# Accumulation and Circulation of the Knowledge Needed for Biotech Business Promotion by Engineers of RD Section in an IT Enterprise: The Case of Hitachi Software Engineering Co., Ltd

Ohta, Hirofumi and Motohashi, Kazuyuki

December 2011

www.sbm.itb.ac.id/ajtm

The Asian Journal of Technology Management Vol. 4 No. 1 (2011) 1-15

# Accumulation and Circulation of the Knowledge Needed for Biotech Business Promotion by Engineers of R&D Section in an IT Enterprise: The Case of Hitachi Software Engineering Co., Ltd

Hirofumi Ota,[1]*[*] and Kazuyuki Motohashi[2]
[1]Department of Advanced Interdisciplinary Studies, Graduate School of Engineering, The University of Tokyo, Japan.
[2]Department of Technology Management for Innovation, Graduate School of Engineering, The University of Tokyo, Japan.

***ABSTRACT***

*Much research has been carried out on the accumulation and effective use of knowledge as a company-specific form of intellectual property. However, insufficient attention has been given to research focusing on the effects of micro-level knowledge absorption and its effective use. In this paper, we try to demonstrate what should be done in order to promote new biotech business from the perspective of each engineer's knowledge, through a micro-level investigation focusing on the life science business section of one IT enterprise. Based on the results of a questionnaire survey of engineers, interviews of several engineers, and patent data analysis, we discuss the progress of the biotech business in an IT enterprise from the aspect of accumulation and circulation of knowledge in a core technology field, the IT business, and a technology field of new entry, the biotech business. This paper reports that the positive growth cycle of biotech business promotion in an IT enterprise, using Hitachi Software Engineering Co., Ltd. as a case, attained by incorporating the latest biotech knowledge from junior engineers and utilizing IT knowledge from middle engineers leads to the recruiting of qualified students.*

*Keywords: accumulation and circulation of the knowledge, biotech business, open innovation, patent data analysis, questionnaire survey.*

[*] Correspondence author. Email: h-ota@mo.t.u-tokyo.ac.jp.

## 1. Introduction

Much research has been carried out on the accumulation and effective use of knowledge as a company-specific form of intellectual property. Asakawa and Nakamura (2005) studied the influence for the attainment of research results of individual researchers in research institutions of pharmaceutical industries, from knowledge acquisition through the collaboration with internal and external sections or institutions. Their research indicates that the acquisition of knowledge from coworkers other than those in the R&D section, exchanges with in-house sections, and the active acquisition and utilization of leading-edge knowledge of research institutions such as universities and academic societies are important for the attainment of research results of individual researchers. On the other hand, Collis and Montgomery (1997) pointed out that the exploitation of new business should absolutely be the source of sustainable growth as well as competitiveness for enterprises, and that knowledge management would be indispensable for that. In fact, it is indicated by several experimental studies that the resources which give rise to the diversification as well as the opportunity of business diversification play an important role.

For example, it is demonstrated that a number of diversifications occur in the business field where R&D rate is substantially high, which means technical know-how facilitates the activities toward the diversification (Ravenscraft and Scherer, 1987). Also, it is shown that marketing resources as well as skills are the important driving forces for the diversification of business (Montgomery and Hariharan, 1991).

Now then, what should enterprises do in order to promote the new business from the knowledge management point of view? According to the report of Narula (2001) and Motohashi (2005), many companies chose independent research and development for R&D with the core technology development of their own, while the success probability would be raised by a linkage to the preceding enterprise or an alliance with external specialized institutions in a new field with high uncertainty for its company. However, insufficient attention has been given to research focusing on the effects of micro-level knowledge absorption and its effective use toward such R&D systems as Independent Research and Development, and a linkage or an alliance.

In this study, with the aim of validating the report of Narula (2001) and Motohashi (2005) on an individual basis, we attempt to demonstrate what should be done in order to promote new business from the perspective of the knowledge of individual engineers through the micro-level investigation. By giving questionnaires of individual engineers belonging to the life science business section of one IT enterprise promoting the life science business as a technology field of new entry, we investigated what kind of knowledge is required, and from where the knowledge can be acquired for the attainment of research results by individual engineers. In order to attain research results for each engineer, we study what type of knowledge is required from which engineer.

We conducted a questionnaire survey at Hitachi Software Engineering Co., Ltd. (hereinafter, HitachiSoft), which in 1970 began the development of databases related to operating systems (OS), networks, and banking systems, starting with the development of OS for mainframes for Hitachi, Ltd. HitachiSoft is a major system integrator, and has abundant experience in system architectures for several industries, including macro scale and mission-critical operation systems. Today, HitachiSoft offers a wide range of IT solutions such as security, Felica, the interactive whiteboard, satellite imagery, and electronic documents, and also provides solutions in the life sciences to support genomic analysis, transcriptome analysis, metabolome analysis, etc.

HitachiSoft's life science business was launched in 1983, and solutions such as the gene sequence analysis software 'DNASIS,' laser scanning image analyzer 'FMBIO,' and the biochip 'AceGene,' developed in cooperation with DNA Chip Research Inc., etc have been provided to the market since then. HitachiSoft holds the top spot in domestic sales for DNA chip solutions (with a 23% domestic share of DNA chip fabrication appliance sales), sales of DNA chip analysis equipment (10%), and DNA chip sales (4%), and hence can be seen as a best practice of start-up business.

The structure of the main discussion is as follows. In Section 2, we introduce HitachiSoft's life science business. In Section 3, we present a theoretical framework for a hypothesis about the acquisition and provision of knowledge in the life science division, along with the contents of the questionnaire survey. In Section 4, the data from the questionnaire survey and the result of analysis are presented. In Section 5, we discuss the results, using patent data analysis and follow-up interviews to chief engineer and chief scientist at HitachiSoft. Lastly, in Section 6, we offer a conclusion, based on the above.

## 2. HitachiSoft's Life Science Business

From our interviews of several engineers at HitachiSoft, it was found that HitachiSoft's life science business developed in the following steps. The business started at the beginning of the 1980s, with several IT engineers launching biotechnology research mainly related to sequencer technology. They developed tools focusing on data entry under the concept of processing DNA sequences written by hand. Thereafter they began to develop software packages using evaluation chances by external researchers. This led to the commercialization of DNASIS, a gene sequences analysis software package. As of 2006, approximately 20,000 copies of DNASIS had been shipped. Thus, DNASIS is still used extensively in university laboratories.

HitachiSoft realized that to expand its business in the life sciences, it would have to go beyond selling only software, and in the late 1980s began to investigate utilizing fluorescent instead of radioisotopes for gene sequences determination. It received technological assistance from the Central Institute of Hitachi, Ltd., and went into the equipment business with the commercialization of FMBIO, a laser scanning image analyzer, at the beginning of the 1990s. A complementary relationship between hardware for software sales and software for hardware sales was created through the release of FMBIO. FMBIO has been used for gene analysis in the US and the research field of expression analysis in Japan since 1994. As of 2006, approximately 500 units had been shipped, and FMBIO is still used for criminal investigations in the US.

Subsequently, in 1995, Professor Patrick Brown and other members of Stanford University announced that gene expression could be analyzed using a microarray, in a continuing series, and Affymetrix produced the first commercial DNA chip in 1996. HitachiSoft, which was seeking to develop new products to follow DNASIS and FMBIO, strengthened into the life science division, hiring engineers with completely new skills, with the aim to shift the technology field from sequencer technology to microarray technology. At the same time, HitachiSoft sent engineers as research students to universities and other educational institutions beginning in the mid-1990s, deepened its partnership with Professor Ken'ichi Matsubara of Osaka University (at that time), an authority in chemical biology, in order to win the backing of its business.

Later, a plan was hatched for the foundation of a bio-venture with Dr. Matsubara, who would soon retire from Osaka University, in line with HitachiSoft's idea of promoting the DNA chip business. HitachiSoft subsequently deepened its partnership with DNA Chip Research Inc., the company founded by Dr. Matsubara, through investment, and eventually released AceGene in 2002. Currently, HitachiSoft is carrying out research on the movement from converted-type chip to focus-type chip, with the aim of expanding the application to the fields of pathology analysis.

We present the relationship with Hitachi, Ltd. and DNA Chip Research Inc. in the life science business of HitachiSoft. Hitachi, Ltd., which entered the life science business in the mid-1980s, mainly approaches the business from the basic research side, chiefly undertakes the development of products such as clinical devices and sequencers, and entrusted development business. By contrast, HitachiSoft is chiefly engaged in software package development and system integration, from a user oriented perspective. DNA Chip Research Inc., for its part, handles all phases from the development of DNA chip contents to experimental system development, while HitachiSoft manufactures DNA chips based on its information processing business.

As of 2006, the life science business of HitachiSoft has been managed by the Life Science Department, which has approximately 70 engineers engaged in R&D including employees temporarily transferred to affiliated companies. The R&D-related organization can be roughly classified into two sections, Biotech Section, and IT Section. The main work of each section and the general resource distribution are as follows.

Biotech Section: Takes charge of "wet" gene experiments which are needed for biochip development and for the biotechnology support needed for biotech-systems development, etc. The number of affiliated engineers is about twenty.

IT Section: Takes charge of information processing of the experimental data obtained from wet experiments, construction of the information processing systems, new algorithm development, and evaluation of analytical skills required for experimental data analysis, etc. The number of affiliated engineers is about fifty.

Remembering the implications from previous works, the history of HitachiSoft, and the steps in the progress of HitachiSoft's life science business as discovered through the interviews with several engineers of HitachiSoft, we can define HitachiSoft's IT business as its core technology field, and its biotech business as a technology field of new entry, from its entry into the DNA chip business in 1995 until the present. In addition, biotech knowledge and IT knowledge refer to the knowledge necessary to perform operations in each section. In this paper, "junior engineer" means a regular engineer while "middle engineer" does an engineer who holds a responsible position. At the same time, "staff" and "senior or above" are used as synonyms for "junior engineer" and "middle engineer" respectively. These words are used in accordance with the context hereafter.

## 3. Theoretical Framework & Hypothesis

### *3.1. Internal and external dependencies of knowledge acquisition in the core technology field and the technology field of new entry*

Chandler (1997, 1990) pointed out that big companies of twentieth century produced the economy of scale and scope by the diversified business as well as the vertical integration from R&D to distribution, thus establishing the competition advantages against the minor or new entry businesses.

On the other hand, Chesbrough (2003) indicated that the innovation models of vertical integration by Chandler (1977, 1990) reached a limit through the practical researches for the industries in late twentieth century US. As a reason for that, he pointed out that especially the high-tech companies became to have a high knowledge fluidity by a high labor fluidity, and venture capitals appeared and opened the knowledge companies. In addition, as the supporting evidence of the shift from Chandler model (1977, 1990), Langlois (2003) presented that the workforces have been modularized and segmentalized among companies as the necessity of the vertical integration has been lost.

Grantstrand et al. (1997) described that the creation of competitiveness in new technology fields could be vigorous learning process, and the acquisition of the external technologies as well as integration with internal technologies would be needed. In fact, Gulati (1998) presented the examples that enterprises attempted to absorb the knowledge by utilizing strategic alliance as well as supplement resources, and these kind of alliance approaches were frequently shown in industries such as biotech business which especially high technologies would be needed (Powell et al., 1996; Langlois and Mowery, 1996; Bekkers et al., 2002).

However, under the decentralized innovation or even under the open innovation, it would not be quite as simple as one paradigm switches to the other paradigm completely. Even in case of the transition from the relatively closed innovation to the open innovation, companies would not necessarily outsource their all researches as well as innovations（Christensen, 2006）. From the report of Laursen and Salter (2006), in order to ensure the success of innovation management, the relationship with the external should be crucially indispensable, it would be a given fact that companies possesses the integrative and vigorous core competences. Namely, companies bring external cutting-edge technologies into the architecture of their new products as well as enhanced products, then they put their prototypes into practical use by utilizing their core technologies（Christensen, 2006.

These previous studies suggest that HitachiSoft acquires biotech knowledge in a technology field of new entry, the biotech business, from the external, while they obtain IT knowledge in a core technology field, the IT business, from the internal middle IT engineers by shifting from Chandler model (1997, 1990). Given the discussion of Christensen (2006) as well as Laursen and Salter (2006), the following hypothesis is derived.

**Hypothesis 1:** In order to attain research results, engineers in the Life Science Department acquired more biotech knowledge in the technology field of new entry from external sources compared with IT knowledge in the core technology field, while they acquired more IT knowledge in the core technology field from internal sources compared with biotech knowledge in the technology field of new entry.

The importance of acquiring knowledge from specialized external institutions in a field such as biotechnology, for the attainment of research results is implied by Liebeskind et al. (1996). From the interviews with several engineers at HitachiSoft, we find that the specialized external institutions used by that company are the Hitachi group and DNA Chip Research, Inc. In addition, the interviews point to the essential nature of the relationships with those institutions. Here, we propose the following hypothesis.

**Hypothesis 2:** The external sources that engineers in the Life Science Department used in order to acquire biotech knowledge necessary for attaining their research results were specialized external institutions such as the Hitachi group and DNA Chip Research Inc.

### *3.2. Position dependencies of the knowledge offering in the core technology field and the technology field of new entry*

According to the historical researches including Chandler (1990), enterprises which have established technological platforms by internal R&D moved forward naturally toward developing new products by utilizing their internal accumulated knowledge, and expanded the .economy of scope. As a result, many industries launched large-scale dedicated R&D organizations, and established the entry barrier through the economy of scale by upholding specific knowledge for each enterprise continuously with bureaucratic organization structures (Teece, 1986; Chandler, 1990).

At the same time, much research has been carried out which has highlighted the importance of external technology. Cohen and Levinthal (1990) discussed about the importance of the investment for the internal researches in order to utilize the external technologies. Moreover, Rosenberg and Steinmueller (1988) argued that the enterprises would encounter profound competition disadvantages if they could not absorb achievement of external R&D. Complying with these trends, Langlois (2003) referred to post Chandler model which promotes the innovation through external technologies with nonhierarchical organization structures gathering talented staffs from both inside and outside of each enterprise.

Relating to the research mentioned above, Osono et al. (2006) examined the innovation of i-mode by NTT DoCoMo from the viewpoint of knowledge-based dynamism. They demonstrated that both the acquisition of knowledge in the new technology field, based on foreign and new knowledge assets, and the use of knowledge from the core technology field, including skills and know-how developed since the foundation of NTT DoCoMo, became the base for producing innovation, and facilitated the spiral process of knowledge creation.

Therefore, based on the previous works and the experimental study by Osano et al. (2006), in HitachiSoft, it is suggested that they provide their specific IT knowledge particularly by middle engineers under bureaucratic organization structures in the IT business, the core technology field （Teece, 1986; Chandler, 1990）, while they take the fresh and new biotech knowledge particularly by junior engineers under nonhierarchical organization structures in the biotech business, the technology field of new entry （Langlois, 2003. Hence, we deliver the following hypothesis.

**Hypothesis 3:** In order to attain research results, it is more important to incorporate biotech knowledge of junior engineers than to use biotech knowledge of middle engineers in the biotech business, the technology field of new entry, while it is more important to use IT knowledge of middle engineers rather than to bring in IT knowledge from junior engineers in the IT business, the core technology field.

## 4. Data from the Questionnaire Survey and Results of the Analysis

The questionnaire survey was conducted to elucidate the following issues. In order to attain research results in areas such as systems engineering, product development, and technical contributions to the operational division, we studied what kind of knowledge would be needed for the engineers belonging to the Life Science Department, from where the knowledge would be acquired. At the same time, in order to achieve results, we investigated what kind of knowledge would be required from which engineer.

In 2006, the questionnaire was distributed to 56 engineers out of the approximately 70 in the Life Science Department; it was not given to employees temporarily transferred to affiliated companies. Replies were obtained from 40 engineers (71.4% response rate). The number of the valid replies was 38 (67.9% valid response rate). The attributes of the surveyed engineers are shown in Table 1. Meanwhile, with the exception of attributes, up to two answers could be written for each question.

Table 1: Attributes of surveyed engineers

| position | section | |
|---|---|---|
| | Biotech | IT |
| "staff" | 10 | 13 |
| "senior or above" | 5 | 10 |

We will describe the analytical results for each of the proposed hypotheses in Section 3. Since the surveyed sample size is small, the result of chi-square test does not necessarily possess high statistical reliability. Based on the concept of Oshio (2005), we apply the Fisher's exact test to the analysis for Hypothesis 1 and Hypothesis 3 dealing with a two-by-two contingency table. On the other hand, we apply the chi-square test to the analysis for Hypothesis 2, since chi-square test is normally applied for one-by-two contingency table even with the small sample sizes.

*4.1. Internal and external dependencies of knowledge acquisition in the core technology field and the technology field of new entry*

**Hypothesis 1:** In order to attain research results, engineers in the Life Science Department acquired more biotech knowledge in the technology field of new entry from external sources compared with IT knowledge in the core technology field, while they acquired more IT knowledge in the core technology field from internal sources compared with biotech knowledge in the technology field of new entry.

The sources of biotech and IT knowledge acquired by engineers are as follows.

Table 2: The sources of the biotech and IT knowledge acquired by engineers

| sources of acquisition | knowledge | | Fisher's exact test | |
|---|---|---|---|---|
| | Biotech | IT | two-sided test | one-sided test |
| internal | 2 | 11 | 0.0394* | 0.0301* |
| external | 13 | 12 | | |

** : p<0.01 * : p<0.05 † : p<0.1

Table 2 shows that the amount of biotech knowledge acquired from external sources is significantly larger than that of IT knowledge, while the amount of IT knowledge acquired from internal sources is significantly larger than that of biotech knowledge. Consequently, the results of the questionnaire survey show that engineers in the Life Science Department, in trying to attain research results, acquired biotech knowledge in the technology field of new entry from external sources, and IT knowledge in the core technology field from internal sources. Hence, Hypothesis 1 is statistically supported. According to Ota and Motohashi (2009), HitachiSoft treats DNA chip as a new technology, and promotes DNA chip business by middle IT engineers who have the accumulated IT knowledge in a core technology field, the IT business, with proactive recruitment of fresh engineers who have completely new skills about microarray technology as well as positive linkage with prominent specialized external institutions. In addition, we interviewed several engineers of HitachiSoft again about the results above. They stated that HitachiSoft has promoted the life science business consistently as a part of its biotech information system. They have taken maximum advantage of their accumulated knowledge and know-how as an IT enterprise, while positively acquiring specialized knowledge from external sources in the biotech business, the technology field of new entry. Therefore, the report of Ota and Motohashi (2009) as well as the implications of the interview reinforced the results of our analysis of the questionnaire survey.

**Hypothesis 2:** The external sources that engineers in the Life Science Department used in order to acquire biotech knowledge necessary for attaining their research results were specialized external institutions such as the Hitachi group and DNA Chip Research Inc.

The specific external sources of biotech knowledge acquired by 14 engineers as shown in Table 2 were confirmed by separating the specialized external institutions such as the Hitachi group and DNA Chip Research Inc.

and publicly available information mainly from the Internet. The results are indicated below. Table 3, which shows the external sources from which engineers acquired biotech knowledge, shows clearly that in a significantly large number of cases they relied on publicly available information such as the Internet, while relying little on specialized external institutions such as the Hitachi group and DNA Chip Research Inc. The result of questionnaire survey shows that when going to external sources to acquire biotech knowledge for attaining research results, the engineers went not to specialized external institutions such as the Hitachi group or DNA Chip Research Inc., but to publicly available information such as the Internet. Hence, Hypothesis 2 is not significantly supported.

We discussed the results with several engineers of HitachiSoft again. They told us that engineers at their company generally use a spiral research process, investigating through the Internet based on hints acquired from specialized external institutions such as the Hitachi group or DNA Chip Research Inc., or obtained comments from specialized external institutions about their ideas culled from Internet searches. However, on the other hand, it may be becoming increasingly common for engineers to acquire biotech knowledge from publicly available information, since the Internet is more accessible to engineers than the specialized external institutions because of its physical proximity. As stated above, the results of questionnaire survey show the importance of publicly available information as a source of the primary knowledge needed for the attainment of research results by individual engineers. The reports from Liebeskind et al. (1996) and the inteviews with several engineers at HitachiSoft, which were used for the derivation of Hypothesis 2, examine closer knowledge exchanges such as the import and utilization of major knowledge compared to knowledge from publicly available information. Therefore, the fact that results obtained do not support Hypothesis 2 may be due to a difference in the type or quality of knowledge used. This idea that the sources of knowledge differ depending on the quality of the knowledge is discussed in a later section of this paper (Section 5.1).

### *4.2. Position dependencies of the knowledge offering in the core technology field and the technology field of new entry*

**Hypothesis 3:** In order to attain research results, it is more important to incorporate biotech knowledge of junior engineers than to use biotech knowledge of middle engineers in the biotech business, the technology field of new entry, while it is more important to use IT knowledge of middle engineers rather than to bring in IT knowledge from junior engineers in the IT business, the core technology field.

The following result is obtained when comparing the offering of biotech and IT knowledge from "staff" to "senior or above," with that from "senior or above" to "colleagues or staff."

Table 4: The offering of the biotech and IT knowledge from "staff" to "senior or above", and from "senior or above" to "colleagues or staff"

| from | to | knowledge | | Fisher's exact test | |
|---|---|---|---|---|---|
| | | Biotech | IT | two-sided test | one-sided test |
| "staff" | "senior or above" | 14 | 6 | 0.0091** | 0.0076** |
| "senior or above" | "colleagues or staff" | 2 | 9 | | |

** : $p<0.01$ * : $p<0.05$ † : $p<0.1$

Table 4 clearly shows that the amount of biotech knowledge offered by "staff" to "senior or above" is significantly larger than the amount of IT knowledge offered, while the amount of IT knowledge offered by "senior or above" to "staff" is significantly larger than the amount of biotech knowledge. The results of the questionnaire survey show that it is more important to incorporate biotech knowledge of junior engineers than to use biotech knowledge of middle engineers in the biotech business, the technology field of new entry, while in order to attain research results, it is more important to use IT knowledge of middle engineers rather than to incorporate IT knowledge of junior engineers in the IT business, the core technology field. Hence, Hypothesis 3 is statistically supported.

We conducted another interviews of same engineers of HitachiSoft about the results above. According to them, junior engineers expand and update biotech knowledge, both wet and dry, obtained during their school days, and provide it to seniors who do not attain biotech knowledge on a daily basis. The Life Science Department has the ability to accept the specialized biotech knowledge brought in by junior engineers. In addition, HitachiSoft, by improving its brand through cooperation with specialized external institutions, based on the deployment of engineers to the laboratories of star scientists, has been widely recognized by educational institutions providing education in new specialized biotech fields such as bioinformatics. Therefore, excellent students with experience utilizing the solutions provided by HitachiSoft came to recognize it as an important employer. Moreover, it is clear, from the interviews, that middle engineers play a role in receiving the knowledge accumulated in the enterprise and handing it down to junior engineers in the IT business, the core technology field. This confirmed the analysis of the results of the questionnaire survey.

## 5. Discussion

### *5.1. Patent data analysis*

The questionnaire survey provides analytical results about the primary knowledge needed for the attainment of research results by individual engineers. Meanwhile, data on closer exchanges of knowledge can be obtained by looking at joint applications for patents. In general, joint applications can be considered to be close collaborative achievements by the joint applicants. Hence, valuable information, complementing the results of the questionnaire survey, can be obtained by analyzing patent data. Here, we also look for the reason that Hypothesis 2 is not significantly supported.

We classified applications for patents related to life science by HitachiSoft by the end of 2003 within the yearly application base. Here, a life science related application patent means one, among all the applications filed by HitachiSoft, that contains G01N, C12M, C12N, or C12Q of the international IPC classification.

Figure 1: Joint applications with external research institutions

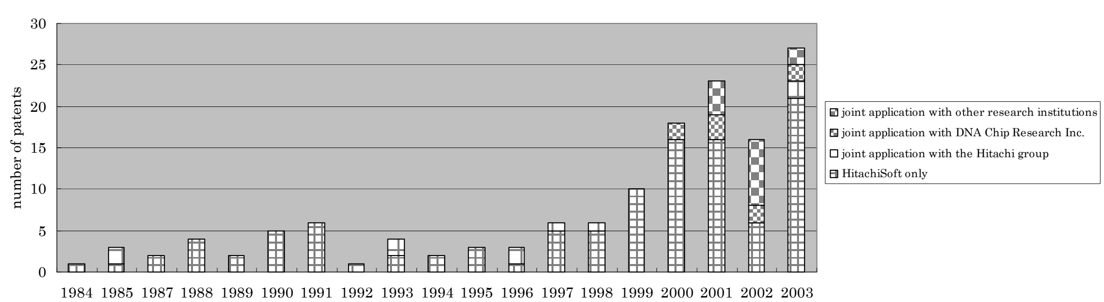



Figure 1 shows the characteristics of joint applications with external research institutions. From the figure, it is clear that there were a number of joint applications with the Hitachi group, especially in the 1990s, and that the number of joint applications with DNA Chip Research Inc. and other research institutions increased after 2000. This supports Hypothesis

1, that engineers positively acquire specialized biotech knowledge in the technology field of new entry. Moreover, based on the results of the questionnaire survey for Hypothesis 2, we obtain the implication that engineers of HitachiSoft acquire the primary knowledge needed for the attainment of their research results from publicly available information such as the Internet, while engineers acquire the major knowledge needed for making joint applications through close collaboration with specialized external institutions. Therefore, the sources of knowledge differ depending on differences in knowledge quality.

Subsequently, we classified data on patent applications in the life sciences by HitachiSoft by the end of 2003 within the yearly application base, by inventor's position, based on interviews of several engineers of HitachiSoft. Position was classified into "staff" and "senior or above" along the lines of the analysis of the questionnaire survey results.

Figure 2: The life science related application patents classified by inventor's position

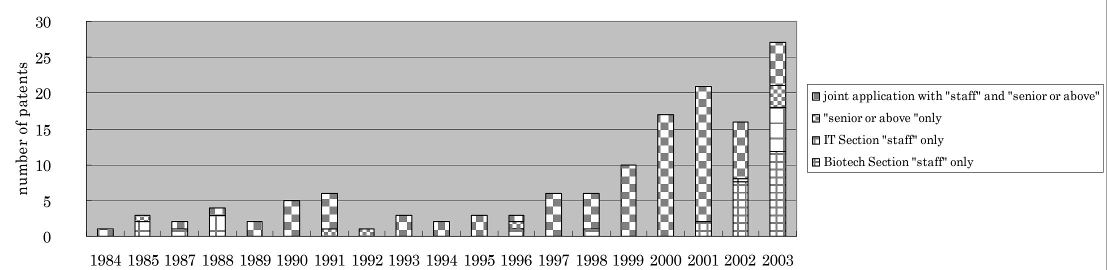
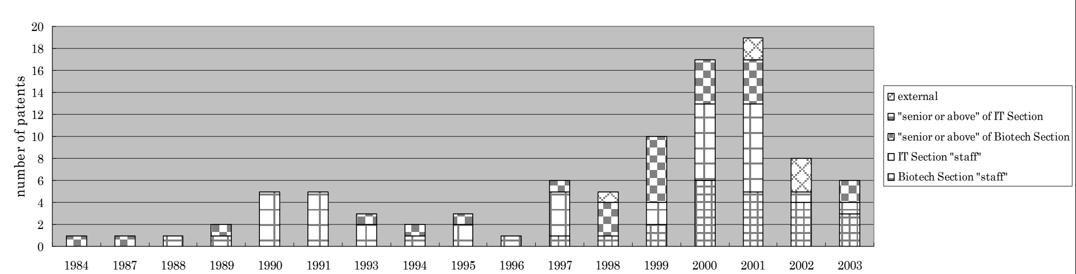



Figure 2 shows that until 2001, almost all patents were applied for under joint applications by "staff" and "senior or above," and that the number of patents began to increase with the aim to commercialize DNA chips starting in 1999. However, in 2002 and after, only the number of patents applied for by "staff" has increased, and "staff" in Biotech Section has had a high patent application rate. This implies that junior engineers in Biotech Section have specialized ability in patent applications. These numbers support Hypothesis 3, that the acquisition of biotech knowledge by junior engineers is more important than the use of biotech knowledge from middle engineers in the biotech field that is the technology field of new entry.

On the other hand, since it is clear that there are a considerable number of joint applications with "staff" and "senior or above" as shown in Figure 2; we studied the roles of "staff" and "senior or above" in joint applications. Generally, it is known that the engineer who plays the most important role in the patent application is listed as the principle inventor. Figure 3 shows the ratio of engineers in each position listed as principle inventors on joint applications between "staff" and "senior or above."

Figure 3: The ratio of engineers in each position listed as principle inventors on joint applications between "staff" and "senior or above"



From Figure 3, we find that there are several joint applications where "staff" of IT Section is listed as the principle inventors. Moreover a certain percentage of "senior or above" from IT Section are listed as principle inventors, whereas this is not true for Biotech Section. Hence, it is possible that middle engineers play a leading role in joint applications with junior engineers in IT Section. This result is in accord with Hypothesis 1, which states that engineers utilize the accumulated knowledge and know-how as an IT enterprise in the core technology field, and also supports Hypothesis 3, that it is more important to use IT knowledge of middle engineers than to incorporate IT knowledge from junior engineers.

### *5.2. Follow-up interviews to chief engineer and chief scientist*

We reinforced our hypothesis testing by the follow-up intensive interviews of two engineers, with reference to the results of a questionnaire survey of engineers and patent data analysis. Interviewees are a chief engineer of product developments whose degree is in agricultural science, and a chief scientist of genome-related researches whose degree is in mathematics.

According to them, while knowledge creation in the IT business is conducted in a cumulative way, based on existing in-house knowledge, discrete new knowledge would be more useful than improvement of existing knowledge and/or technical know-how in the biotech business. Hence, it is the most important for biotech engineers to bring in the latest knowledge from outside where it is more likely that useful knowledge exists. On the other hand, since the knowledge cumulative innovation approach is useful in the IT business, the engineering approach converting highly abstract concepts into tangible forms would be valid. HitachiSoft has established its own guidelines of the system architecture for effective software development, and the new employees at HitachiSoft should master those from the scratch, regardless of their IT-related knowledge from school days.

From a business point of view, when compared to the IT business, the more dynamic customer segment of the biotech business often requires companies to continuously acquire new knowledge from the external sources to accommodate the new customers and/or the new product development. The speed of technological progress of both IT and biotech businesses are tremendous, but the customer and the technology used is more static to some extent in IT as IT projects may continue for years. Consequently, the engineers need to follow HitachiSoft's own guidelines of the system architecture and more acquire IT knowledge from internal sources compared with biotech knowledge in order to perform those IT projects that internal cumulative knowledge and know-how could be applied.

This is the case for engineers in the Life Science Department, so that they may perceive that biotech knowledge is acquired from external sources, while IT knowledge comes from internal sources. This is consistent with our findings regarding Hypothesis 1.

As well as innovation process is occurred discretely, the speed of technological progress is very fast and the new knowledge or the hot issues are more crucial in the biotech business. In that sense they should check the trends or the latest literatures at every moment, thus making the Internet as the important knowledge base. It is common for engineers to search and study successive emergence of new concepts such as epigenetics, metaborome, proteome, omics by the Internet. Since the traditional concept would suddenly be denied in the biotech business based on the new findings, the acquisition of the new knowledge is always critical. This is consistent with our finding regarding hypothesis 2, that is, public information via internet is more useful, as compared to private information through collaborative research with the specialized external institutions.

Engineers may obtain the latest trends by the Internet, however they cannot predict the future trends. The close relationship with the external research institutions would be critical and essential to obtain their ideas or knowledge, since researchers of those external research institutions are researching future trends all the time. For example, the collaborative research of nanoscale particle with Professor Susumu Kuwabata of Osaka University was the most advanced research around 2002. A number of intellectual properties such as patents and research papers have been produced through the process of realizing the concepts of Professor Kuwabata. The company always has the key role of linking the research concept with business in the academic-industrial alliances. The above statement supported that the sources of knowledge differ depending on the quality of the knowledge. In this sense, our findings regarding hypothesis 2 may not capture the factor of information quality, and the results of our analysis should be interpreted with such reservation.

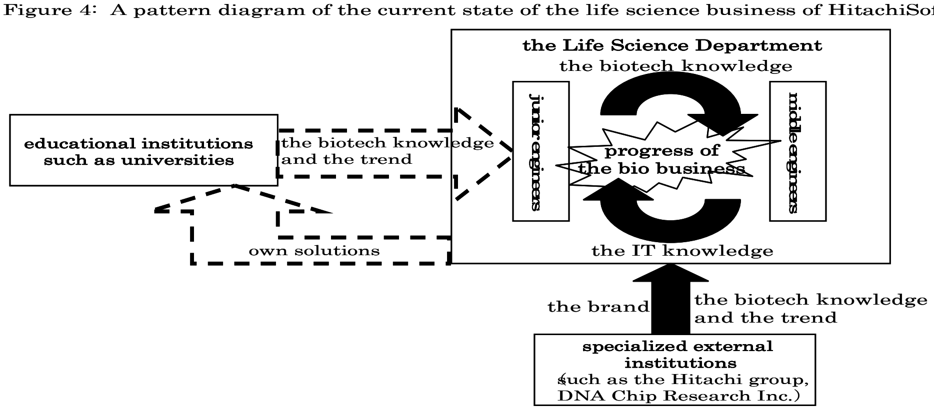
Furthermore, there is a big gap in knowledge from universities for biotech engineers between pre-genome and post-genome era. Middle engineers do not have the knowledge of molecular biology as well as the experience of handling genome sequence from their schools, while junior engineers know certain idea of those. Consequently, middle engineers are likely to ask junior engineers for their opinion in a process of genome-related research.

On the other hand, the cumulative nature of IT innovation does not change even in the generations of Web or XML. Therefore IT knowledge of junior engineers is not enough, when it is compared with that of middle engineers who have substantial experiences of software development. The above indicated that it is more important to incorporate biotech knowledge of junior engineers than to use biotech knowledge of middle engineers in the biotech business, while it is more important to use IT knowledge of middle engineers rather than to bring in IT knowledge from junior engineers in the IT business. Therefore, this is consistent with our findings regarding Hypothesis 3.

### *5.3. Synthesis of our findings*

Figure 4 shows a pattern diagram of the current state of the life science business of HitachiSoft based on the results of the questionnaire survey of engineers, the interviews of several engineers, and the patent data analysis.

Figure 4: A pattern diagram of the current state of the life science business of HitachiSoft




The current Life Science Department continuously acquires biotech knowledge and determines the trend in Biotech Section by carrying out cooperation with the specialized external institutions. We can conclude that the positive growth cycle in the biotech business, achieved by incorporating the latest biotech knowledge from junior engineers and utilizing IT knowledge of middle engineers, leads to the recruiting of qualified students.

## 6. Conclusion

In this study, we analyzed the knowledge required for the attainment of research results by individual engineers, using a questionnaire survey. First, we investigated what kind of knowledge would be required, and from where the knowledge would be acquired for the attainment of research results by individual engineers. We showed that to achieve research results, engineers in the Life Science Department acquire biotech knowledge in the technology field of new entry from external sources, while IT knowledge in the core technology field is obtained from internal sources. This result is in agreement with the studies by Narula (2001), Motohashi (2005), Liebeskind et al. (1996), and the reports by Ota and Motohashi (2009). In addition, support for the results of the questionnaire survey is obtained from interviews of several engineers of HitachiSoft. Also, the results of the questionnaire survey show that when engineers in the Life Science Department acquire biotech knowledge from external sources to attain their research results, they do not get it from specialized external institutions such as the Hitachi group and DNA Chip Research Inc., but from publicly available information, mainly from the Internet.

Based on the interviews of several engineers of HitachiSoft and the patent data analysis, we find that engineers of HitachiSoft acquire the primary knowledge needed for the attainment of their research results from publicly available information such as the Internet, while engineers acquire the major knowledge needed for joint applications through close collaboration with the specialized external institutions. Therefore, the sources of knowledge differ depending on the quality of the knowledge.

Second, in order to attain research results for individual engineers, we studied what kind of knowledge would be required from which engineer. We found that biotech knowledge of junior engineers must be provided to the "senior or above" for the attainment of their research results in the technology field of new entry. This finding is in agreement with the report of Ota and Motohashi (2009) and the implications of the patent data analysis. Hence, the implication that the incorporation of new biotech knowledge from junior engineers is important is obtained through the interviews of several engineers in the Life Science department.

On the other hand, we conclude that IT knowledge of middle engineers must be provided to their "colleagues or staff" for the attainment of their research results in the core technology field. This also accords with the report of Ota and Motohashi (2009) and the implication of the patent data analysis. From the interviews of several engineers of the Life Science Department, it is shown that using the accumulated knowledge and know-how of IT enterprise in the core technology field is important, and that this accumulated knowledge is deployed to the organization through middle engineers.

As described above, we have described the current state of the Life Science Department of HitachiSoft. It acquires biotech knowledge and determines trend in the biotech business from specialized external institutions. HitachiSoft, by improving its brand through cooperation with specialized external institutions, based on the deployment of engineers to the laboratories of star scientists, has been widely recognized by educational institutions providing education in new specialized biotech fields such as bioinformatics. Therefore, excellent students with experience utilizing the solutions provided by HitachiSoft came to recognize it as an important employer. Based on this, we have concluded that the positive growth cycle of the biotech business promotion, attained by incorporating the latest biotech knowledge from junior engineers and utilizing IT knowledge from middle engineers leads to the recruiting of qualified students.

**References**

Asakawa, K. and Nakamura, H. (2005). External and Internal Collaboration as the Sources of R&D Performance: An Empirical Investigation of R&D Researchers in the Pharmaceutical Firms. *Japanese Journal of Administrative Science*, Vol. 18, No. 3, pp. 223-234.

Bekkers, R., Duysters, G. and Verspagen, B. (2002). Intellectual property rights, strategic technology agreements and market structure: The case of GSM. *Research Policy*, Vol. 31, pp.1141-1161.

Chandler, A.D. (1977). *The Visible Hand: The Managerial Revolution in American Business*. Harvard University Press.

Chandler, A.D. (1990). *Scale and Scope: The Dynamics of Industrial Enterprise*. Harvard University Press.

Chesbrough, H.W. (2003). *Open Innovation: the New Imperative for Creating and Profiting from Technology*. Harvard Business School Press.

Christensen, J.F. (2006). *Whither Core Competency for the Large Corporation in an Open Innovation World?. Open Innovation; Researching a New Paradigm*, Oxford Press.

Cohen, W.M. and Levinthal, D.A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, Vol. 35, pp. 128-152.

Collis, D.J. and Montgomery, C.A. (1997). *Corporate Strategy: A Resource Based Approach*. McGraw-Hill/Irwin.

Fuji Keizai Co., Ltd. (2003). *Biotechnology Business Market 2003 edition*. Fuji Keizai Co., Ltd.

Grantstrand, O., Patel, P. and Pavitt, K. (1997). Multi-technology Corporations: Why They Have "Distributed" Rather Than "Distinctive Core" Competencies. *California Management Review*, Vol. 39, No. 4, pp. 8-25.

Gulati, R. (1998). Alliances and Networks. *Strategic Management Journal*, Vol. 19, pp. 293-317.

Hitachi Software Engineering Co., Ltd. (2006). *Company Overview*, obtained through the Internet: http://www.hitachisoft.jp/. [accessed 12/1/2006].

Japan Patent Office (2006). *IPC version 8 Classification Table 2006 Japanese Edition*. obtained through the Internet: http://www.jpo.go.jp/shiryou/index.htm, [accessed 5/2/2006].

Langlois, R.N. and Mowery, D.C. (1996). *The federal government role in the development of the U.S. software industry, The International Computer Software Industry: A Comparative Study of Industry Evolution and Structure*. Oxford University Press.

Langlois, R.N. (2003). The Vanishing Hand: The Changing Dynamics of Industrial Capitalism. *Industrial and Corporate Change*, Vol. 12, No. 2, pp. 351-385.

Laursen, K. and Salter, A. (2006). Open for Innovation: The role of openness in explaining innovative performance among UK manufacturing firms. *Strategic Management Journal*, Vol. 27, No. 2, pp. 131-150.

Liebeskind, J., Oliver, A., Zucker, L. and Brewer, M. (1996). Social networks, learning, and flexibility: Sourcing scientific knowledge in new biotechnology firms. *Organization Science,* Vol. 7, No. 4, pp. 428-443.

Montgomery, C.A. and Hariharan, S. (1991). Diversified Expansion in Large Established Firms. *Journal of Behavior and Organization*, pp. 71-89.

Motohashi, K. (2005). University-industry collaborations in Japan: The role of new technology-based firms in transforming the

National Innovation System. *Research Policy,* Vol. 34, No. 5, pp. 583-594.

Narula, R. (2001). Choosing Between Internal and Non-internal R&D Activities: Some Technological and Economic Factors. *Technology Analysis & Strategic Management,* Vol. 13, No. 3, pp. 365-387.

Oshio, A. (2005). *Psychological surveyed data analysis with SPSS and Amos*. TokyoTosho Co., Ltd.

Osono, E., Kodama, M., Yachi, H and Nonaka, I. (2006). *Embedded Innovation*. Hakuto-Shobo Publishing Company.

Ota, H. and Motohashi, K. (2010.12, posted). The Resources of Enterprises and The Corresponding Research and Development Strategies: The case of Canon Co., Ltd and Hitachi Software Engineering Co., Ltd. in DNA Chip Business, *The Journal of Japan Association of Administrative Science*.

Powell, W.W., Koput, K.W. and Doerr, L.S. (1996). Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology. *Administrative Science Quarterly*.

Ravenscraft, D.J. and Scherer, F.M. (1987). *Mergers, Sell-Offs, and Economic Efficiency*. The Brookings Institution.

Rosenberg, N. and Steinmueller, W.E. (1988). Why are Americans Such Poor Imitators?. *The American Economic Review*, Vol. 78, No. 2, pp. 229-234.

Teece, D.J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy*, Vol. 15, No. 6, pp. 285-305.