

## The Medical Science Research and Development Supported by the Korea Science and Engineering Foundation

This study examined ways of promoting research in the medical sciences by evaluating trends in research funding, and the present status of research funding by the Korea Science and Engineering Foundation (KOSEF). This study analyzed statistics from KOSEF from 1978 to 2003 to examine support for research. In medical science field, group-based programs receive more funding than do individual-based programs. The proportion of research funds allocated to the medical sciences has increased markedly each year. Researchers in the medical sciences have submitted more articles to Science Citation Index (SCI) journals than to non-SCI journals, relative to other fields. Researchers supported by the Mission-Oriented Basic Grants program have published the majority of these papers, followed by those supported by the Programs for Leading Scientists, Regional Scientists, Leading Women Scientists, Young Scientists, and Promising Women Scientists, in that order. Funding by KOSEF reflects many decades of government support for research and development, the development and maintenance of necessary infrastructure, and the education and training of medical scientists.

Key Words : *Research Support; Research; Biomedical Research; Research Activities; Korea*

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### INTRODUCTION

Research and development (R&D) can be classified into basic and applied research. Since there is little consensus on the definition of basic research, various standards have been adopted (1).

Although there is no internationally accepted definition of basic science, it is generally understood to involve the natural sciences, including some of the medical sciences. The Frascati Manual of the Organization for Economic Co-operation and Development (2) includes various definitions of basic research; the best known of these defines it as experimental and theoretical work that is conducted to obtain fundamental knowledge of observable facts and phenomena, without considering specific applications or uses. Basic research does not focus on a particular objective but on experimental and theoretical work with a view to devising new theories and extending knowledge in the basic sciences and engineering (3). The purpose of basic research is to obtain general knowledge and understanding of a certain subject, without necessarily considering specific applications. From an industrial perspective, this

might be defined as not pertaining to specific, commercial knowledge, but as an enhancement of scientific knowledge (4). The importance of basic research is increasing with the development of innovative knowledge, technological innovation, and knowledge-based industries; in addition, this kind of research fosters high-level science and engineering manpower.

There has been a call for increased cooperation among industries, universities, and research institutes with regard to basic research in the medical sciences so that we can face the challenges confronting us in the 21st Century. This kind of approach requires an operating paradigm whereby academia faces no walls or boundaries, allowing internationalization and mobility among academics.

In particular, the importance of focusing university research on basic studies has increased under the National Innovation System. Appropriate research funding should be allocated to ensure commitment and achievement; in addition, the mode of funding is also important. Consequently, it is important to evaluate current research funding to universities, as funding that plays a crucial role in the medical sciences. This study evaluated research in the medical sciences through an

analysis of funding in this field by the Korea Science and Engineering Foundation (KOSEF) by comparing funding in other research sectors over the past 26 yr and examining the number of sector-specific research tasks and funding allocations, the age and scholarship distribution of the research manpower in this field, and the number of their publications, as well as present alternatives for developing the most appropriate research strategies and systems.

## MATERIALS AND METHODS

This study analyzed statistics from the Korea Science and Engineering Foundation from 1978 to 2003 to examine support for research undertaken by individuals, including new professors, basic researchers, core-specific researchers, and by those involved in International Bank for Reconstruction and Development (IBRD) loan-assisted projects, international cooperative research projects, and group/collective studies, including Mission-Oriented Basic Grants (including high-end research projects), and projects for centers of excellence. We examined support for training researchers, including scholarships for masters and doctoral candidates, overseas and domestic post-doctoral training, research infrastructure establishment projects, and operational support for special research material banks and special research information centers. The statistical data do not agree with the annual accounts and project budgets of KOSEF; the statistical analysis only included support for research projects and not support for small-scale academic activities.

Since the research management system of KOSEF does not use a consistent classification system for the areas of research supported, we classified research projects into 15 categories and compiled basic statistics on each. The categories were aging and cancer, allergy and immunology, anatomy and cell biology, biochemistry and molecular biology, clinical sciences, clinical technology and methodology, genetics, hygienic chemistry, neurosciences, pharmaceuticals, pharmaceutical chemistry, physiology and pharmacology, public health and safety, and others. In many cases, it was not clear which category a research project fell into. Therefore, many projects were classified as "other". For projects involving more than two researchers, we attempted to identify the interests of the chief researcher. All research funding was rounded off to the nearest thousand won and the data for the research team were processed using internal data from KOSEF.

## RESULTS

### Analysis of research funding trends in the medical sciences

In Korea, real national R&D started in 1978 with the establishment of KOSEF. National R&D funds have grown con-

tinuously and reached a record 5.28 trillion won in 2003 (5). Between 1978 and 2003, KOSEF invested 129.54 billion won in a total of 38,305 grants. Of this, 19.93 billion won went towards supporting 4,054 projects in the medical sciences. Over the period studied, the medical sciences received between 10.6 and 13.6% of the grant money each year. In 2003, KOSEF spent an estimated 4.25 billion won of its own funds on R&D in the medical sciences, providing 32.6% of the national total of 13.04 billion won (5).

From 1978 to 2003, the total number of projects increased by a factor of 33.5, and the corresponding research expenses increased by a factor of 695.6. For the medical sciences, in 2003, 600 projects (21.9% of the total) received 42.5 billion won (18.9% of the total) in grants, whereas no medical science projects were supported in 1978 (Table 1). In general, support for the medical sciences by KOSEF relative to the total number of projects has increased steadily in terms of both the number of projects and the level of funding since 1978.

In 1983/1984, no medical science projects received grants; this gradually increased to 14.9-24.0% of projects and 11.4-20.3% of total funds for 1999-2003 (Table 1). This parallels the increase in funding for medical sciences in the United States from 23.5-23.9% for 1975-1985 to 28.9-31.1% for 1998-2001. R&D in the U.S.A. has contributed to innovation and growth materially. Federal R&D funds have been espe-

**Table 1.** Number of research projects and expenditures in medical sciences supported by the KOSEF

(Unit: Project, Thousand Korean Won)

Year	No. of Project			Expenditure		
	Med. Sci. (A)	Total (B)	Ratio (A/B, %)	Med. Sci. (A)	Total (B)	Ratio (A/B, %)
1978	0	82	0.0	0	322,400	0.0
1982	2	537	0.4	10,788	1,632,550	0.7
1983	0	629	0.0	0	2,133,010	0.0
1984	0	918	0.0	0	3,558,565	0.0
1985	0	1,097	0.0	0	5,134,633	0.0
1986	2	1,461	0.1	61,500	9,364,947	0.7
1987	8	1,348	0.6	231,000	11,142,596	2.1
1988	8	1,202	0.7	242,000	11,485,090	2.1
1989	23	1,608	1.4	740,000	14,416,002	5.1
1990	26	1,637	1.6	923,000	17,893,409	5.2
1991	45	1,841	2.4	1,639,760	28,492,656	5.8
1992	83	1,585	5.2	2,449,500	37,280,340	6.6
1993	102	1,318	7.7	3,101,200	37,564,963	8.3
1994	128	1,566	8.2	3,860,316	48,054,043	8.0
1995	203	2,170	9.4	6,592,328	67,033,035	9.8
1996	299	2,406	12.4	8,502,546	85,409,824	10.0
1997	303	2,464	12.3	9,761,790	102,699,447	9.5
1998	360	2,617	13.8	10,508,807	106,104,444	9.9
1999	275	1,842	14.9	13,191,006	115,946,728	11.4
2000	398	1,968	20.2	23,584,990	147,730,307	16.0
2001	544	2,576	21.1	30,251,547	184,250,951	16.4
2002	645	2,688	24.0	41,184,599	203,084,546	20.3
2003	600	2,745	21.9	42,477,224	224,271,064	18.9
Total	4,054	38,305	10.6	199,313,901	1,295,408,550	13.6

cially important to the academic sector, which is the source of much of the nation's basic research. Federal funds constituted close to 60% of academic R&D expenditures over the past decade. The majority of expenditures for academic R&D in 2001 went to the life sciences, which accounted for 59% of all academic R&D expenditures, 58% of Federal academic R&D expenditures, and 59% of non-Federal academic R&D expenditures. Within the life sciences, the medical sciences accounted for about 31% of academic R&D expenditures

and the biological sciences for about 18%. The next largest block of academic R&D expenditures went to engineering, with about 15% in 2001 (4, 6).

Analysis of research trends in the medical sciences by type

We examined support for individual research projects, group/collective research projects, research infrastructure,

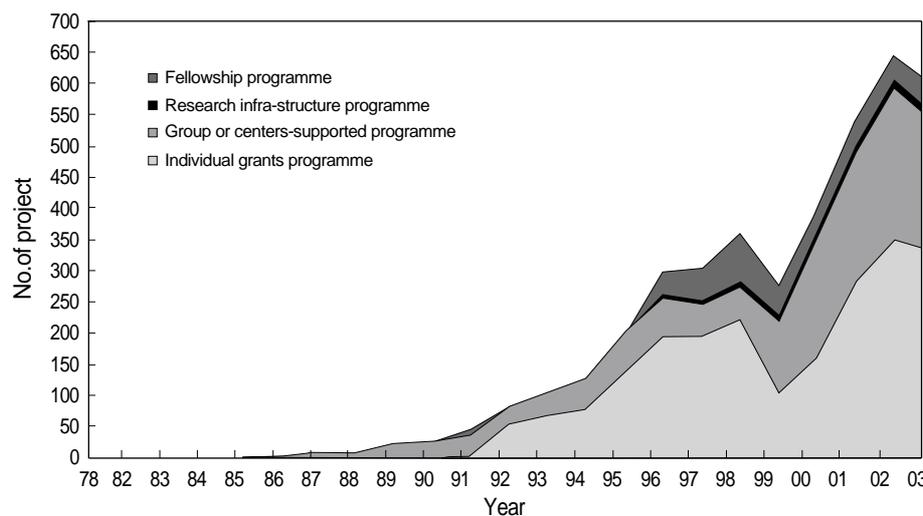


Fig. 1. Types of research programs supported by KOSEF, and the number of research projects in the medical sciences.

Table 2. The number and properties of medical research projects by funding types from KOSEF

(Unit: No. of project)

Year	No. of project		Individual grants programme			Group or centers -supported programme			Research infra-structure programme			Fellowship programme		
	Total (A)	Med. Sci. (B)	Project (C)	Ratio (C/A, %)	Ratio (C/B, %)	Project (C)	Ratio (C/A, %)	Ratio (C/B, %)	Project (C)	Ratio (C/A, %)	Ratio (C/B, %)	Project (C)	Ratio (C/A, %)	Ratio (C/B, %)
1978	82	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
1982	537	2	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	2	0.37	100.00
1983	629	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
1984	918	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
1985	1,097	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
1986	1,461	2	0	0.00	0.00	2	0.14	100.00	0	0.00	0.00	0	0.00	0.00
1987	1,348	8	0	0.00	0.00	8	0.59	100.00	0	0.00	0.00	0	0.00	0.00
1988	1,202	8	0	0.00	0.00	8	0.67	100.00	0	0.00	0.00	0	0.00	0.00
1989	1,608	23	0	0.00	0.00	23	1.43	100.00	0	0.00	0.00	0	0.00	0.00
1990	1,637	26	0	0.00	0.00	26	1.59	100.00	0	0.00	0.00	0	0.00	0.00
1991	1,841	45	4	0.22	8.89	33	1.79	73.33	0	0.00	0.00	8	0.43	17.78
1992	1,585	83	55	3.47	66.27	28	1.77	33.73	0	0.00	0.00	0	0.00	0.00
1993	1,318	102	69	5.24	67.65	33	2.50	32.35	0	0.00	0.00	0	0.00	0.00
1994	1,566	128	79	5.04	61.72	49	3.13	38.28	0	0.00	0.00	0	0.00	0.00
1995	2,170	203	142	6.54	69.95	58	2.67	28.57	3	0.14	1.48	0	0.00	0.00
1996	2,406	299	195	8.10	65.22	63	2.62	21.07	3	0.12	1.00	38	1.58	12.71
1997	2,464	303	196	7.95	64.69	51	2.07	16.83	5	0.20	1.65	51	2.07	16.83
1998	2,617	360	222	8.48	61.67	54	2.06	15.00	7	0.27	1.94	77	2.94	21.39
1999	1,842	275	105	5.70	38.18	117	6.35	42.55	6	0.33	2.18	47	2.55	17.09
2000	1,968	398	162	8.23	40.70	191	9.71	47.99	9	0.46	2.26	36	1.83	9.05
2001	2,576	544	281	10.91	51.65	211	8.19	38.79	7	0.27	1.29	45	1.75	8.27
2002	2,688	645	350	13.02	54.26	248	9.23	38.45	8	0.30	1.24	39	1.45	6.05
2003	2,745	600	332	12.09	55.33	209	7.61	34.83	12	0.44	2.00	47	1.71	7.83
Total	38,305	4,054	2,192	5.72	54.07	1,412	3.69	34.83	60	0.16	1.48	390	1.02	9.62

Table 3. The medical research expenditures by funding types from KOSEF

(Unit: Thousand Korean Won)

Year	Grant amount		Individual grants programme			Group or centers -supported programme			Research infra-structure programme			Fellowship programme		
	Total (A)	Med. Sci. (B)	Amount (C)	Ratio (C/A, %)	Ratio (C/B, %)	Amount (C)	Ratio (C/A, %)	Ratio (C/B, %)	Amount (C)	Ratio (C/A, %)	Ratio (C/B, %)	Amount (C)	Ratio (C/A, %)	Ratio (C/B, %)
1978	322,400	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
1982	1,632,550	10,788	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	10,788	0.66	100.00
1983	2,133,010	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
1984	3,558,565	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
1985	5,134,633	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
1986	9,364,947	61,500	0	0.00	0.00	61,500	0.66	100.00	0	0.00	0.00	0	0.00	0.00
1987	11,142,596	231,000	0	0.00	0.00	231,000	2.07	100.00	0	0.00	0.00	0	0.00	0.00
1988	11,485,090	242,000	0	0.00	0.00	242,000	2.11	100.00	0	0.00	0.00	0	0.00	0.00
1989	14,416,002	740,000	0	0.00	0.00	740,000	5.13	100.00	0	0.00	0.00	0	0.00	0.00
1990	17,893,409	923,000	0	0.00	0.00	923,000	5.16	100.00	0	0.00	0.00	0	0.00	0.00
1991	28,492,656	1,639,760	61,000	0.21	3.72	1,563,000	5.49	95.32	0	0.00	0.00	15,760	0.06	0.96
1992	37,280,340	2,449,500	421,000	1.13	17.19	2,028,500	5.44	82.81	0	0.00	0.00	0	0.00	0.00
1993	37,564,963	3,101,200	548,700	1.46	17.69	2,552,500	6.79	82.31	0	0.00	0.00	0	0.00	0.00
1994	48,054,043	3,860,316	879,716	1.83	22.79	2,980,600	6.20	77.21	0	0.00	0.00	0	0.00	0.00
1995	67,033,035	6,592,328	1,784,368	2.66	27.07	4,354,960	6.50	66.06	453,000	0.68	6.87	0	0.00	0.00
1996	85,409,824	8,502,546	2,525,060	2.96	29.70	5,135,700	6.01	60.40	300,000	0.35	3.53	541,786	0.63	6.37
1997	102,699,447	9,761,790	3,067,790	2.99	31.43	5,248,980	5.11	53.77	580,000	0.56	5.94	865,020	0.84	8.86
1998	106,104,444	10,508,807	3,211,120	3.03	30.56	5,609,300	5.29	53.38	693,000	0.65	6.59	995,387	0.94	9.47
1999	115,946,728	13,191,006	1,502,790	1.30	11.39	9,577,000	8.26	72.60	1,450,000	1.25	10.99	661,216	0.57	5.01
2000	147,730,307	23,584,990	4,407,830	2.98	18.69	17,674,979	11.96	74.94	888,000	0.60	3.77	614,181	0.42	2.60
2001	184,250,951	30,251,547	6,621,920	3.59	21.89	22,231,000	12.07	73.49	958,000	0.52	3.17	440,627	0.24	1.46
2002	203,084,546	41,184,599	8,624,500	4.25	20.94	30,889,000	15.21	75.00	832,000	0.41	2.02	839,099	0.41	2.04
2003	224,271,064	42,477,224	10,647,853	4.75	25.07	29,917,000	13.34	70.43	1,272,000	0.57	2.99	640,371	0.29	1.51
Total	1,465,005,550	199,313,901	44,303,647	3.02	22.23	141,960,019	9.69	71.22	7,426,000	0.51	3.73	5,624,235	0.38	2.82

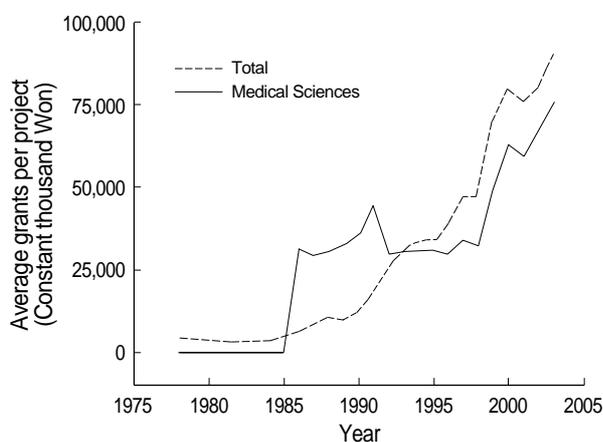


Fig. 2. Research expenditure per project in the medical sciences (\*Grants amounts: Datus of Individual Grants Program and Group or Centers-supported Programme).

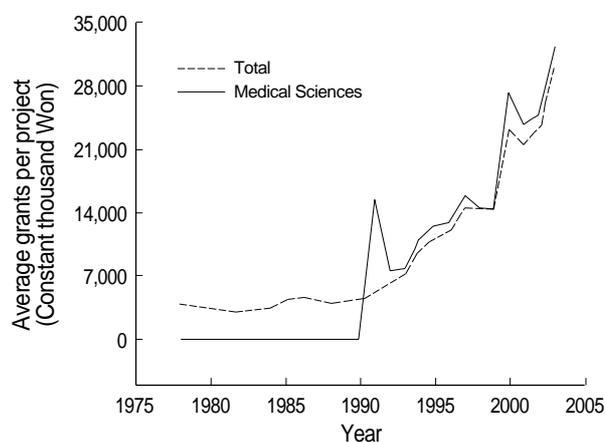


Fig. 3. Individual research grants per project in the medical sciences (Grants amounts: Datus of Individual Grants Program).

and research manpower training. Of 4,054 programs in the medical sciences from 1978 to 2003, 2,192 (54.1%) were individual projects, 1,412 (34.8%) were group/collective research projects, 60 (1.5%) were research infrastructure projects, and 390 (9.6%) were manpower training projects.

Before 1990, 70% of research involved group studies and few significant projects were initiated by individuals. By con-

trast, since 2000, only 35 to 48% of all medical science projects involved group or center-supported programs. In 2003, 332 grants were for individual projects (55% of the total for medical sciences), whereas there were no such grants before 1990 (Table 2, Fig. 1).

Between 1978 and 2003, the medical sciences received 199.3 billion won in grants out of a total of 1,465 billion won (13.6%). Of this, 44.3 billion won (22.2%) went to individ-

Table 4. Manpower in medical sciences in Korea

(Unit: Headcount, %)

Sub-field	Average age (yr)	61-		56-60		51-55		46-50		41-45		36-40		-35		Total		Total	Ratio
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female		
Clinical Sciences	47	42	2	63	3	116	13	200	21	282	47	178	49	27	21	908	156	1,064	23.7
Clinical Technology & Methodology	48	10	10	13	19	29	27	48	56	55	44	26	20	5	15	186	191	377	8.4
Anatomy & Cell Biology	45	12	0	17	1	19	2	44	9	86	20	48	16	19	12	245	60	305	6.8
Aging & Cancer	45	5	0	7	2	31	7	70	10	85	29	62	25	9	12	269	85	354	7.9
Biochemistry & Molecular Biology	44	22	5	26	7	54	7	147	31	181	34	124	32	54	31	608	147	755	16.8
Genetics	45	6	1	8	3	11	1	32	6	45	7	28	7	17	6	147	31	178	4.0
Allergy & Immunology	44	5	0	6	3	13	0	42	12	62	16	47	16	14	13	189	60	249	5.5
Neurosciences	44	12	0	15	0	19	2	82	11	115	19	77	21	30	14	350	67	417	9.3
Physiology & Pharmacology	45	13	1	10	2	34	2	41	10	67	14	45	13	18	11	228	53	281	6.3
Pharmaceutical Chemistry	48	4	1	3	2	6	1	9	0	11	4	8	6	4	0	45	14	59	1.3
Pharmacognosy	46	9	0	9	2	5	5	20	4	25	6	14	8	11	7	93	32	125	2.8
Pharmaceutics	45	4	1	3	0	1	0	9	1	13	4	1	6	4	2	35	14	49	1.1
Hygienic Chemistry	47	4	0	3	1	5	1	5	2	8	4	6	1	3	2	34	11	45	1.0
Public Health & Safety	46	11	3	17	1	26	5	36	11	51	9	34	17	7	9	182	55	237	5.3
Medical Sciences Total	46	159	24	200	46	369	73	785	184	1,086	257	698	237	222	155	3,519	976	4,495	100.0

\*Source, amended from KOSEF Manpower DB (2004).

Table 5. Output of research publications by the researchers registered in KOSEF Manpower database (Unit: Headcount, %)

Output of research publications	Non-SCI		SCI		Total	
	Manpower	Ratio	Manpower	Ratio	Manpower	Ratio
0-5	9,670	21.5	35,535	79.2	7,012	15.6
6-10	7,287	16.2	3,623	8.1	6,900	15.4
11-20	10,025	22.3	3,174	7.1	9,942	22.2
21-30	5,842	13.0	1,193	2.7	6,215	13.8
31-40	3,465	7.7	590	1.3	3,922	8.7
41-50	2,268	5.1	295	0.7	2,653	5.9
51-60	1,449	3.2	177	0.4	1,940	4.3
61-70	1,065	2.4	102	0.2	1,259	2.8
71-	3,804	8.5	186	0.4	5,032	11.2
Total	44,875	100.0	44,875	100.0	44,875	100.0

\*Source, amended from KOSEF Manpower DB (2004).

ual research programs, 142.0 billion won (71.2%) went to group research, 74.3 billion won (3.7%) went to research infrastructure programs, and 56.2 billion won (2.8%) went to manpower training programs (Table 3).

#### Unit cost analysis of medical science research programs

The total number of projects supported by KOSEF has increased every year, especially in the medical sciences. Research funding per project reached 90 million won in 2003.

Since 1978 the average amount of support in the medical

sciences has remained low compared with other fields. Even in 2003 it amounted to only 75 million won, 83.5% of the average investment of 90 million won per other project (Fig. 2). The average amount of the Korean Research Foundation (KRF) support in the medical sciences area showed the same phenomenon, as represented by KOSEF (7).

Based on a constant price index, in the 16-yr period (1978-1993), the average amount granted per project to support the research programs of individuals almost doubled, from 3.9 to 7.3 million won. In the medical sciences, there are no records for before 1990, and support has gradually increased to date. This period can be regarded as a time of supporting wider fields of research. With the budget increases from the government and the implementation of the Science Research Center/Engineering Research Center (SRC/ERC), unit support has increased sharply since 1991.

This trend was a little sluggish in 1999, but improved in 2000 following both the transfer of core special research projects to the Ministry of Education (MOE) and the introduction of a new individual-support program for regional university scientists (25 million won), leading scientists (100 million won), and female scientists (25 million for the most promising and 40 million for excellence).

As of 2003, the unit support amount averaged 30 million won overall and 32.1 million won in the medical sciences, whereas the annual average amount per project for the period 1978 through 2003 was 20 million won for the medical

Table 6. Output of research publications by medical science researchers registered in KOSEF Manpower DB (Unit: Headcount, %)

Output of research publications	Journal type	Clinical Sciences	Clinical Technology & Methodology	Anatomy & Cell Biology	Aging & Cancer	Biochemistry & Molecular Biology	Genetics	Allergy & Immunology	Neurosciences	Physiology & Pharmacology	Pharmaceutical Chemistry	Pharmacognosy	Pharmaceutics	Hygienic Chemistry	Public Health & Safety	Medical Sciences Total	
																Manpower	Ratio
0-5	Non-SCI	86	21	55	36	193	40	60	72	33	15	14	11	6	25	667	14.9
	SCI	761	298	118	173	235	68	77	186	110	18	65	22	27	187	2,345	52.3
	Total	58	17	14	13	46	8	17	32	11	4	6	5	4	21	256	5.7
6-10	Non-SCI	95	35	28	42	98	28	27	42	21	8	12	6	4	27	473	10.6
	SCI	114	31	54	74	161	40	55	78	48	7	12	8	7	26	715	16.0
	Total	94	28	22	29	83	22	20	33	18	3	8	5	1	18	384	8.6
11-20	Non-SCI	219	82	62	61	150	34	35	85	59	15	20	4	13	50	889	19.8
	SCI	107	21	66	55	191	46	67	88	66	17	31	12	7	15	789	17.6
	Total	195	76	54	69	138	43	40	67	42	7	17	7	12	51	818	18.3
21-30	Non-SCI	159	71	41	51	101	17	37	52	38	6	19	4	8	34	638	14.2
	SCI	44	13	34	26	97	15	26	34	23	6	7	3	2	4	334	7.5
	Total	147	66	41	48	127	19	38	73	36	9	15	6	11	30	666	14.9
31-40	Non-SCI	130	41	33	39	64	18	23	39	24	6	22	5	1	37	482	10.8
	SCI	17	2	16	10	40	8	15	17	16	5	2	2	1	2	153	3.4
	Total	129	49	45	35	95	25	34	41	32	10	24	3	2	31	555	12.4
41-50	Non-SCI	80	39	26	18	44	9	15	30	19	5	10	4	2	15	316	7.1
	SCI	7	5	7	5	11	0	8	9	4	0	3	1	0	0	60	1.3
	Total	88	34	28	27	60	12	18	37	25	9	10	2	3	23	376	8.4
51-60	Non-SCI	69	19	14	16	24	10	14	17	20	1	5	1	4	15	229	5.1
	SCI	3	2	5	3	6	1	2	3	5	3	3	1	0	1	38	0.8
	Total	65	20	24	25	58	15	23	27	19	7	9	5	3	16	316	7.1
61-70	Non-SCI	43	14	10	23	19	7	10	14	10	1	3	4	2	9	169	3.8
	SCI	0	1	2	5	4	1	1	1	0	2	0	0	0	0	17	0.4
	Total	54	15	19	15	34	7	11	16	19	3	8	4	2	16	223	5.0
71-	Non-SCI	178	51	35	68	60	16	30	68	53	2	19	10	4	23	617	13.8
	SCI	6	0	2	3	8	0	0	3	5	1	1	0	0	0	29	0.6
	Total	229	68	57	93	112	28	50	93	75	7	27	12	6	29	886	19.8

\*Source, amended from KOSEF Manpower DB (2004).

sciences and 11.6 million won for other fields (Fig. 3). The average total research expense (29,827 thousand won) per project in the individual-support program in all fields in 2003 was 146% that of similar funding (Grants for provincial universities, newly-appointed professors and leading researchers) from KRF (8) during the same period. Such a rapid increase in the amount of support per project has played an important role in improving the stability of the research environment for basic science research programs by enhancing the quality and training of competent research manpower.

#### Analysis of research manpower and number of publications in the medical sciences sector

KOSEF constructed a research manpower database in the mid 1980s, based on data relating to research grantees and evaluations of project participants, for the systematic management of those who had performed and were capable of performing such research. This system was improved in 2000 by allowing data to be updated by the researchers themselves every two years. Accordingly, it cannot be regarded as the

latest data on manpower. Based on the 20,186 researchers who have input their area code out of the total 44,875 registered on the database as of May 2004, the number of research personnel in the medical sciences was 4,495 (22.3%).

By sector, there are 1,064 researchers (23.7%) in the clinical sciences, 377 (8.4%) in clinical technology & methodology, 305 (6.8%) in anatomy & cell biology, 354 (7.9%) in aging & cancer, 755 (16.8%) in biochemistry & molecular biology, 1,778 (4.0%) in genetics, 249 (5.5%) in allergy & immunology, 417 (9.3%) in neuroscience, 281 (6.3%) in physiology & pharmacology, 59 (1.3%) in pharmaceutical chemistry, 125 (2.8%) in pharmacognosy, 49 (1.1%) in pharmaceutics, 45 (1.0%) in hygienic chemistry, and 237 (5.3%) in public health & safety. Among researchers involved in the medical sciences, the youngest average age was 44 yr, in biochemistry and molecular biology, allergy and immunology and neuroscience, while the oldest average age, 48 yr, was in clinical technology and methodology and pharmaceutical chemistry. Male researchers overwhelmingly dominated with respect to numbers: only 22% of researchers were female (Table 4).

We investigated the number of papers published by KOSEF

**Table 7.** Average output of research publications by researchers given grants in medical sciences by program (FYs 2002-2003) (Unit: Project)

Program	Non-SCI	SCI	Total	Non-SCI, recent 5 yr	SCI, recent 5 yr	Total, recent 5 yr
Program for Leading Women Scientists	33	15	50	20	12	32
Program for Promising Women Scientists	17	11	28	13	9	23
Program for Young Scientists	15	14	29	12	12	24
Program for Regional Scientists	42	14	59	26	11	38
Program for Leading Scientists	45	27	72	17	21	39
Mission-oriented Basic Grants	48	21	70	26	15	41

**Table 8.** Expenditure for academic R&D in U.S.A. (Unit: Millions of current dollars)

Field	1975	1980	1985	1990	1995	2000	2001	
							Amount	Distribution, %
Sciences	3,027	5,200	8,268	13,630	18,650	25,494	27,725	84.7
Physical sciences	350	677	1,148	1,807	2,255	2,708	2,800	8.6
Mathematics	40	78	128	222	279	341	357	1.1
Computer sciences	46	124	281	515	682	875	954	2.9
Earth, atmospheric, and ocean sciences	255	508	705	1,069	1,433	1,763	1,827	5.6
Life sciences	1,900	3,218	5,279	8,725	12,186	17,460	19,190	58.6
Agricultural sciences, amount	384	676	999	1,349	1,814	2,175	2,318	7.1
(Agricultural sciences, ratio, %)	11.3	11.2	10.3	8.3	8.2	7.2	7.1	7.1
Biological sciences	630	1,028	1,781	2,859	3,834	5,613	5,944	18.2
<b>Medical sciences</b>	<b>811</b>	<b>1,423</b>	<b>2,318</b>	<b>4,154</b>	<b>6,070</b>	<b>8,986</b>	<b>10,177</b>	<b>31.1</b>
Other	75	91	181	363	468	686	751	2.3
Psychology	80	110	158	253	370	516	582	1.8
Social sciences	256	339	383	703	1,019	1,297	1,436	4.4
Other sciences	100	146	186	336	426	534	579	1.8
Engineering	381	862	1,418	2,656	3,515	4,547	5,000	15.3
Total	3,408	6,062	9,686	16,286	22,165	30,041	32,725	100.0

\*Source: National Science Foundation, 2004, Science & Engineering Indicators 2004, v2. A5-9~A5-11.

researchers in terms of 1) the number of papers published in general academic journals not listed in the Science Citation Index (SCI; hereinafter referred to as “number of non-SCI papers”), 2) the number of papers published in SCI academic journals (hereinafter referred to as “number of SCI papers”) and 3) total number of papers published including 1) and 2) (hereinafter referred to as “total number of papers”). The non-SCI paper statistics show that among 44,875 researchers, most (10,025, 22.3%) had published 11-20 papers, while 8.5% (3,804) had published more than 70. For SCI papers, 35,535 researchers (79.2%) had published less than 5 papers, and 186 (0.4%) had published more than 70. In total, the numbers were 11-20 papers (9,942 persons, 22.2%), >0-5 papers (7,012 persons, 15.6%), >6-10 papers (6,900 persons, 15.4%), >21-30 papers (6,215 persons, 13.8%), >over 70 papers (5,032 persons, 11.2%) (Table 5).

We investigated the publication status of researchers in the medical sciences based on the above statistics. The number of non-SCI papers published was quite uniformly distributed, with 889 researchers (19.8%) publishing 11 to 20 papers, followed by 667 (14.9%) who published 0 to 5 papers. For SCI-papers, most (2,345, 52.3%) were by researchers who

published 0-5 papers, while 789 (17.6%) were by researchers who published 11-20 papers, and only 29 researchers (0.9%) published more than 70 papers. Based on the total numbers of papers, the order was as follows: over 70 (886, 19.8%), > 11-20 (818, 18.3%), >21-30 (666, 14.9%), >31-40 (555, 12.4%), >6-10 (384, 8.6%), >41-50 (376, 8.4%), >51-60 (316, 7.1%), >0-5 (256, 5.7%), >61-70 (223, 5.0%) (Table 6).

**Analysis of papers listed by researchers selected for KOSEF projects**

Researchers selected for Mission-Oriented Basic Grants, which support excellence in small research groups, published an average of 48 papers in non-SCI journals in the most recent 5-yr period, and averaged 15 papers in SCI journals. The team leaders of Mission-Oriented Basic Grants are outstanding researchers who have led and conducted research for an average of three years, and who have participated actively in the activities of academic societies, in addition to contributing frequently to SCI journals.

Researchers in the program for Leading Scientists, which was implemented to further motivate scientists, foster world-

leading scientists, and widen Korea's capacity for basic science to a world-class level, published an average of 27 papers in SCI journals, and over the most recent 5-yr period averaged 21 publications in SCI journals. This is the highest number of any SCI sector.

Researchers in the Program for Promising Women Scientists and the program for Young Scientists have published fewer articles in each sector, as compared to other programs. However, since the selected researchers published an average of 28 and 29 papers each in 2002 and 2003, respectively, and in the most recent 5-yr period averaged a total of 23 and 24 papers each, it is clear that recent performance has improved markedly (Table 7).

#### Analysis of research funding in the major advanced countries

Analysis of academic funding in the USA shows that of a total of 32.7 billion dollars (2001 basis), 31.1% or 2.3 billion dollars were allocated to the medical sciences and 58.6% or 19.2 billion dollars were allocated to all the life sciences, including agricultural science, biology, and others. The increasing trend, evident in annual figures for the medical sciences of 0.811 billion dollars in 1975, 2.318 billion dollars in 1985, 4.154 billion dollars in 1990 and 10.177 billion dollars in 2001, roughly corresponds to the case analyzed in this paper (Table 8).

## DISCUSSION

From an economic applications perspective, derived from basic research, it has been reported that government investment in basic research provides returns to society and makes a crucial contribution to economic growth. Moreover, a percentage of the increase in sales by companies results from taking advantage of university research. Basic research provides society with practical information, new forms of mechanization and methodologies, trained manpower, a systematic organizational structure based on expertise and technological solutions to problems, and leads to the creation of new companies (9).

As a result of the importance of basic research, research spending has been the fastest growing item in the national budget. However, the medical sciences will inevitably require longer-term and more stable investment than is offered to other fields. Stable opportunities for academic and research jobs, in comparison with other fields, will prevent the brain drain of promising new researchers and graduates. It will be necessary to establish a plan to strengthen our research competitiveness in order to entice our brightest minds to return to Korea and occupy positions of leadership in society, as well as in research institutes. This may be effected, in part, by developing new inter-disciplinary studies in the life sciences. In

addition, we must acknowledge the external threats created by grouping specific university graduates.

In this study we analyzed both the strengths and weaknesses of the internal environment for research in the medical sciences, as well as the opportunities offered and threats posed by the external environment surrounding the medical sciences, in relation to other academic fields. As compared to other fields, the major strengths of the medical sciences lies in their research manpower, the advanced level of their research facilities, and research and technological capabilities that are not far behind those of the most advanced countries.

Concerning weaknesses in this area, first, relatively little attention has been paid to strengthening relationships between different academic fields or to generating new inter-disciplinary areas; this is because the relevant societies and research institutes have failed to assume a leadership role in this respect. Second, researchers' preferences for the medical sciences have led to limited research manpower being available for other fields. Third, the distribution of research endeavor on the part of universities has not diversified and has, instead, been grouped according to specific university background. Fourth, few government officials, such as ministers and vice-ministers, are qualified to take part in the decision-making process in this field, as compared to other areas, such as the social sciences, physics, chemistry, agriculture and fisheries, and engineering. Furthermore, opportunities for these officials to do so have been considerably limited.

As for the opportunities offered by the external environment, increasing emphasis has been placed on medical research and there has been increased interest in biotechnology. In addition, many international cooperative research projects are presently underway, thanks to the relatively small gap in capabilities, even in relation to the most advanced countries. Finally, the biotechnology industry is still at a primitive stage and many areas in this field remain to be explored.

In contrast, the external environment can pose a threat in that creative and stable long-term research activities pertaining to basic research in the medical sciences, with relatively long recovery periods, have not been implemented smoothly by the investment of research funds in such visible areas as the 10 Growth Propulsion Power and The National Technology Guidance projects.

#### Research trends in the medical sciences by the type of programme

Around 1990, many large-scale research programs emerged owing to the influence of research in advanced countries. These started with the awarding of group Mission-Oriented Basic Grants, which gave rise to SRC/ERC in February 1990 and inter-disciplinary cooperative research projects. Subsequently, the proportion of funds supporting individual projects and manpower training programs has increased gradually. Support for research in the medical sciences has improved steadily

since 1986, thanks to the Research Support Project for Specialization Encouragement, which was initiated in 1995.

For the sciences in general, support for group research versus individual research has grown rapidly since 2000. With this increase in group research has come an increased awareness of the benefits of inter-disciplinary co-operative research. Programs supporting group research, such as SRC/ERC, Regional Research Center, Medical Research Center, and local university-based research support, play a significant role in enhancing the national level of capability with respect to science technology. For these projects to be successful there must be a sound framework that allows individual researchers at universities and institutes to conduct creative, ongoing projects. Fundamental research in various fields is necessary to meet the needs of a rapidly changing society, and to boost its capability to incorporate future technology. As support has tended to focus on group research, it has become more difficult for individual researchers not involved in groups to undertake research. For this reason, we need to construct a stronger base for basic research.

Comparing the rate of successful applications to the National Science Foundation of the United States (NSF) and the KRF, in 2003, the NSF awarded 10,844 grants in response to a total of 40,075 applications (27%), while in 2003 the KRF awarded 2,433 grants in response to 9,523 applicants (23%). For specific programs sponsored by the KOSEF, the success rate was even lower: 11% for programs supporting research scientists (63 out of 589), 11% for those fostering leading scientists (25 out of 176), and 22% for the program promoting excellence among scientists in regional universities (361 out of 1,656). Furthermore, the rate of support for new projects has decreased each year since 2002: it was 39% in 2002 (932 of 2,380), 26% in 2003 (1,002 of 3,844), and 20% in 2004 (738 of 3,867). In this regard, inter-departmental competition for group research program grants has been severe. Consequently, the funds available to individuals have been greatly limited, and the support for young scientists is decreasing. Therefore, when designing group research programs, it is necessary to establish a solid national support program, as a part of the National Millennium Plan, through extensive evaluation of the expertise available, after considering the opinions of scientists.

In part, the lower proportion of grants for individual research programs, compared to group research programs in Table 3, occurred because the average unit research cost of group research is considerably higher than that of other programs. More attention should be paid not only to increasing the unit cost, but also to enlarging support for individuals, infrastructure, and manpower training programs in order to improve the research environment.

There was considerable support for individual programs up to the late 1980s. Beginning in the 1990s, grants favored group research or center-supported programs, and this trend continued until 2003. The reason for this decline in support

for individual programs was that group research had an advantage in terms of increased output of publications, both qualitatively and quantitatively (10, 11), while fewer research activities were available to researchers who were not invited into large-scale projects. However, even among individual projects, it is not easy to conclude that giving large amounts of money to a few projects increases output, as compared to giving small amounts to numerous projects. Moreover, it has been suggested that group research does not result in output of a quality that is equivalent to that from individuals (10, 11). A slight increase in the rate of grants to individual projects (25.1%) in 2003 might be regarded as an appropriate measure to counter these problems.

Our research support system can be described as an inverted triangle. There was a severe imbalance in the amounts granted in 2001, as only 11% was invested in infrastructure supporting individual and group/collective projects, which were deemed a focus, whereas 37% went to specific research areas, and 52% was poured into special tasks that were initiated nationally. Researchers in charge of infra-research accounted for 15% of the researchers receiving grants. High-level researchers at SRCs/ERCs accounted for 40% (10). Theoretically, the ideal situation occurs when at least 70% goes to individual-oriented tasks, 20-30% to collective research in specific areas by medium-sized groups, with the balance going to special nationally designated large-scale research projects. In the U.S.A. in 2002, most of the university R&D funds, about 74%, were invested in basic research comprised mainly of projects undertaken by individuals, whereas applied research received 22% and R&D 4% (7)

From this perspective, it appears highly advisable to review policy on national R&D projects and research budget allocation. Conversely, coverage by the manpower-training program increased between 1995 and 1999, but then decreased following the discontinuance of the domestic post-doc training program and the curtailment of foreign post-doc training programs as a result of the Korean financial crisis in 1997. Certain measures are needed to enhance the quality of the next generation of researchers in the medical sciences.

#### Unit cost trends in the medical sciences

Research funding per project has increased every year, as seen in Table 4, thanks to the implementation of Mission-Oriented Basic Grants in 1987 and the SRC/ERC program in 1990. Although less than the NSF average of \$135,609 per research project in 2003 (4), it is much more than the sum of approximately 47 million won that was provided by the Korea Research Foundation under the MOE and Human Resources Development (8), and it can be regarded as an appropriate amount in terms of the average amount vs. the per capita gross national product (GNP). The report by the MOE stating that the average R&D expense of 40 million won per university staff in 2003 was 25% (8 million won) higher

than two years ago is further evidence of the improvement.

#### Number of publications in the medical sciences sector

It is noteworthy that among researchers publishing more than 70 non-SCI papers, the percentage in the medical sciences (13.8%) is far higher than in other fields (average: 8.5%; Table 7), as is also the case for the total number of papers published (19.8%). Researchers in the medical sciences published numerous papers in domestic academic journals, and these publications were derived from a more solid research framework than has often been the case previously. In the past, scant attention was paid to the SCI academic journals. The publications in the medical sciences need further consideration in terms, simultaneously, of both their qualitative and quantitative aspects.

### CONCLUSIONS AND SUGGESTIONS

The numbers show that in the medical sciences, more investment has been made in group/collective research than in projects undertaken by individuals, and that the level of funding per unit project has been a little lower than the overall amount in engineering fields. According to the statistics for grants and the numbers of projects supported, medical research expenditure has been the fastest-growing item. The numbers of papers published in the last five years, according to funding, were in the following order: Mission-Oriented Basic Grants>Program for Leading Scientists>Program for Regional Scientists>Program for Leading Women Scientists>Program for Young Scientists>Program for Promising Women Scientists.

Research in the medical sciences is an essential enterprise leading to the benefit of our society. It is undertaken, to a very large extent, in laboratories scattered throughout academic health centers by dedicated, expert scientists who are driven by a quest to help improve the quality of life. Both investment and the numbers of research programs must be increased. Furthermore, we need to take appropriate measures to activate research activities. Finally the medical sciences should maintain their share of manpower, resources and research funds, in competition with other fields of science and engineering. To do so, we need to participate aggressively in political debate. In order to overcome intrinsic weaknesses, we need to seize available opportunities, encourage positive research activities, and utilize our strengths. In the future, as the knowledge-based society evolves, medical science research will play a leading role in biotechnology; hence, the policy measures described above should be implemented. Although funding of medical science research is much lower in Korea

than in the most advanced countries, such research activities can be of value to related industries in that they can facilitate the realization of policy measures, the effective execution and control of research budgets, and the ambitions of researchers.

The ongoing revolution in the medical sciences is of an unprecedented magnitude. Furthermore, it is accelerating dramatically, and it promises almost unlimited opportunity for the betterment of mankind. Despite potential obstacles and unforeseen challenges, the possibilities for progress in the medical sciences and the opportunities for medical research have never been greater. For progress in medical research to continue, sustained and sufficient funding to support the research infrastructure and to encourage innovation is necessary. Indeed, it has been shown that national investment in medical research has produced "outstandingly high returns" in the past and that sustained investment in biomedical research is likely to continue to deliver high returns, not simply by reducing mortality, but more importantly by extending healthy life.

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