Collaborative Research in Biotechnology and Role of Government-sponsored Research Institutes (GRIs)

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Introduction

Government-sponsored research institutes (GRIs) play an important role and occupy a strategic position in national innovation system. Especially, GRIs lead various kinds of research in cutting-edge research fields or technology in areas such as nano-technology and biotechnology, in which private firms cannot invest so much because of high cost and risks. The Korean government designed National Technology Roadmap (NTRM) to develop those technologies efficiently and stimulate collaborative research among universities, firms and public research institutes. NTRM contains of key technology list to be developed and promotion plans year by year to 2012. In this paper, we analyse the technology list of NTRM, especially the list in biotechnology field and matched the GRIs' research areas to the technology list. Through this matching and analysis, we suggest a few ideas about how to collaborate effectively among GRIs.

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There could be mainly two types of collaboration patterns among GRIs. The one is vertical collaborative relationship, and the other is horizontal. Vertical collaborative relationship is formed when a technology cluster grouped by technological similarity has vertical structure. Horizontal collaborative relationship is formed when a cluster has horizontal structure. In these two cases, the role of 'technological coordinator', which mainly conducts the role of funding agency, R&D planning, and designing the collaborative research, etc, is important.

Reasons for collaborative research

Knowledge production methods are changing from Mode 1 to Mode 2.[1] While Mode 1 production process has 'hierarchical', 'disciplinary', 'determinate' characteristics, Mode 2 process has 'networked', 'trans-disciplinary', 'reflexive' features. In biotechnology field, the equivalent changes are also happening. From chance discovery and random screening to rational drug design, screening by design, drug designing methods are changing.[2] The revolution in molecular biology could make this change happen. Dramatic advances in genetics, genetic engineering, peptide chemistry and molecular/cell biology have changed a lot of questions. In his study (Henderson, 1994),[3] in hypertensive drugs, the question is changed from "find me something that lower blood pressure in rats" to "find me something that inhibits the action of the angiotensin-2 converting enzyme.

In the age of chance discovery and random screening, there is a 'target rich' environment but little knowledge of biological underpinnings of specific diseases is available. Some firms and institutes have conducted large scale screening of thousands of compounds. As a result, there are enormous libraries of chemical compounds. In the era, there was relatively little communication of knowledge. But, in the age of rational drug design and screening by design, we could understand the mechanism of action of some existing drugs and the biochemical and molecular roots of many diseases. In this era, high level of information flow across the boundaries of scientific disciplines and therapeutic areas by using cross-disciplinary teams was possible.

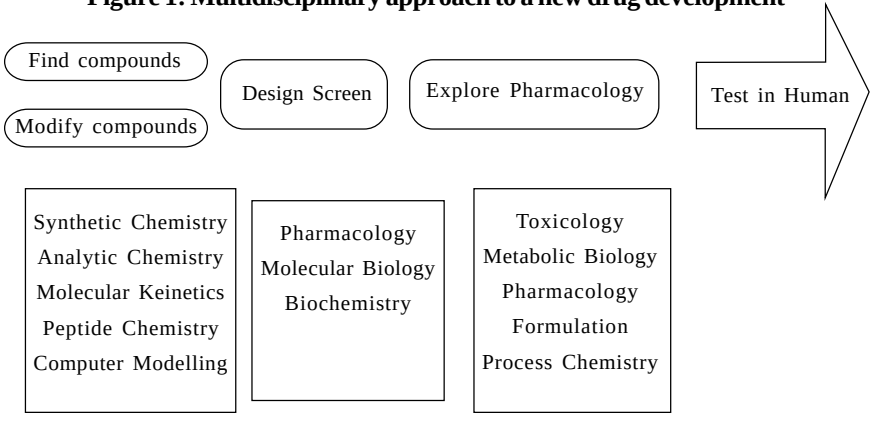
What are the factors and causes of this change? A lot of causes could be explained. Among them, publicly funded research, 'academic' companies,

and the characteristics of biotechnology itself are important factors. Lots of papers and patents addressing knowledge about the cause of disease were produced in universities and institutes. As a result, substantial advances in physiology, pharmacology, enzymology, and cell biology led to enormous progress. Universities and public research institutes played major roles. On the other hand, a lot of 'academic' pharmaceutical companies, especially dedicated biotechnology firms (DBFs) encourage both publication and the presentation of results outside the firms. Those firms also funded academic research. The characteristics of biotechnology are important, too. The industry of biotechnology is still a young science-based industry, but a burgeoning field. Rival's research efforts are complements rather than substitutes. Knowledge of their false starts and failures may help to shape one's own research programme. But in the triple helix (universities, government GRIs and industry) concept, modern bioscience has caused a massive shift in research firepower away from the 'industry' part of the helix to the 'university' and 'GRIs' component by virtue of massive rise in public research investment from the 'government' part.[4]

Collaborative research in biotechnology

Multidisciplinary knowledge fundamental to leading-edge drug discovery and the complex reality of rapidly developing fields is required. To develop a good drug, the following disciplinary fields described in Figure1 are needed.

Figure 1: Multidisciplinary approach to a new drug development



Research breakthroughs demand a range of intellectual and scientific skills that far exceed the capabilities of any single organization. There were as many as 34 coauthors in Alzheimer's disease in 'Nature'.[5] The development of an animal model for Alzheimer's disease appeared in a report coauthored by 34 scientists affiliated with two new biotech companies, one established pharmaceutical firm, and a few leading research universities.[6] There were as many as 45 coauthors in breast and ovarian cancer in 'Science' (Henderson, 1994). A publication identifying a strong candidate for the gene determining susceptibility to breast and ovarian cancer featured 45 coauthors drawn from a biotech firm, U.S. medical schools, government research laboratories, one established pharmaceutical company, etc.[7]

It is generally known that the propensity to cooperate on R&D is higher for firms and institutes from science-based or high technology based sectors with relatively high R&D intensity. Absorption capabilities depend on specific investment, including the existence of an R&D department and enough qualified human resources. Internal R&D capabilities have complex influences on the propensity to cooperate. On the one hand, cooperation may become necessary because internal resources are insufficient to meet the firms' and institutes' strategic goals. On the other hand, the existence of adequate absorption capabilities increases the returns firms and institutes can expect from access to external resources. Especially, this second effect has been found to be stronger in biotechnology (Arora and Gambardella, 1990).

There could be two types of collaborative research patterns among research organizations. Vertical collaborative relationship is formed when the technology cluster grouped by similarity has vertical structure as shown in Figure 2. The technological coordinator plays a role of tuning the flow of the research among each stage. So, the technological coordinator should cover the whole process of research and development. Generally, vertical R&D cooperation is more frequent than horizontal cooperation with rivals.

Horizontal collaborative relationship is formed when the technology cluster has horizontal structure as shown in Figure 3. The technological coordinator should cover main sub areas of the cluster. Horizontal cooperation with rivals is more frequent in high-tech sectors.

Figure 2: Vertical technology cluster and technology coordinator

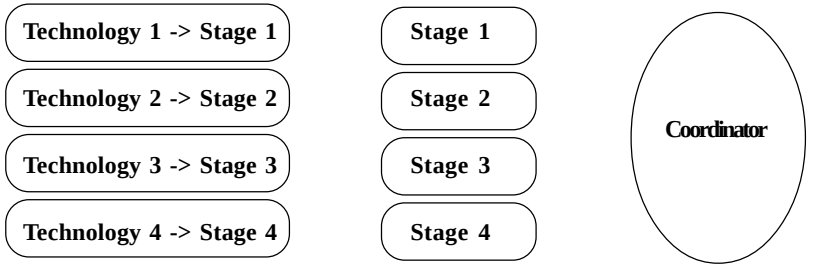
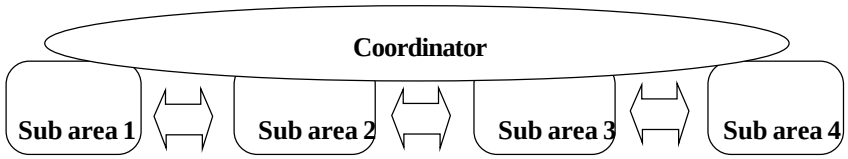


Figure 3: Horizontal technology cluster and technology coordinator



The roles of technological coordinators include:

- R&D planning in the technology cluster
- Funding agency
- Conducting related R&D programmes
- Designing the collaborative research among 'Triple Helix'
- Commercializing technology, especially transferring technology to private sectors.

Through the behaviour of technology coordinator, we can minimize transaction cost and maximize the synergy of collaborative research.

Collaborative research among GRIs

National technology roadmap (NTRM)

Korean government planned to distribute limited R&D resources efficiently through the "selection and concentration" strategy to enhance national competitiveness. It means that intensively supporting technologies, which are likely to acquire world-level superiority in competitiveness, is important.

For this purpose, the government, mainly Ministry of Science and Technology, analyzed industries and technological trends internally and externally, selected promising key technologies that can acquire global competitiveness based on 10 years time span, and designed national technology road map (NTRM) for promoting strategic research and development programmes.[8]

Beyond forecasting industrial development and analyzing technological trend, NTRM proposes visions 10 years from now to enhance the national competitiveness, defines strategic technologies, and suggests a national technology roadmap for key technologies. NTRM provides guidelines for sharing strategies related to key technologies among the government and private sectors and for conducting research and development.

The technology list of Life Science in NTRM is identified in Table 1. Some 21 technologies are listed and analyzed. These technologies are mainly composed of such fields as 'new drug discovery and development', 'innovation in diagnosis and disease treatment', and technologies related to 'Rehabilitation'. From now on we analyze the research areas of five GRIs associated with biotechnology. There are KRIBB (Korea Research Institute of Bioscience and Biotechnology), KIST (Korea Institute of Science and Technology), KRICT (Korea Research Institute of Chemical Technology), KFRI (Korea Food Research Institute), and KIOM (Korea Institute of Oriental Medicine).

Vertical and horizontal technology clusters

The technology cluster related to 'new drug discovery and development' in NTRM is structured vertically. The number of technologies related to 'new drug discovery and development' in NTRM is nine. We can construct the technology cluster of 'new drug discovery and development' as one vertical process. To discover new drugs effectively, target recognition should be conducted at first. Target recognition category contains the target recognition technology, and the target validity verification technology. Then, candidate substance should be screened. The main technologies associated with this category are candidate substance screening technology, candidate substance

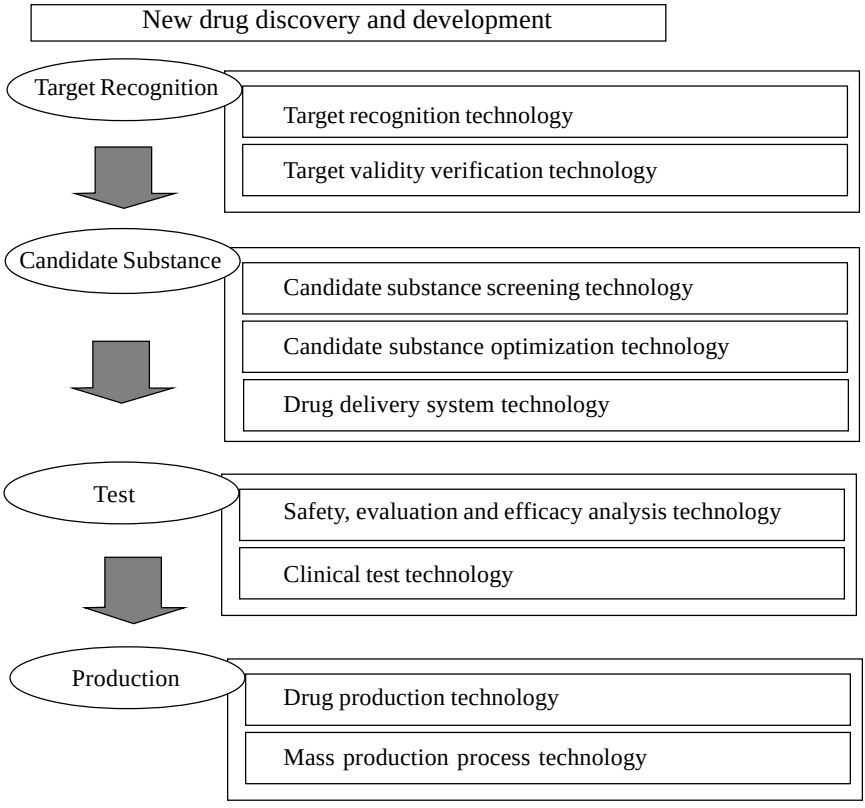
Table 1: The 21 key technologies in life science in national technology roadmap

	Technology title
A	Biological diagnosis technology
B	High-speed analysis system technology
C	Target recognition technology
D	Target validity verification technology
E	Candidate substance screening technology
F	Candidate substance optimization technology
G	Mass production process technology
H	Drug production technology
I	Drug delivery system technology
J	Safety, evaluation and efficacy analysis technology for medicine
K	Clinical test technology
L	Handling technology of biological signal process
M	Handling technology of biological image process
N	Body function analysis technology
O	Bio-machine/robotics technology
P	Bio materials technology
Q	Stem cell cultivation technology
R	Gene identifying and conveying technology
S	Monitoring technology of biological function
T	Bio-information creation and preservation technology
U	Bio-information utilization technology

optimization technology, and drug delivery system technology. Next test should be done, and then production begins. The four processes are linked vertically. We can represent the process in Figure 4.

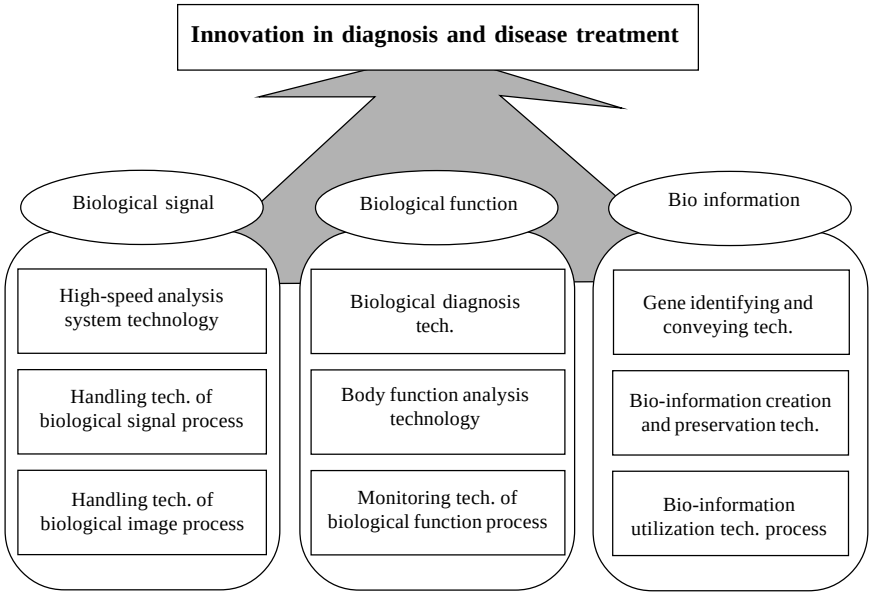
Horizontal collaborative relationship is formed when the cluster has horizontal structure. The technology cluster related to 'innovation in diagnosis and disease treatment' is structured horizontally. In this case, GRIs should form horizontal relationship. Technologies related to 'innovation in diagnosis and disease treatment' in NTRM are as follows.

Figure 4: Vertical technology cluster: new drug discovery and development



The technologies related to 'innovation in diagnosis and disease treatment' could be structured horizontally as in Figure 5. It could be divided into three major categories. Each category forms the horizontal relationship. The category associated with 'Biological Signal' contains the high-speed analysis system technology, handling technologies of biological signal process, and handling technology of biological image. The category related to 'Biological Function' has such technologies as biological diagnosis technology, body function analysis technology, and monitoring technology of biological function. The bio-information category consists of gene identifying and conveying technology, bio-information creation and preservation technology, and bio-information utilization technology. Each category is structured relatively

Figure 5: Horizontal technology cluster: innovation in diagnosis and disease treatment



horizontally compared with the technology cluster of 'new drug discovery and development'. Here, the own success in each technology field is more important. Then the horizontal collaborative relationship could be formed effectively.

The technology list related to 'Rehabilitation' contains bio-machine/robotics technology, bio-materials technology, and stem cell cultivation technology.

Technological coordinators in the collaborative research

In these two cases, the role of 'technological coordinator' is important. Technological coordinator plays a role like tuning the flow of the research between each research stage in vertical collaborative research. Technological coordinator also plays a role like combining each research output in horizontal collaborative research. It also plays the role of R&D planning in the technology cluster, funding agency, conducting related R&D programmes, designing the collaborative research among 'Triple Helix',

commercializing technology, especially transferring technology to private sectors.

How can we select the technological coordinators in the research process? Figures 6 and 7 show the prominent candidates of technological coordinators in terms of research area covered by GRIs. According to Figure 6, KIST and KRIBB cover the whole vertical processes of 'new drug discovery and development'. Other GRIs cover the field partly. To succeed in developing the new drugs, the four procedures should be conducted very efficiently and should be closely linked together. The vertical relationship between GRIs is accented and the R&D programme should be conducted collaboratively. From Figure 7, we can choose KRIBB as a good coordinator in the horizontal technological cluster, 'innovation in diagnosis and disease treatment'.

Figure 6: Technological coordinators in vertical technology cluster

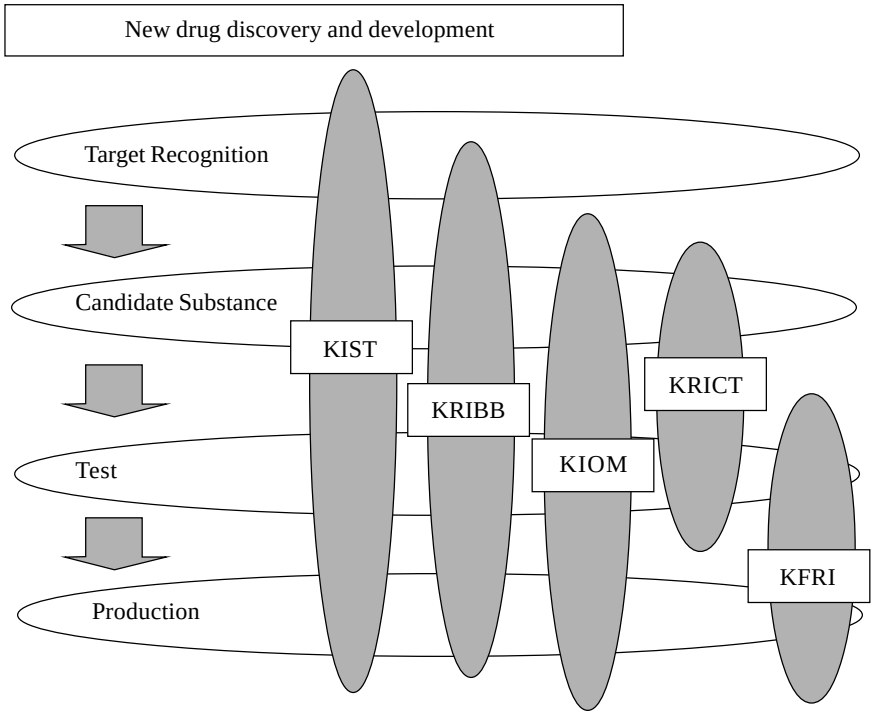
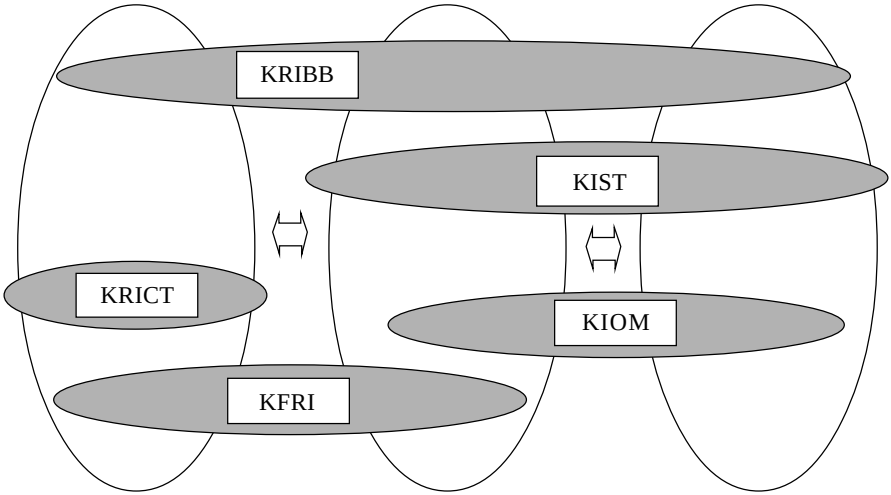


Figure 7: Technological coordinators in horizontal technology cluster



Conclusion

It is clear that there are two types of collaborative research patterns among GRIs. Vertical collaborative relationship is formed when the technology cluster grouped by similarity has vertical structure. For example, the technology cluster related to 'new drug discovery and development' is structured vertically. When GRIs should conduct co-research, they should consider this point. We could construct the technology cluster of 'new drug discovery and development' as one vertical process, target recognition, candidate substance, test, and then production. The four processes are linked vertically. Among GRIs, KIST and KRIBB cover the whole vertical process of 'new drug discovery and development'. Other GRIs cover the field partly.

On the other hand, horizontal collaborative relationship is formed when the cluster has horizontal structure. The technology cluster related to 'innovation in diagnosis and disease treatment' is structured horizontally. It could be divided into three major categories. Each category forms the horizontal relationship. The categories are biological signal, biological function, and bio-information. In this case, GRIs should form horizontal relationship.

In these two cases, the role of 'technological coordinator' is important. Technological coordinator plays a role like tuning the flow of the research between each research stage in vertical collaborative research. So if KIST and KRIBB could be technological coordinator, the whole process may probably be linked effectively. Technological coordinator also plays a role like combining each research output in horizontal collaborative research. Those two institutes can play the role of coordinator well in the horizontal cluster in view of tuning the research flow.

Endnotes

1 Etkowitz & Leydesdorff, 1997.
2 Henderson et al., 1999.
3 Henderson, 1994.
4 Cooke, 2002 and 2003.
5 Henderson, 1994.
6 Nature, Feb., 1995.
7 Science, Oct., 1994.
8 Ministry of Science and Technology *et al*., 2002.

References

Arora, A., Gambardella, A. 1990. Complementarity and External Linkages: the Strategies of Large Firms in Biotechnology. *The Journal of Industrial Economics* XXXVIII (June), 361–379.

Cohen, W.M., Levinthal, D.A. 1989. Innovation and Learning: the Two Faces of R&D. *Economic Journal* 99, 569–596.

Cooke, Philip. 2002. Rational Drug Design and the Rise of Bioscience Megacenters. The Fourth Triple Helix Conference, Copenhagen November 6-9.

Cooke, Philip. 2003. Networks and Hierarchies in Bioscientific Knowledge Management. DRUID Summer Conference 2003, Copenhagen June 12-14.

Etkowitz, H. & Leydesdorff, L. (eds) 1997. Universities and the Global Knowledge Economy, London: Pinter.

Galambos, L., Sturchio, J. 1996. The Pharmaceutical Industry in the Twentieth Century: A Reappraisal of the Sources of Innovation. *History and Technology,* Vol.13 No.2, pp. 83–100.

Henderson, R. 1994. The Evolution of Integrative Capabilities: Innovation in Cardiovascular Drug Discovery. *Industrial and Corporate Change,* Vol.3, No.3, pp. 607–630.

Henderson, R. and I. Cockburn. 1996. Scale, Scope and Spillovers: The Determinants of Research Productivity in Drug Discovery'. *Rand Journal of Economics* Vol. 27, No.1, pp. 32–59.

Henderson, R., Orsenigo, L., Pisano, G.P. 1999. The Pharmaceutical Industry and the Revolution in Molecular Biology: Exploring the Interactions between Scientific Institutional and Organizational Change, In: Mowery, D.C., Nelson, R.R. (eds.), *The Sources of Industrial Leadership*. Cambridge, MA: Cambridge Univ. Press.

Lee, Yong-Gil, Se-Jun Lee, Tai-Yoo Kim. 2003. Identification of Generic Technologies in Life Science Area: Evidence from an Institutional Level in South Korea. *The Portland International Conference on Management of Engineering and Technology (PICMET'03)*, Portland, Oregon USA. July, 20~24.

Luis Miotti, Frédérique Sachwald. 2003. Co-operative R&D: Why and with Whom? An Integrated Framework of Analysis. *Research Policy* 32, pp. 1481–1499.

Ministry of Science and Technology *et al.* 2002. *National Technology Roadmap - Outline*. Seoul: KISTEP.

Pisano, G.P. 1991. The Governance of Innovation. Vertical Integration and Collaborative Arrangements in the Biotechnology Industry. *Research Policy* 20, 237–249.

Powell, W.W. 1996. Interorganizational Collaboration in the Biotechnology Industry. *Journal of Institutional and Theoretical Economics* Vol.152, No.1, pp.197–215.

Powell, W.W., Doput, K.W., Smith-Doerr, L. 1996. Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology. *Administrative Science Quarterly* Vol. 41, pp. 116–145.

Won, Yoo-Hyung, Se-Jun Lee, Yong-Gil Lee, Sung-Bae Park. 2003. How to Identify the Strategic Research Position of Public Laboratories in Nation's Innovation System?: A Case from Korean Government-Sponsored Research Institutes (GRIs). *The 12th International Conference on Management of Technology IAMOT 2003*, Nancy, France. May, 13~15.