986 to "conduct fundamental research of a pioneering nature (Frontier Research) with long-sighted views of science and technology" under an internationally open system.[63] The research works are undertaken in the Institute of Physical and Chemical Research.[64]

Although the program is intended to promote free and innovative basic research, the Frontier Research Program has two major areas of interest: biological and materials science. Research projects, undertaken over 15 years, are designed to be long-range. The program also promotes multidisciplinary approaches. Seven programs and laboratories have been established to conduct their own research. Table 17 lists the institutions involved in the Frontier Research Program.

---

63 A quote from "Message on the Occasion of Launching the Frontier Research Program" by T. Miyazima, President of RIKEN, appeared in Frontier Research Program brochure (1987).

64 The Institute of Physical and Chemical Research (Rikagaku Keenkyujo, more commonly known as Riken) was established in 1917. It is a semi-government research institute financed almost entirely by the government. It carries out both basic and applied research for various projects, and often functions as the core of government-led research projects. With more than 250 in-house Ph.D. researchers and more than 1,000 guest scientists, it is regarded as one of the best scientific facilities in Japan.

Table 17. Frontier Research Program

names of laboratories
*1. Laboratory for Molecular Regulation of Aging
2. Laboratory of Aging Process
3. Laboratory for Intestinal Flora
4. Laboratory for Plant Biological Regulation
5. Laboratory for Quantum Materials
*6. Laboratory for Nonlinear Optics and Advanced Materials
*7. Laboratory for Bioelectronic Materials

* Heads of these projects are non-Japanese.

A notable characteristic of the program is that it attempts to promote international collaboration. Among seven projects conducted today, two American and one French scientists were selected as project leaders.[65] One of the foreign project leaders expressed much praise for and excitement about the Japanese effort. He maintained that the program provides a unique opportunity for young scientists and promotes valuable basic research.[66] He also expressed a favorable view toward Japan's efforts to promote international collaboration in the program.

[65] They are: Dr. Anthony Garito (Nonlinear Optics and Advanced Materials Project), Dr. Kevin Ulmer (Bioelectronic Materials Project), and Gabriel Gachelin (Molecular Regulation of Aging Project).

[66] From personal conversation with Dr. Kevin Ulmer, Summer 1987.

IX. DIFFICULTIES IN GOVERNMENT-LED R&D IN BIOTECHNOLOGY AND CORPORATE RESPONSES

Japanese government industrial policies have worked very well in the past. The government introduced cooperative research programs to acquire the necessary technology in manufacturing semiconductors. This project was called the VLSI (Very Large Scale Integrated Circuit) Project.[67]

This kind of government-backed success may be more difficult to realize in biotechnology, however. Knowledge of basic technologies themselves, such as rDNA, won't necessarily guarantee success in commercialization. This is especially true in the development of new drugs. To achieve success, firms must introduce the "right" drug. Whether a firm should invest in interferon or TPA, or alpha or beta interferon is not clear at the time of initial investment. Faced with rapid scientific progress, predicting the product of tomorrow is very difficult.

A brief comparison between semiconductor and biotechnology should clarify the difference between MITI's VLSI Project and its biotechnology

---

[67] It focused on technology not directly related to VLSI itself, but related to its production process, such as microprocessor technology, crystal technology, process technology, testing and evaluation device technology, and design technology. Ken-ichi Imai, "Japan's Industrial Policy for High Technology Industry," in Hugh Patrick, ed., Japan's High Technology Industries (Seattle: University of Washington Press, 1986). The project worked well because it helped Japanese firms learn the technologies necessary for the manufacture of semiconductors, and because Japanese firms could make relatively direct use of the knowledge gained. Also, the research was not directly related to the VLSI in which companies were competing in the market, but to general production technologies. Thus member firms had an incentive to cooperate without worrying about competition. Indirect association with final products also avoided antitrust restrictions. Many Japanese firms became low-cost producers of memory chips, utilizing technologies suitable for mass production.

projects. In the VLSI Project, member companies worked to develop the technologies necessary for production of the final product. In the production process, companies had to share process technologies, some of which are patented. However, in developing biotechnology-based products, there is little incentive to cooperate since it is not necessary for firms to share techniques.[68]

Additionally, in biotechnology a new finding or new microorganism created by rDNA technique is itself "self-contained" and can be the proprietory focus of a patent. Thus there is a strong incentive to innovate secretly and exclude potential rivals from the market rather than cooperate. This difference in the importance of patents for semiconductor and biotechnology-based products makes cooperation in R&D in biotechnology much more difficult than in semiconductors.[69]

To overcome such difficulties, in the Next Generation Program MITI tried to focus its joint biotechnology R&D on "areas in which Japan does not have a competitive edge in basic research or in industrial

---

[68] "Most of the innovations in biotechnology...are science based, relying on breakthroughs achieved through basic research and large-scale experimentation rather than through a learning process based on the accumulation of know-how. Unlike electronics and machine-related technologies, in which innovation is made possible by the combination of various technologies, the main manufacturing technology is in a self-contained form generally protected as a proprietary process or by patents." Keni'chi Imai, "Japan's Industrial Policy," in Hugh Patrick (ed.), Japan's High Technology Industries (Seattle: University of Washington Press, 1982), p. 148.

[69] The Managing Director of Sumitomo Chemical maintained that this difference between biotechnology and other manufacturing technologies makes it almost impossible to cooperate with other firms. Bio21 Group, Baio Bijinesu no Yume to Genjitsu ("Dreams and Reality of Bio-business"), Tokyo: IPEC, 1987.

technology."[70] However, the failure of one of the three projects enacted under the Next Generation Project demonstrates the difficulties in realizing an effective joint R&D effort in biotechnology.[71] Imai maintained that Japanese biotechnology policy has been overestimated by other industrial nations.[72]

Although the extent of success from such government-led efforts in biotechnology is unclear, and although some private firms are openly questioning their effectiveness, others are still trying to be selected by the government to participate in a joint research association. Some companies aggressively recruit retired government officials in hopes of increasing their chances of being selected to an association.[73]

---

[70] Imai, "Japan's Industrial Policy," p. 149.

[71] It was decided that the joint research association for bioreactor study should be ended. A MITI official I interviewed admitted that member companies didn't want to cooperate, and therefore the association had to be terminated.

[72] There are a few other difficulties in forming policies to promote biotechnology. As Japan rapidly catches up with the U.S. and moves toward the technological frontier, targeting the future product mix and technologies will not be easy.

One other thing to note is the flexibility and applicability of the technology. Although basic techniques, such as rDNA and cell fusion, are necessary in the manufacturing of a variety of products, efforts to develop one product are not easily converted to the development of other products. For example, R&D in interferon cannot be readily converted to the study of TPA. Each product requires product-specific R&D and clinical testings. This is very different from the applicability of technology in the manufacture of other products, such as automobiles and steel, and even in other high-technology products, such as semiconductors and super-computers.

[73] Kobe Steel, 15th largest steel maker in the world, tried to be selected by the governemnt to participate a biotechnology joint research group. To increase its chances, the firm established its own life sciences laboratory and hired the top scientist from MITI's biotechnology research institute to manage the new laboratory. Nikkei Business, 9/16/85.

Many companies are also trying to create an interdisciplinary, innovative environment. Kao Corp. adapted a so-called "Big-Room (Open) System" to its R&D effort.[74] By removing partitions between different research groups in the same large room, the firm is hoping to stimulate interactions among groups having a range of scientific abilities.[75]

Companies not enthralled by government-led joint biotechnology projects are trying to promote their own strategic alliances. Joint research projects helped Shimazu Corp., the leading manufacturer of precision equipment, to market equipment that supports biotechnology research.[76] With Wakunaga Pharmaceutical, it jointly developed DNA synthesizing equipment and developed cell fusion equipment with Kyoto University.

In order to keep their technology secret from rivals, joint R&D projects are emerging among companies belonging to the same keiretsu family.[77] In 1986, Mitsui Group (Mitusi Toatsu Chemical, Toray, Oji Paper, Mitusi Petrochemical, Mitsui & Co., Mitusi Bank, etc.) established a laboratory for plant biotechnology R&D.[78] Its prime rival, Mitsubishi Group, formed its own joint research program.

---

[74] Kao is the top manufacturer of synthetic detergents, including laundry detergents, shampoos, and rinses.

[75] Kikuhiko Okamoto, "Kao Corp. Expanding Uses of Fats and Oils Through R&D Efforts," in Business Japan, September 1986, p. 51.

[76] Junichi Akiyama, "Joint Research Projects Help Shimadzu Enter Biotechnology Field," Ibid., p. 65.

[77] A Keiretsu is an industrial grouping in which an oligopolistic organization of several industries is dominated by conglomerates. Broadly defined, it also means a pyramid structure of vertical networks of large firms and smaller subcontractors.

[78] Bio21 Group, Baio Kakumei, p. 76.

Mitsubishi Chemical and Mitsubishi Corp. established its own laboratory, Plant Research Institute, for the same purpose.[79]

In summary, it is fair to say that even though the extent of impacts on commercial applications is unclear, the government's efforts to coordinate firms in learning basic technologies, i.e. rDNA, have helped major Japanese firms gain necessary skills in the initial stage. Private firms are also forming joint R&D alliances based on their traditional Keiretsu, taking advantage of the government's passive antitrust enforcement.

X. CONCLUSIONS

In his study of the Japanese biotechnology, Gary Saxonhouse concluded that "Japan gives less formal aid and comfort to its high technology sectors and to biotechnology in particular than do the governments of most other advanced industrialized economies...there is nothing abnormal about Japanese trade and industrial patterns."[80] Our discussion has shown the existence of long-term, strategic government policies in Japan. Thus we conclude that Japan in fact gives more formal aid and comfort to its biotechnology sector.

Whether such policies are working is a second issue. Although there are some problems in conducting cooperative R&D in biotechnology in Japan, one should not conclude that government policies will not work at all. Japanese bureaucrats, especially at the MITI, are known for

---

79 BIDEC News, June 1987.

80 Saxonhouse, "Industrial Policy and Factor Markets," p. 132.

their flexible and pragmatic approaches to industrial problems. The MITI introduced the Key Technology Center to stimulate private incentives to cooperate; STA introduced programs to promote an innovative environment.

Private companies, well aware of deficiencies in government programs, are utilizing their own keiretsu networks. They may be able to achieve an increased level of multidisciplinary interaction and introduce more intellectually dynamic environments to their R&D efforts.

Robert Fujimura, who worked as biomedical attache to the U.S. embassy in Tokyo, like Saxonhouse concluded that "if Japan is second to the U.S.A. in biotechnology development, it is a distant second."[81] However, we conclude that the competition in biotechnology has just begun, and competitive advantage is a dynamic, not a static, concept. With strategic policies and its financial commitment in the public sector, as well as an increasing level of cooperative effort in the private sector, Japan may in fact come out as front-runner, not a distant second.

---

[81] McGraw-Hill's Biotechnology Newswatch, March 16, 1987, p. 5.

___8. Competitiveness (Vol. III of the Report of the President's Commission on Industrial Competitiveness), Cohen, Teece, Tyson and Zysman, 11/84. 40pp. $5.00.

___9. Technological Innovation and Deregulation: The Transformation of the Labor Process in the Insurance Industry, Baran et al., 1/85. 270pp. $19.00.

___12. The Impacts of Divestiture and Deregulation: Infrastructural Changes, Manufacturing Transition, and Competition in the United States Telecommunications Industry, Borrus et al., 9/84. 305pp. $21.00.

___13. Reversing Attrition: A Strategic Response to the Erosion of U.S. Leadership in Microelectronics, Borrus, 3/85. 40pp. $5.00.

___14. Telecommunications Development in Comparative Perspective: The New Telecommunications in Europe, Japan and the U.S., Borrus et al., 5/85. 60pp. $6.50.

___15. The Dynamics of Techno-Industrial Emulation: Growth Patterns of Industrial Pre-eminence and U.S.-Japanese Conflicts in High Technology, Yakushiji, 8/85. 180pp. $14.00.

___16. Technology and the Relocation of Employment in the Insurance Industry, Ross, 7/86. 125pp. $10.50.

___17. Beating Our Plowshares into Double-Edged Swords: The Impact of Pentagon Policies on the Commercialization of Advanced Technologies, Stowsky, 4/86. 60pp. $6.50.

___18 High Technology, Economic Policies and World Development, Castells, 3/86. 120pp. $7.50.

___19. Innovation in Production: The Benetton Case, Belussi, 3/86. 50pp. $5.50.

___20. Conditionality and Adjustment in Socialist Economies: Hungary and Yugoslavia, Tyson et al., 10/84. 52pp. $5.00.

___21. MITI, MPT, and the Telecom Wars: How Japan Makes Policy for High Technology, Johnson, 6/86. 95pp. $7.50.

___22. The U.S. and the World Economy in Transition, Tyson, 7/86. 30pp. $4.50.

___23. Creating Advantage: Strategic Policy for National Competitiveness, Tyson, 1/87. 48pp. $6.00.

___24. Adjusting the U.S. Trade Imbalance: A Black Hole in the World Economy, Thurow and Tyson, 3/87. 36pp. $5.00.

___25. Information and Communications Technologies for Economic Development, Bar, 6/87. 24pp. $4.50.

___26. Dynamic Markets and Mutating Firms: The Changing Organization of Production in Automotive Firms, Quinn, 8/87. 100pp. $10.00.

___27. The Weakest Link: Semiconductor Production Equipment, Linkages, and the Limits to International Trade, Stowsky, 8/87. 78pp. $7.50.

___28. From Public Access to Private Connections: Network Policy and National Advantage, Bar and Borrus, 9/87. 20pp. $4.00.

___29. The Japanese Challenge in Biotechnology: Industrial Policy, Yoshikawa, 11/87. 60pp. $8.00.

___30. Politics and Productivity: Developmental Strategy and Production Innovation in Japan, Tyson and Zysman, 11/87. 136pp. $11.00.

___31. The Developmental City-State in an Open World Economy: The Singapore Experience, Castells, 2/88. 100pp. $9.00.

___32. Manufacturing Innovation and American Industrial Competitiveness, Cohen and Zysman, 2/88. 27pp. $4.50

___33. Japanese Biotechnology: New Drugs, Industrial Organization, Innovation, and Strategic Alliances, Yoshikawa, 1/88. 70pp. $9.00.

___34. Perceptions of Work Reorganization: Interviews with Business and Labor Leaders in Four Industries, Turner and Gold, 5/88. 90pp. $11.00.

___35. Corporate Strategy Lessons From the Trade Disaster: You Can't Control What You Can't Produce Competitively, Cohen and Zysman, 8/88. 27pp. $4.50.

___36. Are Labor-Management Partnerships for Competitiveness Possible in America?: The U.S. Auto Industry Examined, Turner, 10/88. 30pp. $4.50.