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BIOTECHNOLOGY : THE COMMUNITY'S ROLE

"Background note"

"national initiatives for the support of biotechnology"

(Communication from the Commission to the Council)

NATIONAL INITIATIVES FOR THE SUPPORT OF BIOTECHNOLOGY

A comparative assessment of the United States, Japan, and the Member States of the European Community

SUMMARY

Based on published reports and statistics, this paper describes national efforts for the promotion of biotechnology ; with particular reference to public sector R & D expenditure. The multi-disciplinary nature of biotechnology and its many sectors of application give rise to major problems of definition and of international comparability. Figures given are therefore tentative, and wide ranges reflect definitions varying from very narrow, to those substantially overlapping agricultural and medical research. With these caveats, the following figures are deduced for publicly supported R & D in biotechnology and related areas, at approximately 1982/83 :

U.S. : at least $ 200 m. p.a. ; up to $ 550 m. p.a. on "broad basis" ;

Japan : at least $ 50 m. p.a. ;

E.E.C. : 146 m. Ecu on narrow basis, up to 355 m. Ecu on broad basis ($ 156 m. - $ 380 m. p.a.).

NATIONAL INITIATIVES FOR THE SUPPORT OF BIOTECHNOLOGY

(A comparative assessment of the United States, Japan and the Member States of the European Community)

The rise of interest in the significance of biotechnology was marked by a series of national reports, rising to a peak in 1981 when more than 10 were published (see list attached, page 5).

Many of these reports recommended the establishment of special agencies, ad hoc committees, interminisnterial groups etc., and the allocation or increase of funds for research and development activities in biotechnology. Through these administrative actions and the funding of "mobilisation programmes", significant additional research and related activity in biotechnology is now being implemented, throughout the countries of the European Community and in most other developed industrial countries.

This annex provides some statistics on the scale of these expenditures ; but in appraising the relative strengths of different countries in the field, the problem of defining biotechnology has to be borne in mind. Since different countries include different activities in their understanding of the term, objective comparisons are difficult. Fuller details are given in the document XII-37/83 "Plan by Objective : Biotechnology", one of the papers prepared in support of the Community's R & D Framework Programme (1983-87)*. This paper includes some more recently published and up-to-date figures ; but there remain major problems of interpretation. The resulting estimates of expenditure on biotechnology, or "biotechnology-relevant" R & D, are therefore given as indicative ranges.

1. MAJOR NON-COMMUNITY COUNTRIES

1.1. The United States of America

1.1.1. Federal Support

The main federal support for activities related to biotechnology is channelled through two sources : the National Science Foundation (NSF), which is the principal federal agency for the support of basic research across all fields of science, and the National

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* available, in English or French, from the Commission's Directorate-General XII, for Science, Research and Development.

Institutes of Health (NIH), which are responsible for basic research in medicine and health care, and are also responsible for the registration of federally funded research work on recombinant DNA. The U.S. Department of Agriculture is also funding basic research related to agriculture, including projects and techniques which may be described as biotechnology ; similarly the Department of Energy's studies of biomass-based energy sources involve basic biology and biotechnology.

In fiscal year 1980, the NIH supported 717 basic research projects involving recombinant DNA at a cost of $ 91.5 million. At the request of the OTA (see below), the NIH recently estimated what proportion of their budget ($ 3.74 bn. estimated outlays for fiscal year 1983 ; $ 3.44 bn FY 1982) might be classified as "biotechnology" : for FY 1982, approximately $ 380 m., versus $ 170 m. in 1980 ; plus $ 20 m. for equipment in the "biotechnology resources program". The $ 380 m. figure is "a maximum approximation... the total costs of the awards not limited to the subject of the search" ; [**] the 1980 rDNA figure of $ 90 m. might be taken as a minimum.

"Biotechnology-relevant" research supported by the NSF in fiscal 1980 amounted to $ 66 m. according to Zaborsky [***].

** Special report, "R & D Spending on Biotechnology in the U.S.", from the Science, Technology and Energy Section of the Commission's Washington office.

*** Paper by Oscar Zaborsky, of U.S. National Science Foundation, at Eastbourne, April 1981 : Second European Congress of Biotechnology.

KEY REPORTS IN BIOTECHNOLOGY

1974	W. Germany	DECHEMA, for BMFT : Biotechnologie
1976	Japan	MITSUI : Present and Future on Enzyme Technology
1976	U.K.	A.N.EMERY, for Science Research Council : Biochemical Engineering.
1977	Commission of the E.C.	DG XII : Possible Action of the European Communities for the optimal exploitation of the fundamentals of the new biology in applied research.
1978	Europe	DECHEMA organise first European Congress of Biotechnology, Interlaken, Switzerland ; European Federation of Biotechnology founded.
1979	France	F.GROS, F.JACOB, P.ROYER : Sciences de la vie et société pour le Président de la République.
1979	France	J. de ROSNAY : Biotechnologies et Bio-Industrie.
Jan. 80	W. Germany	BMFT Leistungsplan 04 : Biotechnologie
Mar. 80	U.K.	"SPINKS REPORT" Biotechnology : report of a joint Working Party (ACARD,ABRC, Royal Society).
May 80	Belgium	SPPS : Développements en matière de biotechnologies.
Sept.80	Canada	MILLER et al : Biotechnology in Canada.
Feb. 81	Canada	Report to Minister for Science and Technology : Biotechnology : a development plan for Canada.
Feb. 81	France	J.C. PELISSOLO : la Biotechnologie, demain ?
Mar. 81	U.K.	Govt.White Paper : Biotechnology (response to SPINKS).
Apr. 81	U.S.A.	O.ZABORSKY : Biotechnology at the National Science Foundation.
Apr. 81	U.S.A.	Office of Technology Assessment : Impacts of Applied Genetics : Micro-Organisms, Plants and Animals.
May 81	Netherlands	STT : Biotechnology : a Dutch perspective.
May 81	Ireland	NBST : Biotechnology Trends.
Sept.81	U.S.A.	Office of Technology Assessment : Project Proposal for a Comparative Assessment of Biotechnology.
Sept.81	Spain	La ingenieria genetica en la biotechnologia (Centro para el Desarrollo technologico Industrial, Ministerio de Industria y Energia).
Oct. 81	Japan	Report : Heading toward new Research and Development, by the Study Association for the Foundation of a Long-Term Plan for the Development of Industrial Technology.
Nov. 81	UNIDO	The Establishment of an International Centre for Genetic Engineering and Biotechnology (ICGEB) report of a group of experts (proposal).
Nov. 81	Australia	Biotechnology R&D : the application of DNA techniques in research and opportunities for biotechnology in Australia (Commonwealth Scientific and Industrial Research Organization).
Dec. 81	U.S.S.R.	Speech by Academician OVCHINNIKOV at the Annual General Meeting of the Soviet Academy of Sciences.
Apr. 82	Netherlands	Programmacommissie Biotechnologie : Innovatieprogramma Biotechnologie (Chairman : Prof. R.A. SCHILPEROORT).
Sept.82	OECD	International Trends & Perspectives in Biotechnology : A State of the Art Report by A.T.BULL, G. HOLT and M.D. LILLY.
Dec. 82	France	Programme Mobilisateur of the Mission Biotechnologie.
Dec. 82	Italy	ENI group : le Prospettive dell'Ingegneria Genetica.
Jan. 83	C.E.C.	FAST report, recommending Community Strategy for Eur. Biotechnology.
Summer 1983	Ireland	NBST : Major national policy document on biotechnology.
Autumn 1983	U.S.A.	OTA : Comparative Assessment of the Commer. dev. of Biotechnology.

The Office of Technology Assessment study "Impacts of Applied Genetics : Micro-organisms, Plants and Animals" (1981) gives details of federal support for projects on plant molecular genetics and other biological topics of agricultural significance. Their figures include some NSF programmes in plant research ; the other main channel is the U.S. Department of Agriculture (USDA). USDA's Competitive Grants Programme (1982: $ 16.5 m.) supports new research directions in plant biology. But as with the NIH budget, the biotechnology-relevant research is overshadowed by the total budget of the Agricultural Research Service ($ 458 m. proposed for fiscal 1984).

The ARS budget itself forms only part of the Dept. of Agriculture's total R & D spending ($ 830 m. estimated outlays in FY 1983), and including state programmes the total is over $ 1.5 bn. a year.

The biotechnology element was estimated as $ 40 m. out of $ 426 m. in FY 1982, and the proportion is rising. In addition, federal ($ 15 m.), state ($ 15 m.) and private ($ 5 m.) funding supports the State Agricultural Experimental Stations'* work in biotechnology research.

The structure and control of U.S. agricultural research are the subject of intense current debate**. A factor in this debate is the relevance of the new biotechnology to agriculture, which has been emphasised by long-term studies, particularly

(i) "The Impending Revolution in World Agriculture", Futures Group (1982), and

(ii) "An Assessment of the Global Potential of Genetic Engineering in the agri-business Sector, Chicago Group (1981).

The latter points out that the market for agricultural products is "close to ten times the size of the market for all pharmaceutical health care products in the U.S. alone", and consequently predicts that the market for new genetically engineered products in agriculture could ultimately outstrip the medical market by tens of billions of dollars.

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* "Emerging biotechnologies in agriculture : issues and policies". Progress report November 1982, Division of Agriculture Committee on Biotechnology, National Association of State Universities and Land-Grant Colleges.

** "Science for Agriculture", report of a workshop (June 1982) on critical issues in American agriculture research, jointly sponsored by the Rockefeller Foundation and the Office of Science and Technology Policy ; pub. by Rockefeller Foundation, October 1982.

Combining the figures mentioned suggests U.S. federal expenditure of at least $ 200 m. p.a. in areas directly relevant to biotechnology ; but of equal or greater relevance to the country's strategic capability, are the much larger sums referred to in health and agricultural research. In both these fields, reasonable judgements seem to indicate that some 10 % may be viewed as "biotechnology-relevant" ; hence one can build up the following estimate on this broader basis :

NIH :	10 % of $ 3.7 bn/NIH estimate =	380
	Biotechnology resource Program	20
NSF :	(1980, careful estimate)	66
USDA :	10 % of ARS $ 426 m. (1982) =	40
	+ biotechnology elements of State Agricultural Experiment Stations (50 % federal, 50 % State)	30
+ Dept.	of Energy and other agencies	10-20
		550

The U.S. Government is examining its strategy in the field of biotechnology. The Office of Technology Assessment is responsible and by means of a 2 year study (1981-83 ; to appear in autumn '83) will consider issues of Government policy, funding and regulatory requirements in this field, university/industry relationships and relevant features of the educational system, industry characteristics and patent law. The study will be comparative and extend therefore to Japan, West Germany, Great Britain, Canada, France, Switzerland and the USSR.

1.1.2. The role of industry

It is clear that biotechnology research and development is being substantially funded in the U.S. Industrial funding is probably several times that of federal expenditure (narrow definition), which is concentrated at the fundamental end of the research spectrum. Venture capital activity on the other hand is aiming for payback (either revenue, or capital gain) in the short and medium term, particularly in the bio-medical and pharmaceutical fields ; but larger companies (particularly the major oil, chemical and pharmaceutical groups) are investing in longer term potential, with the expectation that research breakthroughs during the next ten years will lead to commercial products in the years beyond.

1.2. Japan

1.2.1. National Support for Biotechnology R & D

Government support for biotechnology dates from the beginning of the 1970s. The Science and Technology Agency initiated the new government biotechnology programmes by establishing a Committee for the Promotion of the Life Sciences in 1973. Rogers * describes how "Since then, the scale of Government support for biotechnology R & D has steadily increased. Support in 1981 for Life Science in general is estimated at a minimum of Yen 50,000 million ($ 210 m.), ** and if one considers only the more restricted areas which are currently referred to as biotechnology the support was of the order of Yen 5,600 million in 1981 (i.e. approximately $ 24 million). Government financial support has received fresh impetus in the last year with the announcement of the Ministry of International Trade and Industry's (MITI) biotechnology national projects. These new projects are the Biomass Development Project concerned with alcohol production (7 years from 1980-total budget Yen 12,300 million : $ 52 m.) and the next Generation Industries national project which has three biotechnology themes (10 years from 1981 - total budget in the biotechnology sector is in excess of Yen 30,000 million : $ 127 m.)".

Adding the above three elements : $ 24 m, plus $ 52 m/7 = $ 7 m. p.a., plus $ 127/10 = $ 13 m. p.a., gives an estimate of $ 44 m. p.a. ; but in the absence of details of the $ 24 m. figure quoted, this is probably a significant under-estimate, omitting in particular any reference to the funding through the Ministries of Agriculture, Health and Education, all of which give some support for Biotechnology research, and the "coordination funds" from the Council for Science and Technology.

A more recent report *** quotes 7,471 Y for government expenditure on biotechnology R & D in 1982, and 7,906 m. Y ($ 33.2 m.) budgetted for 1983, apparently including all ministries and agencies ; if this omits the national projects cited, the total must be well over $ 50 m. p.a. for 1983.

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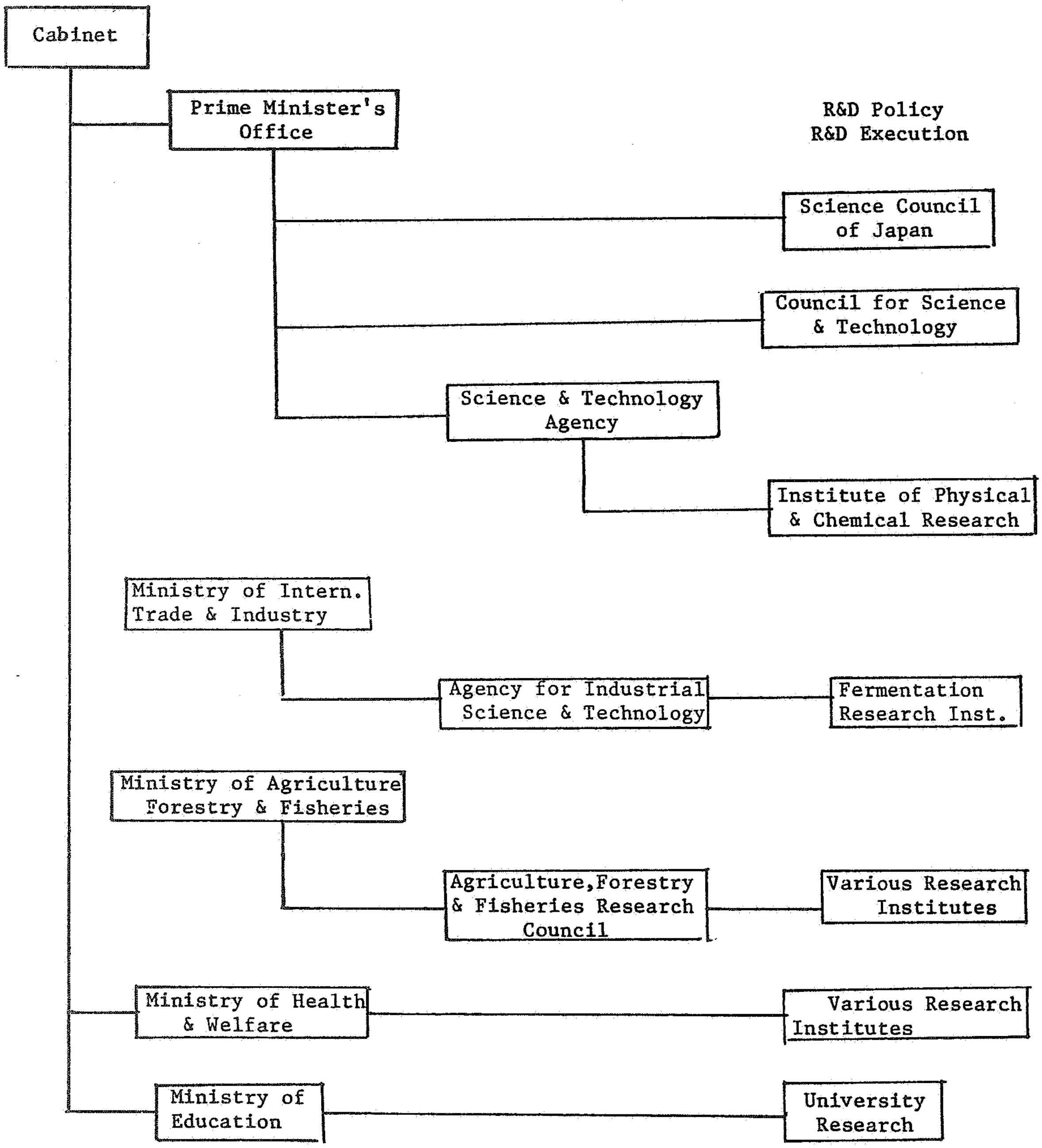
* Rogers, M.D. "The Role of the Japanese Government in Biotechnology Research and Development", Chemistry and Industry, 7 Aug. 1982.

** Y 236 /$, April '83.

*** McGraw Hill "Biotechnology Newswatch", 21 March 1983 : "Japan's R & D biobudget jumps 5.8 %".

Diagram 1 The Main Organisations Involved in Japanese Government Support for Biotechnology



Source : Rogers, op. cit.

A detailed qualitative description of government support for biotechnology R&D is given in the JETRO report* ; the following summary is based on both reports, the figures being from Rogers.

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* Japan External Trade Organization (JETRO) : The Japan Industrial and Technological Bulletin, Special Issue 14, 1982 : Research on Biotechnology in Japan.

1. The Council for Science and Technology (CST), chaired by the Prime Minister and including the President of the Science Council of Japan (the top scientific body), establishes general science policy and passes recommendations to the various ministries for executive action. It is responsible for overall coordination, and in biotechnology JETRO mentions seven biotechnology-related research themes being promoted in 1982 from CST's "Special Coordination Funds" : no figures available.

2. The Science and Technology Agency (STA) has two roles :

   a) policy and inter-ministry coordination
   b) its own R & D programmes, including biotechnology.

   It has to overcome inter-ministerial rivalries, and Rogers considers it "fairly effective in the field of biotechnology, not least because STA was involved from the beginning with its own programmes and because it has taken a central role in the setting of rDNA regulations". It attempts to establish national science and technology strategy and to help coordinate departmental efforts.

   The STA Life Sciences Programme is directed by the Committee for the Promotion of Life Science, the 15 projects managed and controlled through the (nominally) independent Institute of Physical and Chemical Research ("RIKEN"). Expenditure on the projects was Y 640 m. in 1981 ($ 2.7 m.). The essential distinction between the STA biotechnology projects and those of MITI (see below) is that the former concentrate on basic medical aspects and longer-term advanced bioreactors, whereas those of MITI are mainly concerned with fine chemicals, alternative routes to petrochemicals, enzyme technology, and general applications of biotechnology to the chemical industry.

   A feature of interest at RIKEN is its role in coordinating national policy for culture collections, and the establishment of a Life Science Information department to develop "NISLO" : National Information System for Laboratory Organisms. (cf. the Community's Task Force for Biotechnology Information, under the Committee for Information and Documentation in Science and Technology).

3. The Ministry of International Trade and Industry (MITI) inaugurated a major national programme on 1st October 1981, "The Next Generation Industrial Foundation Technology Development System". Of this 10-year, Y 104 bn. programme, some Y 30 bn ($ 127m) is for biotechnology. MITI has since (June '82) established a "Bioindustry Office" designed to draft "comprehensive measures for smoothly cultivating the new industrial field known as the bioindustry", and "plans and measures to promote domestic biotechnology research and international cooperation in the development of the industry, while projecting the industry's future vision".
The programme of research is being implemented partly through the ministry's own institutes - particularly the Fermentation Research Institute - and partly through the private sector in a grouping of 14 firms (predominantly chemical majors) known as the "Research Association for Biotechnology" or "Biotechnology Forum".
MITI has also launched the Biomass Development Project already referred to, establishing (May 1980) within its Basic Industries Bureau a "Biomass Policy Office" to establish the feasibility of Biomass utilisation in Japan and the most promising lines for development. Projects are being executed through the 22 member companies of the "Biomass Research Association (petroleum, chemical and fermentation)" (Rogers) or "Research Association for Petroleum Alternatives Development (RAPAD)" (JETRO).

4. The Ministry of Agriculture, Forestry and Fisheries is conducting research through its institutes, including rDNA work, "with the aim of developing innovative technologies conducing to the stabilization of food supplies and sophistication of agriculture" (JETRO). The JETRO report describes three themes : green energy, biomass conversion (particularly waste utilisation), and genetics. Rogers gives figures for the second of these : Y 300 m. ($ 1.3 m.) in 1982. Noteworthy is the fact that over 30 % of Japanese government R & D is spent on Agriculture (1979)*.

5. The Ministry of Health and Welfare is engaged in research on biotechnology, including rDNA, "with the specific aim of applying related technologies to health preservation and medical treatments" (JETRO), through the National Institute of Health and other institutes. No details.

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* Economist, 6 Nov. 1982 : "International R & D spending.

6. The Ministry of Education supports fundamental research in the university research organisations, and extends "Science and Technology Research Subsidies" to projects advancing the progress of science and technology in Japan. No details.

1.2.2. Industrial activity

Japan is particularly strong in fermentation technology, for historical reasons going back a century (government revenues from the sake industry) ; public initiatives reinforced this pre-eminence in the post-war period. Gregory* claims that "By the 1970s, Japan's fermentation industry had a 10-year lead over others in the world.... In 1979, 7 of the 11 new antibiotics introduced across the world came from Japanese laboratories and in 1980 the Japanese industry ranked second only to the US in producing new drugs". The pharmaceutical firms are among the leaders in perfecting third-generation cephalosporins, in spite of R & D budgets small in comparison to those of the U.S. and European firms. (Takeda, the largest, \$ 100 m. in 1981 ; cf. Hoechst \$ 270 m. ; Merck \$ 275 m. ; Eli Lilly \$ 235 m. ; Hoffmann-La Roche, \$ 400 m. ; Johnson & Johnson \$ 161 m.).

But Pharmaceuticals may be less important than the food sector as leading edge in biotechnology (the reverse of the U.S. position). Japan's fermentation expertise originated in the food sector, and is reflected in dominance of world production of amino acids (which may be used as food additives for flavouring, or in order to improve the amino-acid profile of protein foods or feedstuffs). This is a \$ 1.4 billion market worldwide. Ajinomoto, one of the major food companies, has developed (and is patenting) genetic engineering methods for amino acid production, which it claims will double existing yields. A major dairy firm, Showa Brand Milk Products is building a \$ 20 m. biotechnology laboratory for completion in March 1983 and later expansion ; it started work on biotechnology research only in January 1981, concentrating on food, enzymes and fermentation. Future plans include pharmaceuticals.

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* New Scientist, 29 July 1982 : "Biotechnology-Japan's growth industry", by Gene Gregory, professor business studies at Sophia University, Tokyo.

Japanese firms (Kanegafuchi, Dianippon) originated the development work on hydrocarbon-based single-cell protein production, although consumer acceptance problems subsequently delayed development. The technology was subsequently licensed to European Producers such as Liquichima (Italy) and Roniprot (Rumania).

As part of the strategy of establishing independent technology Japanese pharmaceutical firms are seeking to buy their way into interferon production and the genetic engineering technology which provides one route into it. Green Cross has an agreement with Collaborative Genetics for research on a yeast based process for interferon, and another with Genex for research on albumin production.

In October 1981, it concluded an agreement with Biogen for marketing the latter's hepatitis B vaccine. Takeda, Japan's largest drug company has signed a contract with Hoffman-La Roche for joint research and production of interferon in Japan, using the latter's genetic engineering technology. Other companies mentioned as buying foreign genetic engineering technology are Kyowa Hakko (for interferon) and Mitsubishi. The most significant joint venture involving licensing agreements is Takeda's alliance with the American firm Abbott. Takeda-Abbott Products have manufacture and marketing rights for all new American drug patents obtained by Takeda, who also have joint ventures involving Bayer (West Germany) and Roussel Uclaf (France).

Gregory suggests that a conservative estimate of current output from industrial microbiology in Japan is Y 11-12 trillion (S50 bn.) in food, pharmaceuticals and refined metals, i.e. some 5 % of GNP ; but recent Japanese sources quote only Y 4tn for 1979, presumably using a narrower definition. MITI's Agency for Industrial Science and Technology forecasts a Japanese domestic market of Y 7 tn. by year 2000 ($ 30 bn.).

A detailed survey of research on biotechnology by Japanese corporations was conducted by MITI in August 1982, and the results are reported in full by JETRO (op.cit.). They show (see table below) rapidly rising industry research expenditure on biotechnology over the last three years : the 1982 total is Y 47.8 bn. ($ 203 m.).

Table 1.

Total Research Expenditures and Biotechnology Research Expenditures

Unit Y 1 million

Fiscal Year	Medical Drug: Total research expendit.	Medical Drug: Biotechnology research expenditures	Chemical: Total research expendit.	Chemical: Biotechnology research expenditures	Textile, Paper & Pulp: Total research expendit.	Textile, Paper & Pulp: Biotechnology research expenditures
1980	77,417	4,831	161,562	13,616	50,898	4,131
1981	80,993(4.6)	5,711(18.2)	176,394(9.2)	15,912(16.9)	56,570(11.1)	5,090(23.2)
1982	90,063(11.2)	6,860(20.1)	193,046(10.7)	19,113(20.1)	61,212(8.2)	6,123(20.3)

Fiscal Year	Food: Total research expendit.	Food: Biotechnology research expenditures	Others: Total research expendit.	Others: Biotechnology research expenditures	All Industries (Total): Total research expendit.	All Industries (Total): Biotechnology research expenditures
1980	27,734	6,979	308,351	3,502	625,962	33,059
1981	32,668(17.8)	9,318(33.5)	346,737(12.4)	3,873(10.6)	693,362(10.8)	39,904(20.7)
1982	38,352(17.4)	11,920(27.9)	390,795(12.7)	3,807	773,468(11.6)	47,823(19.8)

Note : 1. These figures represent tabulation of replies from 112 firms. (medical drug 12, chemical 47, textile, paper & Pulp 9, food 22 and other industries 22).

2. Figures in ( ) show increases over the preceeding fiscal year.

2. R & D RESPONSES : MEMBER STATES OF THE EUROPEAN COMMUNITY

The following sections give fuller details of activities and R & D policies relating to Biotechnology, in the Member States of the Community. Although inevitably brief and uneven, being summarised from heterogenous source materials, these descriptions indicate the common perceptions and needs, and hence provide a background for the discussion of European Community activities and policy for R & D in biotechnology.

A final section, 2.10, summarises the statistical picture with estimates of total expenditure on R & D in biotechnology and related areas.

2.1. Federal Republic of Germany

Germany has for many years had outstanding industrial strength in all major areas of biotechnology. Initiatives by DECHEMA (Deutsche Gesellschaft für Chemisches Apparatewesen) led to a major report in 1974 on the significance of biotechnology, and a revised version was subsequently commissioned by the Bundes Ministerium für Forschung und Technologie (BMFT)*.

BMFT has summarised in "Leistungsplan 04" a clear picture of federal expenditure on R & D in biotechnology : Figure 1 is based on the plan as at January 1980, showing the breakdown of the planned expenditure of DM 53 m. on project expenditures. To this should be added some DM 17 m. for support of biotechnology at the Gesellschaft für Biotechnologische Forschung and other institutions. Planned project expenditures for 1983 : DM 63m. (increase : 14.5 %). Figure 2 shows the historic growth.

The BMFT also makes extensive use of collaborative agreements in research with many other countries, including Japan, Sweden, and Canada as well as with EC partners.

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* Biotechnologie : Studie über Forschung und Entwicklung : Möglichkeiten, Aufgaben und Schwerpunkte der Forderung, DECHEMA, 1976.

The major strengths of German biotechnology lie in its large chemical and pharmaceutical companies : BASF, Bayer, Boehringer Mannheim, Boehringer Ingelheim, Degussa (amino acids), Hoechst, Merck, Schering. There is close collaboration with educational institutions, and with the industrially-oriented activities on the GBF and DECHEMA.

Hoechst is the largest of the chemical/pharmaceutical companies, and attracted considerable comment when in 1981 it signed a 10-year, $ 67 m. research agreement with Massachusetts General Hospital for work on molecular biology and genetics. This should be seen in the context of the company's total pharmaceuticals R & D budget of some $ 270 m. p.a. With BMFT support, Hoechst has developed a single-cell protein now being tested for human nutrition (production scale 2000 t. p.a.).

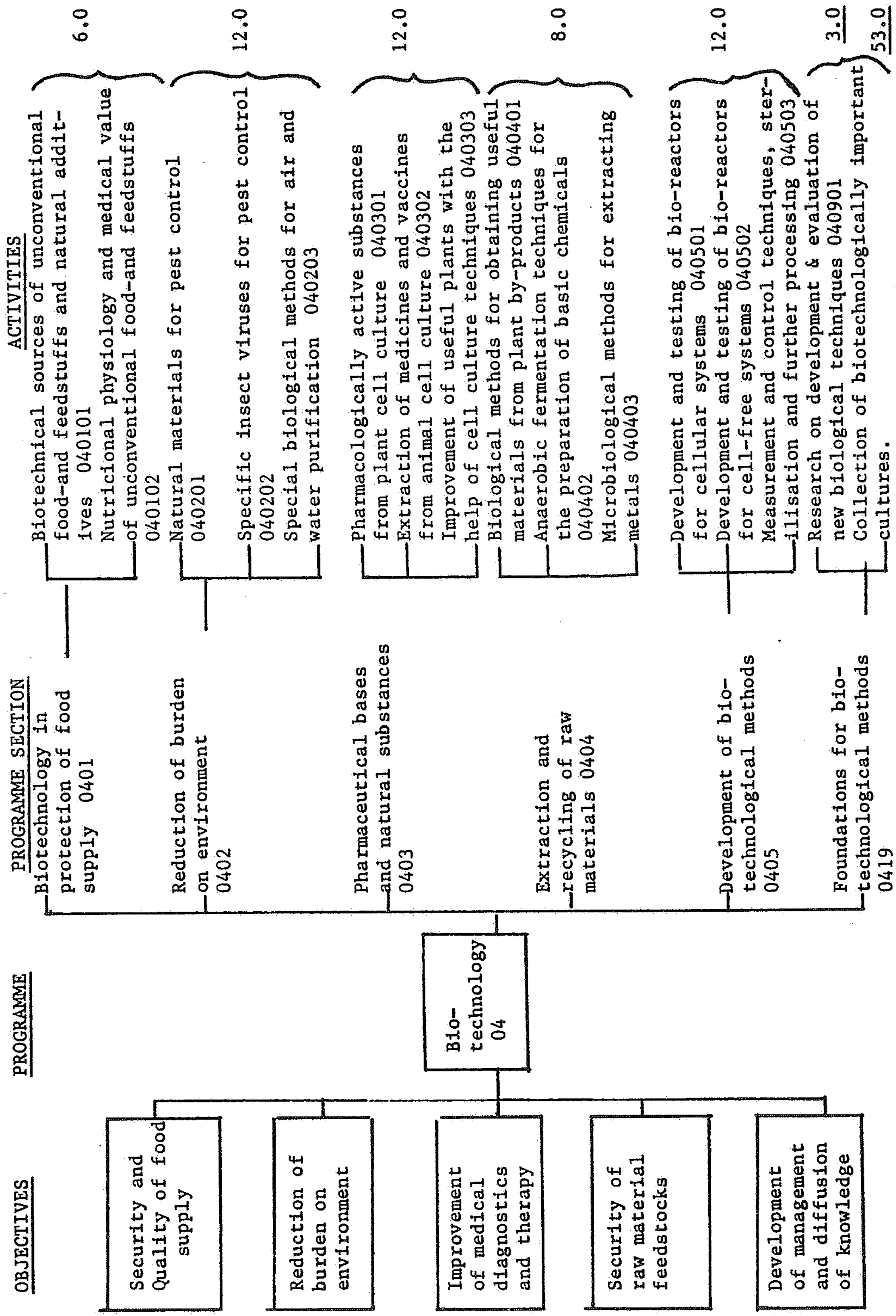
Chemical Engineering (12 July 1982) quotes an estimate that "West German firms will boost their biotechnology R & D outlays from the current (estimated) $ 90 million/year to nearly $ 200 million by 1985".

There is additional expenditure on biotechnology through local government, often in collaboration with industry. The Baden-Württemberg regional government has, for example, approved DM 30 m. for the construction of a new molecular genetics institute at Heidelberg, which will be supported also by the BMFT (DM 13 m. over 3 years) and by BASF (DM 4 m. over 5 years). A similar project in Berlin is being jointly financed (DM 40 m. each over 10 years) by Schering AG and the city.

Figure 1 : Breakdown by objectives and activities

of FRG Biotechnology R & D

(Leistungsplan 04 :
Planned 1982 expenditure DM 53 mio.)



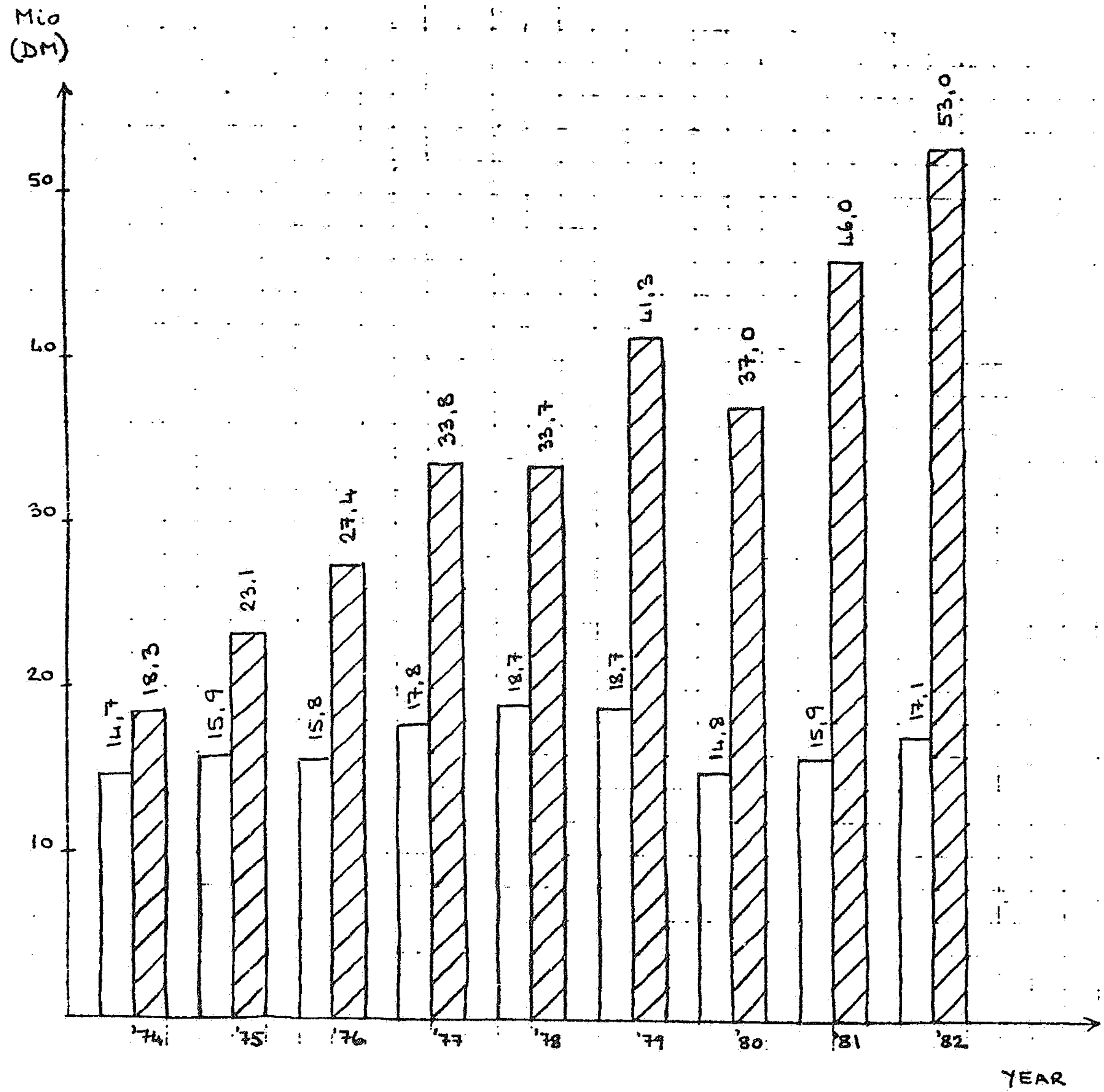


Figure 2 : growth of expenditure on biotechnology R & D in FRG, 1974-1983.

Project expenditures

Institutional support
Gesellschaft für Biotechnolologische Forschung
Gesellschaft für Strahlen und Umweltforschung
Kernforschungsanlage, Jülich

2.2. France

The President of the Republic commissioned from Professors Gros, Jacob and Royer a major study, "Sciences de la Vie et Société", whose publication in October 1979 is a convenient starting point for the consideration of public policy towards biotechnology*. This report was very "European", emphasizing that the diversity and complexity of advanced teaching and biological research have become such that a sufficiently large and competent group can be organized only on a European rather than a national basis. Concerning the basic tools of biological research - measuring devices, biological materials, buildings, databanks and stocks of living materials, France is seen as excessively dependent on foreign sources ; but with adequate investment, the authors believe that French industry should be able to correct the situation within 10 years.
Parallel to the Gros, Jacob and Royer report, Joël de Rosnay produced an informative document ** giving details of French and foreign capabilities in each area of biotechnology.

A briefer and more succinct, policy-oriented report was requested by the Prime Minister, and J.C. Pelissolo was charged with this responsibility. His report *** considers in turn public sector research, industry and the controlling administrations. It aims to identify strengths and weaknesses, and identify the principal problems to be solved to ensure industrial success.

Public sector research is seen as of good quality, but its transfer to, and exploitation by, industry is restricted by inflexibilities. Pelissolo sees French industry as backward in biotechnology, behind not only the U.S. and Japan, but also Germany, the Netherlands and Britain. There is insufficient knowledge in the leading industrial teams. He considers several specific fields in detail :

- Health : strong in pharmaceuticals (Rhône-Poulenc, Roussel Uclaf), but a major deficit in antibiotics ; strong in immunology.

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* Documentation Française

** "Biotechnologies et Bio-Industrie", Joël de Rosnay, Documentation Française, 1979.

*** "La Biotechnologie, Demain ?", Jean-Claude Pelissolo, rapport à M. le Premier Ministre, Documentation Française, December 1980.

- Agriculture : risks of external dominance of the seed industry ; need to exploit INRA genetics research and *in vitro* plant propagation know-how.

- Agro-food : traditional brewing and cheese-making lacks research and innovative strength ; more active are the food- and feed-additive industries, with 10-50 % (depending on product) of world amino acid production (70-80 % exported), and a major converter of maize (1.3 m. tonnes of maize processed into 300 different products). The EEC iso-glucose regulations are seen as damaging, benefitting only the Japanese and still more the American producers in the long term.

- Chemicals : biotechnological applications currently modest, but expected to increase : French industrial interest lagging behind American and German activity.

Pelissolo set as first objective the increase of France's research potential, and of its utilization by industry. High quality fundamental research must continue to be financed by the state. France must make good from foreign sources what she cannot find at home, buying foreign firms, and promoting academic and industrial exchanges of research fellows with the best foreign laboratories. Amongst his many specific recommendations, Pelissolo included the creation of a Mission for Biotechnology, to orchestrate and stimulate national competence in the field.
The subsequent change of administration in France reinforced the strong public commitment to biotechnological development, coordination being focussed by the creation of the "Mission Biotechnologie", under Professor Pierre Douzou.
This had a budget of some FF 70 m. (10 m.Ecu) to spend on research, but as its Director has pointed out, funds from other national agencies (such as the Agence Nationale de Valorisation de Recherches : ANVAR) could double or treble this amount. The research Ministry's new strategy involves the creation of four technology transfer centres for biotechnology : Compiègne, Toulouse and two in Paris : Institut Pasteur and an expanded INRA fermentation centre, at Grignon. At these, scientists will be encouraged to work in collaborative "cells" with engineers and technologists from local companies. Also planned are some 60-80 fellowships to encourage

scientists in universities and in industry to do applied research and/or update their knowledge.

Total expenditure by the French government was estimated to have been some FF 200m. (29 m. Ecu) on education and research in biotechnology.

The Mission Biotechnologie completed its work at the end of 1982 with the production of a "Mobilisation Programme" for promotion of biotechnology*, advocating for the first 3 years of the 10 year programme a total budget of FF 690 m. (1982 francs), i.e. FF. 230 m. p.a. (36 m. Ecu), for the Ministry of Industry and Research's agencies DESTI and ANVAR ; and advocating related budget increases for key national research agencies (CNRS, INSERM, INRA) and institutions (particularly Institut Pasteur). Many of the projects also depend upon inter-ministerial co-operation, with Agriculture, Education and Health.

Following the currency realignments of March 1983 and subsequent economic measures, a number of the planned budgets have had to be reduced, including in particular that of the Mobilisation Programme.

2.3. Italy

The Italian government's support for life sciences and biotechnology research is channelled mainly through the Council for National Research (CNR). The CNR has announced a Task Programme on Genetic Engineering, to run 1983-1987, with a financial commitment of the order of 15 m. Ecu over the 5 years (i.e. some 3 m. p.a.).

The projects relating to human health are grouped in a programme on "Genetic Engineering and Molecular Bases of Hereditary Disease", comprising 3 sub-programmes :

1) Genetic engineering,

2) Cellular Biotechnology,

3) Molecular Bases of Hereditary Diseases.

Financial commitment for the first year is (in M. Lire) 880 for 1), 420 for 2), and 1100 for 3, total 2400. Mention should also be made of the CNR Task Programme on "Increase of Agricultural Resources Productivity", covering several research projects involving genetic engineering relevant to agriculture.

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* Ministère de la Recherche et de l'Industrie : Mission des Biotechnologies : "Programme mobilisateur : l'essor des Biotechnologies", 1982.

There has also been reported (Scrip, 26 July 1982) a plan to spend $ 91 m. on biotechnology over the next 5 years, over half of this from government and the rest from private industry. The intention is to draw extensively upon the experience gained in CNR's biomedical technology research programme (say 10 m. p.a. ; 10 + 3 = 13 m. Ecus p.a.).
Other public sector initiatives include support for biomass energy projects, and generous financial support for the installation of anaerobic digesters to cope with the effluent problems of intensive animal units.
Of special interest is the recent agreement between FIAT (Soria), ENI (Sclavo) and MONTEDISON (Carlo Erbe-Famitalia) for common precompetitive research in the field of monoclonal antibodies for diagnostic methods and developments. Financing of this project (1983-198?) has been approved by the government amounting to 5 m. Ecu, through an IMI contract (via Tecnobiomedica).
CNR also supports a number of research institutes of major relevance to biotechnology : such as the Institute of Genetics and Biophysics in Naples, the Institute for Germplasm in Bari, the Institute of Cell Biology in Rome, and the Institute of Mutagenesis and Differentiation in Pisa. It also supports several centres located in universities such as the Centre for Nucleic Acids and the Centre for Molecular Biology in Rome.
Turning to industrial research, mention should be made of the advanced work in immobilised enzymes for detoxification, particularly within FIAT (Sorin) and ENI (SNAM progetti).
Italy has developed a substantial fermentation industry for pharmaceuticals, citric acid and single cell protein.

2.4. The Netherlands

An extensive review of both biotechnology and of Dutch national capability was published in April 1981* by STT, and some key points from this are summarized below. A government-sponsored committee was set up in May 1981, under the chairmanship of Professor Schilperoort of the University of Leiden, with the aim of coordinating research on the Netherlands and increasing its emphasis on commercial

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* "Biotechnology : A Dutch perspective", ed. J.H.F. van Apeldoorn ; Stichting Toekomstbeeld der Techniek (Netherlands Study Centre for Technology Trends).

applications.The Committee includes experts from industry, universities, and the governmental applied research organisation TNO. Four million florins a year has been made available for the biotechnology committee to allocate to selected projects.

The committee reported in April 1982, and has emphasized not the creation of new centres for biotechnology, but the strengthening of cooperation between government institutes, universities and industry. It urges the government to provide extra support to stimulate innovation in biotechnology - at least an extra 75 m. florins (28 mua) over the period 1982-1988 - drawing on the government's fund for industrial innovation.

The Committee emphasizes applied research in areas of existing strengths of Dutch companies - agriculture, dairy industries, fermentation and antibiotics ; and for future research, the development of host-vector systems, somatic cell hybridation, second generation enzyme reactors, and downstream processing technology.

The Committee, echoing widespread earlier calls from industry, universities, and the STT report, recommends bringing the Dutch regulations on DNA experiments into line with the less strict criteria adopted elsewhere, and harmonized on a single national, rather than municipal, basis.

Professor Schilperoort sees the need to improve internal communication structures : Dutch industry and universities often have extensive contacts abroad at the expense of national collaboration. The country has a large fermentation industry, in many respects of international standard. Research facilities outside industry are very limited, reducing the potential for international competitiveness. In the food industry, Dutch breweries and dairy plants are sophisticated and internationally competitive.

The Netherlands has an excellent tradition of microbiology, biochemistry and process engineering, and has a leading international position in effluent treatment, developed in response to the needs of the food industries.

The company Gist-Brocades is Europe's major producer of penicillin, with corresponding expertise in fermentation technology. It is also one of the world's major producers of enzymes, and is carrying out intensive study on their production, isolation and application, on laboratory and commercial scale. Related research is under way at the universities of Delft and Wageningen ; details of these and other university research centres are given in the STT report. In a paper on education for biotechnology in the Netherlands, it is estimated that research expenditure in the universities amounts to 19.3 m. Dfl p.a. (7.6 m. Ecu).

2.5. Denmark

Biotechnology is critical for Denmark. The agricultural (24 %), food (34 %) and chemical (10 %) industries together dominate the "manufacturing" economy. Everyone has heard of the Carlsberg brewery, with its traditional skills in brewing, which have supported the creation of an international research centre with outstanding competence in plant genetics and cell biology. Everyone has also heard of Novo, which dominates the world market in industrial enzymes. Novo practised biotechnology before the word was invented, and is now arguably the world's leading company in the field.

Denmark spends about 700 m. Kroner annually (86 m. Ecu, private and public sector) on biotechnology research, somewhat less than 1 % of product value, but heavily biased towards the chemical sector (Novo contributes 200 m. of this). It is now being argued by some that research investment in agriculture and food should be increased.

In 1978 the Danish Technical Research Council, under the chairmanship of Prof. O.B. Jorgensen, took the first initiative in the field and supported projects in genetic engineering scale-up problems (with particular reference to genetic stability), product recovery (with special reference to selective recovery of intracellular products) and on protein synthesis. More recently, a Ministry of Industry "initiative group" recommended against creating a new institute specially for biotechnology because the subject was of such widespread interest that it needed to be practised widely. In April 1981, another Ministry of Industry "initiative group" was formed under the chairmanship of Prof. Ulrik V. Lassen, research manager of Novo, to consider applied genetic engineering in Denmark.

It reported in November 1981 and recommended that individual research proposals should be supported and that appropriate guidelines or rules to govern applied research and industrial use of genetically manipulated micro-organisms should be developed. Its principal recommendation was that a Working Group to study the genetic manipulation of microorganisms should be set up at the Technical University, with a view to the appointment of a Professor at a later date. This working group was started in October 1982 and now comprises 4 scientists and 3 technicians. It will aim to provide a microbial genetics service to industry.

Denmark is developing a unique biotechnology, based on a unique biotechnology company ; with cooperation from government and university.

2.6. The United Kingdom

2.6.1. Government policy and Research Council activity

A major report on biotechnology was published in April 1980 by a Joint Working Party drawn from the Cabinet's Advisory Council for Applied Research and Development, the Advisory Board for the Research Councils and the Royal Society. This report is usually known as the Spinks Report after the Chairman of the Working Party, Alfred Spinks, formerly Director of research at ICI.
Seeing large potential growth in the field, both for existing industries and new ones, the report recommended a policy of "technology push" reflected in a firm commitment to strategic applied research, and funded by Government intervention. Detailed recommendations were that Research Councils should spend at least £ 3 m. (5 m. Eu) annually on biotechnology research, and that the Government should spend about £ 2.5 m. a year (including existing projects) in a coherent programme of industrial R & D to involve industry, Government research establishments, universities and research associations. A further specific recommendation was for the establishment of a research-oriented biotechnology company (suggested cost £ 2 m.).

The initial response of the Government, in a White Paper on the subject, was strongly to emphasise the role of market forces and the private sector, to exploit British scientific and technical discovery and build up its competitive position by importing good developments through licences or otherwise as well as from its own research and development.

Initially at least this attitude, and the lack of specific policy on the vital area of education for biotechnology, were seen as clearly differentiating the Government's attitude from that of France, West Germany and Japan.

Subsequently however, many aspects of the Spinks report have been implemented, illustrated by the following developments :

- the Research Councils now spend more than £ 7 m. between them on narrowly defined biotechnology, and a coordinating committee has been set up ; indeed their evidence to the Parliamentary Committee currently investigating biotechnology gave the figures shown in Table 2, suggesting a possible total exceeding £ 25 m. (43 m. Ecu), mainly attributable to the medical "underpinning" research.

TABLE 2 : U.K. Research Councils annual expenditure on biotechnology (£m)

- Agricultural Research Council (total 1982/83 budget about £92 m.p.a.)=		
. genetic manipulation (primarily of plants =		1.5
. other areas of biotechnology including veterinary, vaccines and monoclonal antibodies etc for veterinary diagnostics		2.5
. related "under-pinning" research =		"of the same order"
	Total	"about £ 5 m."
- Medical Research Council (total budget about £107 m. p.a.)		
. on a rigorous definition (research directed specifically to the development of something with a foreseeable commercial end such as a vaccine or diagnostic reagent) = of the order of		1.7
. conceptual underpinning = molecular biology, molecular genetics : "approximately 10" (verbal answer) ; underpinning research (e.g. in the chemistry, organisation and function of genes) = "the Council spent £ 17 million in 1980-81" (written submission)		17
	Total	18.7
- Science and Engineering Research Council		
. current annual expenditure on biotechnology research (divided roughly into two-thirds for basic biological research and one-third for engineering research) = £ 1 million, including DNA, aspects of microbiology and molecular genetics, immobilised enzyme and cell systems, fermentation including downstream processing, waste treatment and the leaching of metals from ores. Planned to increase to £ 2.5 million by 1985/86		1
	Total	1
- Natural Environment Research Council Present role relatively minor (£0.6 million p.a.), but many interactions and areas of research activity of relevance :		
. management of biomass production (seaweed, organic wastes, woodlands, algae, fish)		
. selection, sterile culture and propagation of tree clones		
	Total	0.6
. pest control		
. ecology, physiology, biochemistry and genetics of micro-organisms (soil and aquatic)		
. taxonomy, culture technology and collections		
	For the 4 councils :	25.3

Source : Minutes of Evidence of the House of Commons Education, Science and Arts Committee, Session 1981-82, "Biotechnology" : 21 April and 10 May 1982.

- a special Biotechnology Directorate has been established within the Science and Engineering Research Council to coordinate SERC grants for research in the field and encourage British scientists to take up research in related areas.

- a coordinating committee between Government departments has been set up, and a number of senior industrial executives have been seconded to form a "think tank" to identify biotechnology opportunities.

- Department of Industry support for R & D is now at least at the level recommended in the Spinks report (£2.5 m.) and support for industrial investment in the area is around £ 15 m., a further £ 16 m. industrial support programme was announced in December 1982.

- the University Grants Committee has been given increased funds of £ 1 m. per annum to finance 20 extra teaching posts and research (a recent Royal Society report estimated that over the next 10 years, Britainwould require 1000 extra graduates and 4000 technicians trained in biotechnology ; an assessment which has been accepted by the government as a basis for planning) ;

- a research-oriented company, Celltech, has been launched, its £ 12 m. capital being 44 % public (via the British Technology Group), 56 % private (Prudential Assurance, Midland Bank, British Commonwealth Shipping, Technical Development Capital). Celltech has a special responsibility for commercialising useful discoveries from Medical Research Council supported laboratories ; plans are also well-advanced for the launch of a corresponding company to exploit the results of work financed by the Agricultural Research Council, provisionally (May '83) known as "Agricultural Genetics Company". Private funding (possibly Ultramar and Advent Technology) is expected to contribute about two thirds of expected initial financing of £ 15 m., the remainder from British Technology Group.

2.6.2. Industrial activity

Whilst the United Kingdom's academic strength in the field of biotechnology rests on the large number of University departments in the life sciences, many associated with research units dependent on the Research Councils, its commercial strength is based on large and successful companies in chemicals, pharmaceuticals and food processing, whose research and production facilities, like those of some important subsidiaries of non UK firms (e.g. G.D. Searle), are based in the UK. Imperial Chemical Industries Ltd. has played a major role in the development of biotechnology in Britain, in fields as diverse as plant protection chemicals (esp. pyrethroids) sewage treatment (e.g. the deepshaft process for recycling, on limited land space, water contaminated by organic effluents) and single cell protein. The last has been widely publicised, with the bringing on stream early in 1981 of the "Pruteen" plant producing 60.000 tons of single cell protein rich in the essential amino acid lysine. Based on a feedstock of methanol, produced from North Sea gas, this product competes with soya and other protein sources. It has also had to overcome the regularoty hurdles faced by any novel feedstuff. The project itself is of great significance as a prototype for large-scale biotechnology and the development of the related process engineering. Attempts to improve the energy efficiency of the micro-organism have included the use of genetic engineering to produce a manipulated variant. Others strong in the field of biotechnology include innovative pharmaceutical firms such as Glaxo and Beechams. Groups such as ICI, Shell and BP have significant research and production capabilities in pharmaceuticals and agricultural chemicals. Major food firms and brewing groups in the UK are also showing active interest in biotechnology, eg. Rank Hovis McDougalls fungal single cell protein and Grand Metropolitan Hotels investment in Biogen (the only European shareholder).

Unilever's expertise at all stages of vegetable oil production (palm tree cloning) and manipulation (inter-esterification, e.g. to convert palm-oil mid-fraction to the equivalent of cocoa butter fat) is another strong point of AngloDutch biotechnology : the examples cited indicate also the Third World implications.

2.7. Belgium

Belgium has a strong chemical industry, and outstanding strengths in its universities and research institutes in the biomedical sector (e.g. the Institute for Cellular and Molecular Pathology) and in plant genetics (University of Ghent), as well as in other areas (e.g. bacteriology in various institutions). The international pharmaceutical companies are also attracted by the high quality environment provided by the research teams in the various universities of the country. The rather open economy and the presence of numerous multinational companies (chemicals,

pharmaceuticals, foods) create the problem for the public authorities of balancing the advantages of attracting foreign investment against the drawbacks of a potential internal "braindrain" into these companies, with insufficient spin-off benefits to the local economy.
At the level of the regional authorities, Wallonie, Flanders and Brussels are seeking to attract foreign investment in high technology sectors such as biotechnology. Hybritech (the U.S. leader in hybridoma technology and marketing) has established a plant at Liege ; Biogen (the Swiss and U.S.-based group owned by Monsanto, International Nickel, Schering-Plough and Grand Metropolitan Hotels) is to establish a subsidiary at Ghent (Biogent). At the level of the national authorities, the IRSIA - a national industrial research association - is coordinating R & D projects on biotechnology topics (e.g. on vectors, yeasts, plant tissue culture) at Belgian research centres, and funded by 14 Belgian companies (2 year budget, some BF 200 m).

The SPPS (National Science Policy Department) has been supporting centres of excellence in molecular biology, through "Concerted Research Actions" for the last 10 years (yearly budget 200 MFB).

In addition, the organization of coordinated national collections of micro-organisms has been started, with fungi at Louvain-la-Neuve, and bacteria at Ghent (based on substantial existing collections).

2.8. Ireland

Ireland, like Belgium, is vigorously seeking to attract foreign investment, to take advantage from its developed educational system, and to stimulate greater exploitation of the country's under-utilised agricultural potential.

The 1981 report by the National Board for Science and Technology, "Biotechnology Trends" emphasised chemicals, pharmaceuticals, health-care and food processing as sectors within which there are processes and products of special potential significance. The possibility of gaining technology transfer from innovative U.S. companies is noted. A major national policy document is planned to appear by mid-1983, outlining a development plan for Irish biotechnology ; focussing on industrial, research and educational policy and their integration.

2.9. Greece

The Ministry of Coordination, in consultation with the Ministries of Science and Technology, Education and Agriculture, is currently developing plans to stimulate awareness, education and application of biotechnology, in the context of the 1983-88 5-year plan for economic and social development. This includes a programme for scientific and technological development, an element of which concerns "key technologies" : containing three themes :

a) microelectronics and informatics
b) biotechnology
c) technologies relating to marine exploitation.

This choice reflects top-level political decisions, and ambitious plans are now being implemented to create the necessary foundations. A key potential asset are the many highly-qualified Greek scientists working abroad, a survey of whom has identified many willing to return if suitable posts and facilities are available (e.g. Professor Kafatos of Harvard will establish the life sciences institute at the University of Crete).

Biotechnology and life sciences research is also being vigorously promoted at several other universities (Athens, Patras, Thessalonika) and at research centres such as the National Hellenic Research Foundation, the Cancer Research Centre (Salonika), and NRC Demokritos (Athens).

Professor Stavropoulos, associated with the science-based biotechnology company Vioryl (food additives, preservatives, flavourings, plant nutrients), is working with the government planners to identify new industrial opportunities in biotechnology. Plans are now well advanced for the launching of a national company, "Bio-Hellas", which would work in close association with the research centres mentioned.

2.10. Comparative National Expenditure Statistics on R & D

Reference has been made to the inter-disciplinary character of biotechnology and to its diverse fields of application. These make it particularly difficult as yet to obtain a clear and comparable quantitative picture of biotechnology R & D activity in the member states of the Community. In particular, the subject cuts across four of the "NABS" categories (Nomenclature for the analysis and comparison of science programmes and Budgets) customarily used in European Community R & D expenditure statistics :

3. Protection and improvement of human health.
5. Agricultural productivity and technology
6. Industrial productivity and technology
10. General promotion of knowledge

A more detailed analysis of the 1981 figures is available, and Table 3 shows expenditure by country on 12 areas more closely related to biotechnology ; the expenditure on biosciences is most likely to be correlated with strength in at least the foundation disciplines of biotechnology, but there are problems of comparability caused by the mapping of different national systems into the NABS categories. The U.K. figures appear to under-represent the country's degree of activity as compared with France and Germany. The total under biosciences, 292.3 m.Ecu (385.3 m. Ecu in 1980), may perhaps be set against the figure quoted by Rogers for Japanese government expenditure for life sciences in general : 50 bn Yen, i.e. 195 m. Ecu.

Combining chapters 31 (Medical research : 526.5 m. Ecu), 103 (Medical sciences : 1091.2 m. Ecu) and 1013 (Biosciences : 292.3 m. Ecu) gives a figure for the EC of 1.9 bn. Ecu in 1981 ; the 1982 outlays of the U.S. National Institutes of Health were $ 3.4 bn.

As a rough estimate of "biotechnology-relevant" research in the European Community, one can simply total the relevant expenditure headings of Table 2, update (say by 10 %) for inflation to 1982, and assume (as with the U.S. medical and agricultural figures previously) that 10 % of this total may be described as "biotechnology-relevant". This gives an estimate of some 350 m. Ecus ($ 380 m.) for the countries listed.
Summarising the figures presented in the text, and applying to the figures of Table 3, the above "broad basis" estimate of "biotechnology-relevant" research expenditure, gives the estimates presented in Table 4.
A meeting of the Statistics Sub-committee of CREST will give particular attention to the problems posed by "biotechnology" at a meeting in the latter half of 1983.

TABLE 3

PUBLIC R & D FUNDING OF SELECTED NABS SECTIONS 1981 ('000 ECU)

Within NABS Chapter :	SECTION	FED.REP. GERMANY	FRANCE	ITALY	NETHERLANDS	BELGIUM	UNITED KINGDOM	IRELAND	EUR 9 *
3. protection & improvement of human health	31 : Medical research (incl.biomedical & engineering)	137.807	274.672	32.762	3.642	35.041	40.442.	2.110	526.476
	32 : Food hygiene & nutrition	19.927	20.199	2.776	–	4.946	11.208	–	59.056
	33 : Pollution	126.789	69.868	36.229	27.213	16.522	67.972	275	344.868
5 : Agricultural productivity & technology	50 : Research of general nature	56.904	28.312	10.613	7.766	4.054	37.425	674	145.748
	51 : Domestic & wild animal products	6.500	84.107	8.558	14.198	9.439	86.198	11.405	220.405
	52 : Crops (incl. forestry & wine	64.602	123.843	26.537	32.075	10.767	86.706	4.731	349.261
	53 : Fishing & Fishery products	10.623	23.179	2.176	2.455	1.150	11.734	2.881	54.198
6 : Industrial productivity & Technology	632 : Pharmaceutical products	–	–	24.156	–	2.559	–	–	26.715
	681 : Food, drink & tobacco	18.800	31.623	8.319	–	3.689	4.854	2.981	70.266
	686 : Utilisation of industrial agricultural & domestic wastes	–	–	511	–	1.188	1.945	41	3.685
10 : general promotion of knowledge	1013 : Biosciences	110.740	104.803	36.542	–	34.060	5.514	628	292.287
	103 : Research in medical Sciences	644.246		117.474	145.724	–	183.680	43	1.091.167
	12 – Section Total	1.196.938	760.606	306.653	233.073	123.415	537.678	25.769	3.184.132

* no comparable Danish figures

TABLE 4

SUMMARY ESTIMATES BY COUNTRY OF PUBLIC EXPENDITURE ON BIOTECHNOLOGY R & D

(M. ECUS - 1982/1983)

	Biotechnology	"Biotechnology-relevant"
F.R. GERMANY : (BMFT) : DM 63 m. (projects) plus 20 m. (institutional support) = DM 83 m. :	36	
Alternatively, estimate 10 % of medical, agro-food and life-sciences research as "biotechnology relevant", i.e. "broad basis" :		132
FRANCE : FF. 200 m. on education and research in biotechnology in 1982 :	31	
Alternatively, "broad basis" :		84
UNITED KINGDOM : £ 28.8 m. (Research Councils, UGC, Dept. of Industry) :	46	
Alternatively, "broad basis"		59
ITALY : CNR 5-year programmes on genetic engineering and biomedical/industry programme :	13	
Alternatively, "broad basis"		34
NETHERLANDS : Schilperoort recommendation of Hfl. 75 m. ('82-'88) plus university research 10-20 Hfl. p.a. (Bruin) : say Hfl. 26 m. p.a. :	10	
Alternatively, "broad basis" :		26
BELGIUM : SPPS (molec. biol. etc. : FB 200 m. p.a.) plus IRSIA (100) : at least FB 300 m. p.a. :	7	
Alternatively, "broad basis" :		14
DENMARK, GREECE, IRELAND, LUXEMBOURG : say	3	6
	146 -	355
(U.S. $ m. :	156 -	378)