tion, and succeeded in deliverying twins of cattle and goats from artificially split fertilized eggs. It is hoped that this technology will be before long used widely by animal breeders. Vaccine production is also one of the important targets sought in livestock industry, and National Institute of Animal Health succeeded in tissue culture of infectious equine anemia virus for the first time in the world and thereby developed an effective diagnostic method (immune precipitation) of infected horses. Some private firms are also developing animal vaccines and diagnostics using biotechnology.

One of the successes of biotechnology development in food industry is in the area of bioreactors. Japan has been one of the leading countries in fermentation industry, and is now one of the most advanced in the immobilized enzyme or cell system technology. This technology is successfully utilized for the production of fructose from glucose by means of immobilized glucose isomerase.

1-2-3 Characteristics of Agricultural Research in Japan

Table II-1-4 shows expenditures on research and development by field of science in research orgnizations of various sectors in Japan. The total size of the expenditures on agricultural research is one third of those on engineering. As mentioned elsewhere, the development of the major crops other than vegetables and fruits has been carried out by the public sector in Japan. As seen in the table, a total of ¥164,636 million was spent on agricultural research and development by the central and local governments in FY1984. The figure is about 94% of the entire expenditures on agricultural research. The private sector spent a total of ¥274,987 million on research and development in FY1984, but only 3.5% of the expenditures went to agriculture. This may reflect that the size of the market for agriculture is not that attractive for the private industries to take part in, compared with other lines of business.

However, the situation is now changing rapidly due to the recent progress in modern biotechnology. The Government is trying through deregulation to attract the private sector participation in agricultural research, because it is considered that the public sector needs to catch up with new developments of technology through transfers of technology from the private sector. Moreover, a number of private industries have taken strong interest in the possibilities of applying biotechnology to agriculture. They hope that they can apply developed technologies to agriculture, along with ongoing deregulation efforts of the Government.

Table II-1-5 shows expenditures on research and development by purpose of study. In general, agricultural research is oriented to applied research, and Japanese agricultural research has been conducted largely along this line. Due to the recent developments in modern biotechnology, however, the importance of fundamental research has begun to be emphasized, and Japan's agricultural research is currently in transition, shifting to a more basic research oriented structure from that of applied research.

Table II-1-4 Research and Development Expenditures in Various Sectors by Field of Science

(¥ million)

Organi-zation/Field \ Fiscal Year	1980	1981	1982	1983	1984
Total	717,612	848,834	894,310	915,254	976,102
Science	215,208	236,389	240,118	270,066	277,743
Engineering	302,348	395,723	430,407	418,865	458,732
Agriculture	154,762	167,204	168,010	165,900	175,265
Health	45,294	49,517	55,775	60,423	64,362
Government owned	185,372	191,956	195,747	200,863	208,062
Science	27,852	28,690	26,207	27,406	24,034
Engineering	96,140	98,854	105,639	111,852	116,404
Agriculture	45,096	47,173	44,859	42,961	45,738
Health	16,284	17,239	19,043	18,604	19,886
Local Govern-ment owned	165,966	177,702	177,766	178,222	185,658
Science	16,934	16,215	12,804	12,608	12,952
Engineering	28,074	33,142	34,415	36,204	36,057
Agriculture	105,214	113,232	115,650	113,047	118,898
Health	15,744	15,113	14,897	16,364	17,720
Private	122,533	213,394	244,198	248,087	274,987
Science	7,799	17,451	20,396	18,066	18,352
Engineering	97,595	172,740	195,212	195,499	220,088
Agriculture	3,873	6,038	6,755	9,065	9,791
Health	13,266	17,165	21,835	25,456	26,756
Public corporations	243,742	265,783	276,599	288,082	307,396
Science	162,624	174,034	180,711	211,986	222,405
Engineering	80,539	90,988	95,142	75,270	84,153
Agriculture	579	761	746	826	837
Health	-	-	-	-	-

Source: Science and Technology Agency, ed., Indicators of Science and Technology, Tokyo, 1985.

Table II-1-5 Research and Development Expenditures by Character of Work

FY 1984

Character of work / Organization/Field	Total (Disbursement)		Basic research		Applied research		Development	
	¥ million	%	¥ million	%	¥ million	%	¥ million	%
Total	951,167	100.0	124,464	13.1	289,185	30.4	537,518	56.5
Science	275,696	100.0	25,304	9.2	43,781	15.9	206,610	74.9
Engineering	436,574	100.0	31,243	7.2	114,598	26.2	290,732	66.6
Agriculture	175,035	100.0	33,822	19.3	105,159	60.1	36,054	20.6
Health	63,863	100.0	34,094	53.4	25,647	40.2	4,122	6.5
Government owned	185,600	100.0	58,831	31.7	70,884	38.2	55,885	30.1
Science	22,243	100.0	9,124	41.0	8,693	39.1	4,426	19.9
Engineering	97,733	100.0	15,970	16.3	39,405	40.3	42,357	43.3
Agriculture	45,738	100.0	20,961	45.8	17,896	39.1	6,880	15.0
Health	19,886	100.0	12,775	64.2	4,589	24.6	2,222	11.2
Local Government owned	184,746	100.0	25,582	13.8	117,911	63.8	41,252	22.3
Science	12,721	100.0	2,909	22.9	8,769	68.9	1,043	8.2
Engineering	35,799	100.0	3,133	8.8	18,031	50.4	14,635	40.9
Agriculture	118,685	100.0	10,264	8.6	83,092	70.0	25,329	21.3
Health	17,540	100.0	9,276	52.9	8,019	45.7	245	1.4
Private	273,426	100.0	30,323	11.1	86,804	31.7	156,299	57.2
Science	18,327	100.0	3,543	19.3	12,734	69.5	2,050	11.2
Engineering	218,888	100.0	12,140	5.5	57,161	26.1	149,587	68.3
Agriculture	9,775	100.0	2,597	26.6	4,170	42.7	3,008	30.8
Health	26,436	100.0	12,043	45.6	12,738	48.2	1,654	6.3
Public corporations	307,396	100.0	9,728	3.2	13,586	4.4	284,082	92.4
Science	222,405	100.0	9,728	4.4	13,586	6.1	199,091	89.5
Engineering	84,153	100.0	-	-	-	-	84,153	100.0
Agriculture	837	100.0	-	-	-	-	837	100.0
Health	-	-	-	-	-	-	-	-

Source: Science and Technology Agency, ed., Indicators of Science and Technology, Tokyo, 1985.

1-3 High Technology Development and Application in Agriculture

Among the technologies available for increasing food production, plant and animal breeding offers great potentials. Application of genetic principles to the improvement of maize has, for example, been responsible for half the 300% increase in its yield that has taken place in the United States during the past 50 years.

Based on the past experiences, genetically improved crop varieties usually offer the most cost-effective means of increasing yields. It is also believed that crop yields can be increased by genetic improvements without taking any risks of greater use of chemical fertilizers and pesticides. Modern biotechnology, which consists essentially of genetic engineering and cell culture techniques, is believed to give new tools for plant and animal breeding, in addition to the conventional breeding techniques.

However, it has been found that modern biotechnology also creates new problems. For example, modern biotechnology competes for scarce funds with conventional plant and animal breeding and other related efforts important for agricultural production. Application of modern biotechnology to plant and animal breeding requires scientists who are not accustomed to working together with plant and animal breeders to coordinate their own with the latter's efforts. The possibility of genetic engineering heightens the importance of preserving germplasms. Modern biotechnology also raises new questions about the importance of cooperative research efforts between the public and private sectors and hence the need to establish effective and efficient relationships between them.

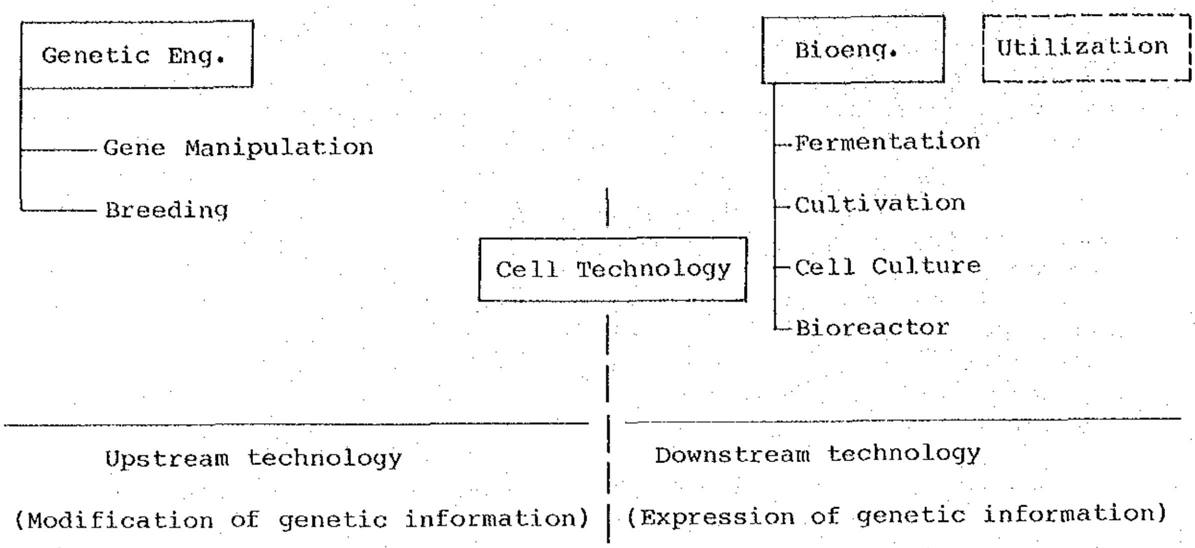
The Ministry of Agriculture, Forestry and Fisheries in Japan has already recognized these problems and has launched significant reorientation for the purpose of establishing a new research structure which will be suited to the requirements of new technology development.

1-3-1 Application of Biotechnology to Agriculture

Biotechnology, as shown in Figure II-1-3, essentially consists of three different groups of technologies. One group is for introducing a new function or functions to a given organism of interest. This group of technology includes genetic engineering and breeding. The second group is to maximize the functions of various living organisms for producing materials useful to mankind. Agriculture and animal husbandry are part of this group of technology. The third group of technology is for utilizing various products by means of bioprocessing and other techniques. In other words, biotechnology is a system of technologies with the manifest purpose of maximum utilization of biological functions, by means of introducing new genetic information and/or letting efficient expressions of genetic information.

The functions of a living organism are essentially determined by its built-in genetic information. A living organism cannot express a function which is not included in the genetic information it originally

Figure II-1-3 Structure of Biotechnology



Source: Biotechnosystem Inc.

has. Thus, the technology of cultivation, or of livestock rearing, is for inducing a maximum expression of genetic information from a given crop or animal. Limitations in the capability of a crop due to its genetic constraint can be overcome only by introducing new genetic information.

Plant breeding has existed as an art for more than ten thousand years, but it has been assisted by sciences for only about 1000 years. Mankind had been practicing various measures to move genetic materials from one plant to another long before plant breeding and genetic transformation established themselves as a branch of technology.

Today, the methods used in the genetic improvement of crops fall into two broad categories: conventional plant breeding and application of advanced technologies, including modern biotechnology.

"Conventional" plant breeding means those techniques which are based on mating different strains of plants or animals for the purpose of producing and identifying offspring that combine the desirable traits of the parents. It makes use of many supporting sciences conducted in laboratories.

"Modern biotechnology", as it is defined, includes a number of new technologies based on cellular and molecular biology. The best known of these technologies is genetic transformation: namely, movement of a gene or genes from one plant to another through the recombinant DNA technique and tissue or cell culture. The latter technology provides new opportunities for selecting plants which have some desirable characteristics by exposing their cells (rather than whole plants) to certain stresses or toxins under laboratory conditions.

Thus the conventional plant breeder works primarily in the field and the greenhouse, making carefully controlled crosses of strains, evaluating the resulting progeny and refining those that exhibit traits needed by farmers. The biotechnologist primarily works in the laboratory and the greenhouse, moving genes through molecular (recombinat DNA, nonsexual) techniques and making selections of superior plants by exposing cells to various controlled environments or selective agents.

It is not economically or politically feasible to produce food in favored environments and transport it throughout the world or to dramatically alter production environments. Thus the future demand for plant and animal technology will be in the area of improved adaptation of crops or livestock to their present physical, biological, and sociological environments. Technologies that are presently emerging may permit mankind to attain that goal. This is one of the reasons that biotechnology becomes an important branch of technology. Genetic transformation has paved a road for artificial manipulation of genetic materials, and it is believed that genetic transformation of plants and animals will eventually overcome the weakness of conventional agriculture, that is to say, uncertainty in production.

Conventional breeding has had remarkable success in improving the yields and quality of a wide range of crops and livestock. It is generally considered that a half of the increase in yield in cereal and tuber crops can be attributed to positive breeding and selection of lines that are resistant to pests and diseases and also tolerant of many stressful environmental conditions. Continual needs for satisfying demand for food and developing varieties which can make best use of changing environments necessitate the further improvement of breeding techniques and lines. Modern biotechnology will be a powerful tool for this purpose.

(1) Application of *in vitro* technologies to breeding

(a) Cell and tissue culture

A series of discoveries in the past 20 years have enabled scientists to study, manipulate, and select plant cells in cultures, as have been done with microbes for decades. Scientists can readily screen desirable traits that are expressed at the cellular level. One key problem is that the ability of the selected cells to regenerate whole plants is often lost, and that even if regeneration is successful, the complexity in development may cause the important trait not being expressed. It is generally considered that more accurate understanding of molecular and cellular mechanisms that are involved in the expression of important traits is required for the application of this technology. One possible area of importance for the application of this technology is production of useful products directly from plant cells.

(b) Somatic hybridization

It is often desirable to make sexual crosses between wild and domesticated crop species that are sexually incompatible: in these cases, crosses are not possible and germplasm flow is impeded. Certain in vitro techniques now provide solutions to such problems and allow rapid generation of useful plant types which would normally be obtained only after many years of intensive breeding cycles. The non-specific fusion of protoplasts from the same or different species of a plant can be achieved by using either chemical fusogens or by electrical depolarization.

Somatic hybridization has important potentials in the following areas.

(a) Production of fertile amphidiploid somatic hybrids of sexually incompatible species.

(b) Production of heterozygous lines within a single species which normally could be propagated only by vegetative means, e.g., potato and other tuber and root crops.

(c) Transfer of limited parts of the genome from one species to another by the formation of heterokaryons in which unidirectional sorting of cytoplasmic elements occurs.

(d) Production of novel interspecific and intergenetic crosses between plants that are difficult or impossible to hybridize conventionally; e.g. a fusion between protoplasts of Lycopersicon esculentum (tomato) and Solanum tuberosum (potato), now well known "pomato" created by Melchers et al. in 1978.

There are limitations, however, to these types of somatic hybridization, because plants regenerated from some combinations are not always fertile and do not produce viable seeds. Experience now indicates that the main opportunities for use of somatic hybridization is likely to be more successful if centered around hybridization within the same genus or between closely related genera.

(2) Potential application of genetic engineering to breeding

The basis of crop breeding is the transfer of genetic information between plants in order to develop desired phenotypes. Plant genetic engineering called the recombinant DNA technique allows directed and highly specific manipulation of a genetic material. Once applied and developed to a sufficient degree, it promises ultimately to provide a powerful additional tool to plant breeders. Above all, the technique broadens the possibilities of transferring genes between unrelated organisms, and creating novel genetic information by the specific alteration of cloned genes.

However, it must be emphasized that, unlike microbial systems, a conventional vector system for higher plants is still lacking. The key limiting factor in the present technology development is lack of understanding in the genetic components responsible for plant characteristics. Following are the examples of the application of genetic engineering to agriculture.

(a) Development of disease-resistant varieties

Substantial crop losses occur each year due to attacks by insect pests or microbial pathogens. The former are largely controlled by spraying crops with large quantities of agricultural chemicals, which is not only expensive but also has detrimental effects on ecosystems. Some cultivars of crops species already exhibit resistance to pests and diseases to some extent, but there would obviously be a good market for cultivars resistant to a wider range of stresses. One possible approach to the development of disease resistant varieties is the transfer of microbial genes which produce substances toxic to pests and diseases.

(b) Development of increased photosynthetic efficiency of crops

The most important process carried out by plants is photosynthesis. However, even the most efficient crop plants can utilize only 3-4% of full sunlight. The key question is how to improve photosynthetic efficiency for the purpose of increasing the yields of biomass or crops.

It is known that the first enzyme in carbon fixation, ribulose bisphospate carboxylase, is an extremely inefficient catalyst. Many scientists have suggested that it may be possible to engineer this enzyme by the recombinant DNA technique to improve the efficiency of the catalysis.

(c) Development of nitrogen-fixing cultivars of non-leguminous crops

Yields of many crops, particularly of cereals, have increased over the years by the application of large quantities of nitrogenous fetilizers. Many cultivars have been specifically selected to give high yields in response to fertilizer application.

The natural supply of nitrogen to certain plants, legumes in particular, is achieved by close association between them and nitrogen-fixing microorganisms. The key question is how to exploit this natural phenomenon for a wider range of crop species. For example, one line of research is in extending the host range of <u>Rhisobium</u> spp. to include cereals and forage grasses. The interaction between plant and bacterium is extraordinarily complex, and the molecular and genetic details are far from being fully understood. Broadening the host range would require changes in the recognition system between plant and bacterium. In addition, the plant genes required for the establishment of symbiosis may well be unique to legumes and, if this is the case, these genes would have to be transferred to the new cereal host.

Recent advances in the understanding of bacterial <u>nif</u> genes have offered the prospect of transferring nitrogen-fixing ability of the plants themselves.

1-3-2 Importance of Coordinated Approach

Biotechnology is a huge interdisciplinary system and it is even more true in plant biotechnology. Table II-1-6 shows the flow of research and development in plant biotechnology, and also the key roles to be played by various sectors in each segment of the technology development. For example, research and development in plant agriculture require first of all the preservation of germplasms. Technology development in genetic engineering without support by the germplasm systems is impossible. After collection of germplasms, analysis of genes usually has to follow. These two approaches usually require time, manpower, and funds. It is generally considered that the government sector should be responsible for this task, since most of the private industries cannot afford to carry out this type of work continuously, particularly when the unexploited germplasms are involved.

The next stage of technology development would be the basic research for understanding, for example, the mechanisms of plant gene expression. This type of research is better to be carried out either by universities or government laboratories. The private sector is usually more inclined to applied research and precommercialization development than the other two sectors.

Such characteristics of biotechnology is the reason why many Japanese private enterprises want the Government's involvement in "the promotion of basic research" and "cooperation in research and development between the governmental and private sectors", and expect the governmental initiative in the promotion of basic research.

The intervals between basic discoveries and their application have been steadily decreasing. In the area of biotechnology, what is today's basic research is tomorrow's new technology. Accordingly, establishment of a dynamic industry-university-government relationship becomes a key issue of agricultural biotechnology development in Japan.

Figure II-1-4 shows an example of the joint research system between the government and private industries. It is hoped that by that arrangement, research and development in agriculture can be enhanced.

1-3-3 Directions of Agricultural Biotechnology Research in Japan

As mentioned above, the Ministry of Agriculture, Forestry and Fisheries has reorganized and integrated its research and experiment organizations for promoting biotechnology development. In FY1985, a total of ¥1,960 million was budgeted for this purpose, an increase by 53% from the previous year. For FY1986, a further increase of budget allocation is being proposed (Table II-1-7). The areas of research include cell fusion, DNA recombination, nuclear implantation, improvement in photosynthesis and utilization of micro-organisms and enzymes with high activities, and this suggests that the Ministry places

Table II-1-6 Roles of Various Sectors in Research and Development of Plant Biotechnology

Sector / Area	Public	University	Industry
Germplasm			
Sellection	◎	○	○
Preservation	◎	○	○
Analysis	○	◎	○
Research			
Basic	○	◎	
Applied	○	○	◎
Commercialization			◎

Source: Biotechno System Inc.
Note: ◎ indicates the key role.

emphasis on promoting fundamental biotechnology.

The current key policy issue in agriculture-related high technology is to develop agricultural biotechnology under a new program that can meet the long-term national needs by establishing close industry-university-government cooperation. The new program consists of the following four actions.

(a) Promote a systematic approach to develop agricultural biotechnology relating to production and processing.

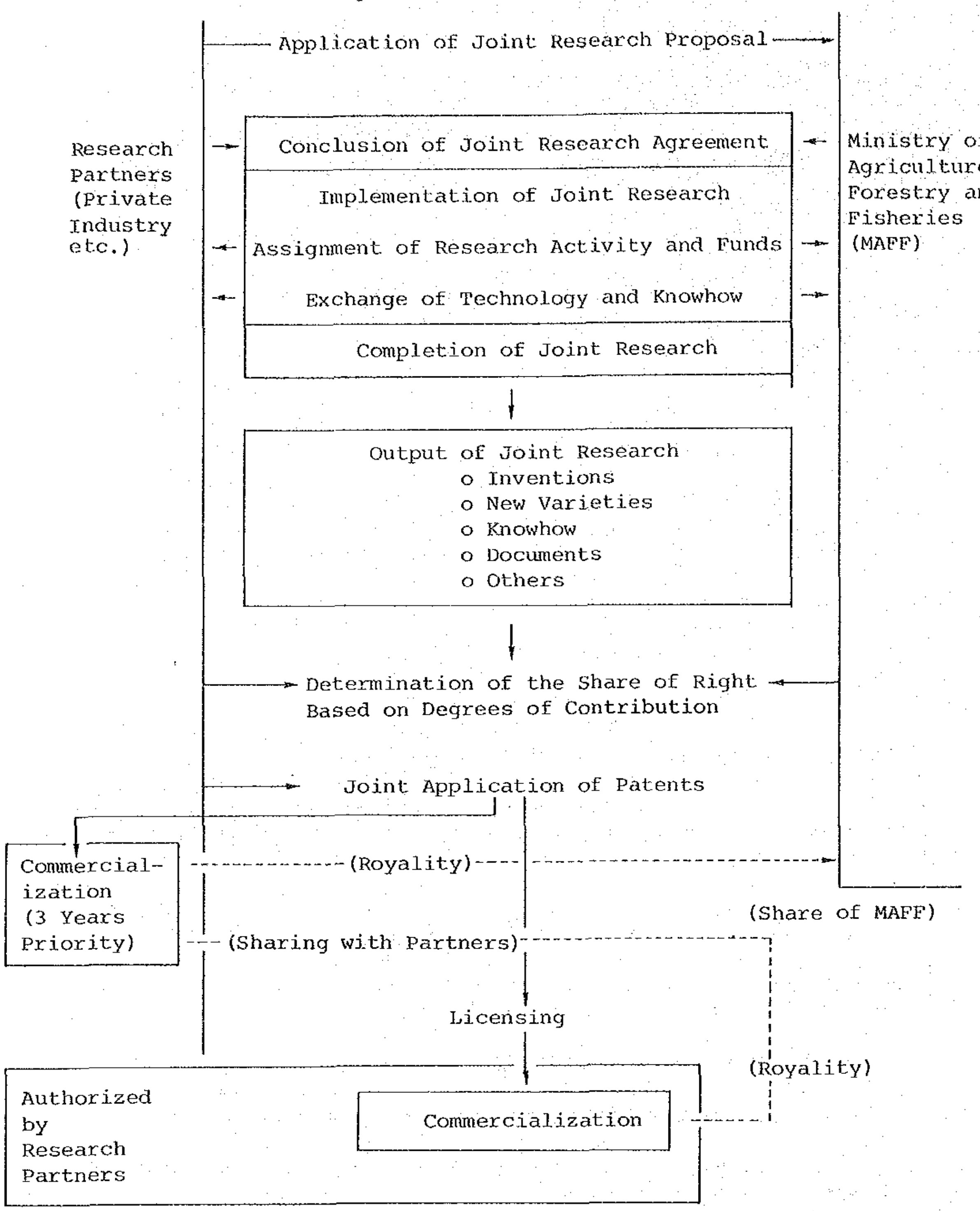
(b) Establish a "Seed and Seedling Center (tentative)" and enhance research efforts related to germplasms.

(c) Establish a "High Technology Center (tentative)" to promote research cooperation between the government sector and private industries through funding and technology exchange.

(d) Promote international research cooperation, for example, by participating in big research projects.

In FY1986, as shown in Table II-1-7, the Japanese Government is to continue stepping up its efforts to promote agricultural biotechnology research by starting a number of new programs. The Program for Promotion of Molecular Breeding Technology toward the 21st Century is

Figure II-1-4 Joint Research System of Ministry of Agriculture, Forestry and Fisheries and Private Industry



Source: Materials from MAFF

Table II-1-7 Government Budget for Biotechnology Promotion in Agriculture, Forestry, Fisheries and Food Industry

(Unit: ¥ million)

Programs		1985 (Budget)	1986 (Proposed)
1. Promotion of Molecular Breeding Technology Toward 21st Century	Subtotal	1,539 [1)]	2,132
1-1 Institutional Development		836	969
(1) Manpower development and international cooperation (1986-88)		0	10
(2) Collection and management of genetic resources and information		836	959
(a) Development of the Gene Bank System		(729)	(833)
(b) Research on long-term storage of animal genetic resources		(107)	(126)
1-2 Research and Development		703	1,163
(1) Systematic approach to plant breeding based on biotechnology (1986-2000)		317	461
(2) Promotion of regional biotechnology research and development		0	260
(3) Development of new breeding technology		246	252
(a) Development of new biological resources by cell fusion and nuclear implantation (1982-86)		(115)	(112)
(b) Development of technology for improving microbial and plant cells by cell fusion and nuclear implantation (1984-88)		(48)	(48)
(c) Development of technology for efficient production of seeds and seedlings by tissue culture (1983-87)		(55)	(64)
(d) Development of breeding biotechnology for fish and seafood (1985-89)		(28)	(28)
(4) Development of founding technology		140	190
(a) Research for developing "seed" pioneering biotechnology		(100)	(100)
(b) Identification of the mechanisms of genetic expression in agro-biological resources (1984-88)		(40)	(56)
(c) Analysis of genetic structures of agrobiological resources (1986-90)		(0)	(34)
2. Promotion of technological innovations related to food and other industries	Subtotal	410	599
(1) Development of bioreactor systems in food industry (1984-1990)		244	295
(2) Development of common founding technology for developing new materials for plant protection (1984-88)		66	66
(3) Development of simple diagnostic methods for animal diseases, utilizing immune precipitation (1984-88)		45	46
(4) Development of founding technology for utilizing biologically active substances for developing new fertilizers (1986-90)		0	29
(5) Development of new technology for utilizing microorganisms and enzymes for biomass conversion (1982-90)		45	46
(6) Research on dynamism of root environments and development of control technology (1986-90)		0	100
	Total	1,960 [1)]	2,731

Source: Agriculture, Forestry and Fisheries Research Council

Note: 1) Subtotal and total figures for FY1985 include budgets allocated for other programs not specified in the table due to the reorganization of program in 1985.

commonly referred to as "Biotech Breeding 2000," and considered the key public sector program for the advancement of biotechnology in agriculture, aiming for the year 2000. The program contains four major subprogram as follows.

Firstly, "Systematic Approach for Plant Breeding Based on Biotechnoloy" consists of the following three major areas of research;

(a) Development of common founding technology for plant technology

- Cell technology development, such as efficient methods for culturing and fusing cells
- Recombinant DNA technology, such as gene identification, separation and analysis, and vector development

(b) Development of new breeding materials by biotechnology

- Stress resistant plants
- High nutrition plants
- High photosynthetic plants

(c) Breeding of novel plant varieties and creation of new useful plants

Secondly, "Promotion of Regional Biotechnology Research and Development" is aimed at developing technologies which are considered important for local industries, in cooperation with research organizations of local governments.

Thirdly, "Development of New Breeding Technology" is aimed at advancing and refining new techniques for breeding such as tissue and cell culture, cell fusion and nuclear implantation.

Fourthly, "Development of Founding Technology" contains the folllowing areas;

(a) Pioneering technology which constitutes "seeds" for future advancement of biotechnology

- Research on genetically controlled mechanisms of growth in plant, animal and fish
- Search for marine microorganisms with useful character
- Research on functions of enzymes for developing artificial enzymes

(b) Identification of the mechanisms of genetic expression in agrobiological resources

- development of a DNA library of microorganisms involved in major animal diseases
- Analysis of genetic structures of antigens
- Identification of the mechanisms of expression with respect to useful genes

(c) Analysis of the structures of genes in agrobiological resources

- Separation of useful genes
- Cloning of useful genes
- Analysis of the structures of useful genes

In order to back up research efforts in the above-mentioned areas of molecular breeding technology, collection and management of genetic resources and information will be expanded and strengthened, as shown in Table II-1-7. Preservation of germplasms is one of the key requirements for promoting efficient biotechnology development. The Ministry of Agriculture, Forestry and Fisheries plans to expand its gene bank by 1992 to 230,000 accessions from approximately 100,000 in 1985 for plants and to 13,000 species from 5000 in 1985 for microorganisms.

The Program for Promotion of Technological Innovations Related to Food and Other Industries covers two key areas of research, as follows:

(a) Development of bioreactor systems for food industry

- Screening of enzymes and microorganisms
- Development of immobilization technology
- Development of biosensors
- Development of bioreactor systems

(b) Development of founding technology for producing biologically active substances

- System development for production of biologically active substances of microbial origin
- System development for production of biologically active substances of animal origin

Another key issue in Japan's promotion of agricultural biotechnology is the establishment of a "High Technology Center," starting from FY1986. As mentioned above, the structure of agricultural research in Japan has particular characteristics. Unlike other developed countries, the private sector's participation in agricultural research and development has so far been limited.

The nature of biotechnology research requires a flexible structure to adapt to rapid technological progresses, on the one hand, and a stable mechanism for promoting long-range research, on the other. In other words, complementary cooperation between government and industry is the key to efficient development of biotechnology.

From the viewpoint of the private sector, the following measures are considered essential for Japanese agricultural biotechnology to survive international competition.

1) Governmental funding of basic research
2) Establishment of training programs for biotechnologists
3) Deregulation on research and development activities
4) Establishment of a system to provide germplasms for technology

development

Based on the above findings, the Japanese Government has decided to establish a "core center" for promoting agricultural research and development, by encouraging dynamic cooperation between government and industry through funding and technology exchange. The details of the proposed Center is still unknown, but its key roles have been specified as follows.

1) Funding and assisting public and private organizations which conduct research in agricultural biotechnology

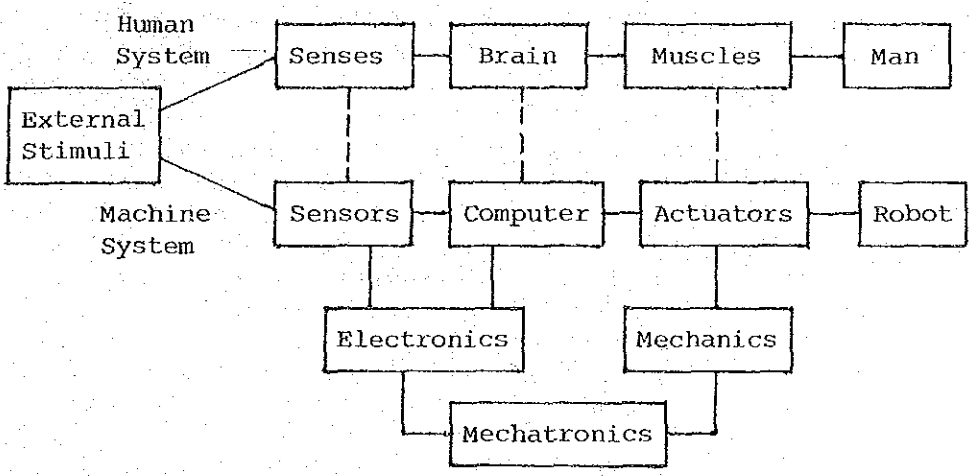
2) Funding and assisting public and private organizations in the application of developed agricultural biotechnologies

Biotechnology is essentially a huge interdisciplinary system and it is necessary to establish a number of programs with a broad spectrum of approaches for its development. Japan is currently reorienting its directions of research to meet the challenges of high priority national needs in agricultural technology development.

2. USE OF ELECTRONICS IN JAPANESE AGRICULTURE

Introduction

This section deals with the application of electronics in Japanese agriculture, including some on-going research and development efforts. The application of electronics in agriculture largely evolves around sensing and computing technologies, which can be interfaced to motor activities through a varieties of actuators, such as cylinders, solenoids (electromagnetic devices which convert electric current to linear motor movement) and motors. The structure of application can be shown by association with human functions as follows.



The on-going application of electronic technologies not only in agriculture but also in other fields of activity is thus roughly divided into computing systems which collect, analyze, display and store data given by external stimuli, and manipulating and controlling systems, with varying degrees of complexity, which assimilate and judge data from a given object or objects to be controlled and relay appropriate commands through actuators to the object or objects. The latter systems are generally called "mechatronics" in Japan. The manipulating and controlling systems range from simpler systems which utilize ICs and are based on the so-called wired logic to more complex systems which utilize computers and thus offer much greater flexibility and maneuverability to users through software technology.

The recent development of sensors and computers helps the optimization of production and marketing by farmers and enables increasingly automatic control of agricultural machinery and fixed facilities like greenhouses. It must be pointed out, however, that the actual utilization of electronic/mechatronic technologies is necessarily conditioned by micro- and macro-economic considerations and requirements. For example, such technologies, both hardware and software, must be available at reasonable costs relative to prices of agricultural products paid to farmers, on the one hand, and they have to fit the basic characteristics of a given economy, notably the structure of factor supply such as labor, land, energy, etc., on the other.

Moreover, agriculture differs from conventional manufacturing industries in that it deals with living organisms. In other words, correct knowledge of crop and animal biology and their responses to stimuli from ecosystems is essential to design specific application systems to agriculture. The advancing biotechnology discussed in the preceding section is likely to ease such limitations in the future by accelerating the speed of breeding varieties to suit human needs and economic conditions. At the present moment, the application of electronic/mechatronic technology to agriculture is going on within a variety of technical and economic constraints in Japanese agriculture.

2-1 Postwar Agricultural Mechanization in Japan

2-1-1 Institutional Supports for Mechanization

The rapid pace of mechanization in postwar Japanese agriculture was buttressed by various government measures taken as institutional supports. As mentioned already in the beginning of the preceding section on biotechnology, the Japanese Government promulgated the Agricultural Mechanization Promotion Law in 1953, later revised twice in 1962 and 1965, while the Land Improvement Act of 1949 and the Agricultural Basic Law of 1961 promoted the land base consolidation programs, i.e., irrigation and drainage, land readjustment, construction and improvement of farm roads, etc., which facilitated the introduction of machinery to paddy fields.

The Agricultural Basic Law which emphasized the structural change and selective expansion of Japanese agriculture also served to promote structural improvement projects, by providing subsidies and other assistance to agricultural mechanization and construction of various agricultural facilities in rural areas. Various demonstration and training programs on mechanization set up by the central and local governments have been instrumental to the rapid diffustion of power tillers and other machines during the 1950s and the 1960s.

The Agriculture, Forestry and Fisheries Finance Corporation, a governmental lending institution, the Agricultural Improvement Fund set up by the Government in 1956, and the Agricultural Modernization Fund system established in 1961 in which the Government subsidized part of the interests to be paid by farmers who borrowed funds for investment from the agricultural cooperative organizations, all contributed financially to the mechanization of Japanese agriculture.

With respect to agricultural machinery, the Farm Machinery Testing Office was established in the Ministry of Agriculture, Forestry and Fisheries after the promulgation of the Agricultural Mechanization Promotion Law of 1953, and subsequently the Institute of Agricultural Machinery was established in 1962 by joint contributions from national and local governments, farmers' organizations and manufacturing industries and took over the testing functions of the Office after 1962. With testing codes and standards they developed, the Office and the Institute greatly contributed to the standardization and constant quality improvement of small-scale agricultural machinery manufactured in Japan.

2-1-2 Characteristics and Processes of Mechanization in Japanese Agriculture

In order to understand the on-going application of electronic/mechatronic technologies to Japanese agriculture, it is necessary to refer to some salient characteristics of postwar agricultural mechanization in Japan. The most important characteristics are as follows. Firstly, mechanization in postwar years evolved mostly around paddy cultivation. Secondly, the development efforts focused on small-scale agricultural machinery, because the average farm size has been very small in Japan (e.g., 1.0 ha in 1960 and 1.17 ha in 1980), and furthermore each farm generally consisted of fragmented lots. This is interrelated with the third characteristic that the individual ownership of machinery has been strongly valued among Japanese farmers. Some large-scale machinery or facilities have been collectively purchased and operated by cooperatives and farmers' groups. They consist of rice processing centers, country elevators, vegetables and fruits grading stations and storage facilities, seedling culturing facilities, pest control facilities, and so on. The rapid diffusion of individually-owned agricultural machinery has been also related to the fact that the educational level of Japanese farmers has been relatively high. Fourthly, farm machinery has been required to have the high operating accuracy and the adjustability of running speed and other functions partly because of the small farm/lot size which necessitated intensive agriculture and partly because of topographic variations in the terrains. For example, the grain loss of the currently marketed combines averages less than 3%.

Table II-2-1 and Figure II-2-1 summarize the process of mechanization in Japan's paddy production in postwar years. As already discussed in the beginning of the preceding section on biotechnology, the rapid growth of the Japanese economy since the late 1950s through 1960s was accompanied by the large outflow of rural labor to rapidly industrializing urban areas, thus necessitating the mechanization of agriculture. Until the mid-1960s, mechanization took place mostly in land preparation, drying and threshing. From 1955 to 1965, draft animal was almost entirely replaced by small walking-type tractors (7 - 8 ps for rotary tilling and 2 - 3 ps for pulling Japanese plows and light cultivating machines), sun-drying by simple forced-air driers, and traditional pedal driven threshers by hand-feeding power threshers and then by self-feeding power threshers.

Mechanization of paddy production extended to harvesting operation, (binders plus mobile threshers and head-feeding combines) since the mid-1960s, and then to the transplanting operation, the most arduous task in paddy cultivation, since the early 1970s. Head-feeding combines and transplanters have many unique characteristics which are suitable for the varieties of paddy grown in Japan as well as to smallholder agriculture. Riding-type tractors (10 - 15 ps) suitable for paddy fields were developed through combined efforts of government research institutions and private manufacturers and marketed in the mid-1960s, and soon began to replace walking-type tractors in the 1970s.

By the mid-1970s, the entirely mechanized system of paddy cultivation was established in Japan. By 1982, 93% of the transplanted area and 97% of the harvested area were reported to be mechanized. Such mechanization brought about considerable labor saving in paddy cultivation. According to the study undertaken by the Ministry of Agriculture, Forestry and Fisheries, the number of labor hours per 0.1 ha of paddy fields dropped from 191.8 hours in 1955 to 81.4 hours in 1975 and then to 56.5 hours in 1984.[1)]

With respect to crops other than paddy, mechanization of farm operations has been generally slow except in certain regions. In the northernmost island of Hokkaido where land holdings are much larger than the national average, cultivation of field crops like wheat and soybean, root crops like potato and beet, fodder crops, etc. are mechanized partly with foreign-made large-scale machinery for special operations and partly with domestic small-scale machines including regular-purpose machines such as forage harvestors, hay balers, harrows and plows as well as head-feeding combines. For the cultivation of soybean varieties grown in Japan which have easily shattering pods and low podding height, small-scale driers, threshers, graders and two-row harvesters have been developed.

With respect to tree fruits like oranges and apples, mechanization has progressed chiefly in pest control (air blast sprayers) and for transportation of inputs and fruits (hillside monorails). With respect to the cultivation of vegetables in outfields, mechanization has been limited to land preparation by small four-wheel-drive tractors, and transplanting and harvesting operations are yet largely unmechanized. However, some efforts are being made at national and prefectural experiment stations to develop harvesters of such vegetables as cabbage and lettus.

The Agricultural Basic Law of 1961 emphasized the "selective expansion" of agriculture, notably, increased production of vegetables and fruits and livestock products. This was realized apace with the high growth of the Japanese economy during the 1960s which increased and diversified the demand for food among the Japanese population. Over the 1960s and 1970s, Japan saw a tremendous expansion of greenhouse horticulture which mostly utilized as outer coverings vinyl and other plastic sheets made available by the growth of domestic petrochemical industry. The total area under glass and plastic-sheet greenhouse horticulture was 1,707 ha in 1960, and expanded to 21,131 ha in 1973 and 36,632 ha in 1983, thereby realizing the year-round supply of vegetables and the off-season production of certain fruits. These greenhouses were gradually equipped with a number of mechanical, and increasingly more sophisticated, devices to control indoor temperature, irrigation and other

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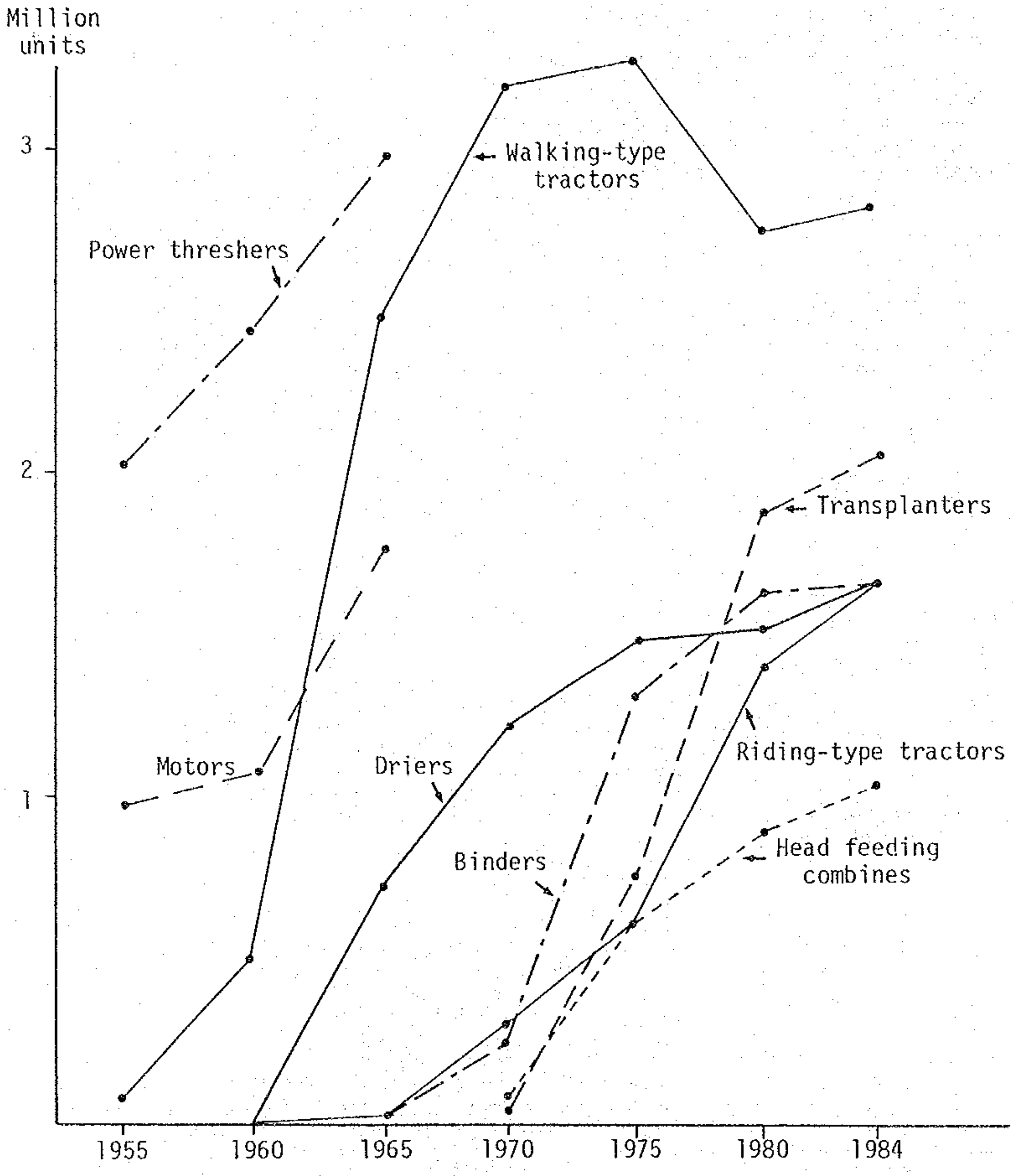
1) MAFF, Survey Report on Production Cost of Rice 1984, 1984.

Table II-2-1 Mechanization of Paddy Cultivation in Postwar Japan

Major Types of Machinery in Use	Remarks
1945-55 Motors for agricultural use Power threshers Hullers Rice millers	1952 Survey: - No. of power tillers in use 25,000 units; used by 1.5% of farming households; used for 2.65% of the total area under paddy, and 0.7% of the area under dryland crops - Agricultural Mechanization Promotion Law (1953) and Farm Machinery Testing Office established by Ministry of Agriculture, Forestry and Fisheries
1956-65 Power sprayers Power dusters Power tillers(walking-type tractors) Automated threshers	- Percentage of agricultural machinery and equipment in fixed capital formation of the agricultural sector rose from 24.5% in 1955 to 41.2% in 1962 and 31.3% in 1965 - No. of power tillers per 100 farming households (2ha) rose from 9.2 units in 1955 to 76 units in 1962 - 2,184,000 units of walking-type tillers, 13,000 units of riding-type tractors, 3,085,000 units of power threshers (individually owned), and 724,000 units of rice driers (individually owned) in use (Dec. 1964) - Wide diffusion of the small-scale mechanized systems of paddy cultivation (excluding transplanting and harvesting) - Agricultural Basic Law (1961) - Institute of Agricultural Machinery established (1962)
1966-75 Riding-type tractors Rice transplanters Binders Head feeding combines	- Establishment of the entirely mechanized system of rice cultivation : no. of units per 100 farming households rose during 1970 - 1975 from 0.6 to 14.9 for rice transplanters 4.9 to 26.8 for binders and 0.9 to 6.9 for head feeding combines - 3,375,000 units of walking-type tractors, 339,000 units of riding-type tractors, 435,000 units of rice transplanters, and 217,000 units of head feeding combines in use (Jan. 1974) - Percentage of mechanization: 33% of the rice transplanted area and 70% of the rice harvested area (1975)
1976-Present	- Wide diffusion of the entirely mechanized system of rice cultivation; 37.5 units of rice transplanters, 34.7 units of of binders and 19.8 units of head feeding combines per 100 farming households (1980) - Percentage of mechanization : 93% of the rice transplanted area and 97% of the harvested area (1982) - 1,650,000 units of riding-type tractors, 2,062,000 units of rice transplanters, 1,042,000 units of head feeding combines, and 1,672,000 units of binders in use (Jan. 1984) - Upgrading of agricultural machinery; e.g. introduction of multiple-row rice transplanters - Improvement and development of machinery for dryland crops to be grown on paddy fields (measures for restructuring the utilization of paddy fields)

Sources: Ministry of Agriculture, Forestry and Fisheries, Statistical Yearbook of Agriculture, Forestry and Fisheries; Census of Agriculture and Forestry; and Annual Sample Survey of Agriculture, various issues, and Management and Coordinating Agency, Current Situations and Problems of Farm Machinery Utilization, 1984.

Figure II-2-1 Mechanization of Paddy Production



Source: MAFF, Statistical Yearbook of Agriculture, Forestry and Fisheries, various issues.

conditions necessary for cultivation in order to speed up the vegetative growth of crops, to save labor, and after two oil crises, to save energy.

In the livestock and poultry sector, gradual increases in herd size and rapid expansions in the scale of operation with respect to layers and broilers accelerated the introduction of machinery and equipment such as pipeline milkers, bulk milk coolers, barn cleaners, heaters, automatic feeders and waterers and facilities like windowless barns. These machines and facilities are domestically produced, but in contrast with head-feeding combines and rice transplanters, their structural and technical characteristics are largely conventional, chiefly taking after models developed in the Western developed nations.

2-1-3 Recent Trends and Problems in Mechanization

After the mid-1970s, development efforts have been directed increasingly to larger-scale and technically more sophisticated farm machinery for paddy production. Riding-type tractors of over 20 ps became common since around 1975 and those of over 80 ps have begun to be produced in recent years. Walking-type transplanters have been gradually replaced with riding-type ones which transplant 5 - 6 rows or more of seedlings, and head-feeding combines have also increased the number of rows to reap. Moreover, efforts are being made to diversify the versatility of head-feeding combines and transplanters, by having them handle crops other than paddy or such operations as simultaneous fertilizer application and seeding.

These changes are partly related to the overproduction of rice which emerged since the late 1960s and necessitated a substantial reduction in the area under paddy and the diversification into other crops in the former paddy fields. The two oil crises also called for energy-saving technologies to be employed in farm machinery and equipment, while increased accidents in field operations due to the wide diffusion of farm machinery necessitated the improvement of safety devices.

More importantly, the aging of farming population and the increased role of female labor in farm operations, which resulted from the movement of labor away from agriculture to industry and services and the numerical dominance of part-time farm households earning a larger proportion of income from non-agricultural employment, called for more simply manageable, or in other words automated, types of farm machinery.

As mentioned earlier, most of the farm machinery developed and marketed in Japan has been small to suit individual ownerships by smallholders, and contributed greatly to the reduction of labor hours spent on paddy cultivation. However, a reduction in labor hours, or a reduction in labor costs, brought about by mechanization gradually ceased to offset the cost of mechanization during the earlier half of the 1970s. This was partly due to the increased scale and sophistication of farm machines which pushed up their prices, and partly due to the low-level utilization of machinery owned and used individually by smallholding farmers. Especially after the first oil crisis which sharply raised fuel costs, the progress of mechanization did not necessarily contribute to a further reduction in production costs.

In order to rectify the state of such overinvestment in farm machinery, the Government of Japan has been trying to promote an expansion of the operating scale of farming through various measures within the framework of the Agricultural Land Law which was promulgated in 1952 following the agrarian land reform and underwent some revisions in later years. For example, the system of entrusting farming operations to *agricultural cooperatives or similar farmers' organizations* has been established to promote organized farming, while farmers are encouraged to share the purchase and utilization of large-scale farm machinery and agricultural facilities through subsidies and institutional financing. The technical sophistication of the existing farm machinery in terms of durability, operating accuracy, multi-purpose versatility, and so forth is also expected to contribute to the solution of the problem. Electronic/mechatronic technologies offer great potentials to the development of farm machinery toward this direction.

2-2 Use of Electronics in Japanese Agriculture

The advantages of applying electronic/mechatronic technologies to agriculture might be summarized as (a) labor saving and simplification in farm operations through varying degrees of automation, (b) improvement of the operating accuracy of agricultural machinery and facilities, (c) improvement of safety in farm operations, (d) energy saving, (e) simiplification and labor saving of maintenance and improvement of durability, and (f) increased flexibility in the use of farm machinery through software technology and optimization of farm management. In other words, micro-processors (CPUs) and memory chips are extremely small in size and consume much less energy, but can handle multiple inputs simultaneously and speedily through software technology, and therefore, they would make it possible to reduce the size and simplify the structure of agricultural machinery and facilities, thereby reducing the costs of such machinery and facilities and their operation.

However, it must be pointed out that, although memory chips and to a lesser extent CPUs are becoming smaller and cheaper every year or even every month apace with the introduction of new ICs and LSIs, mechatronic technologies, or the manipulating and controlling systems as mentioned in the beginning of this section, require sensors, actuators and peripheral equipment. If the number of such accessories and equipment increases, the costs of the resultant systems could be higher than the benefits which would accrue from them. This is true at least at the present moment because the structure and operating mechanism of the existing machinery are conventional, or "analogue," in the sense that they originated before the electronic age. Accordingly, the actual use of electronic technology in agricultural machinery and facilities has been based more on the wired logic built into ICs which responds to one kind of input. If the number of inputs increases beyond a certain level, computers will become more economical than the juxtaposed chains of wired logics. Another point to be made is that the outdoor durability and stability of more sophisticated mechatronic systems are yet not completely established.

2-2-1 Mechatronics in Farm Machinery

The development and application of mechatronic technologies are well-advanced in Japanese industries, and automobiles and many other consumer durables as well as capital goods have built-in eletronic systems. Such applications can be, and are, employed in agricultural machinery and facilites.

The use of electronic technologies in farm machinery has largely to do with automatic control and operation. Sensors are attached to power tillers for automatic draft control, or to rotary tillers for automatic control of the plowing depth and the level position. For hydraulic drive tractors which are capable of continuous change in the running speed and rotating frequency of the rotor shaft, the increment of cut as well as the plowing depth is automatically controllable. Because the number of inputs for such control is several, such as running speed, draft, plowing depth, height of three point hitch, etc., the existing mechanism is being replaced by a microcomputer system.

For head-feeding combines which carry out more than one operation such as reaping, threshing, grading, etc., it is necessary to keep constant balance between loads on various operating parts of the mechanism. The available combines already have a system of automatic control to maintain operating accuracy and save labor. Because the number of inputs (sensing terminals) and outputs (manipulating terminals) are many, the system is gradually being replaced by a microcomputer system, by adding automatic control of running speed and direction, reaping height and threshing depth, an alarm system on clogging, automatic switch-off of the engine in case of accidents, and so on. Similar application will be made on the multi-purpose machinery which is now being developed for use in non-paddy fields.

The application of microcomputers is being tried on mobile boom or speed sprayers to control uniform or selective spraying and to ensure the safety of operators. Similar attempts are going on with respect to harvestors of easily damageable crops like leafy vegetables and fruits, and on seeders equiped with optic sensors for maintaining efficient seeding rates and patterns. In addition, some trials are being done on complete automation of some or entire agricultural operations, such as automated plowing guided by electromagnetic signals from underground cables and an automated gantry production system.

With respect to post-harvest operations, electronic/mechatronic technologies are commonly used in paddy driers of circulation type as well as in rice processing centers. Grading and sorting of agricultural and livestock products have so far been done largely in terms of weight and size, but the development of phototransisters now makes it possible to sort by outward appearances like coloring and shape. One of the examples is the recently developed sorter of oranges equipped with a CCD camera for detecting ripeness and surface damages by pests and diseases. Efforts are being made to develop systems capable of sorting or grading different crops, and electronic technology, especially software, will be central to such development. Small graders of similar capability are also being developed for individual farmers to use, and it has been reported that the application of a microcommuter system reduced labor hours spent on grading and packing by 50 - 60%. Packing and packaging of agricultural and livestock products, usually done collectively by agricultural cooperatives, increasingly relies on mechatronic technologies of varying complexity. One of the examples is a system for packing easily damageable strawberries.

The application of electronic/mechatronic technologies, especially the on-going development efforts and investments in machinery for grading, sorting, packing and packaging vegetables and fruits, has been partly for labor- and energy-saving purposes and partly for improving the quality of products to fetch better prices in the market. In other words, such attempts are economically justifiable because the market and consumers differentiate agricultural products in terms of quality.

Future directions for mechatronic development in farm machinery might be to incorporate mechanisms to sense, analyze, and respond to physiological conditions of crops and differences in environmental factors like nutrient contents in the soils, thereby optimizing the application of fertilizers, agricultural chemicals and other necessary agricultural inputs.

2-2-2 Control of Growing Environment

Electronic/mechatronic technologies are utilized to control environmental conditions necessary for raising crops or livestock. Such application has been developed in glass and plastic-sheet greenhouse horticulture and rearing of swine and poultry. Cultivation of rice, the most important staple in Japan, generally does not use electronic technologies other than those built into agricultural machinery like transplanters and head-feeding combines, because its production techniques are well-standardized and prices and marketing are guaranteed by the Government. In horticulture and animal husbandry, there are severe competition and price fluctuations in the market, and thus there is much larger room to gain by improving the efficiency and productivity of operation by technological innovations.

According to the study undertaken during 1982-83, the area under glass or plastic-sheet greenhouse horticulture totalled 36,600ha in Japan as of July 1st, 1983. 79% of the area is used for growing vegetables such as cucumbers, tomatoes, melons, strawberries and leafy vegetables, 11% for fruits like grapes, navel oranges and peaches, and 10% for flowers.

As shown in Table II-2-2, greenhouse horticulture in Japan uses a variety of equipment. 37 - 39% of the total area is equipped respectively with heating systems, automatic irrigation systems, or one-layer movable screen for insulation, 16% with ventilation fans, 3% with carbon dioxide generators, and so on. Some equipment, like heating, ventilation, movable screens and carbon dioxide generators, are equipped

Table II-2-2 Control Devises Used in Greenhouse Horticulture in Japan (July, 1983)

(Unit: 1,000 m^2)

	Total	(%)	Vegetables	Flowers	Fruits
Total Area	366,326	(100.0)	289,080	36,987	40,259
Area with heating devices	135,589	(37.0)	98,993	21,087	15,509
of which, with variable heating devices	72,982	(19.9)	56,354	8,160	8,468
Area with automatic irrigation	143,644	(39.2)	112,630	17,145	13,869
Area with solution culture devices	2,930	(0.8)	2,712	218	0
Area with carbon dioxide generators	9,944	(2.7)	9,018	882	44
Area with one-layer screen	140,153	(38.2)	114,602	14,551	11,000
of which, with heating devices	71,605	(19.5)	53,930	10,504	7,181
Area with multi-layer screen	42,089	(11.5)	32,655	5,714	3,720
of which, with heating devices	36,681	(10.0)	28,452	5,022	3,207
Area with automatically adjustable windows	19,477	(5.3)	13,644	4,947	886
Area with ventilation fans	58,388	(15.9)	40,578	9,003	8,807
of which, with automatic ventilation devices	38,837	(10.6)	26,108	5,510	7,219
Area with multiple-control devices based on solar radiation levels	900	(0.2)	791	99	10
of which, controlled by micro-computers	429	(0.1)	365	61	3

Source : Ministry of Agriculture, Forestry and Fisheries, ed., Current Situations in Glass and Plastic Greenhouse Horticulture, Tokyo, 1984.

with mechanisms of feedback control, most commonly timers and thermostats. Such equipment has been developed primarily to control a single environmental element like temperature or water.

As mentioned earlier, greenhouse horticulture contributed to realizing the year-round supply of most of the vegetables and some fruits. But the two oil crises necessitated the development of energy-saving systems. Recent research and development efforts have been directed to controlling the crop environment as a system in order to optimally enhance photosynthesis and other functions of crops. As shown in the table, 0.2% of the area under greenhouse horticulture is equipped with a system which controls environmental elements like temperature, carbon dioxide density, irrigation, etc., on the basis of the level of solar radiation. As the number of sensing and manipulating terminals is several, microcomputer systems have begun to be employed in recent years. Moreover, microcomputer systems are more flexible in the choice of crops to be grown in accordance with market conditions, as long as software programs are available. As shown in the table, 0.8% of the area under greenhouse horticulture has solution culture systems, which use water or gravels instead of soils to grow crops. Some of these systems also utilize electronic technologies to optimize fertilizer application as well as controlling environmental conditions.

In the livestock and poultry sector, electronic technologies have been employed chiefly in the spheres of research and test equipment of breeding stock, some machinery like self-feeders and incubators, grading or sorting of livestock and poultry products like milk and eggs. The gradual increase in the herd size and worsening marketing conditions (such as oversupply of fresh milk, lagging demand for pork, increased market competition with imported livestock products) since the later 1970s have necessitated producers or producers' organizations to make use of electronic/mechatronic technologies more extensively than before in order to improve productivity. An example is the introduction of windowless barns for swine in which temperature, humidity and sanitary conditions are controlled by electronic equipment. A sensor system has been also developed to prevent baby pigs from dying under the weight of their mother. Similar and in fact more automated and large-scale facilities are currently used for rearing layers and broilers.

Compared with greenhouse horticulture mentioned above, livestock farmers in Japan have to keep watch of day-to-day inputs and outputs of individual animals in order to improve their productivity throughout the year. Such close management of the swine herd size of over 30 or 50 is extremely hazardous without the use of computers. Accordingly, the livestock sector uses more all-purpose personal computers for data processing than greenhouse horticulture mentioned above which relies more on the manipulating and controlling systems.

2-2-3 Database Development

In addition to the application to production management on the level of individual farmers, electronic technologies are essential to database development on much larger scale. In order to service farmers in a given locality or a region, agricultural cooperatives, research institutions of local governments, or associations of producers and distributors have begun to compile computer databases which will provide necessary and timely information on production technologies for specific crops or specic breeds of livestock, or will diagnose farm management of individual producers. Moreover, the Ministry of Agriculture, Forestry and Fisheries initiated in 1985 a five-year program to develop data processing technologies for the establishment of new production management systems for agriculture, allocating ¥135 million each for FY1985 and FY1986. These development efforts will eventually evolve into national and regional network systems.

3. DEVELOPMENT OF FISH CULTURE AND FARMING IN JAPAN

3-1 Introduction

It is perhaps useful to distinguish conceptually two types of artificial rearing and multiplication of fish, shellfish, edible aquatic plants and so on which are practiced in Japan. One type is called yooshoku in Japanese, literally meaning reared multiplication, and utilizes fresh, brackish or marine surface water which is artificially enclosed, or "segmented", commonly by embankments or nets. This type of artificial multiplication and rearing has been variously translated as fish (or shellfish, aquatic plants, etc., as the case may be) culture, aquaculture or mariculture in English.

The other type utilizes open surface water, chiefly in lakes and coastal marine waters, and human interventions are chiefly directed to the artificial rearing and release of seedlings, the physical improvement of their natural habitats, and the control of fishing operations to catch, or rather harvest, the released species. The Japanese term commonly used for this type is zooshoku, literally meaning increased multiplication. This type of fisheries has been practiced just as long as yooshoku, and is now actively promoted in coastal and nearer offshore waters. In this paper, this type is referred to as fish (or shellfish, aquatic plants, etc. as the case may be) farming, although the distinction in Japanese might be lost in English.

Two types of fisheries mentioned above are conceptually distinguishable from the normal exploitation of natural fishery resources which reproduce and grow in their natural habitats. In the currently popular Japanese phraseology, they are called by a new term saibai gyogyoo which literally means "cultivated fisheries," or fisheries "to produce" in contrast to fisheries "to catch." In this sense, fish culture can be considered a more intensive type of fish farming.

It must be pointed out, moreover, that there is a considerable overlapping of technical components between fish culture and fish farming as defined above. Furthermore, the two types of artificial rearing and multiplication can be positioned in the same continuum with "fisheries to catch", from the viewpoint of increasing and/or stabilizing the productivity of aquatic environments by means of human interventions for effective resource management and economical exploitation.

There are several criteria to classify the culture and farming of fish, shellfish, useful aquatic plants, etc. which are practiced in Japan. Normally, they are divided into inland water and marine cultures and farming, and the different degrees in intensity of human interventions, such as artificial feeding, application of fertilizers, rearing of seedlings, necessary physical engineering works and fixed capital investments, and manipulation of water flows, are used to classify different types of cultures and farming. Figure II-3-1 shows one way of classifying cultures and farming practiced in Japan.

Figure II-3-1 Classification of Methods for Fish Culture and Farming

- Marine Waters
  - Culture
    - Feeding
      - Pond (on land) culture
        - Flowing stream — Prawn, black sea bream
        - Semi-flowing stream — Prawn, blue crab, mullet, black sea bream, eel
      - Sea (segmented) culture
        - Segmented by embankments (bay, strait type) — Yellowtail, red sea bream, globefish, parrot bass, amberjack, prawn
        - Segmented by nets — ditto
        - Surface and middle layer enclosures (ikesu) — ditto
    - No feeding — Sea (not segmented)
      - Raft, long rope — Oyster, pearl oyster, scallop, laver, Wakame (Underia spp.), tangle
      - Nets, thickets, sticks — Laver, oyster
      - Sown in shallows — Short necked clam, clam, ark shell, scallop
  - Farming
    - Release of artificially grown seedlings — Salmon, trout, prawns, blue crab, abalone, scallops, red sea bream, scorpionfish, grey rock cod, flatfish
    - Transplanting natural seedlings — Abalone, topshell, short necked clam, ark shell, scallop, spiny lobster, rock trout
- Inland Fresh Waters
  - Culture
    - Feeding
      - In ponds
        - Flowing water — Carp, rainbow trout, eel, sweet fish, landlocked red salmon, humpback salmon, pink salmon
        - Stationary water — Carp, eel, goldfish, silver carp, grass carp, fresh water shrimp
      - In paddy fields — Carp, loach
      - In reservoirs — Carp, mullet
    - No feeding (application of fertilizer)
      - In paddy fields — Loach
      - In reservoirs — Carp, mullet
  - Framing
    - Release of artificially grown seedlings — Humpback salmon, landlocked red salmon, sweet fish, pond smelt, carp, rainbow trout, fresh water shrimp, pearly fresh water mussel
    - Transplanting natural seedlings — Sweet fish, common fresh water clam, fresh water mussel

3-2 Historical Background

The practices of culture and farming in Japanese fisheries have a relatively long history, and their past development and growing importance in recent years must be understood as part of the historical growth of Japan's fisheries as a whole.

Primitive forms of fish culture were reportedly practiced in medieval Japan, utilizing paddy fields, reservoirs and banked canals for fresh water fish like common carp, crucian carp and loach. At any rate, the traditional methods of culture in premodern Japan seem to have developed mainly for fresh water fish in land-locked areas with difficult access to the coasts, and this tradition of fresh water fish culture has been maintained to this day in land-locked prefectures. The techniques for crossing and selecting better strains and for artificially rearing seedlings were also traditionally developed for goldfish and calico carp. This premodern tradition made it easier to diffuse in Japan the techniques of the rainbow trout culture introduced from the USA during the late 19th and the early 20th centuries when Japan began to modernize its society and economy.

The fish and shellfish culture and farming in coastal marine waters were relatively less developed in premodern Japan, because coastal and offshore waters were then sufficiently rich in fishery resources to satisfy local demands. The earliest known practice of culture in coastal marine waters is that of oyster dating back to the 17th century, and traditional techniques of farming in coastal waters were also developed for laver, an edible seaweed, in premodern Japan. The early development of fish culture and farming took place after the turn of the 20th century, such as the eel culture in brackish waters and the cultures of young yellowtail and common scallop in coastal marine waters. But their operations generally remained small in scale until the mid-20th century.

The growth of Japanese fisheries during the early half of the present century centered on "fisheries to catch", partly buttressed by the successive governments' promotional policies. Along with technological innovations applied to fishing boats, fishing methods and fishing equipment and gear, coastal, offshore and distant-water fisheries grew steadily in Japan. After the setback experienced immediately after the end of World War II, Japanese fisheries expanded their landings rapidly from the mid-1950s to the mid-1960s. The growth of production was most pronounced in offshore and distant-water fisheries of meidum- and high-grade fish and shellfish like salmons, trouts, tunas and crabs in this period.

In terms of volume, the domestic fishery production continued to increase during the later half of the 1960s and the early 1970s, but its structure changed significantly. The production of the medium- and high-grade fish mentioned above either stagnated or declined, partly due to the increased international control over their fishing in distant waters. On the contrary, landings of cheaper fish species like Alaska pollack in the northern waters, and sardine and anchovy, mackerels and saury in offshore waters increased sizably. Excepting perhaps Alaska pollack for which the technology of fish paste (surimi) production was developed to increase its human consumption, the increased landings of the low-grade pelagic fish species provided cheaper feedstuffs for fish and shellfish culture as well as for livestock. The consumption of cheap pelagic fish as feedstuffs began to increase during the early 1960s and continued to increase throughout the 1970s.

The period of the 1960s and the early 1970s coincided with the rapid growth of the Japanese economy which expanded the domestic demand for higher-grade (= higher-priced) fish and shellfish. Coupled with the stagnation and decline in production of the favored higher-grade species from Japan's coastal and offshore waters, this increase in demand gave a decisive impetus to the growth of aquaculture. In addition to yellow-tail, eel, common scallop and oyster, such species as sea breams, prawns and shrimps, flounders, globefish, and jack mackerel began to be cultured in coastal waters as profitable business undertakings. New species were also introduced from other countries to be cultured in or transplanted to Japanese waters, such as tilapia, pejerey, silver salmon, and some tropical fresh water prawns.

The modern Japanese fisheries grew in postwar years by extending the areas they operated in, from coastal waters to offshore waters and then to more and more distant waters. Two oil crises and the institution of the Law of Sea during the 1970s fundamentally changed the outlook of Japanese "fisheries to catch." The immediate consequence was the decline of domestic distant-water fisheries in terms of production. Distant-water fisheries accounted for roughly 40% of landings in 1972, but their share declined to less than 20% by 1980. With the increased fuel costs and the institution of 200-mile territorial waters, fisheries-related policies in Japan began to emphasize the high-level utilization of the territorial waters, which basically evolves around aquaculture, fish farming and effective resource management by means of intensified research on fishery resources and environments and increased investments to improve the productivity of aquatic environments.

The concept of "fisheries to produce," especially fish farming, has now assumed increased importance, and has been actively promoted by both the central and prefectural governments for coastal fisheries. Artificial rearing and release of seedlings had been long practiced in Japan for salmons, abalone and some other species, but in recent years, prawns, scallop, blue crab, urchin, sea breams, a variety clams and many other fish and shellfish species of established commercial values have been added as target species for farming in different regional waters.

Furthermore, the Ministry of Agriculture, Forestry and Fisheries has recently announced the policy concept of "marine ranching," which aims to tame target species and feed them in ranches set up in marine waters. The Ministry has also been promoting the application of modern biotechnology for controlling reproductive and growth processes of certain fish species and ultimately for artificially creating new species for human consumption. On-going research and development activities along these lines of pursuit will no doubt influence the technical components of fish culture and farming in the future.

3-3 Production Trends and Major Cultured Species

3-3-1 Production Trends

It is not possible to obtain production figures for fish farming, because its harvests are indistinguishable from the landings from normal fishing operations. Therefore, the discussion on production deals with only marine and fresh water cultures.

As shown in Table II-3-1, domestic production of fisheries in Japan increased by 5.5% per annum in terms of value during the decade from 1974 to 1984. The output from inland water fisheries accounted for 6% of the total production throughout the period. The total value of the output from cultures increased at an annual rate of 8.1% compared with 4.6% of the normal fishing operations, and its percentage in the total fishery production thus increased from a little over 17% during 1974-1976 to 22% in 1983-1984.

As seen from the table, the output from cultures accounted for the greater part of the production in inland water fisheries, fluctuating between 63% and 69% of the total. By comparison, the percentage of cultures in total output is small in marine fisheries, but it expanded appreciably from a little over 14% in 1974-1976 to 19% in 1983-1984. The higher rates of growth observed in the output from fresh water and marine cultures were partly due to the fact that higher-priced species are generally cultured.

Table II-3-1 Fishery Production in Japan (1974-1984)

(100 million yens)

	Total Output	Of which, Cultures	Marine Fisheries	Of which, Cultures	Inland water Fisheries	Of which, Cultures
1974	17,084	2,947	16,114	2,325	970	622
1975	18,870	3,249	17,740	2,536	1,130	713
1976	21,862	3,744	20,635	2,933	1,226	811
1977	25,451	4,452	24,035	3,522	1,416	930
1978	24,511	5,089	22,927	4,013	1,584	1,076
1979	26,480	5,393	24,788	4,229	1,691	1,164
1980	27,779	5,797	26,023	4,687	1,688	1,110
1981	29,640	5,629	26,090	4,565	1,689	1,064
1982	29,640	5,804	27,685	4,556	1,957	1,248
1983	29,032	6,356	27,239	5,186	1,794	1,170
1984	29,290	6,404	27,450	5,171	1,840	1,233

Source: Statistics and Information Dept., Min. of Agriculture, Forestry and Fisheries, Fisheries Statistics of Japan 1984, 1986.

Table II-3-2 shows the volume of production in inland water cultures during 1974-1984. The total production of fish species increased from 67,000 to 97,000 tons, or at an annual rate of 3.7%. In terms of tonnage, eel, common carp and rainbow trout have large percentages in total production, but the latter two species either decreased its output or recorded only a small increase, while eel more than doubled its output. The other fish species all increased their output, and especially rapid growth is observed in other trouts, sweet fish and tilapia which was transplanted from overseas in late 1970s. With respect to other cultures, fresh water pearl decreased its output, while softshell turtle recorded a six-fold increase in ten years. The culture of fresh water prawn started in the beginning of the 1980s, but the production remains yet small.

Table II-3-3 shows the volume of production in marine cultures during 1974-1984. The increase of fish production was more rapid than in fresh water cultures, growing at an annual rate of 7.0% over the same period. Young yellowtail has the largest production, accounting for 80% in 1984, but its growth over the decade was considerably slower than jack mackerel and sea breams which recorded a six-fold and an eight-fold increase respectively over the period. Furthermore, the increase of more than thirty times observed in "other fish" indicates the rapid diversification of fish cultures especially since the late 1970s.

With respect to other major marine cultures, prawns, Laminaria seaweed (kombu in Japanese) and pearl recorded rapid increase (8.4%, 19.9% and 7.9%, respectively, per annum). Common scallop, oyster and laver which have been traditionally cultured show much slower annual growth (1.7%, 2.5% and 1.6% respectively) over the same period.

3-3-2 Major Species in Fresh Water Cultures

Major fresh water fish species currently cultured for human consumption in Japan are carps, eel, sweet fish, trouts, and loach. In addition, goldfish and calico carp are artificially reared as ornamental pets. Current situations of important species among them are discussed below.

(1) Common carp

As mentioned earlier, the culture of common carp has a long history in Japan. Before the present century, carp was cultured in ponds with stationary water. The carp culture in ponds with water flow commenced in 1897 in one of the land-locked prefectures, and through the extension services provided by the central and prefectural governments, this more productive method was disseminated to other parts of the country. A recent innovation is to culture carp in an ikesu, a farm lot partitioned by durable synthetic nets, in inland lakes.

Because seedlings are easy to produce, and because the intensive culture is possible in small ponds with water flow, the techniques of carp culture have been exported to other countries. Feedstuffs of old times were chiefly rice bran and chrysales of silkworms, but nowadays

Table II-3-2 Production of Fresh Water Cultures

(ton)

Year	Total fish	Rainbow trout	Other trouts	Sweet fish	Carp	Crucian carp	Eel	Tilapia [1]	Other fish	Prawn	Softshell turtle	Others	Pearl [2]
1974	67,035	16,684	947	4,712	26,323	841	17,077	-	451	-	57	-	6.9
1975	72,032	15,557	1,168	4,991	28,129	968	20,749	-	470	-	81	-	6.2
1976	76,539	15,332	1,505	5,726	26,289	954	26,251	-	482	-	100	-	6.3
1977	82,016	16,033	1,584	5,875	29,295	1,007	27,630	-	592	-	137	-	5.6
1978	89,735	17,166	1,863	7,185	29,160	1,292	32,106	-	963	-	192	-	6.1
1979	94,356	16,714	1,750	8,455	24,452	1,263	36,781	1,526	415	-	207	-	5.8
1980	93,475	17,698	2,274	7,989	25,045	1,151	36,618	2,392	308	-	233	-	6.3
1981	91,714	17,819	2,415	9,492	23,784	1,289	33,984	2,465	466	-	256	-	6.0
1982	96,091	18,230	2,459	10,222	24,093	1,215	36,643	2,640	590	25	266	7	6.1
1983	93,666	17,817	2,896	10,318	22,397	1,592	34,489	3,233	924	29	301	3	6.0
1984	96,874	16,772	3,047	11,705	21,071	1,492	38,030	3,544	1,212	24	367	1	6.0

Source: Statistics and Information Dept., Ministry of Agriculture, Forestry and Fisheries, Fisheries Statistics 1984, 1986.

Notes : 1) The sign (-) indicates that the production figures are included in "Other fish".
2) The figure concerns only Biwa and Kasumigaura Lakes.

Table II-3-3 Production of Marine Cultures

(ton)

Year	Fish					Crustaceans		
	Total Fish	Jack Mackerel	Yellow-tail	Sea breams	Other fish	Prawns	Sea Squirt	Others
1974	97,084	619	92,946	3,298	221	912	5,036	59
1975	97,998	920	92,407	4,462	209	936	6,313	41
1976	109,258	704	101,786	6,572	196	1,042	8,390	42
1977	124,410	743	115,098	8,245	324	1,124	7,463	16
1978	135,008	809	121,956	11,315	928	1,184	5,759	11
1979	170,561	1,461	155,053	12,492	1,555	1,480	5,287	22
1980	169,717	2,272	149,449	14,973	3,023	1,546	5,746	25
1981	174,903	3,195	150,907	18,243	2,558	1,666	6,909	8
1982	175,005	3,613	146,486	20,648	4,258	2,000	7,382	11
1983	190,931	4,266	156,170	25,304	5,191	1,949	7,889	2
1984	190,355	3,708	152,946	26,282	7,419	2,037	8,901	41

Year	Molluscs			Seaweed				Pearl
	Scallop	Oyster (with shell)	Others	Laminaria	Undaria	Laver	Others	
1974	62,651	201,583	129	10,201	153,762	339,314	-	30
1975	70,313	201,173	114	15,759	101,937	278,127	-	30
1976	64,946	226,278	73	22,096	126,701	291,050	-	34
1977	83,213	212,779	92	27,260	125,798	279,031	64	39
1978	67,750	232,068	207	21,890	102,665	350,471	194	37
1979	43,622	205,509	173	25,291	103,788	325,686	1,161	40
1980	40,403	261,323	372	38,561	113,532	357,672	2,904	42
1981	59,106	235,241	470	44,220	91,273	340,510	5,329	46
1982	76,876	250,287	276	42,978	118,338	263,312	1,888	52
1983	85,134	253,247	372	44,343	112,837	360,694	2,326	58
1984	73,981	257,126	490	62,754	114,588	396,530	3,894	64

Source: Statistics and Information Dept., Ministry of Agriculture, Forestry and Fisheries, Fisheries Statistics 1984, 1986.

formulated feeds are commonly used.

(2) Eel

The culture of eel began around the end of the last century in a brackish water lake on the Pacific coast of the main island, and spread to other similar coastal areas. Because it is not possible to produce seedlings artificially, the annual production of cultured eel depends on the quantity of natural seedlings (elvers) caught from the sea. In the early 1970s, the domestic catch of elvers declined to 30 - 50 tons compared with the annual demand of some 100 tons. Elvers of different strains began to be imported from France, the USA and elsewhere. Fingerlings of the same strain of eel are also imported from China.

The method of eel culture changed from ponds with stationary water to those with water flow and tanks with water circulation. Feedstuffs were chrysales of silkworms and others in early years, but changed to sardine and anchovy and mackerels during the 1960s. In recent years, formulated feeds are commonly used. Because eel is carnivorous, fishmeal is added as the major source of protein in feeds. The current feed conversion ratio (the ratio of feeds in kg necessary to obtain 1 kg of eel) is about 7 (or 2.3 - 2.5 in dry weight equivalent).

The neighboring countries like Korea, Taiwan and China began to culture eel and have been increasing eel exports to Japan. Because of increased competition with cheaper imports, the number of eel farms in Japan has been decreasing in recent years.

(3) Sweet fish

Sweet fish is both cultured and farmed. Seedlings are either artificially produced or reared from the fry caught in coastal waters during the spring. Because the fish is favored by anglers, seedlings are released to rivers and the fishing period is strictly regulated. Seedlings cultured in ponds with water flow grow faster than those released to rivers, and can be marketed at higher prices before the fishing season. It took some time to develop the method of producing seedlings artificially, and the technique developed for raising live feedstuffs for the fry of sweet fish has been successfully applied to other fish species.

(4) Trouts

Major cultured species are rainbow trout, brook trout and brown trout. The Japanese Government began to import spawns of rainbow trout from the USA in 1877, and distributed them to prefectural experiment stations in order to encourage the development and diffusion of artificial hatching and rearing of seedlings and their release to rivers and lakes in mountainous regions. The promotional legislation introduced in 1925 contributed to the development of technologies related to the culture and farming of trouts and salmons in inland waters. By the end of the 1930s, more than 600 hatcheries were in operation, producing 600 million seedlings.

After the setback during World War II, the production of cultured trouts quickly recovered in postwar years, reaching 3,000 tons in 1962 which exceeded the prewar record. The trout culture grew steadily afterward, and the production increased nearly seven times by the early 1970s. Cultured rainbow trout was exported to the USA during the 1950s, but along with the rapid growth of the Japanese economy, they are now chiefly sold to the domestic market. Raw fish and wheat flour were mainly used as feedstuffs before, but they have been replaced by formulated pellets in recent years.

Through the efforts made by prefectural fishery experiment stations, the techniques for producing seedlings of such species as humpback salmon and mountain trout (landlocked Oncorhychus spp.), which had been considered impossible, have been established in recent years. No commercial culture of these species is carried out yet, but the demand for artificially produced seedlings has been increasing to release them to rivers. Advanced techniques for chromosome manipulation have been and are being developed to hatch only female trouts which bring better prices than males, or triploids which grow-faster and bigger.

3-3-3 Major Species in Marine Cultures

Major marine fish and shellfish species which are currently cultured for human consumption are yellowtail, red sea breams, prawns, oyster and common scallop. In addition, great many species are cultured, such as globefish, flounders, parrot bass, amberjack, and a variety of bivalves and ark shells.

(1) Yellowtail

The culture of yellowtail began in the late 1920s in parts of the Inland Sea which separates the southern part of Honshu Island (the main island of Japan) and Shikoku Island. The culture of this migratory fish species steadily spread to the surrounding areas since, partly because it is relatively easy to obtain natural seedlings, and partly because they grow fairly quickly to enable their marketing at high prices during the period when their natural catches decrease.

The rapid growth of the yellowtail culture took place during the 1960s when durable synthetic nets were introduced to be used for the farm partitioning and cheaper feedstuffs became available. The increase in production was also related to the development of cold chains in the country, which enabled the distribution of fresh yellowtail and fresh feedstuffs. With the increase in cultured production, the total dependence on naturally available seedlings is now considered to become a limiting factor in the future, and efforts are being made to develop techniques of the artificial rearing of seedlings to stabilize the supply.

(2) Red sea breams

The early culture of red sea breams began some 20 years ago, mixed with yellowtail, along the coasts of the Inland Sea. The full-scale culture began in the late 1960s in southern parts of Japan, such as prefectures in the Kyushu Island and Shikoku Island. It did not take long before red sea breams became the second most profitable species in fish culture after yellowtail.

The culture of red sea breams uses fingerlings of about 10 - 20 g which are caught from the sea and placed in relatively deep segmented ikesu (farm lots partitioned by nets) of about 10 m in depth. The seedlings are reared for two to three years until they grow to weight from 600 g to 1 kg and fetch good prices. Feedstuffs must be selected and mixed carefully to obtain desirable red coloring of the fish. Warm sea areas where the temperature does not go down below 10°C during the winter are particularly suitable for the culture of red sea breams.

At present, seedlings of red sea breams necessary for culture chiefly depend on natural supply. The techniques of the artificial rearing of seedlings have been developed, and seedlings are now cultivated at various places in 100,000 to 1,000,000 units to stabilize the total supply of seedlings.

(3) Prawns

Prawns are one of the most expensive seafood favored in Japan. The early form of prawn (Penaeus japonica) culture was begun in one of the prefectures in the southern Kyushu Island mainly to keep them alive for a short period to favorably adjust their shipments to the market. The full-scale culture was established during the 1960s after some period of trial and error on artificial seed collection, intermediate rearing of seedlings and final rearing in ponds. The developed methods are applied through some modifications to the culture of other prawns including tropical species.

The methods of culture can be divided into extensive and intensive types. The former type utilizes the sites of old salt-fields on the beach or natural inlets, and takes advantage of the tidal range to exchange water in dyked ponds twice a day. Pumps are employed to stir up pond water during the summer when the water temperature gets high and the oxygen level drops. Costs of pond construction and power for pumps are not expensive, but the productivity is generally low, harvesting 200 - 300 g per square meter, and 400 g at the highest.

The intensive type of culture uses a pond with two bottom layers to clean the bottom water and sand. Pond water is changed frequently by pumps to raise the productivity. In one prefecture in Kyushu Island, a round concrete pond of 1,000 square meters with double bottoms change water five to six times a day and keeps water flowing, and produce 2.5 - 5.0 kg of prawn per square meter.

(4) Oyster

The traditional culture of oyster began in Hiroshima Prefecture on the coast of the Inland Sea, utilizing the shallow waters planted with sticks called hibi. Around the mid-1920s, this method was taken over by the new method developed in Northern Europe, which utilized rafts and hung holders of oysters perpendicularly from them. The new method rapidly spread to other areas, because it enabled more efficient three-dimensional utililization of deeper coastal waters and realized higher weight gains than the traditional method.

The method of perpendicular hanging not only contributed to the increase in production and the spread of the oyster culture in Japan but also served as the forerunner of the similar types of cultures which utilized rafts or long ropes for hanging down seedlings, such as those methods developed for pearl, common scallop, and edible seaweeds like wakame (Undaria spp.) and kombu tangle (Laminaria japonica).

(5) Common scallop

Common scallop is a bivalve which prefers cold water. The full-scale culture began in one of the northern prefectures of Japan's main island in the early 1960s, and quickly spread to the surrounding prefectures and the northernmost Hokkaido Island partly to offset the decline of natural production due to overexploitation. The methods of culture somewhat vary depending on local conditions. The long rope method and the raft method have been developed to hang holders of scallop seedlings, but the former method is said to be more practicable. Holders of scallop seedlings vary from different types of mesh bags to ropes.

Seeds of scallop are collected during May and June by having them attach themselves to certain types of twigs, cloth, or nets hung in the sea, and then they are reared to seedlings either for the subsequent culture in, or release to, coastal waters.

In the past, common scallop was mostly consumed locally in the northern parts of Japan, but along with the development of transportation and cold storage and the increased mobility of population, the domestic market expanded to the southern parts of the country, most notably in large urban markets like Tokyo and Osaka. In line with the increased production, mechanical devices have been developed to clean harvested shells and process scallops.

3-4 Technologies for Fish Farming

As mentioned earlier, technologies associated with cultivated fisheries, or the farming in open waters of fish, shellfish and other useful aquatic fauna and flora, consist of the release of seedlings to open surface water, the improvement of their natural habitats, involving both minor and major civil engineering works, and the effective control of fishing efforts to ensure economical harvests of farmed species. And it must be carried out with the accurate understanding of biological traits and behaviors of the target species and their favorite natural habitats, including the effective conservation and improvement of aquatic environments. Therefore, the governmental supports, both financial and technical, have played a much larger and more direct role in developing the technologies for fish farming than in aquaculture.

Governmental promotional measures for coastal fisheries in postwar years were chiefly directed to (i) the improvement of fishing grounds, (ii) conservation and multiplication of fishery resources, and (iii) intensification of research and development activities at prefectural fishery experiment stations. However, public sector efforts during the 1950s were limited to salmons and trouts, common scallop, hard clam, and short-necked clam, partly because the Japanese fishery sector at the time was more interested in expanding distant-water fisheries, and partly because the government policies emphasized the economic development through industrialization which brought about the deterioration of coastal fishing grounds.

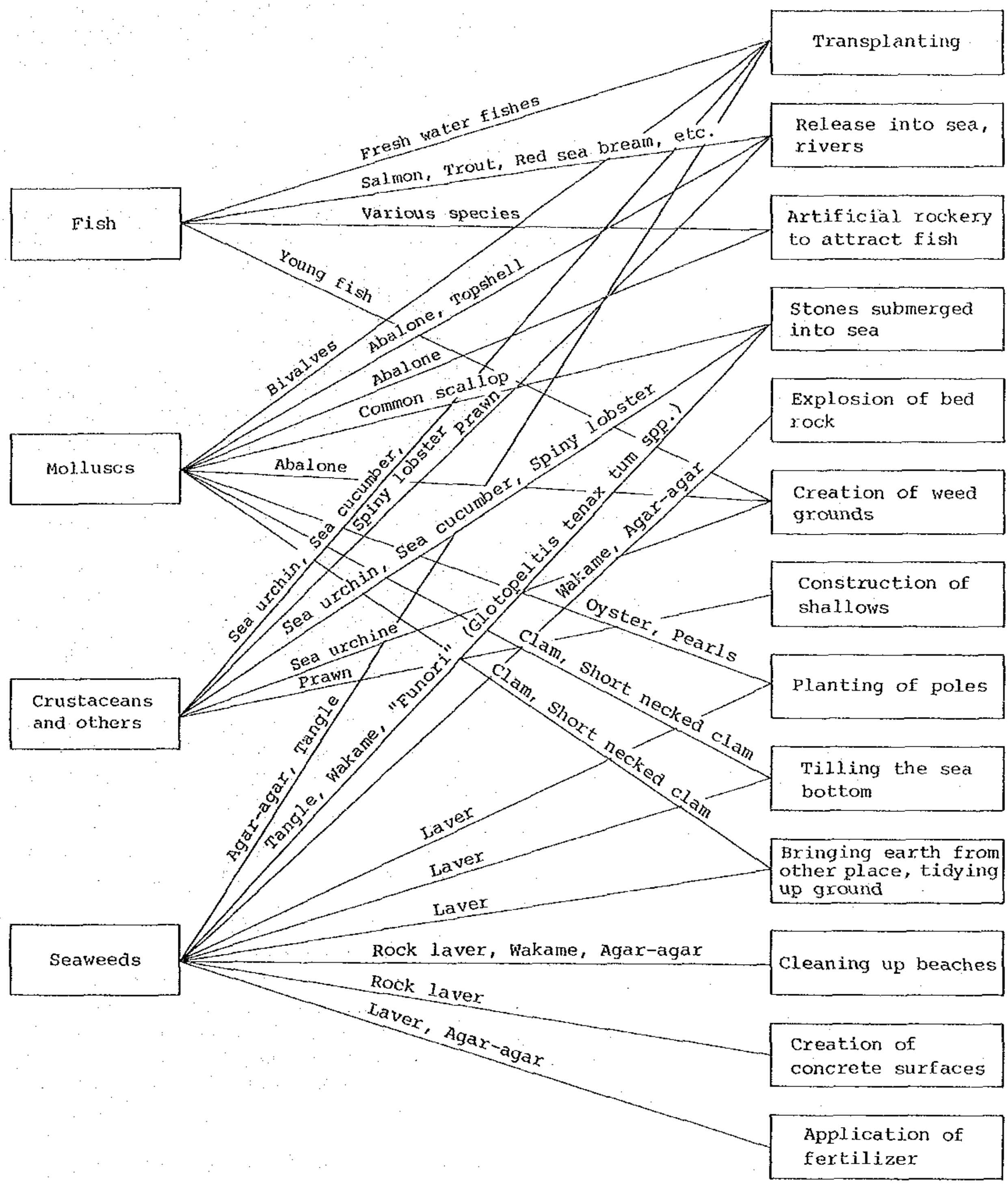
The concept of cultivated fisheries in coastal waters was first explicitly used in the governmental pilot program initiated in 1963 for the fisheries in the Inland Sea. During 1971-1974, extensive ecological studies in coastal waters were conducted in preparation for the implementation of similar programs in other coastal areas. To develop necessary technologies, cultivated fisheries centers were established first by the central government and by prefectural governments since 1973, and the centers now number some 40.

With an appropriate legislation in 1973 to ensure the coordinated efforts of the central and prefectural governments and fishermen's cooperatives, the Japanese Government began its investment program for the development and improvement of coastal fishing grounds since 1976, in addition to the program for the structural improvement of coastal fisheries which had been started in 1962. In recent years, the Government allocated a total of ¥400 billion (US$20 billion at the exchange rate of ¥200 to a dollar) for development and improvement works in coastal fishing grounds during 1982-1987, and ¥200 billion (US$10 billion) for structural improvement works for coastal fisheries during 1979-1989.

The coordinated efforts of the public sector and coastal fishermen's cooperatives have been successfully applied to salmons and trouts, prawns, red sea breams, blue crab, common scallop, seaweeds, etc. The above mentioned prefectural cultivated fisheries centers played an important role in increasing the production and release of seedlings, which improved the survival rates of fry. The number of fish and shellfish species targeted for the release of seedlings are now increased substantially, and many public sector research institutes and private organizations are now cooperating in related basic and applied research projects.

The improvement of coastal fishing grounds consists of a variety of works. In order to aid the survival and growth of spawns, spores, fry, or released seedlings, it is necessary to develop better beds of seaweed, to submerge thickets, rocks and concrete blocks, artficial

Figure II-3-2 Major Methods for Fish Farming



reefs, etc. as shelters in the sea, to clean or construct suitable shallows and beaches, to improve fish ways and facilitate water currents by widening bays and river mouths or dynamiting floor rocks, to abate wave strength by sinking breakwaters or floats, to apply fertilizers for increasing planktons, to eliminate predators, and so on. Figure II-3-2 shows major construction works done for the selected fish, shellfish and aquatic plant species in coastal waters.

It is difficult to measure quantitatively how much these practices have contributed to increasing catches of coastal fisheries. But the reported cases of increased landings in specific localities have been increasing.

3-5 Concluding Remarks

The development of fish culture and farming as briefly described above is ultimately based on the characteristics of consumption in Japan. Japan is one of the largest consumers of fishery products in the world. Per capita daily intake of protein in Japan is about 82 g, of which 49% is derived from animal food, and fish and shellfish account for 45% of the total daily animal protein intake of about 40 g. Although the growth rate of total per capita consumption of fish and shellfish has been slowing down in recent years by comparison with meat, the consumption of higher-grade (= higher-priced) species like prawns, tunas, salmons and others have been steadily increasing, reflecting the growth of per capita income.

As large consumers of fishery products, the Japanese finely differentiate the grades of diverse fish and shellfish they eat, and this is reflected in the wide differences in price between high-grade fish and low-grade fish. In 1984, for instance, the wholesale price in producing regions of sardine and mackerel, two low-grade fish species, is ¥17 per kg compared with ¥1,906 for albacore (a tuna species), ¥711 for yellowtail, ¥1,745 for flatfish, and ¥1,436 for red sea bream.

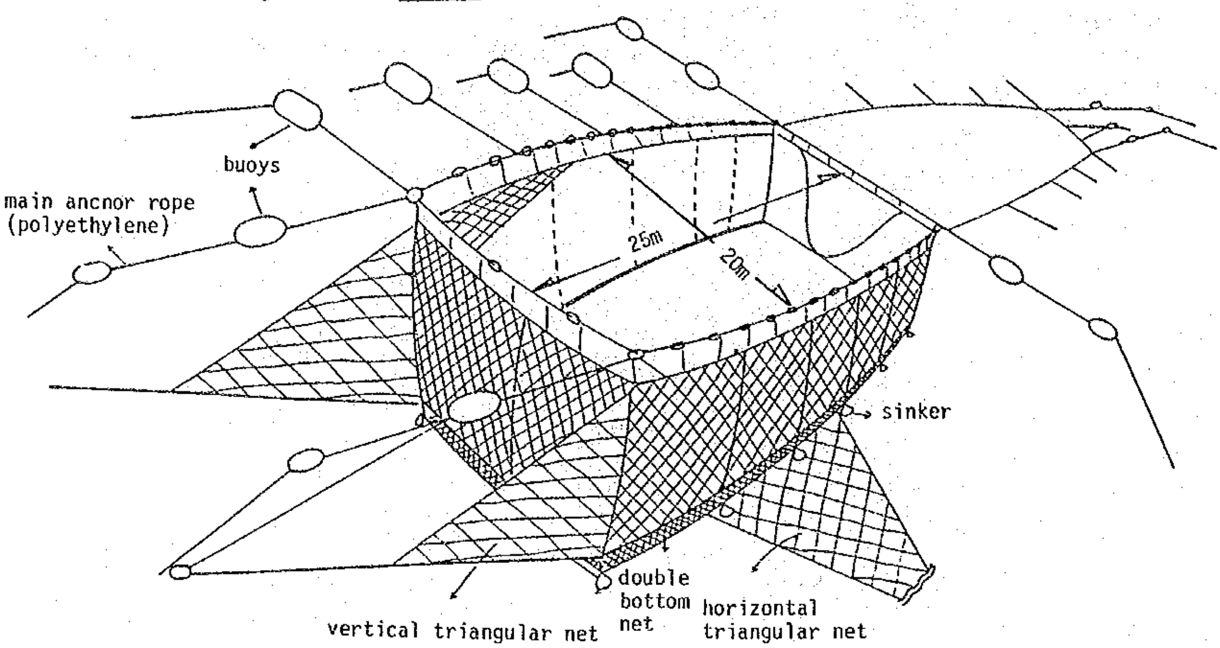
The Japanese have developed various methods to prepare and cook fish and shellfish, in which the freshness and tastes are highly valued. This is also reflected in price differences. In other words, Japanese fish culture and farming grew to provide higher-grade fish and shellfish species as fresh as possible to the consumers. This is fundamentally different from the kind of fish culture being promoted in developing countries in order to provide a cheap source of animal protein to the population.

In order to produce 1 kg of high-grade fish and shellfish species, it is normally necessary to give 6 to 10 kg (wet weight) of feeds. Fish and shellfish cultures thus depend on the stable and abundant supply of cheap fish. In addition, their cultures require considerable initial investments in physical facilities. The same applies to fish farming, in which government subsidies and direct investments play a crucial role.

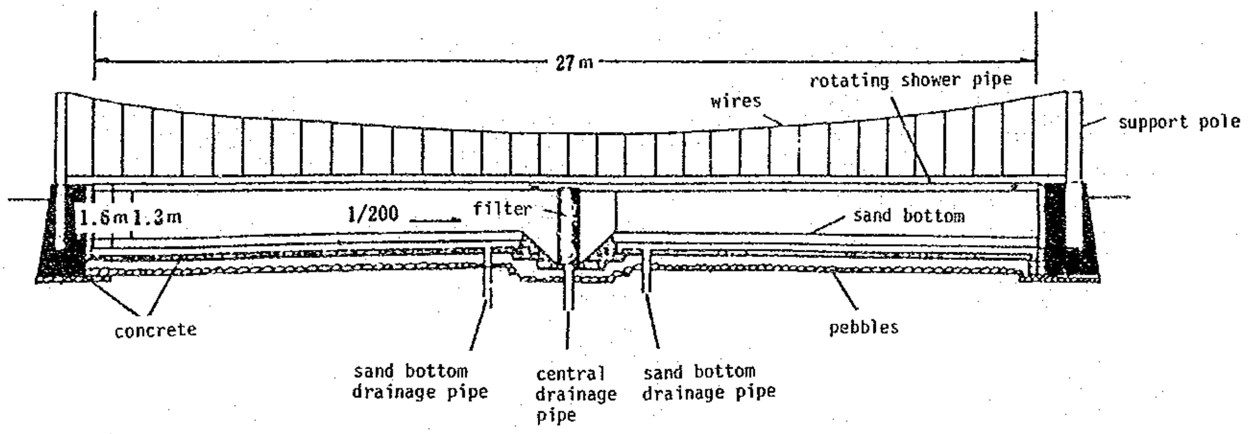
Moreover, fish culture and farming must be supported by the basic and applied research work on fishery resources and their habitats in order to apply most suitable human interventions for increasing their productivity and quality in culture and farming. One of the serious problems in marine cultures in Japan is the repeated occurrence of the red tide caused by the sudden blooming of vegetable planktons during the Summer, and efforts are being made to minimize the losses due to the red tide. All these efforts and investments have been possible, primarily because Japan's domestic consumers have been able to pay high prices to high-grade fish or shellfish.

APPENDIX TO FISH CULTURE

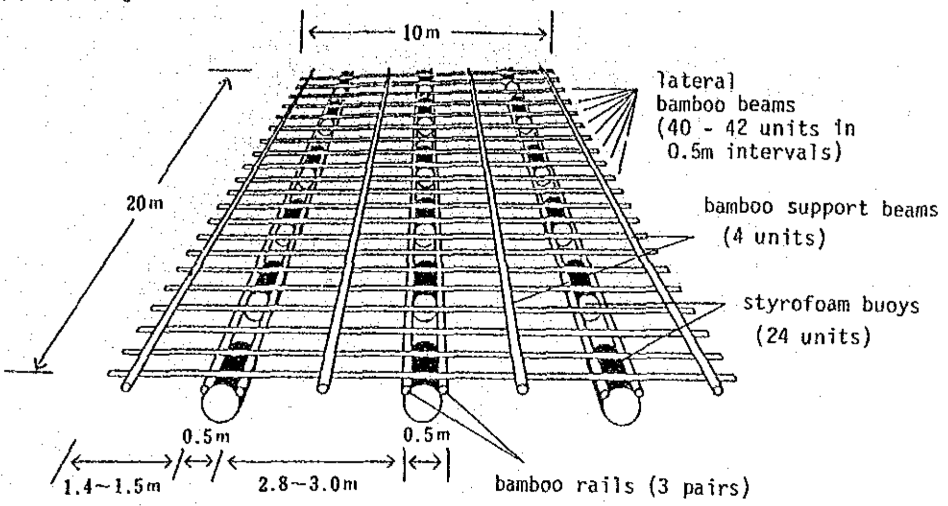
Net Cage Corf (ikesu) for Fish Culture (Black Tuna)



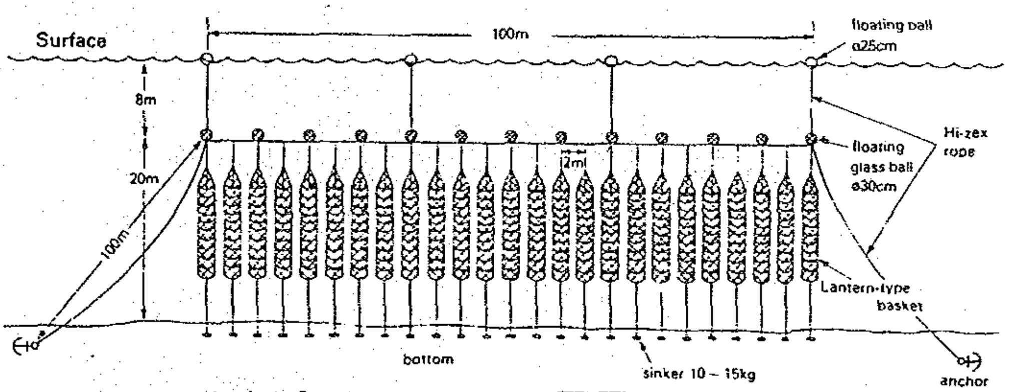
Round Culture Tank for Prawn



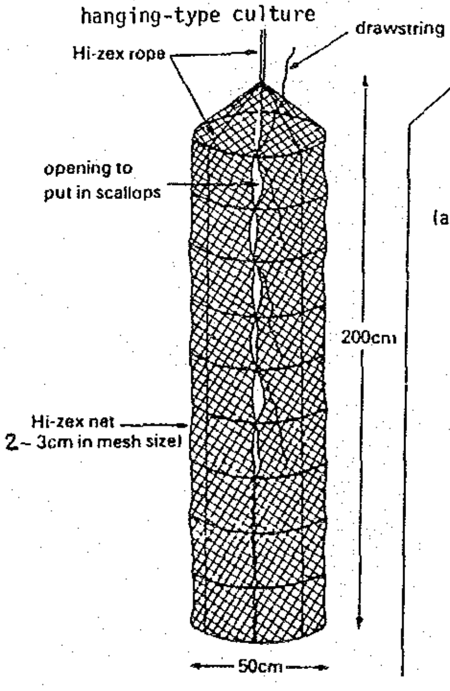
Raft for Oyster Culture



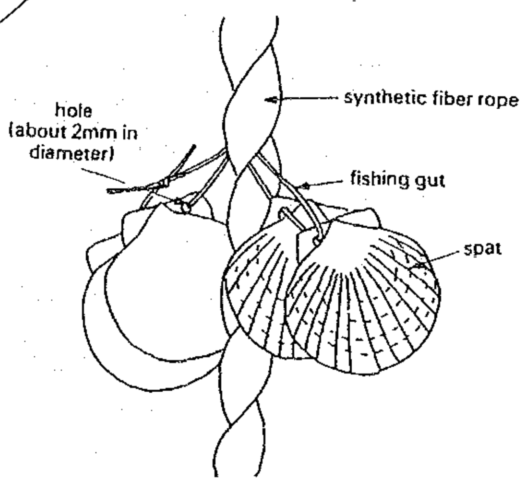
Middle Layer Scallop Culture (Longline Type)



Lantern net basket for
hanging-type culture



Ear-hanging method for
hanging-type culture



III. INDUSTRY

III. INDUSTRY

1. INDUSTRIAL DEVELOPMENT AND INDUSTRIAL POLICY IN POSTWAR JAPAN

1-1 Industrial Development and structural Change

As shown in I-1-1 (Chapter I "Macroeconomy"), the growth of the Japanese economy after World War II is demarcated into the following three stages (see Table I-1-3, P.3). The first stage covers about 15 years from immediately after the War to the 1950s, during which Japan achieved postwar reconstruction and prepared for the next high economic growth period. In this first stage, Japan overcame the runaway inflation after the War, and secured economic self-reliance.

The second stage covers the high economic growth period from the end of the 1950s to the first oil crisis, during which Japan achieved heavy and chemical industrialization through a great structural change in its economy.

The third stage covers the period from the first oil crisis to the present time, during which the economic growth rate decreased significantly compared with that of the second stage. During this period, income was increased through the high economic growth, which, however, produced such negative influences as pollution. Therefore, Japan has come to aim for qualitative economic expansion rather than for conventional quantitative growth.

This section chiefly covers the process of the growth of the manufacturing sector, which has supported the expansion of the Japanese economy since the end of the War, and also covers the structural change of this segment of the economy.

Table III-1-1 shows the change (based on value of shipments) in structure of the manufacturing sector, and Table III-1-2 provides the contribution of each industry to growth. As shown in these tables, the postwar industrialization with enhanced importance for economic growth has not been accompanied by the continuous growth of only one industry, but rather by structural changes in this sector, that is, each period having a different leading industry.

Let us classify the manufacturing sector into two groups, in order to recognize the changes in economic importance of each group. The first is the heavy and chemical industries group, which consists of the chemical, metal, and machinery and equipment industries. The second is the light industries group, which consists of all others. The relative importance of light industries has decreased dramatically, for instance 55.9% in 1950, 41.1% in 1960, 34.2% in 1970 and 31.6% in 1980. In particular, the textile industry had the highest share of 21.5% among 21 industries in 1950, but this dropped to as low as 3.8% in 1980, with 11.2% in 1960 and 6.4% in 1970. On the other hand, the share of heavy and chemical industries increased from 44.1% in 1950 to 64.3% in 1980. Of this, the most rapidly increases were in the latter half of the 1950s

Table III-1-1 Structure of Manufacturing Sector

(%)

code	Industry	1950	1955	1960	1965	1970	1975	1980	1982
	< VALUE OF SHIPMENTS >								
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	Food products	13.4	17.9	12.4	12.5	10.4	11.9	10.5	11.0
2	Textile	21.5	16.2	11.2	8.8	6.4	5.1	3.8	3.6
3	Apparel & related products	1.7	1.3	1.2	1.5	1.4	1.7	1.4	1.4
4	Lumber & wood products	3.9	4.1	3.5	3.6	3.2	2.8	2.5	1.9
5	Furniture & fixtures	0.8	1.0	1.0	1.4	1.5	1.5	1.4	1.1
6	Pulp.paper	3.5	4.2	3.9	3.8	3.3	3.3	3.2	3.0
7	Publishing.printing	3.2	3.3	2.5	3.1	2.9	3.3	3.3	3.4
8	Chemical products	12.9	11.0	9.4	9.5	8.0	8.2	8.4	8.0
9	Petroleum & coal products	1.4	1.9	2.4	2.8	2.6	5.9	7.1	6.9
10	Rubber products	2.4	1.4	1.5	1.3	1.1	1.1	1.2	1.1
11	Leather products	0.8	0.6	0.5	0.6	0.5	0.5	0.5	0.4
12	Ceramic.stone & clay products	3.3	3.4	3.5	3.6	3.6	3.8	3.9	3.7
13	Iron & steel	13.0	9.6	10.6	9.1	9.5	8.9	8.3	7.6
14	Non-ferrous metal products	0.0	4.1	4.3	4.0	4.4	3.1	3.8	2.9
15	Metal products	3.0	3.2	3.9	4.7	5.4	5.2	5.0	4.9
16	Ordinary machinery	4.8	4.6	7.8	7.8	9.9	8.3	8.2	8.7
17	Electrical m. & equipment	3.1	3.7	8.3	7.8	10.6	8.5	10.4	12.0
18	Transport equipment	5.2	5.5	8.5	9.7	10.5	11.6	11.6	12.5
19	Precision instruments	0.8	0.8	1.1	1.3	1.3	1.4	1.6	1.6
20	Ordnance & accessories	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
21	Others	1.5	2.0	2.5	3.3	3.6	4.0	4.1	4.1
	Light industries	55.9	53.5	41.1	40.1	34.2	35.0	31.6	30.5
	Heavy and chemical industries	44.1	44.7	56.4	56.6	62.3	61.0	64.3	65.2
	Chemical industries	14.3	12.9	11.8	12.3	10.6	14.1	15.5	14.9
	Metal industries	16.0	17.0	18.8	17.7	19.3	17.1	17.1	15.4
	Machinery and equipment	13.9	14.8	25.8	26.6	32.3	29.8	31.8	34.8
	< VALUE ADDED >								
	Total			100.0	100.0	100.0	100.0	100.0	100.0
	Light industries			41.1	43.3	37.9	42.0	38.8	38.0
	Heavy and chemical industries			58.9	56.7	62.0	57.9	61.2	62.0
	Chemical industries			12.1	12.1	11.2	10.2	10.6	10.4
	Metal industries			16.1	14.9	16.0	14.7	16.4	14.5
	Machinery and equipment			30.7	29.7	34.8	33.0	34.1	37.0

Source : MITI , *Census of Manufactures* , various issues.

Note : Light industries = code 1-7,10-12,21
Heavy and chemical industries = code 8,9,13-20
Chemical industries = 8,9 Metal products = 13-15
Machinery & equipment = 16-20

Table III-1-2 Contribution to the Increases of Value of Shipments by Subsector

(%)

code	Industry	1950-1955	1955-1960	1960-1965	1965-1970	1970-1975	1975-1980	1950-1960	1960-1970	1970-1980
	< VALUE OF SHIPMENTS >									
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	Food products	20.4	8.1	12.7	8.7	13.7	8.5	12.2	9.8	10.5
2	Textile	13.3	7.3	6.2	4.5	3.5	1.9	9.3	5.0	2.6
3	Apparel & related products	1.0	1.1	1.9	1.3	2.1	1.0	1.1	1.5	1.4
4	Lumber & wood products	4.1	3.1	3.6	3.0	2.4	2.1	3.5	3.1	2.2
5	Furniture & fixtures	1.1	1.1	1.7	1.5	1.7	1.2	1.1	1.6	1.4
6	Pulp,paper	4.5	3.6	3.7	2.9	3.3	3.0	3.9	3.1	3.1
7	Publishing,printing	3.4	1.9	3.7	2.7	3.7	3.2	2.4	3.0	3.4
8	Chemical products	10.0	8.2	9.6	6.9	8.4	8.6	8.8	7.6	8.5
9	Petroleum & coal products	2.2	2.7	3.2	2.5	9.9	8.7	2.6	2.7	9.2
10	Rubber products	0.9	1.6	1.0	1.0	1.1	1.2	1.3	1.0	1.2
11	Leather products	0.5	0.4	0.7	0.4	0.5	0.4	0.4	0.5	0.5
12	Ceramic,stone & clay products	3.5	3.5	3.7	3.6	4.0	4.1	3.5	3.6	4.1
13	Iron & steel	7.8	11.4	7.5	9.8	8.1	7.6	10.2	9.2	7.8
14	Non-ferrous metal products	6.4	4.4	3.6	4.8	1.5	4.8	5.1	4.5	3.5
15	Metal products	3.4	4.4	5.5	6.0	4.9	4.7	4.1	5.8	4.7
16	Ordinary machinery	4.5	10.2	7.7	11.4	6.5	8.0	8.3	10.5	7.4
17	Electrical m. & equipment	4.0	11.8	7.2	12.7	6.0	13.1	9.2	11.3	10.2
18	Transport equipment	5.7	10.9	11.0	11.2	12.9	11.6	9.1	11.1	12.1
19	Precision instruments	0.9	1.3	1.5	1.3	1.4	2.0	1.2	1.3	1.8
20	Ordnance & accessories	0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	Others	2.2	3.0	4.2	3.8	4.4	4.3	2.7	3.9	4.3
	Light industries	55.0	34.7	43.2	33.5	40.4	30.9	41.5	36.0	34.7
	Heavy and chemical industries	45.0	65.3	56.8	66.5	59.6	69.1	58.1	64.0	65.3
	Chemical industries	12.2	10.9	12.8	9.4	18.3	17.4	11.3	10.3	17.7
	Metal industries	17.6	20.2	16.5	20.5	14.5	17.0	19.3	19.5	16.0
	Machinery and equipment	15.2	34.2	27.5	36.6	26.8	34.7	27.9	34.2	31.6
	< VALUE ADDED >									
	Total			100.0	100.0	100.0	100.0		100.0	100.0
	Light industries			45.7	34.5	47.7	34.1		37.2	39.3
	Heavy and chemical industries			54.3	65.5	52.3	65.9		62.8	60.7
	Chemical industries			12.0	10.7	8.9	11.2		11.0	10.3
	Metal industries			13.7	16.8	12.9	18.9		16.0	16.6
	Machinery and equipment			28.6	38.1	30.5	35.8		35.8	33.8

Source : MITI , Census of Manufactures , various issues.
Note : Light industries = code 1-7,10-12,21
Heavy and chemical industries = code 8,9,13-20
Chemical industries = 8,9 Metal industries = 13-15 Machinery and Equipment = 16-20

and again, in the late 1960s. Within the heavy and chemical industries, the growth rate of each industry varied significantly from one year to the next; that is, the share of metal industries and machinery & equipment industries increased during the high economic growth period, while chemical industries were depressed.

After entering the stable-growth period of the 1970s the share of machinery and equipment industries, especially electrical machinery & equipment and transport equipment, rose.

In parallel with these changes in industrial structure, a great structural change has been developed in trade, especially in exports. The value of exports was only 800 million dollars in 1950. The amount, however, increased to as high a level as 169.7 billion dollars in 1984, after progressing from four billion dollars in 1960, to 19.3 billion dollars in 1970, and to 130.4 billion dollars in 1980. In the 30 years from 1950 to 1980, the value of Japanese exports increased at an annual rate of 18.4%, which exceeded the corresponding world trade rate of 12.2% by 6.2 percentage points. As the result, the Japanese share of world exports expanded to 7.0% in 1980 from 1.4% in 1950. During the period 1980 to 1984, while total world exports decreased by 1.5% in average annual terms, Japanese exports achieved 6.7% positive growth, though this was lower than previous years' figures. Accordingly, the share of Japanese exports in the world market increased to 9.6% by 1984.

The rapid expansion in exports after the War was supported by the increased export of heavy-industrial products, especially machinery and equipment.

Table III-1-3 shows the change in the export structure during the period 1950 to 1984. The export of light industrial products, with textiles as the leading item, dropped in percentage terms from 68.2% in 1950 to 13.8% in 1984, with 56.0% in 1960 and 27.6% in 1970. In contrast with this change, the export of heavy and chemical industrial products rose in percentage terms up to as high as 86.2% in 1984 from 31.8% in 1950, and 72.4% in 1970. Above all, the total share of exports of machinery and equipment increased to as high as 70.4% of total exports in 1984, from only 10.5% in 1950. Since the latter half of the 1960s the additional export value of machinery and equipment has accounted for more than 50% of the total additional value exported from Japan, especially during the first four years of the 1980s, when the percentage reached as high a level as 90%.

During the years following the War, the low international competitive position of heavy and chemical industrial products became one of the factors restricting the industrialization of Japan, so that the importing of intermediate and capital products expanded rapidly. For a country such as Japan, with no noteworthy natural resources, it was an urgent task for the purpose of export expansion, to raise the international competitive position of heavy industrial products, which have higher income elasticity and added-value than light industrial products. The acceleration of heavy and chemical industrialization from the latter half of the 1950s reinforced international competitiveness of the heavy and chemical industries, particularly in machinery and equipment, which

Table III-1-3 Export Structure of Japan

(%)

	1950	1955	1960	1965	1970	1975	1980	1984
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Light Industries	68.2	62.0	56.0	38.0	27.6	16.7	15.6	13.8
Food	5.9	6.2	6.3	4.1	3.4	1.4	1.2	0.8
Textiles	48.7	37.3	30.1	18.7	12.5	6.7	4.8	4.0
Others	13.6	18.5	19.5	15.2	11.8	8.7	9.5	9.0
Heavy & Chemical Industries	31.8	38.0	44.0	62.0	72.4	83.2	84.4	86.2
Chemical Industries	1.9	5.1	5.4	4.5	6.4	7.0	5.3	4.5
Metal Industries	19.4	19.2	14.0	20.3	19.7	22.4	16.5	11.3
Machinery & Equipment	10.5	13.7	25.5	35.2	46.3	53.8	62.7	70.4

Source: Statistics Bureau, Management and Coordination Agency, Japan Statistical Yearbook.

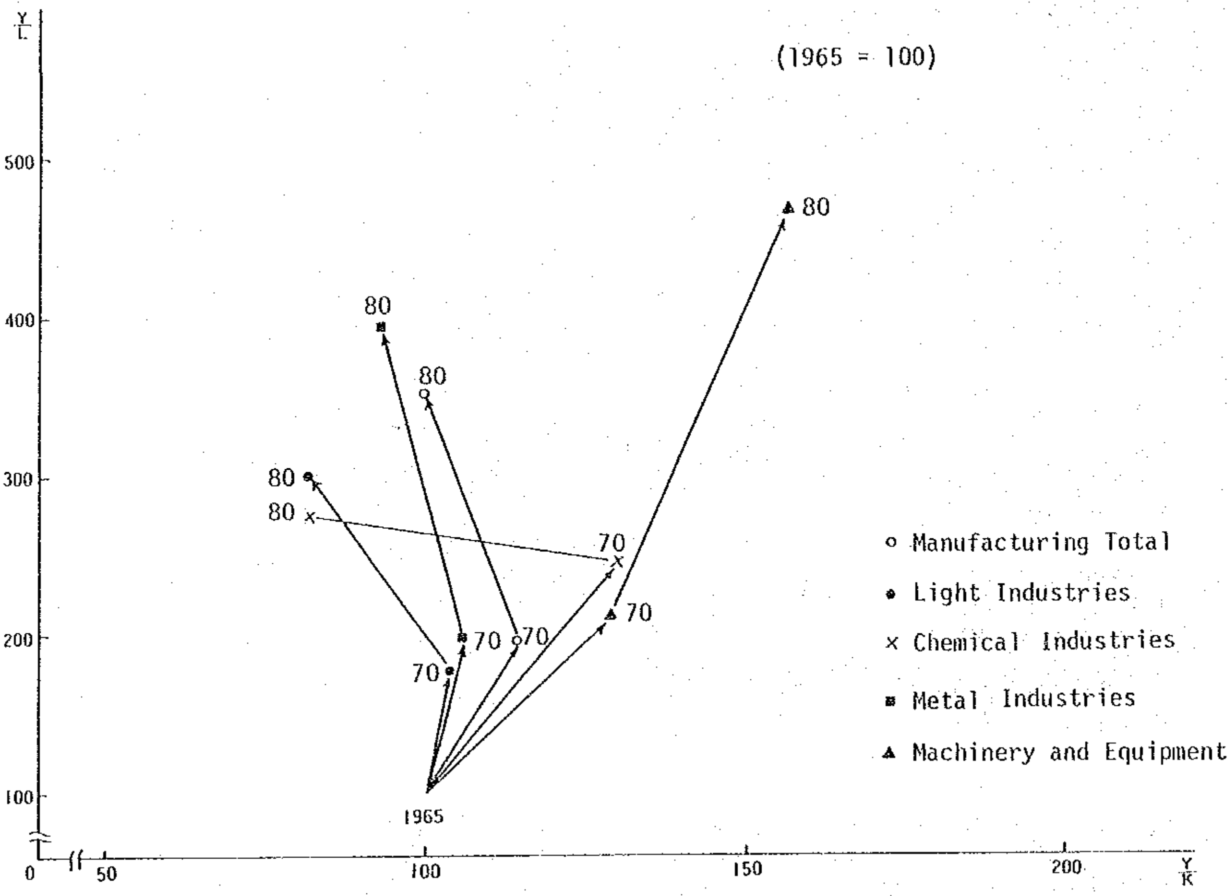
turned out to be the leading sector for export expansion in the latter half of the 1960s. The fundamental factors to support the reinforcement of international competitiveness were the efforts to raise productivity, through modernization of equipment and the introduction of new technology, thus reducing costs and improving quality.

For the 15 years from 1965 to 1980, the nominal capital amount per laborer (K/L) increased 4.7 times (3.4 times if expressed at 1980 prices), while nominal labor productivity (Y/L) increased 7.2 times. Figure III-1-1 shows the change in real labor and capital productivity in 1970 and 1980 with the base of 100 in 1965. The real labor productivity increased during these 15 years by an average of 3.4 times in the manufacturing sector, but 4.7 times in the machinery and equipment industry in particular. Due to the low levels in the 1970s, real capital productivity leveled off roughly for the 15 years as an average for the manufacturing sector. However, a significant increase of 1.6 times was observed in the machinery and equipment industries.

From above, it can be said that the increased productivity of the machinery and equipment industries has rapidly reinforced the international competitiveness and contributed significantly to the expansion of Japanese exports.

The progress of industrial growth in Japan from the end of World War II to the present time has been accompanied, as mentioned above, by

Figure III-1-1 Labor and Capital Productivity



Source: MITI, <u>Census of Manufacturers</u>.

Note: Labor productivity ($\frac{Y}{L}$) = value added per employee

Capital productivity ($\frac{Y}{K}$) = value added per fixed assets

many structural changes. In these changes, emphasis has been shifted from the light industries, with textiles as the leading industry, to the heavy and chemical industries, and in particular to the machinery and equipment industries.

The industrialization associated with such structural changes has been led or supported by Japanese postwar industrial policy. This policy will be described briefly hereunder.

1-2 Japan's Postwar Industrial Policy1)

1-2-1 Reconstruction and Internal Consolidation Period: (from late 1940s through 1950s)

According to the data from the Economic Stability Headquarters run by the postwar Government, Japan lost a total of 36% of its national wealth through World War II, and most of its industrial facilities had been destroyed. At the end of the War, industrial activity in Japan was at a near stand still, and production of consumer goods was at only 30% of the prewar level and that of producer goods at mere 8%.

Therefore, the first objective of the policies of the Japanese Government immediately after World War II was directed to the reconstuction of the economy. To achieve this objective, it was first necessary to rebuild basic industries such as coal, steel and electric power. The Japanese Government took action to give priority to those basic industries' redevelopment in its allocation of limited raw materials, capital and foreign currencies available at that time (called "the Priority Production System"). Reconstruction of the economy was nearly finished by the mid-1950s, but industrial policies adopted during the reconstruction period continued or were newly applied during the latter part of the 1950s to prepare for the further steps to establish economic self-reliance.

(1) Priority Production System

Coal was the only domestically produced raw material in adequate amounts in Japan. In the light of this fact, the Government planned to achieve the recovery of overall national industrial and mining production on the basis of recovery of coal and steel production. In December 1946, the Japanese Government decided to adopt the "Priority Production System" intended to enable expansion of the coal and steel production. The System was designed to:

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1) This section was mainly based on the following publications:
1. Sangyo Kozo Shingikai (Industrial Structure Council), Hachijunen-dai no Tsusho Sangyo Seisaku (Vision of MITI Policies in the 1980s), 1980.
2. do., Nanajunen-dai no Tsusho Sangyo Seisaku (Vision of MITI Policies in the 1970s), 1971.
3. Japan Trade and Industry Publicity, MITI Handbook, 1984.
4. Tsusho Sangyo Gyosei Kenkyukai (Industrial Policy Study Group), Tsusho Sangyo (Industrial Policy), Vol. I and II, 1983.
5. Industrial Structure Division, Industrial Policy Bureau, MITI, Japanese Industrial Policy, 1985.
6. JETRO, Japan's Postwar Industrial Policy, 1985.
7. Keiichi Konaga, "Industrial Policy: The Japanese Version of a Universal Trend", Journal of Japanese Trade & Industry, July/August 1983.
8. OECD, The Industrial Policy of Japan, 1972.

(a) supply all imported residual oil to the steel sector and allocate coal supplies to the steel industry on a priority basis,
(b) supply resultant steel products to the coal industry,
(c) encourage the coal industry to improve mining facilities using this steel, thus promoting both coal and steel production.

The Reconstruction Finance Corporation which was established in October 1946 to supply private companies with necessary capital funds for industrial redevelopment from the Government budget, played an important role in financing the Priority Production System. The Reconstruction Finance Corporation raised funds by issuing and selling its bonds to the Bank of Japan, the Japanese central bank. The Reconstruction Finance Corporation lent a total of 47.5 billion yen to the coal mining industry during the three years from FY1946 to FY1948, which was 36% of total outstanding of its loan, and total of 3.5 billion yen to the steel industry during these years.

In addition, large amounts of collateral funds (Government yen funds deposited with the Bank of Japan starting from April 1949 and originated from revenues of Government sales of foreign commodities aid from the GARIOA and EROA[1] schemes) were poured into the two industries. Furthermore, price adjustment subsidies and import subsidies worth 76 billion yen were given to the steel industry from FY1947 to FY1949.

Because of the Government support for production expansion, national coal output rose from 22.5 million tons in 1946 to 34.8 million tons in 1948 and 37.3 million tons in 1949, and steel output from 0.55 million tons in 1946 to 1.71 million tons in 1948 and 3.11 million tons in 1949. With the increase of coal and steel production, overall national industrial and mining production recovered remarkably, and the industrial and mining production index for FY1948 rebound to 46% of prewar productin levels (see Table III-1-4).

Table III-1-4 Production Indexes of Basic Industries

(1934-36 Level as 100)

	Total mining & industrial production	Coal	Steel	Electric power
1946	27.6	55.3	22.4	129
1947	34.7	73.7	29.3	136
	(25.7)	(33.3)	(30.8)	(5.4)
1948	45.8	90.6	49.2	156
	(32.0)	(22.9)	(67.9)	(14.7)

Source: JETRO, Japan's Postwar Industrial Policy, 1985. (Original source: Nippon Kaihatsu Ginko Junenshi (10-Year History of the Japan Development Bank)).

Note: Numbers in parenthesis indicate percentage growth over the previous year.

1) GARIOA = Government Appropriation for Rehabilitation in Occupied Area
EROA = Economic Recovery in Occupied Area

(2) The Dodge Line - An Economic Stabilization Program

The Japanese postwar economy trod a deviant reconstruction path, where most working funds were provided through Allied Forces' aid and Japanese Government subsidies. In this reconstruction process, the economy suffered from wild inflation. At December 1948, the GHQ (General Headquarters of the Allied Forces) issued "Nine Principles of Economic Stability" pointing to ways to stabilize the economy, and then the reconstruction path was given a new direction. The Nine Principles were:

(a) Balancing the Government's general budget
(b) Strengthening tax collection
(c) Stricter selection of creditees
(d) Stabilization of wages
(e) Strengthening price regulation
(f) Strengthening foreign exchange control
(g) Improvement of commodity rationing for export promotion
(h) Production expansion
(i) Improvement of food delivery

The directions of the Nine Principles were put into action in an economic stabilization program called the "Dodge Line" drawn up by U.S. Diplomatic Representative Joseph Dodge. The objective of the program was to curb inflation through balancing the Government budget, to link the Japanese economy with the international economy by fixing the exchange rate of yen, and to attain economic independence of the country through export promotion and industrial modernization.

As a part of the program, subsidies to industry were slashed and activities of the Reconstruction Finance Corporation were suspended in FY1949. At the same time, the exchange rate of Japanese yen was fixed at 360 yen to the U.S. dollar, on April 23, 1949. All in all, the Dodge Line succeeded in stabilizing the Japanese economy. Inflation rates dropped from 65% in 1949 to 18% in 1950 for wholesale prices and from 26% to -7% for consumer prices.

(3) Promotion of industrial modernization

Additionally to production expansion, it was necessary to reduce production costs and upgrade product quality through modernization of the industry in order to promote exports. In September 1949 the Cabinet meeting of the Government decided the basic policies for industrial modernization. The Japanese Government set reduction of Japanese product prices to international levels as the foremost goal and required individual companies to make stronger efforts to modernize their activities. In the Cabinet meeting, the following measures were agreed to for industrial modernization:

(a) Initiation of industrial standards and greater utilization of the labeling system
(b) Formulation and dissemination of standard production control methods

(c) Encouragement of research and development, and dissemination of superior technology
(d) Securing modernization funds
(e) Promotion of incoming foreign capital

And in the meeting an Industrial Modernization Council was established as an advisory body to the Minister of International Trade and Industry composed of members appointed from industry, finance and government. In August 1950 the Council proposed the "Modernization Measures for Steel and Coal Mining" and in February 1951 submitted a paper entitled "Methods of Modernizing Japanese Industry", emphasizing the importance of accumulating capital stock. In order to increase the supply of funds to industry, the Council proposed a revision in the tax law, utilization of Government funds and development of the securities market. The Council put stress on electric power development, shipbuilding, and modernization of steel and coal industries.

While Japan was engaging in modernization of these basic industries, the Korean War broke out and its war-prompted demand made expansion of Japanese mining and industrial production. It became apparent that basic industries were too underdeveloped for the smooth expansion of mining and industrial output. Consequently, the Government responded to the proposals of the Council and adopted a series of measures to modernize these basic industries. Through those steps, the Japanese Government aimed to increase exports and upgrade industry as a whole.

The two main modernization measures were preferential tax treatment and Government funded programs for promoting modernization investment and capital stock. Preferential treatment in the tax law was initiated in FY1950 and expanded by the Enterprise Rationalization Promotion Law enacted in March 1952. Tax preferences were aimed at increasing capital stock directly or indirectly, such as:

(a) Re-appraisal of assets (1st appraisal in 1950, 2nd in 1951-52, 3rd in 1954-55)
(b) Corporate accounting preferences, such as tax-free reserves for special repairs and uncollected credits (1950-53)
(c) Special tax exemptions and deductions, such as tax exemptions on income from strategic products such as synthetic fibers and tax deductions on income from exports
(d) Special depreciation schemes, including special depreciation on modern machinery

The Government also increased investment and financing activities of the Japan Development Bank to stimulate corporate investment which was established in 1951 as the Government's principal organization in supplying equipment funds to industry. Government collateral funds and Japan Development Bank's funds were poured into the private sector, particularly the four strategic industries. Power and shipbuilding industries were able to borrow funds at preferentially lowered interest rates and foreign currency loans of the Bank of Japan were used to aid the steel industry in importing equipment.

(4) Introduction of foreign capital and technology

Along with preferential tax treatment and allocation of Government funds, the introduction of foreign capital and technology also played an important role in the modernization and technological development of Japanese industry. Japan's foreign capital introduction policies were based on the Law Concerning Foreign Investment legislated in May 1950. The purposes of the Law Concerning Foreign Investment were approval of foreign capital considered beneficial for development of the Japanese economy and improvement of the Nation's international balance of payments, assurance of profit remittance as a result of foreign capital introduction and creation of a favorable environment for inbound investment through appropriate measures which protect investment from abroad.

Foreign capital introduced by Japanese companies from FY1950 to 1961 totaled $1,536 million and was brought in largely by electric power, gas, metal, transportation and telecommunication, and oil refining. Most of them came to Japan in the form of loans. As for introduction of technology, machinery and chemical industries played leading roles. Number of approved contracts for introduction of foreign technologies from FY1949 to FY1961 was 1,670 of which the machinery industry had the share of 54% and the chemical industry had 21%.

In 1951, an import duty exemption scheme for "important" machinery was introduced as a result of a revision of the Customs Tariff Law. Under this Law, duty-free importation was permitted for, first, new or high-performance industrial machinery difficult to be produced in Japan and, second, those machinery beneficial to the achievement of self-sufficiency in Japan's economy. Other programs aimed at improving the national technological standard, such as tax incentives and research and development subsidies by the Government and loans by the Japan Development Bank.

1-2-2 High-Growth Period (1960s)

The 1960s for Japan was characterized as a decade of remarkable economic growth and economic liberalization through freer trade and capital resulting from de-regulation. The main objective of industrial policy during this period was to strengthen industry's international competitiveness in order to overcome international balance of payments constraints on economic growth and catch up with the developed nations quickly as possible. As far as policy measures are concerned, this decade witnessed a transition from direct and regulatory way to indirect and indicative way. Strong economic growth achieved by the private sector was one of the backgrounds of this transition.

It was considered that social capital, such as roads, harbors, industrial-use water supply, was underdeveloped relative to productive capital, resulting in bottleneck for the overall economic growth. Therefore the development of social capital was set as one of the government basic tasks for the realization of high economic growth.

Also for "upgrading industrial structures" and "narrowing structural gaps between large and small enterprises", the Government projected assertive policies in which it defined its role as that of "providing the private sector with such targets as would enable the Government to guide free industrial activity". This was considered to be the beginning of a new, stronger approach of the Government toward an industrial policy.

(1) Promotion of heavy and chemical industries

Promotion of heavy and chemical industries was accelerated in 1955, in response to a number of laws and cabinet decisions aimed at bolstering the automobile, petrochemical, industrial machinery and electronic machinery industries. However, at that time, it was uncertain whether industry-by-industry programs would be sufficient to build a Japanese economy capable to competing in the international market.

The Government's general approach to industrial policy was to avoid direct intervention in private industrial activity but provide guidance by setting overall industry-wide goals. For strategic industries, however, the Government provided much stronger protective programs, encouraging the Diet to legislate accordingly. Laws were designed to strengthen specific industries and included the 1956 Law on Temporary Measures for Machinery Industries and the 1957 Law on Temporary Measures for Electronic Industries. Both laws were designed to modernize machinery industries through improved production systems and accumulated capital and technology among component manufacturers.

The Machinery Industries Law, initially legislated as a temporary (five years) law and later extended by five years, contained the following programs:

(a) Formulation of basic modernization plans and working plans: The Government was authorized to formulate basic modernization plans for industries specified by the Minister of International Trade and Industry, indicating five-year targets for product quality and production costs, equipment required for modernization, necessary funds and schedules for scrapping old equipment, among other programs. Modernization plans were to be enforced according to associated working plans drawn up annually by the Government.

(b) Acquisition of funds: The Government was required to collect funds necessary for execution of working plans.

(c) Direction to cooperate: The Minister of International Trade and Industry was empowered to advise companies to carry out joint activities considered necessary to achieve modernization goals stated in basic modernization plans, unrestrained by the Anti-Monopoly Law.

(d) Machinery Industries Council: Established for the deliberation of "important" matters concerning promotion of machinery industries.

(2) "Vision of the 1960s"

In December 1963 the Industrial Structure Council drew up and presented the "Vision of the 1960s". This was the first time a scenario was adopted as the guiding nucleus for specific programs to modernize the Nation's industrial structure, setting a precedence for the Government to devise an industrial structure "Vision" for future decades.

In the "Vision", two criteria for a desired industrial structure to attain higher economic growth were introduced: (a) "income elasticity criterion" focusing attention on the demand aspect, and (b) "productivity increase rate criterion" focusing attention on the supply aspect. Applying these criteria the path of heavy and chemical industries was chosen as the most desirable.

In its "Vision" submitted to the Minister of International Trade and Industry, the Industrial Structure Council clearly envisaged Japan as a newly industrializing country and stressed the importance of strengthening international competitiveness through improved economies of scale. The Council also proposed a wide range of future policies including industrial organization policies based on industry-government cooperation, new industrial financing, stable supply of basic commodities, and liberalized trade policies.

(3) Liberalization of trade and capital

Japan got membership of the General Agreement on Tariffs and Trade (GATT) in September 1955. The Japanese Government on June 24, 1960 announced the "Foreign Exchange and Trade Liberalization Plan," aimed at raising the rate of trade liberalization from 41% to 80% in three years, to make current foreign exchange transactions free in principal within two years, and gradually abate restrictions on capital transactions. The trade liberalization schedule was soon advanced at the request of the IMF and other international organizations, and the rate of trade liberalization jumped to the 88% level by October 1962 (see Table III-1-5).

Japan was accepted as a member nation by the International Monetary Fund (IMF) in May 1952. And in April 1964 it joined Article VIII nations in the IMF, thus obligated not to control payments and money flow involved in current international transactions due to the balance of payment reasons. As a result, Japan put an end to its Foreign Exchange Budget System which had been introduced in 1950 aimed to restrict foreign exchange activities. At the same time, Japan joined the Organization for Economic Cooperation and Development (OECD), thereby signing the "capital movement liberalization agreement" and "invisible trade liberalization agreement." As a result, Japan pushed ahead with liberalization programs for incoming foreign direct investment.

Table III-1-5 Progress of Japan's Trade Liberalization

	No. of liberalized items	No. of items remaining	Liberalization rate (%)	Major liberalized items
Apr. '60	586	—	41	Coffee bean, nickel ore
July '60	61	—	42	Precious stone, phthalic anhydride
Oct. '60	481	—	44	Cocoa bean, zinc ore
Apr. '61	660	—	62	Textile raw materials, radio, sewing machine
July '61	112	—	65	Soy bean, instant coffee
Oct. '61	500	—	68	Silver, watch, titanium
Dec. '61	170	—	70	Stainless steel, apparel
Change of system to list non-liberalized items				
Apr. '62	8	492 (466)	73	Coconut oil, specialty steel, socks
Oct. '62	230	262 (232)	88	Crude oil, mutton, raw silk, pearl
Nov. '62	8	254 (224)	88	Sweater, safety razor
Apr. '63	25	229 (197)	89	Banana, copper ingot
June '63	2	227 (195)	89	Accordion, felt hat
Aug. '63	35	192 (155)	92	Sugar, battery
Jan. '64	3	189 (152)	92	Kaoliang, lauan
Feb. '64	7	182 (145)	92	Lead, zinc
Apr. '64	8	174 (136)	93	Color television, naphtha
May '64	—	174 (136)	93	Lemon
Oct. '64	12	162 (123)	93	Gin, cotton yarn, tractor

Source: JETRO, Japan's Postwar Industrial Policy, 1985. (Original Source: Customs and Tariff Bureau, Ministry of Finance)

Note: Numbers in parentheses exclude items not required to liberalized under GATT.

The first steps towards capital liberalization were taken in July 1967 and almost complete liberalization was effected by 1973 (see Table III-1-6).