Koichi Hishida *Editor*

Fulfilling the Promise of Technology Transfer

Fostering Innovation for the Benefit of Society

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Preface

As one of the strongest economic stimuli to help Japan recover from the severe economic recession in the 1990s, the Japanese government took swift action in introducing various kinds of measures to effectively return university research results to society. This included establishment of the accredited technology licensing office (TLO) system in 1998 and the Japanese version of the Bayh–Dole Act in 1999. The Ministry of Education, Culture, Sports, Science and Technology (MEXT) also supported this trend by encouraging the establishment of intellectual property (IP) management offices in universities (during the fiscal years 2003–2007) and promoting international university–industry collaborations and related activities (during the fiscal years 2008–2012). Through such processes, universities acquired a new function in addition to education and research enabling them to "return research results to society." The revision of the Basic Act on Education in 2008, in which "returning research results to society" was clarified as the "third mission" of a university, accelerated this historical change.

Ways to manage inventions have changed as well, from individual- to organization (university)-oriented management, and technology transfer offices (TTO), which have come to play a central role in technology transfer activities by using the research results produced at universities. More than a decade has passed since the introduction of this new system, and each of these activities has become an important function of Japanese universities.

We at Keio University established the Intellectual Property Center in 1998 as an in-house organization. Since then, we have expanded our university–industry collaboration activities. We have accumulated necessary patents derived from the university, promoted technology transfer, and supported the creation of start-ups based on IP and joint research. Various examples of successful licensing and start-ups can easily be provided, which implies that the process of "returning research results of universities to society" has already started to become more visible. University researchers interested in university–industry collaborations have also become well aware of the significance of having an effective IP management system to obtain competitive research funds, launch joint research projects in various industrial circles, realize smooth transfers of technology, and establish start-ups. Moreover, exchanging written agreements has become common in university–industry collaborations over the years. The result is that the qualities of maintaining transparency, risk management, and compliance at universities have improved greatly.

Conversely, the expense of patent filing, prosecution, and hiring experts for technology transfer at Keio University is much larger than that of licensing income—a case similar to that of other TTOs at other universities in Japan. Although it seems difficult to change TTOs, regarded as "cost centers," into profit-making organizations, stakeholders regard the university IP management system as important for promoting university–industry collaborations, creating start-ups and facilitating technology transfer. The financial support provided by MEXT over the past decade is scheduled to finish by the end of fiscal year 2012. Now is the time for universities to consider how IP offices should function at universities.

Against this backdrop, we held a symposium on September 28, 2012, at Keio University that focused on international university–industry collaborations. We looked back at our activities of technology transfer and university–industry collaborations and explored future prospects for the activities of our IP office and technology transfer. Under the title, "Role, Challenges and Perspectives of Universities and Public Research Institutes to Foster Innovation," researchers and technology transfer and start-up experts from the USA, Europe, and Asia attended as speakers to share and exchange their knowledge and experiences.

This book aims to share the experiences and know-how discussed at this symposium in a broad manner by using free electronic publication in addition to print publication. The book contains essays by Professor Kenichi Hatori (Keio), Mr. Takafumi Yamamoto (CASTI), Professor Robert Kneller (The University of Tokyo), Professor Yasuhiro Koike (Keio), Professor Hideyuki Okano (Keio), Dr. Benjamin Chu (UCLA), Mrs. Kirsten J. Leute (Stanford), Dr. Ruth M. Herzog (DKFZ), Dr. Christopher Wasden (PricewaterhouseCoopers), and Dr. Lily Chan (NUS), who attended the symposium, and also the speech of Professor Mark Spearing (University of Southampton), who spoke at the seminar held at Keio.

Universities are expected to play important roles in the creation and dissemination of seeds of innovation for the future. To attain this goal, we need to leverage experiences of the past decade to find an effective position for universities and ways to successfully collaborate with partner industries. It will be our great pleasure if people in universities, industry, government, and public institutes concerned with this issue find this book useful in exploring powerful solutions and initiatives.

We would like to finish by expressing our greatest thanks to the writers for contributing chapters and cooperating in the editing process amid their tight academic and business schedules.

Tokyo, Japan

Koichi Hishida
Kenichi Hatori

Contents

Chapter 1
Technology Transfer from Keio University: Development of Professionals Fostering Innovation over the Past Decade

Kenichi Hatori and Koichi Hishida

Abstract It has not been long since Keio University started university–industry collaborations and technology transfer as one of its mandates. The Japanese government had great expectation for universities to overcome the recession of the 1990s and quickly developed several measures to harness universities' potentials. Keio established the Intellectual Property Center in 1998 as an internal office, almost simultaneously with other well-known Japanese universities. Thereafter, during the next decade, Keio gradually secured institutionally-owned patent applications and set about exploiting them and university–industry collaborations. The foundation for university–industry collaborations and technology transfer has accordingly been established and some successful examples can be found, but these collaborations have not reached the level of self-sustainability as with many other universities. However, not all university–industry collaborations are the same and should thus vary depending on the scale, nature, culture, and history of each university. This chapter looks back at some of the successes and activities of Keio and considers what universities can do to foster innovation for the benefit of society.

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1 Introduction

In 1858, Yukichi Fukuzawa founded a private school called Rangakujuku, which was the predecessor of Keio University (Fig. 1.1). In 1861–1862, he visited Europe to serve as an interpreter. He was overwhelmed by the advanced European culture in contrast to Edo-era Japan. The industrial revolution in the United Kingdom in the late 1700s leapt to Belgium and France in the early 1800s, and then to Germany in the late 1800s. After studying the background of this industrial revolution, Fukuzawa discovered the patent system there. Consequently he became the first man to introduce the European patent system to Japan through publishing “Seiyo jijyo” in 1867 [1]. Because the book was so popular and thus was copied for sale without author’s permission, it was said that he needed to introduce the Copyright Act to protect his work from infringement. The Japanese Patent Office started its duties approximately 20 years after he introduced the patent system to Japan.

This chapter outlines the current system of university–industry collaborations and intellectual property management at Keio University. Keio has headquarters at its Mita campus and several dispersed campuses such as the Medical School and its graduate school at Shinanomachi, the Faculty of Science and Technology and its graduate school at Yagami, and the Faculty of Environmental and Information Studies and its graduate school at Shonan Fujisawa. Each campus has research administration offices which mainly handle the management of externally acquired research funds and the office management of collaborative research agreements with external institutes. The Headquarters for Research Collaboration and Administration carries out the planning and serves as the contact office of university–industry collaboration, intellectual property management, and technology transfer [2] (Fig. 1.2).

1.1 Historical Background of Intellectual Property Management at Keio

The economy in Japan was very strong in the 1970s and 1980s. Indeed, the economy of the late 1980s was said to be a “bubble.” In the 1990s, however, the Japanese economy fell into recession. Japan rapidly lost international competitiveness from the late 1990s and the government started to reform universities to secure sources of innovation to overcome this recession [3]. This was similar to the situation in the United States in the early 1990s. When Japan and Germany were prosperous in the 1970s, the United States was suffering from a recession and decided to start to strengthen intellectual property strategies, including the promotion of technology transfer from universities to industry. The symbolic legal revision of this was the Bayh–Dole Act [4], which the United States introduced for the first time in 1980. Triggered by this law, patent applications derived from university research results were to be owned by the university (Fig. 1.3).

The Japanese government took these policies into account and quickly introduced several new laws such as the TLO Act [5] and the Japanese version of the

Fig. 1.1 Keio University, current building (*left*); Yukichi Fukuzawa, the founder of the Rangakujuku (*right*)

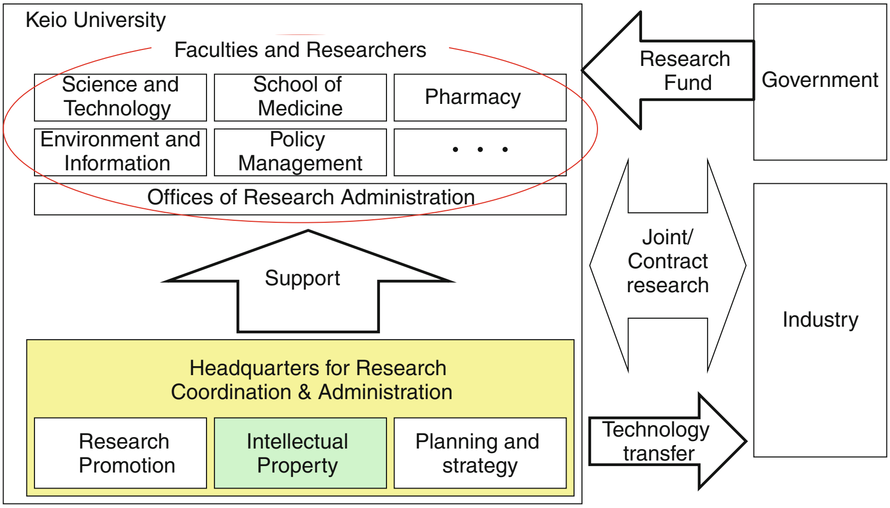

Fig. 1.2 Keio's System for Industry-University Collaboration & Technology Transfer

Bayh–Dole Act [6] to change universities to meet new demands. The Basic Act on Education was also revised [7] to include "contribution to society" as the third mission of universities in addition to "education and research." In the midst of these movements, Keio established in 1998 the Intellectual Property Center to embark on management of institutionally owned patent applications and technology transfer from the university. Mr. Keisuke Shimizu, former professor of the Faculty of Business and Commerce and the first director of the Center started this organization from scratch at the university. In the first 5 years, university patent applications increased steadily. Recently, Keio has nearly 130–150 domestic patent applications and nearly 30 Patent Cooperation Treaty applications per year (Fig. 1.4).

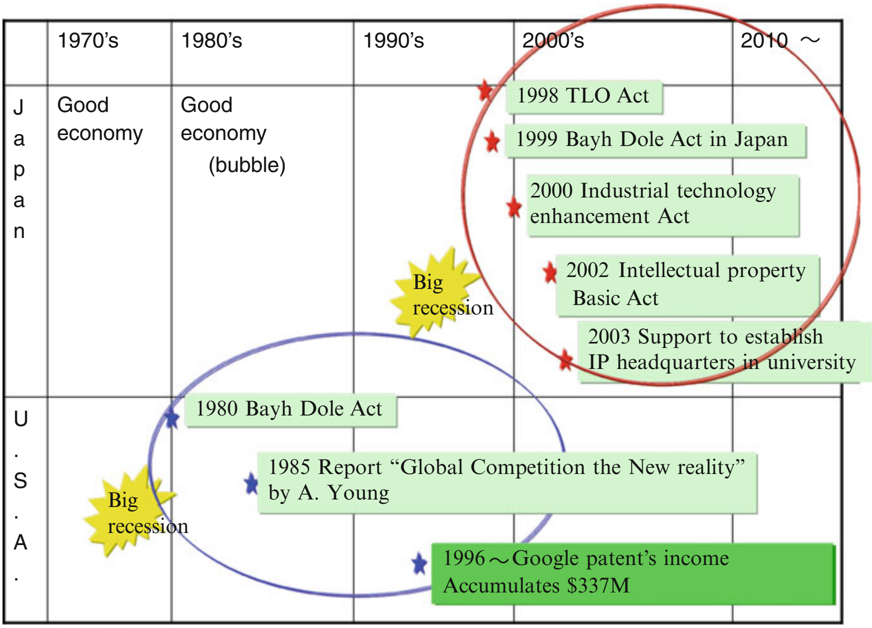

Fig. 1.3 Toward IP strategic nation—Expectation to the University

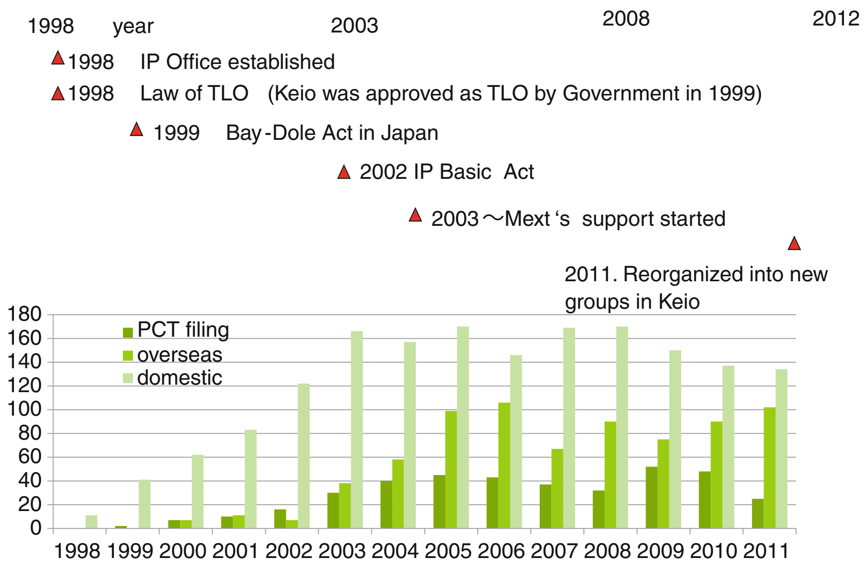

Fig. 1.4 History of intellectual property office (center/headquarters) in Keio

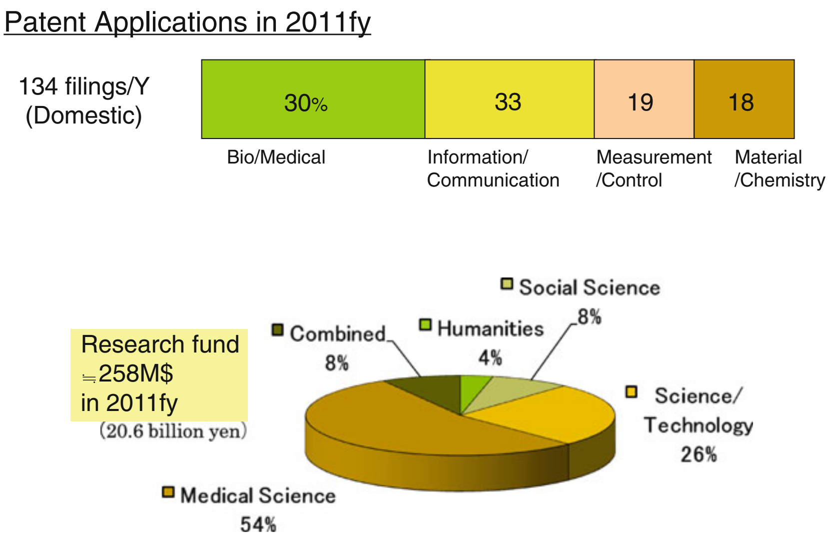

Fig. 1.5 Research Fund & Technical Fields of Keio's IP

Table 1.1 Research fund from external entities, number of IP and license revenue

	2010 fy	2011 fy
Research fund from external entities	20.09 billion ¥ (≒251 million $)	19.78 billion ¥ (≒247 million $)
Contract research	5.88 billion ¥ (≒73 million $)	4.63 billion ¥ (≒58 million $)
Joint research	1.9 billion ¥ (≒24 million $)	1.6 billion ¥ (≒20 million $)
Patent applications (domestic filing)	137	134
Patent applications (PCT filing[a])	48	25
License revenue	50 million ¥ (≒0.63 million $)	42 million ¥ (≒0.53 million $)

[a]Filing by Patent Cooperation Treaty

Patent applications were mostly in the information and communication field (33%), biology (30%), measurement and control (19%), and material science (18%) in the 2011 fiscal year. A large amount of competitive research funds awarded to Keio researchers enables creation of inventions from their promising research results. Research funds from external entities totaled nearly $247 million, contract research funds nearly $58 million, and joint research funds nearly $20 million in the 2011 fiscal year. Additionally, there were about 130 domestic patent applications, and licensing income was about $0.5 million (Fig. 1.5, Table 1.1).

2 Activities of the Intellectual Property Center

The Intellectual Property Center at Keio is an internal office with experts who do the prosecution work as well as technology transfer. Additionally, they sometimes check and study some terms of collaborative research agreements from the point of view of securing intellectual property assets and supporting startups from the university based on Keio's intellectual property. When a researcher creates an invention, an expert visits the inventor to understand the invention and make some prior art searches. On the basis of this expert's findings, Keio holds a judgment meeting to decide whether to file a patent application (Fig. 1.6).

The judgment meeting is held every week and includes the director and experts in the intellectual property division. Around 60–70% of inventions are filed, with the remainder basically being returned to the inventor. When the decision to file an application is made, the filing procedure is entrusted to an external patent attorney. After filing, an expert takes steps to transfer the technology to industry. The incentive to the inventor is very high because 42.5% of licensing income is allocated to inventors, with the remainder going to the university. Additionally, the executive director of Keio gives a Keio intellectual property award at the end of the fiscal year to the researcher making the most important achievement in the year concerning intellectual property and technology transfer activity (Fig. 1.7).

2.1 Examples of Contribution to Society Through Technology Transfer

Keio has been involved in a number of inventions that have benefitted society. For example, Professor Masanobu Maeda and colleagues, previously of the System Design Department, invented a method for the measurement of minute droplets. Previously, it was difficult to measure the size and distribution of minute droplets such as fog in engine vaporizers and air bubbles in wine because the circular outlines of these droplets overlap. This invention used an optical system to detect the overlapping circles by separating them through conversion into horizontal lines by compressing the image into the y-plane.

Another example involves a system of generating fonts from handwriting, invented by Professor Masato Nakajima, previously of the Electronics Department, and colleagues. Characters are conventionally displayed in a standard computer font, but this system allows users to turn their handwriting into a font in a very simple way. By merely inputting about ten handwritten characters into a tablet, the system analyzes the personal characteristics of the characters, such as the shape of sharp upward slants or round letters, and then memorizes it. Afterward, according to a user's preference, they can easily turn their handwriting into a font.

A number of important startups based on Keio's patents have also been made. V-cube [8] is a company established by Mr. Naoaki Mashita who invented the company's

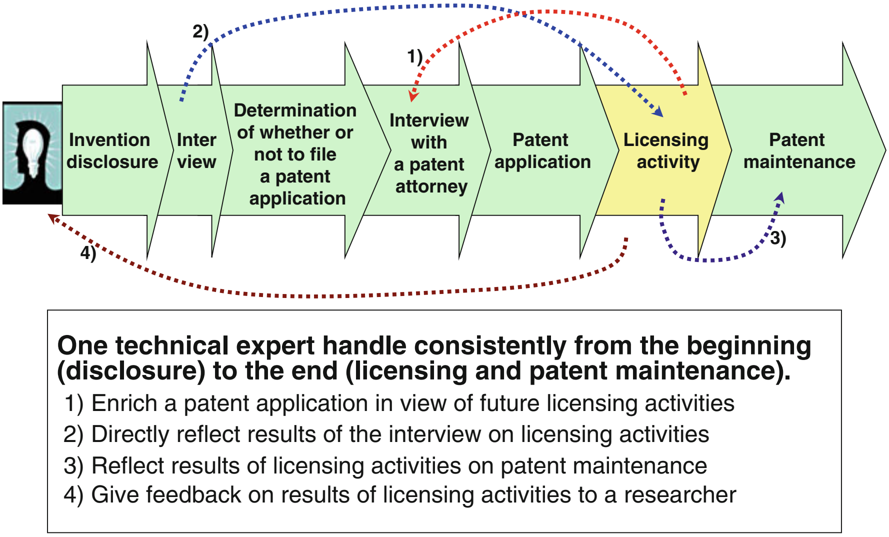

Fig. 1.6 Work Flow from invention disclosure to licensing and patent maintenance

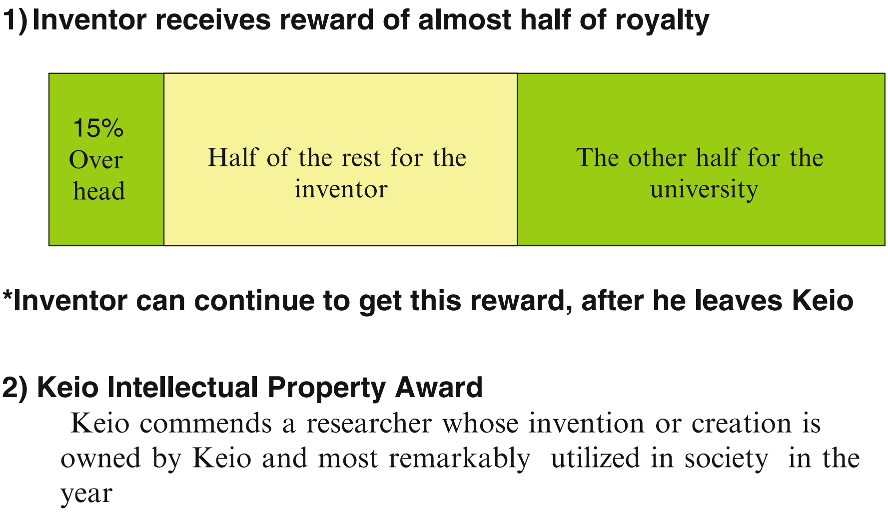

Fig. 1.7 Incentives for inventor

fundamental technology when he was a graduate student at Keio. This company provides web meeting systems and has had the number one share for 5 consecutive years in the Japanese market. Users can easily hold a web meeting among multiple people, and can display figures and lists together. Its ability to be operated in the cloud, without the need for installing any software to the user's computer, has made it attractive.

Fig. 1.8 Metabolome analysis by CE-MS equipment

Human Metabolome Technology [9] is a company established by inventor and Professor Tomoyoshi Soga and Director and Professor Masaru Tomita of the Institute for Advanced Biosciences at Keio Tsuruoka campus. This company's main business is to receive consignments of metabolome analyses from industries such as the pharmaceutical and food industries. They can examine approximately 3,000 metabolites at once with capillary electrophoresis–mass spectrometry (Fig. 1.8). In addition to this consignment work, they have attracted attention because of the possibility of detecting early stage cancers using human blood or saliva.

Another startup called SIM-Drive [10] was established by Professor Hiroshi Shimizu of the Faculty of Environmental and Information Studies. Professor Shimizu invented in-wheel motor technology which is a structure that attaches a motor inside a car's tires. It runs on batteries. The company's purpose is not to manufacture electric vehicles by themselves, but to provide the highest level of electric vehicle technology and information, at the lowest cost, to all stakeholders dealing with electric vehicles. This company's main business is to design and develop prototypes of electric vehicles and to transfer their technology for customers.

3 Challenges of Many Universities in Japan

Looking back over the past 14 years of technology transfer activities, university–industry collaborations, and startups at Keio, a number of challenges arose and were overcome. These provide instructive examples from the viewpoint of Japanese universities.

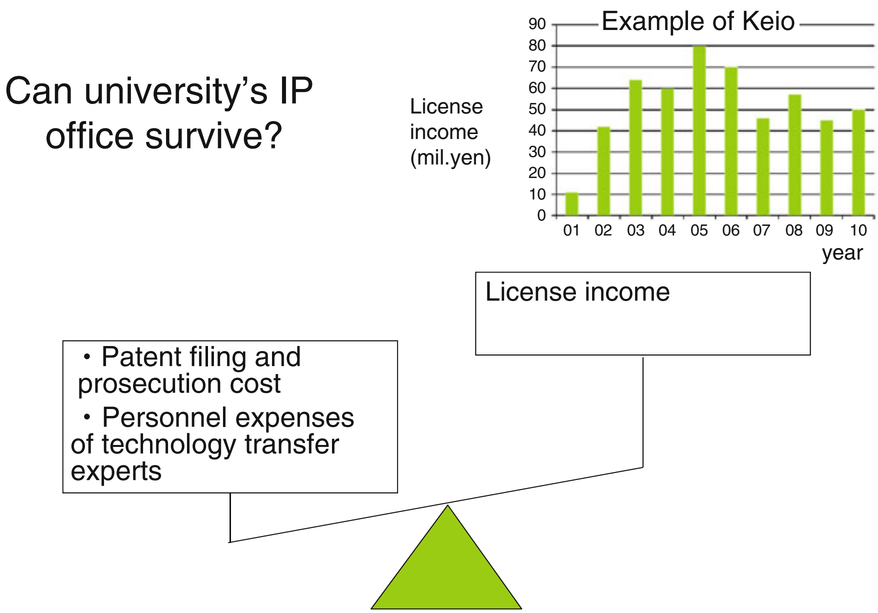

Fig. 1.9 Challenge of many universities

On the other hand, the balance of income and expenses in technology transfer at universities is a common issue. Many Japanese universities operate in the red if we consider the narrow meaning of income and expenses for technology transfer, where income consists of licensing revenue and expenses consist of patent application filing costs and employment expenses of experts (Fig. 1.9). For example, at Keio, this income has been only around 50 million yen whereas expenses have exceeded 100 million yen per year. Conversely, Stanford University and the University of California, as discussed in the previous chapter, are in the black.

Why are we in the red in Japan? We think there are several reasons. First, it has been more than 30 years since the United States established a system to use universities for industry development, including enactment of the Bayh–Dole Act and establishment of offices for technology transfer from universities to industry. Conversely, only 10-odd years have passed since the Japanese government established a similar system, including the Japanese version of the Bayh–Dole Act and a technology licensing office system.

Second, university research results are usually advances in basic knowledge, and the experiences of universities in the United States show that it takes about 10 years before basic research generates products and begins to benefit society. For example, research at Keio enabled development of a new outside-the-body diagnostic agent for the autoimmune disease systemic scleroderma. This became accepted by health insurance companies and began being sold as a diagnostic agent in 2010. It took about 10 years to reach this stage since Keio filed the patent application in 2001.

Based on this example, a period of at least 10 years is necessary to pay off a deficit. Even if the period exceeds it, it is difficult for many universities to move the licensing business (technology transfer in a narrow meaning) income and expenses into the black except at a very large university.

Do we thus abandon returning university's research results to society? We would like to say "no," because we believe that technology transfer is one of the important exits to foster innovation and a critical factor in resuscitating the Japanese economy. Additionally, the intellectual property of a university and its management plays an important role in sponsored research and startups in addition to the licensing business (Fig. 1.10). Therefore, we think it will become an important strategy for the mid and long term to continue managing the prosecution and exploitation of necessary intellectual property of a university. This includes balancing the income and expenses of all university–industry collaboration activities. Thus, we think that creation of innovation from universities can be promoted.

3.1 Required Professionals

To foster innovation and use university research results, a certain type of professional, in addition to organizational reform, is necessary. This professional should have the ability to grasp social needs and current/future issues and to plan the best matching strategy between a university's research results and industry's business/commercializing function. They must be able to execute this strategy, including bringing together stakeholders and acquiring sponsored funds from a bird's eye view to cope with these needs. We would like to name this professional the next-generation university research administrator ("Next-Generation URA") (Fig. 1.11).

Current URAs that are being deployed in some Japanese universities might be postdoctoral researchers, accountants, retired employees of companies, or other types of people not easily pigeonholed given the avant-garde nature of next-generation URAs. At Keio, we offer a leading graduate school program named "Science for Development of Super Mature Society" [11] as part of our graduate school reform. We believe that this program holds the possibility to develop a professional fulfilling the roles of this next-generation URA. This program was inaugurated in April 2012 and has started to develop a new generation of highly advanced doctoral students in a curriculum spanning 5 years. It also includes a dual Master's and doctoral degree program which integrates elements of both the sciences and humanities (Fig. 1.12).

In teaching and researching in these primary and secondary major programs, mentors from industry and government educate students and discuss with students real issues and challenges in Japan and the world based on their experiences and perspectives. Additionally, in these courses, students participate in self-planned overseas internships. This is meant to inculcate strong-willed leaders with an international outlook.

After having acquired appropriate experience in an international organization, government, and public institutions, some professionals trained in this manner might find a job in research administration or the university–industry collaboration division of a university. He or she would become a Next-Generation URA (Fig. 1.13).

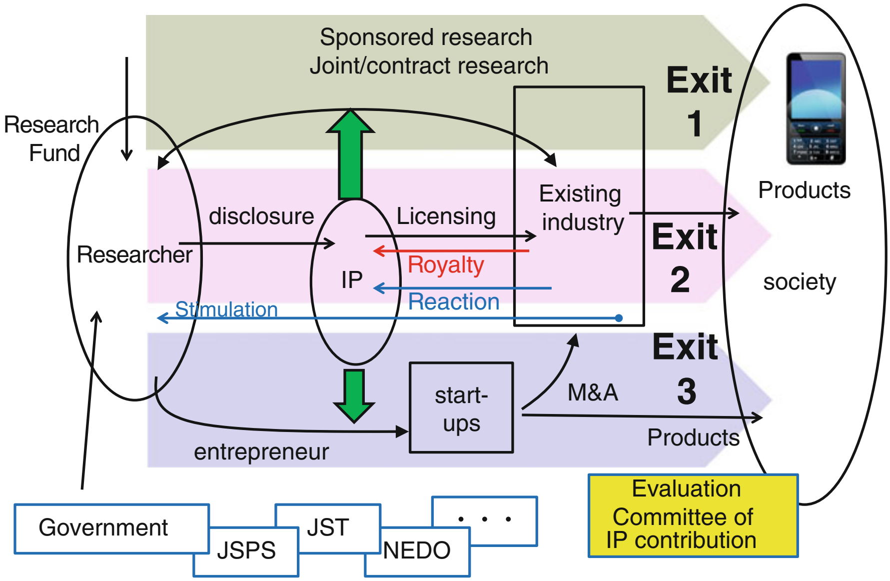

Fig. 1.10 IP for the benefit of society through three exits; joint research, licensing and start-ups

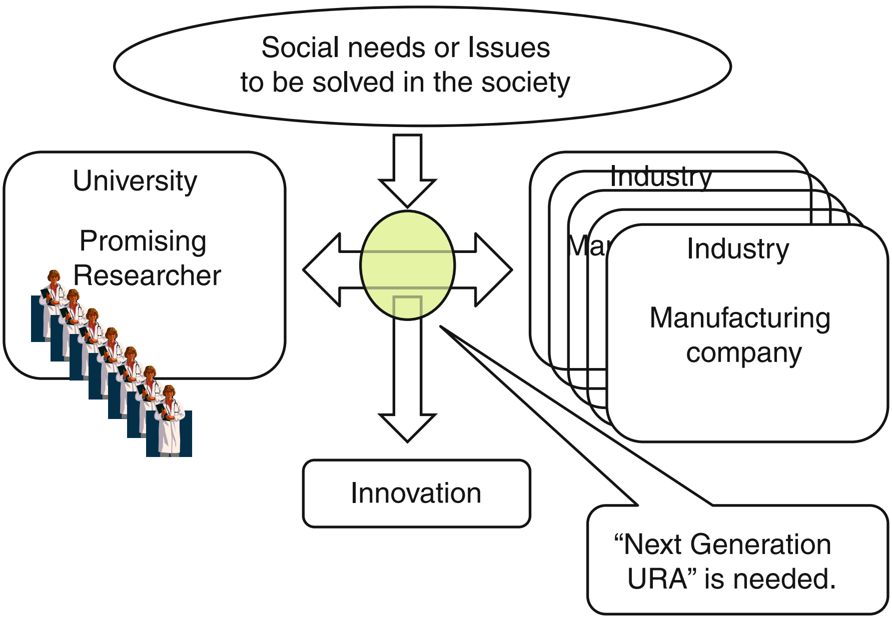

Fig. 1.11 Structure of creating innovation derived from university

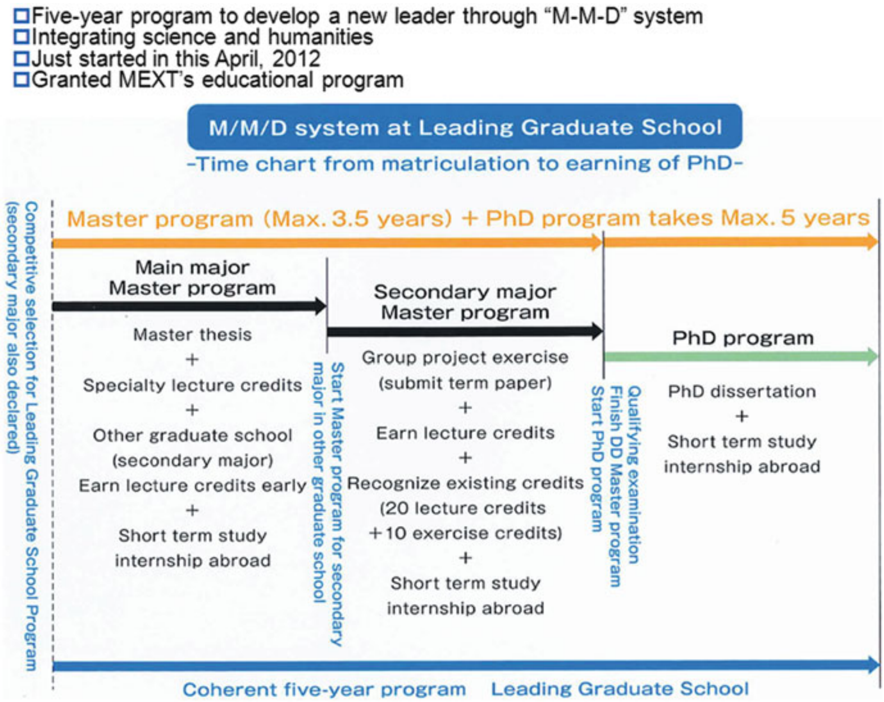

Fig. 1.12 Professional skill development—sample

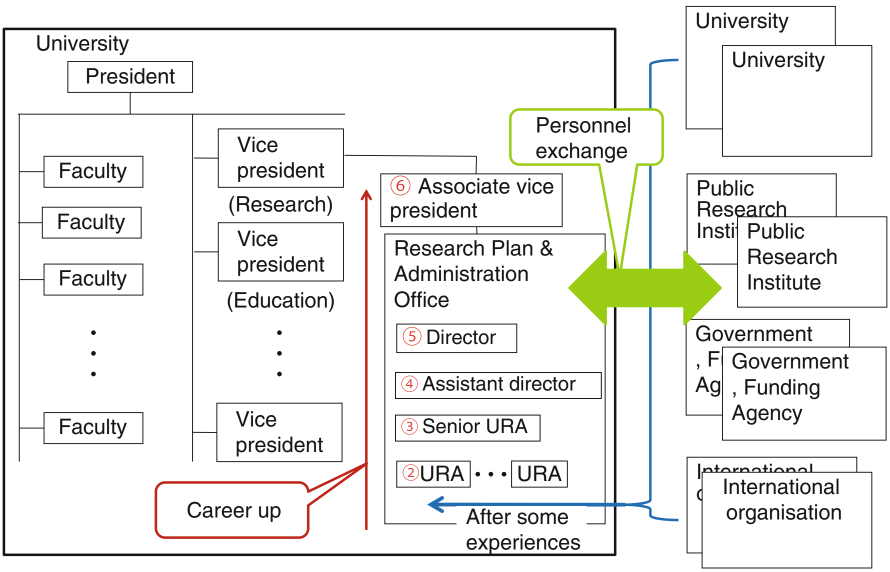

Fig. 1.13 One of the examples, "Next Generation URA"

At the university, he or she would fine-tune the outlook, planning ability, and international negotiations after interacting with a variety of people, organizations, other universities, and competitive funding agencies. In this circumstance, he or she would be expected to produce a new project tied to an invention which is a combination of the university's research results and industry's commercial ability based on societal needs.

Through his or her job, the third mission of the university "to return research results of university to society" would be carried out. It is our desire to foster innovation based on promising research results of a university on an outstanding level and he or she would enter the top of the research planning and administration office which supports the vice president responsible for the university's research.

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Chapter 2
Does Technology Transfer from Universities to Industry Contribute to Innovation?

Takafumi Yamamoto

Abstract Japan's industry-academia collaborations started against the backdrop of economic stagnation. A variety of legislation was passed, leading to the birth of technology licensing offices and head offices of intellectual property. However, industry-academia collaborations really started to take off in 2004. That is why it is too soon now to determine whether technology transfer contributes to innovation in Japan. However, the prospects for the future look bright if we take into consideration the fact that the number of licenses from universities has now reached the level that the United States was at 20 years ago and is continuing to grow steadily. Furthermore, promising university-based startup companies (university spin-offs) are continuing to form, and technology transfer intermediaries are continuing to learn and grow. Thus, technology transfer from universities to industry is likely to contribute to innovation.

1 The Background of Industry-Academia Collaborations in Japan

The growth of industry-academia collaborations in Japan occurred against the backdrop of Japan's sustained economic recession. The technology licensing organization (TLO) bill was passed in 1998, approximately 5 years after the collapse of Japan's bubble economy. At around that time in the United States, Google was born in Stanford University, Netscape was born at the University of Illinois, and Sun Microsystems and Cisco Systems, companies that had been formed more than 10 years earlier, were already growing rapidly. For Japan, the success stories of

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industry-academia collaborations in the United States had a powerful impact. In every era, people look for a silver bullet when faced with sustained economic stagnation. The Japanese government was also keenly interested in finding a way to escape from the era that would later be referred to as Japan's Lost Decade. It appears they put their hope in industry-academia collaborations. The TLO bill of 1998 led to the formation of numerous technology transfer institutions known as technology licensing organizations (TLOs) around universities. At that time, inventions made in universities generally belonged to the inventor. Thus, if the university professor who made an invention had no interest in patents, no patent application would be made, and the research results would merely be presented to academic conferences and published in technical journals. The advantageous aspect of this situation was that anyone could use published research results. However, no special advantages could accrue for Japanese companies. According to an independent survey by a large European pharmaceutical company, approximately 15% of the world's medicines were first discovered in Japanese universities. Unfortunately, the majority of these medicines were not made into products and sold by Japanese companies. Foreign pharmaceutical companies further developed the research results of Japanese universities to come up with marketable therapeutic and diagnostic medications. Because neither the university nor the researchers applied for patents in the early stages of the pharmaceutical development process, neither received royalties from the medications. Some university researchers may have been aware of the possibility of applying for patents before they released their findings to the public. However, for researchers who believe that having their research results recognized is everything, applying for patents and forming licensing contracts seemed like extraneous labor. That is why the majority of research results were provided to industry free of charge.

To change this situation, it was necessary to make the technological findings of universities into intellectual property before transferring them to industry. TLOs were established as specialized organizations for carrying out this conversion and transfer of technology. Also, in 1999, the year after the TLO bill was passed, the Japanese version of the Bayh–Dole Act was passed. This law stipulated that the results (primarily patents) of research funds from the government belong not to the government but to the university to which the researchers belong. The passing of this law in 1980 in the United States had a significant impact on the state of industry-academia collaborations. However, the impact of the Japanese version of the Bayh–Dole Act was not actually felt until 2004. This is because until 2004 national universities did not have corporate status; just as the universities did not have their own land (at the time, the land of a national university belonged to the government of Japan), they also did not have their own patents. The legal framework truly came to resemble that of the United States when national universities gained corporate status in 2004. Thus, industry-academia collaboration activities in Japan became fully functional in 2004. It is thus still too early to argue about the effects of industry-academia collaborations in Japan. This is because at Stanford University, for example, licensing started to earn the university money about 15 years after the foundation of the Office of Technology Licensing (OTL). Also, after the founding of Stanford's OTL, Niels Reimers was dispatched to the Massachusetts Institute of Technology (MIT) and used his experience to create a TLO there. It took about 10 years for licensing to start earning MIT money. Given these examples, it seem that the effects of industry-academia collaborations in Japan will start to appear sometime after 2015.

2 The Position of Industry-Academia Collaborations and Innovation in Japan

Currently, Japan needs to develop a system to take advantage of highly advanced technology. The concern is spreading that even though Japan has the necessary technology, it may become a country that loses in business. The essential question for Japan is how to develop a system within the country that takes advantage of technology. I would like to avoid imposing a strict definition of innovation here. Whether we are talking about Schumpeter's "new combinations" or the more common concept of technological innovation, there is a limit to how perfectly we can define innovation. However, as a long-time participant in industry-academia collaborations, I sense that in universities there are clearly many potential seeds of new high-level technologies that could have a tremendous impact on future generations. There is no way for Japan to commercialize highly advanced technologies without commercializing university technologies. Thus, if we examine how technology transfer from universities to industry is progressing, we will see whether industry-academia collaboration activities have the potential to trigger innovation.

2.1 Comparing the Number of Licenses in Japan and the United States

It is worth noting that according to the 2011 University Technology Transfer Survey (Daigaku Gijutsu Iten Survey)—the most recent survey of the University Network for Innovation & Technology Transfer (UNITT) [1], which could be considered to be the Japanese version of the Association of University Technology Managers (AUTM)—the total number of new licensing contracts made by Japanese universities, TLOs, and research corporations in 2010 was 1,673. According to a survey by the AUTM of the United States, the number of licenses in 1991, when the AUTM started taking surveys, was 1,229. Thus, Japan is at the same level the United States was at 19 years ago (Fig. 2.1). In the United States, the number of licenses in 2009 increased fourfold compared with 1991, to 5,328. Thus, the question of whether Japan can catch up to the United States is important. The number of active licenses (contracts whose licenses are continuing) in Japan in 2010 was 5,770. This is the same level that the United States was at 19 years ago (Fig. 2.2). In the United States, 33,523 active licenses existed in 2009. Looking at these figures we can thus see that the state of industry-academia collaborations in Japan is the same as it was in the

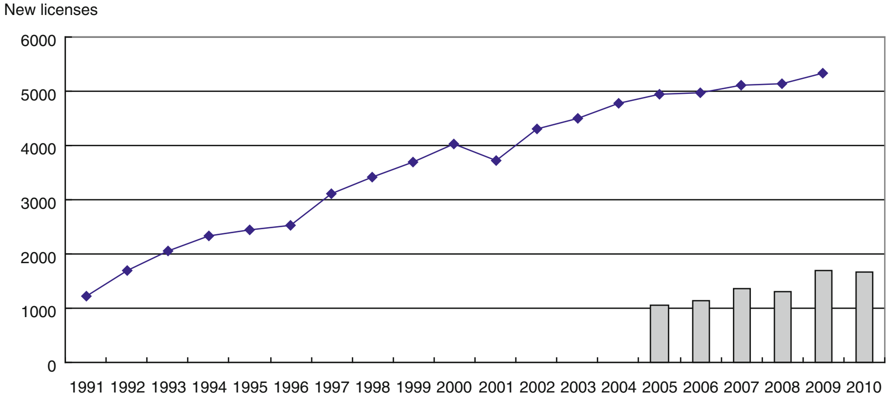


Fig. 2.1 The *line graph* shows the number of new licenses at United States universities, and the *bar graph* shows the number of new licenses at Japanese universities

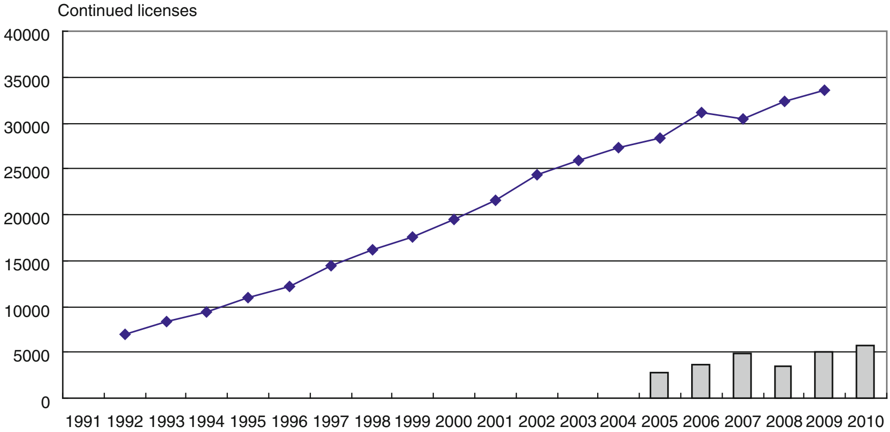


Fig. 2.2 Trend diagram of continued licenses in Japan and the United States. The *line graph* shows the trend in the United States, and the *bar graph* shows the trend in Japan

United States about 20 years ago. Of course, it would be incorrect to interpret this as meaning that Japan is a full 20 years behind the United States in this regard. However, as mentioned above, the Japanese legal framework for innovation was in a development phase until the acquisition of corporate rights by national universities in 2004. Before then there was almost no technology transfer. I believe a more constructive interpretation of the above data is that Japan has finally caught up to the United States of 20 years ago. Over the past 20 years in the United States the promotion of industry-academia collaborations has led to the stimulation of innovation. This means that the issue facing Japan is how to sustain and grow industry-academia collaborations.

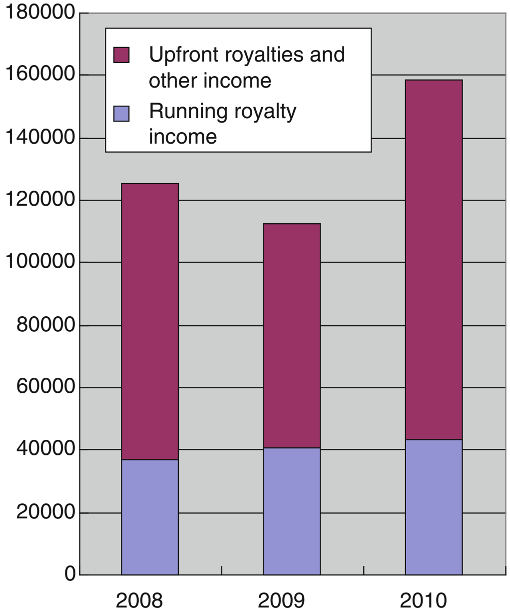
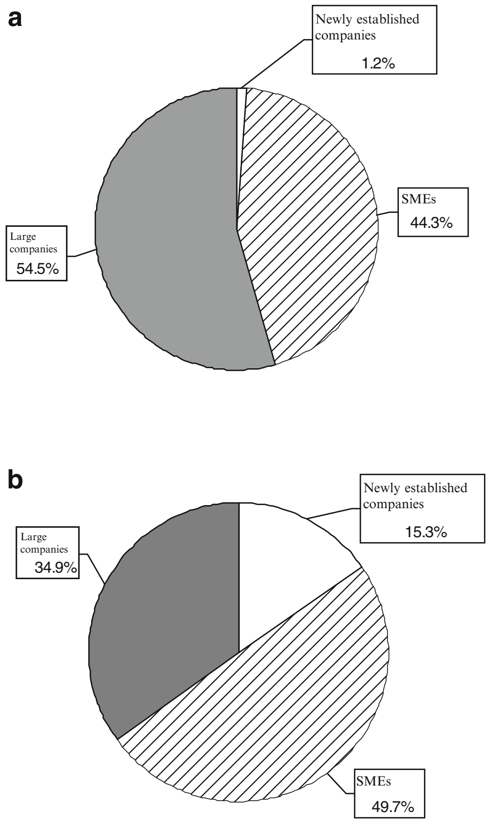


Fig. 2.3 Breakdown of income from licensing by Japanese universities to industry

2.2 *Royalty Breakdown*

When considering future prospects for industry-academia collaborations, looking at a breakdown of licensing income is informative. In the United States, approximately 20% of the income that universities receive from licenses is paid in the form of upfront royalties, which are paid when a licensing contract is made. Approximately 80% of the income is paid in the form of royalties that correspond to product sales (running royalties). Figure 2.3 shows that in Japan upfront royalties account for an overwhelming majority of licensing income. This is not a result of any unique feature of the licensing system in Japan but rather stems from the fact that most of the technology that is licensed in Japan is still in the development phase and has not been commercialized. Thus, considering the numbers of licenses discussed previously, we can expect that running royalties will increase in the future. In fact, The University of Tokyo is in such a situation. At The University of Tokyo, running royalties are expected to increase, and royalties are expected to increase sometime around 2015. Other universities have made similar announcements. It is too early to take a pessimistic view of the situation. Licensing to foreign companies has also been increasing recently. If Japanese universities produce quality technology, we can expect to see the same trend in Japan as has been observed in the United States.

Fig. 2.4 Comparison of licensee company sizes in Japan and the United States. Sizes of companies that universities license to in Japan (**a**), the United States (**b**)



3 New Developments for University-Based Startup Companies (Spin-Offs)

Significant differences between Japanese and United States industry-academia collaborations can be found in various areas. For example, as shown in Fig. 2.4, the scales of the companies that universities license their technology to are very different in Japan and the United States.

In the United States, the percentages in this figure have changed very little in the past 10 years. Universities transfer approximately 15% of their technology to startup companies and about half to small and medium-sized enterprises (SMEs). Large companies are the recipients of about one third of the transferred technology. Meanwhile, in Japan, the amount of licenses that go to startup companies is very small. Even when we look at past data, in the year when the most licenses went to startup companies these licenses still only accounted for 5% of the total number of licenses. Any baseball or soccer team whose young players do not actively participate loses vigor. In this sense, there is a problem with the strategies for supporting startup companies in Japan.

It is certainly the case that there was a phenomenon that could be called a boom in university-based startup companies that took place around the time of the initial public offerings (IPOs) of AnGes MG in 2002 and OncoTherapy Science in 2003, when university-based startup companies went public one after the other. However, the economic stagnation and collapse of Lehman Brothers that followed sent the boom into hiding.

Not all the news has been bad. If we look at the IPOs that have taken place over the past few years, we can see that they have included a number of university-based startup companies, also known as spin-offs. Examples of spin-offs that have had successful IPOs over the past few years include the 2009 IPO of Tella, a spin-off from The University of Tokyo; the 2011 IPO of Morpho, another spin-off from The University of Tokyo; and the 2011 IPO of Chiome Bioscience, a spin-off from RIKEN (The Institute of Physical and Chemical Research). Of course, IPOs are not the only sign of a successful spin-off. For example, The University of Tokyo spin-off PeptiDream has not yet had an IPO, although it has been producing good results since its founding in 2006 and is forming alliances with various large pharmaceutical companies in Europe and the United States. Thus, while there might not be as many startup companies in Japan as there are in the United States, startup companies that have commercialized university technology and are growing steadily are continuing to form, and there is a strong possibility that promising enterprises will arise from these companies.

Looking at the past, Teijin started as a spin-off from Yamagata University, TDK started as a spin-off from the Tokyo Institute of Technology, and Ajinomoto and Ebara started as spin-offs from The University of Tokyo. These companies were formed and grew in an era when there were no head offices of intellectual property or TLOs. When discussing startup companies, many people emphasize the differences between the economic and cultural environments of Japan and the United States. Nevertheless, it is clear that Japan has successfully brought forth innovation in the past.

4 Training Industry-Academia Collaboration Intermediaries

As has been set forth thus far, Japanese research seeds are being steadily patented and transferred to industry. Sometimes this has led to the formation of promising university spin-offs. Focusing on the present, it may appear that Japan’s industry-academia collaborations are lagging behind, but that is not necessarily the case when we look at the issue on a larger time scale. There is a professor at the University of Texas whose analysis of industry-academia collaborations in Japan concludes that it is amazing and proceeding at a breathtaking pace. As someone who is involved in industry-academia collaborations, there are in fact times when I feel a sense of sluggishness, although I can still see that this field is growing steadily.

To solidify this trend and bring about even greater development, it will be important to train workers in the field of industry-academia collaborations. For a new sport from a foreign country to be established in a new country, it is important for new players of the sport to be trained. For industry-academia collaborations, the question can be asked whether technology transfer intermediaries are being trained.

The answer is both yes and no. When it comes to this issue, differences between universities are extremely pronounced. There are a variety of reasons for this. One reason is that at many universities, technology transfer intermediaries are hired for limited terms. It is difficult to attract talented workers to a profession that requires a person to change his or her job every 3 or 5 years. Whether a university has a leader who can manage licensing and marketing and guide his/her younger associates is also a significant issue that sets universities apart. When national universities gained corporate status, many universities not only did not understand technology transfer, they also did not understand the step before technology transfer of applying for patents. That is why many national universities hired people from the intellectual property and patent divisions of private sector companies. While there is a great deal of individual variation, most people from intellectual property divisions are professionals in applying for patents but have little experience when it comes to licensing and marketing. Universities do not commercialize technology on their own, so rather than the ability to patent technologies, what industry-academia collaboration intermediaries really need is intimate knowledge of licensing and the ability to market technologies. This type of hiring mismatch can be seen in various universities.

Overall, however, the training of industry-academia collaboration intermediaries is proceeding. It is impossible to quantitatively measure how the skills of industry-academia collaboration intermediaries are growing. Thus there are no data that clearly show this growth. However, the UNITT holds an annual conference similar to the annual meeting held in the United States by the AUTM. The 9th conference will be held in 2012. Each year, about 500 people associated with universities gather at the conference and discuss a variety of themes for 2 days. The content of these discussions has been increasingly advanced each year. Also, UNITT holds a number of fundamental and applied licensing training seminars each year. These seminars teach participants what they need to know about licensing. At these seminars, I have spent about 10 years teaching a variety of people associated with universities how to license university technology. I have seen how the participants in these seminars have become more capable over the past few years. In that sense, I think the overall level of technology transfer intermediaries is rising.

Human potential is incredible. Only 66 years after the first flight of the Wright brothers, humankind made it to the moon. In the field of industry-academia collaborations in Japan, we are probably at the point where we have finally managed to get an airplane to fly. However, I believe that this single step is sure to pave the way to new innovations, and I am looking forward to the future.

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Chapter 3
Commercializing Promising but Dormant Japanese Industry–University Joint Discoveries via Independent, Venture Capital Funded Spin-Offs

Robert Kneller

Abstract This chapter outlines a way to foster science-based entrepreneurship and to develop some of the promising discoveries made jointly by Japanese universities and corporate researchers. The core proposal is to encourage the formation of independent, venture-capital-backed spin-offs based upon technologies jointly discovered by universities and companies that are lying dormant, but that have significant commercial potential. This chapter outlines the rationale for this proposal and a process for doing so. It discusses one spin-off that appears to be successful so far—TeraView—spun off from Toshiba Research Europe and the Cavendish Laboratory of the University of Cambridge, as well as barriers to replicating this promising example. Ultimately, the success of this endeavor will depend upon established Japanese companies and university researchers both realizing that they stand to benefit. Success also depends upon altering longstanding practices in some industries related to intellectual property (IP) management, particularly the cross-sharing of IP rights and the reluctance to exclusively out-license technologies.

1 First Rationale: New Companies Are Important for Innovation

New companies (i.e., startups or venture companies) have proved to be superior compared to established companies in developing many innovative technologies, provided they can grow in an environment that is supportive of science-based entrepreneurship.

This is clear in the case of pharmaceuticals. A review of all the new drugs approved by the United States Food and Drug Administration between 1998–2007 clearly shows

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that new companies (biotechs) are much more likely than established pharmaceutical companies to undertake the initial development of innovative drugs—in other words, drugs that have a new physiological mechanism of action or new chemical structure, or drugs that offer significant health benefits over existing drugs [1]. This is especially true in the case of orphan drugs (which usually have small markets), biologics (complex protein drugs whose discovery is not amenable to mass screening techniques), and drugs discovered in universities. Indeed, it is extremely rare for pharmaceutical companies to undertake initial development of groundbreaking drugs discovered in universities. Instead, since about 1980 the world has relied upon new companies to undertake this development to bring such discoveries closer to public benefit.

Similarly, new companies are leaders in fields such as robotic surgery, gene sequencers, therapeutic biomedical devices, wireless medical monitoring devices, applications of stem cell technologies, lab-on-a-chip systems, 3-D printers, and, of course, Internet communications and social media. They are among the leading companies in industries such as vascular endoscopes, semiconductor manufacturing equipment, high efficiency solar cells, microelectromechanical systems (MEMS) sensors for high-stress environments, and wave energy power generation.

In Japan, one often hears the mantra that new companies cannot succeed in industries with high capital or manufacturing costs or where large companies are active [2]. Yet this common belief is belied by the semiconductor companies that rose to prominence in the 1980s, such as LSI Logic, VLSI Technology, Cypress Semiconductor, and Cisco Systems [3], and also by the companies that pioneered small hard disk drives, such as Seagate, Maxtor, and Western Digital that spun off from IBM [4]. The ability of new companies to succeed with new technologies while large companies with much greater resources fail, depends upon the new companies' ability to obtain large investments (usually from private venture capital), to protect their discoveries with patents and copyrights, and to outsource manufacturing. But their success is also often a result of large companies not perceiving the value of new technologies, considering the market for them to be too small, considering new technologies to be too removed from the needs of their main customers, and simply being too bureaucratic to develop them rapidly [4–6]. Henderson [7] suggests that, considering the internal competence of large firms and the way they are geared to meeting the needs of current customers, it may be rational for them to ignore innovative discoveries. This may be particularly true if they can outsource the risky development of innovative technologies to start-ups, on the assumption that they can buy the startups or partner with them, once the startups have shown proof of concept [1, 8].

2 Second Rationale: Barriers to Science-Based Entrepreneurship in Japan

In almost all the examples cited above of industries where startups are leaders, most of the leading startups are based in the United States. However, the pharmaceutical data show that not only America, but also Canada, Australia, Israel, and to a lesser extent, the United Kingdom, are countries where startups are lead innovators [1]. The patterns of pharmaceutical innovation for Japan and continental Europe, in particular Japan and Germany, are very similar. There, new drug discoveries occur almost exclusively in the in-house laboratories of established companies, and these drugs are generally not innovative.

There are some signs of startups playing a larger role in Japanese innovation. The number of Japanese biomedical therapies being developed by startups has increased. In 2004, about 135 Japanese biotechs were developing new medical therapies but only about five had new drugs (or other therapies) on the market or in clinical trials. Five years later in 2009, the number of therapeutic-oriented biotechs had decreased slightly (to about 115). However, these had about 45 new Japan-invented drugs, drug delivery systems, regenerative medicine therapies, or therapeutic vaccines on the market or in clinical trials. This is probably a higher number of domestic-origin therapies than from startups in any continental European country [1]. Also, more recent graduates of elite Japanese universities seem to be starting new companies than 10 years ago [9].

However, outside of biomedicine, progress is weaker. Few new companies with unique technologies that have international market potential seem to be on a growth trajectory. Without going into details, several companies that seemed to have growth potential have stalled. In some cases they have been overtaken by overseas startups. In other cases they have been slow to seek overseas markets and have been confined to alliances with Japanese companies. Moreover, since the 1990s, few if any spin-offs from established companies have succeeded in becoming leaders in Japan, much less in the global market. However, there have been many failures, often related to interference from the parents [6].

Numerous interrelated and complex factors make the environment for science-based entrepreneurship less supportive than in North America or Australia. Many of these are related to deeply rooted social and institutional factors of the type that distinguish liberal market economies (including the United States, Canada, and Australia) from coordinated market economies, such as Japan and continental Europe.[1] A possible list might be as follows[2]:

[1]Exactly in line with the pharmaceutical data above, *liberal market economies* are said to produce relatively more radical innovations while *coordinated market economies* tend to excel in incremental innovations. The greater propensity for new companies to undertake radical innovation, and the relatively more supportive environments for science-based entrepreneurship in liberal market as opposed to coordinated market economies, may be the missing link explaining this phenomenon. Liberal market economies are characterized by relatively high labor mobility, low job security, low reliance on in-house training, minimal government and organized labor involvement in business decisions, and a tendency for equity as opposed to loan financing for business expansion; while the opposite features characterize coordinated market economies [10].

[2]Along with the specifically cited references, see [6] for reasons 1–7 and [11] for reasons 8–10.

1. Low mobility for skilled professionals (hesitancy to work in startups and to change jobs)
2. Limited access to capital, in particular few angel investors and lack of business and technical expertise among venture capital (VC) investors
3. Preference in large companies for autarkic (self-reliant) innovation [12]
4. Tendency for Japanese startups to focus on the domestic markets and alliances and to ignore more competitive but more rewarding overseas opportunities—a tendency reinforced by language barriers and the dearth of personnel comfortable dealing with overseas organizations
5. Preemption of university IP and researchers' energy by large companies [13]
6. Limited preference for small businesses in Japanese government procurement, and a cumbersome Japanese government equivalent to the United States' SBIR program
7. Japanese entrepreneurs prefer service or value-chain companies to more confrontational and disruptive "gazelles"
8. The system of allocating government support for university R&D (i.e., the way research proposals are solicited and selected for funding) creates disincentives to pursue innovative research
9. The system of patronage-based university recruitment and promotion similarly creates disincentives to pursue innovative university research
10. Cultural and institutional barriers to horizontal, inter-organizational information sharing and cooperation as described by Nakane [14]

Among these, probably the first is the most important. The close relationship between a fluid labor market, entrepreneurship, and innovation has been described by Saxenian [15], Hyde [16], and Fujimoto [17]. A fluid, or high velocity, labor market ensures that persons who join startups usually can continue their careers if their company fails. When combined with easy entry and exit of startups, a fluid labor market constantly reallocates the most precious resource of all—human capital—among companies where it is most needed and rewarded. It also creates a network where information is shared rapidly across organizational boundaries. It results in high dedication to work and high alignment of corporate and individual goals. All these factors decrease the perception of risk for investors contemplating investing in startups. The tendency for professionals to spend most of their careers in one or two companies is probably the single most important factor underlying the similarities between Japan and Germany with respect to entrepreneurship and innovation. Many of the factors that distinguish liberal and coordinated market economies impact labor mobility (footnote 1 and Hall and Soskice 2001 [10]).

The proposal at the heart of this chapter does not address labor mobility directly. However, if successful, it will go a long way towards creating a critical mass of mobile entrepreneurial scientists and managers that will address this most important issue. However, it does address the barriers listed above as 2, 3 and 5, as well as 4, provided overseas investors can be included in the spin-off process. In particular, barrier 5 is addressed by the following rationale for this proposal.

3 Third Rationale: The Number of Dormant Industry–University Joint Inventions Is Large

Joint applications for patents covering industry–university collaborative research discoveries are the dominant form of technology transfer in Japan, vastly exceeding licenses of independently invented university discoveries. Since 2007, such joint applications have consistently accounted for about 60% of the approximately 9,000 total annual university patent applications to the Japan Patent Office (JPO). Because only a fraction of the remaining 40% of university applications are licensed, the ratio of jointly patented collaborative research inventions to inventions transferred under independent licenses is roughly 3:1 in major universities and probably even higher in lesser known universities. The vast majority of the industry co-owners of these patents are large Japanese companies [18, 19].

At the other end of the international patent application process, patents co-owned by Japanese universities and private companies account for about one third of all United States patents covering Japanese university inventions.[3] The vast majority of these companies are established Japanese companies. This situation is probably unique among major industrialized countries. Only about 15% of German university inventions that have been awarded United States patents are co-owned by companies. For Canadian and United Kingdom university inventions, the proportions are about 10% and 6%, respectively [19].[4]

Having companies lined up as development partners for such a large proportion of university inventions may provide Japan a unique advantage. However, with co-ownership comes automatic control with no development incentives. Interviews with over 20 Japanese companies recently engaged in collaborations with universities indicate that many collaborative discoveries are not developed, or are not developed to anywhere near their full potential (Kneller et al. under review [21]).

This can be referred to as the "lock up" problem. It is partially alleviated by the fact that about half of Japanese joint industry–university patent applications are abandoned after 3 years and essentially dedicated to the public (Ministry of Education, Culture, Sports, Science & Technology data compiled by Watanabe [18]). These are considered to be "defensive" patent applications because they are filed mainly to preempt

[3]This is based on reviewing a random 13% sample (68 patents) of all the approximately 525 US patents issued between June 2011 and May 2012, where at least one owner (assignee) is a Japanese university.

[4]The percentage of United States university patents that are co-owned by companies is less than 5%. However, this is due in part to a unique aspect of United States patent law which permits patent co-owners to transfer their rights without the permission of other co-owners, thus making co-ownership of a United States patent equivalent to a transferable, royalty-free, non-exclusive license. In all other industrialized countries, the permission of all co-owners is necessary for any license or assignment, and thus co-ownership of a non–United States patent is equivalent to a non-transferable, royalty-free, exclusive license [20].

rivals from patenting the same discovery and thus to preserve freedom to operate. This may increase the patent commons and reduce the patent thicket problem. However, the incentives for any company, particularly a startup, to invest substantial resources to exploit the full potential of these discoveries are greatly diminished once the discovery is publicized and patent protection is not available.

As for the joint research patent applications that are not abandoned, a fraction[5]—about 175 over a recent 12-month period—issue as United States patents. A review of a sample of these jointly owned patents suggests that about half are narrow or cover manufacturing processes destined to be used by the sponsoring company. In other words, the lock-up danger is low. However, the remainder (currently about 90 United States patents issued annually) are broad patents that probably could be useful to several companies or represent potentially significant technical advances with a potentially significant market impact (note 3). If the company co-owners of these technologies do not try to develop them, or do not at least seriously look into the feasibility of development, this would represent a loss of potential future benefits to society and of past taxpayer support for the university research that led to these inventions.[6] Presumably, some of the approximately 2,500 joint research inventions that are not abandoned but never issued as United States patents are similarly broad. Some companies have revealed that they apply for patents on some collaborative university discoveries to deny their use to rivals, even though they do not intend to develop the discoveries themselves [18].

These indications that lock-up is a significant problem for joint industry–university discoveries reflect a more general problem of technology hoarding in large Japanese manufacturing companies. In 2007, about 60% of Japanese manufacturing companies said that most of their technologies that they do not commercialize themselves are simply abandoned and are never made available to outside parties [2].

The following account describes one promising technology that would have been abandoned had not the company made a difficult, courageous, and probably also far-sighted decision to let the inventors and VC investors spin off an independent company to develop it.

4 Case Example: TeraView

TeraView was spun off in 2001 from the Cavendish Laboratory of the University of Cambridge's physics department (CCL) and Toshiba Research Europe (TRE). TRE was established in 1991 and its main laboratory was situated near CCL to facilitate

[5] See note 3. Based upon data in Watanabe [18], this fraction is probably between 5% and 10%.

[6] Corporate funding for joint research in Japan does not cover the salaries of full-time faculty, nor the tuition or stipends of graduate students, and only a fraction of infrastructure costs. It sometimes does cover costs of some special equipment and the salaries of a growing number of non-tenured so-called "project" assistants, associate and even some full professors. The former are often persons beginning their academic careers. Some of the latter are senior company scientists dispatched to the university. In general Japanese companies pay much less per collaborative research project than do American companies [6, 19].

collaboration between these two laboratories. One of the joint research areas related to applications of terahertz frequency light. This revealed potential applications in fields such as dentistry, security (detection of weapons or explosives), pharmaceutical quality control, semiconductor manufacturing quality control, and cosmetics. However, Toshiba assessed that none of these applications were related to its core business and none would earn sufficiently large revenues to justify its moving into new development and business areas. Normally it would have abandoned the technology. However, two of the Cambridge scientists wanted to spin the terahertz technology off as a new company and one was eager to take on the responsibilities of an entrepreneurial company president.

TRE supported this plan in principle, reasoning that otherwise the technology would die (or at least not be developed for many more years). If TeraView became successful, Toshiba would benefit as a major stockholder. Also, it was not unreasonable to believe that there might be some synergies between Toshiba's and TeraView's operations and that some of the technologies TeraView might pioneer would be useful for Toshiba—and that TeraView would turn to Toshiba for some of its equipment needs.

However, two issues that needed to be overcome were the longstanding principle among Japanese electronics companies that they not out-license exclusive rights to their IP (in this case, IP that had arisen from joint research with CCL) and also their longstanding practice of sharing among each other non-exclusive rights to some of their IP. In other words, Toshiba had to consider not only its own IP strategy, but also the expectations of other Japanese electronics companies. On the other side, the VC investors, whom TRE and the entrepreneurial CCL scientists had lined up, refused to invest if TeraView did not have exclusive rights to the patents covering its core technology. After an extended process, exclusive IP rights were granted and TeraView was established.

Today, most of its main projects are still in development phase and expenses still exceed revenues. However, employment has been growing and private investors have enough confidence in the company to provide it additional rounds of funding. Toshiba considers that the most important factor in overcoming the above-mentioned hurdles was the competence and enthusiasm of the Cambridge researchers who wanted to establish TeraView, particularly Donald Arnone, who is its CEO/President, and Dr. Michael Pepper, Director of CCL and founder of TeraView.

5 Lessons from TeraView

A recent Ministry of Economy, Trade and Industry study noted the small number of successful spin-offs from Japanese manufacturers and lack of support systems within such companies for entrepreneurial activity and spin-offs [2]. It also noted that Japanese managers tend to be risk averse. It advocated a low-risk low-return approach where spin-offs would not be independent from their parents and would continue to receive from them various forms of support [2]. These semi-independent spin-offs, where the parent retains control of key management decisions and which receive some financial, managerial, or marketing support from the parent are henceforth called “tethered” spin-offs.

However, the likelihood is probably small that this strategy will result in many companies that will develop innovative technologies and be successful in global markets. If manufacturers maintain control over their spin-offs (including their IP) this would almost certainly drive away potential overseas investors. As overseas investors are one of the main sources of networking with overseas customers, alliance partners and other investors, this would make overseas growth harder. Even Japanese VC investors would not like being in the position of passive investors. While the parent may regard forming a tethered spin-off as an opportunity for risk sharing, Japanese VC investors would be hesitant to share substantial risks under such circumstances, and they would be unlikely to invest in a novel technology such as terahertz. Furthermore, case study analyses from both the United States [22, 23] and Japan [6] suggest that spin-offs that are controlled by their parents usually fail—unless, as in the case of Fanuc spinning off from Fujitsu, the spin-off’s operations already have substantial sales at the time of formation. The most common reason is that continuing control by the parent over management decisions usually vitiates the advantages of nimbleness and ability to seek freely funding and customers that are vital to the success of most startups.

With these barriers to tethered spin-offs in mind, the TeraView model of creating a truly independent VC-backed spin-off might be the most practical way to develop the large number of dormant inventions that are not being developed by large companies. It might also be the most likely way the parent will benefit from its dormant technologies—technologies that probably would otherwise die or languish undeveloped for many years.

Even though the spin-off would be independent, the parent would probably benefit from its success in several ways. First, the parent would likely hold 20% or more of the spin-off’s stock in return for having licensed to it the core IP and possibly also having made cash investments [23]. The parent may have a seat on the board of the directors. Even if it did not, the parent would be able to keep track of its R&D progress. The spin-off would likely turn to the parent, when possible, for equipment and services. At least in the case of large American IT companies, such as IBM, Intel, Cisco, and Qualcomm, spin-offs and other startups have often come to supply the parent with technologies it needs [8, 16]. The VC investors probably would insist on the right to sell the startup or to take the startup public through an initial public offering of its stock. However, the parent may have the right to buy the spinoff at a set period of time (e.g., 3 years) following its formation. If the parent seconded some of its researchers to the startup, the parent’s influence would increase and the spin-off might come to resemble a joint venture between the parent and the VC investors. In the process, the parent would gain valuable entrepreneurial experience.

The founders would very likely come from universities and managers would be recruited by VC investors. This would avoid the problem noted in the METI study that company employees often perceive the risks associated with leaving the mother company are too high [2]. In general, VC investors would consider investing in a spin-off to be less risky than investing in startups based only on independent university research, provided the parent company had done its own evaluation of the university discovery, and especially if it had carried out development work and moved the discoveries closer to proof of concept.

In any case, the initiative for starting a spin-off may have to come from university researchers who understand the technology, know that the company is not developing it, and know whom to approach in the company. If the company is interested in exploring the possibility, the university or the university inventors may have to take the lead in contacting VC investors. From this point on, the structure of the agreement spinning off the company will probably have to be worked out by the parent, VC investors, and founders, with the university playing a facilitating role. The prospective parent company should always have the right to say it does not want to go through with a spin-off.

However, to preserve the parent's option of forming a spin-off, universities ought to require that any sublicenses (even of only non-exclusive rights) of jointly owned inventions be made only with the universities' prior approval. As joint owners, universities have this right under Article 73 of Japan's Patent Law (note 4). They ought not to give up it up. Universities should permit the collaborating company to grant non-exclusive sublicenses only if there are clear public policy reasons to do so, and they ought not to permit such sublicenses if it appears that the company probably will not develop the discovery, but that some other company (especially a startup) might be able to do so.

6 Conclusion

The story of TeraView is consistent with Christiansen's accounts [4, 5] of how large companies often fail to develop new technologies. This comes about because companies do not perceive their value, think the market is too small, consider the technologies to be too removed from their main business or main customer needs, or simply are too bureaucratic to develop them rapidly. The unusual aspect of the TeraView case is that Toshiba agreed to let TeraView have exclusive rights to the startup's core IP. This provides a model for how more Japanese spin-offs can grow successfully.

This chapter noted the dearth of promising Japanese startups outside of biomedicine and the many barriers facing spin-offs and other startups in Japan. Considering these difficulties, Japan could basically give up on startups and concentrate on improving relations between universities and established companies, hoping that the established companies will turn themselves around and produce market breakthroughs with a series of fundamentally new technologies. However, recent trends, the evidence of hoarding of dormant technologies by manufacturing companies and their frequent reluctance to enter new technical fields, plus the analyses of Christensen and Henderson cited above, all suggest this will not come to pass. Moreover, as countries such as China increase their ability to produce high quality manufactured products at a substantially lower price than Japanese manufacturers, Japanese industry as a whole risks being trapped between these technically advancing lower-cost manufacturers and overseas companies that can stay ahead by developing breakthrough innovations.

Particularly with respect to the development of university discoveries where startups are proven to be more successful than established companies, Japan needs to foster the growth of more science-based startups. Mobilizing some of the many dormant but promising university discoveries arising under joint research by spinning off independent companies and letting VCs and entrepreneurs undertake the risk of development is one of the best ways to tackle this problem.

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Chapter 4
Realization of Photonics Polymer Technologies in the FIRST Program

Yasuhiro Koike

Abstract This is a review of progressive efforts to realize novel photonics polymer technologies to contribute to society. The new technologies that we developed at Keio University are represented by the ultra-high-speed graded-index plastic optical fiber (GI POF), highly-scattered optical transmission polymer (HSOT), and zero-birefringence polymer. The phenomena behind each technology were discovered through detailed fundamental studies; for example, how polarized waves or photons relate to various polymer chains, their aggregation, higher-order structures, and huge heterogeneous structures. By using these core technologies, we are developing and proposing a face-to-face communication system that is the world's fastest GI POF with 40 Gbps directly connected to a high-quality large display for homes and offices. It realizes sensational face-to-face communication with clear motion pictures without any time lag. To make these research results practically useful for society, we are actively advancing this research and development in cooperation with more than ten companies under the Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST) of the Cabinet Office of Japan.

1 Back to Fundamentals

1.1 Advantage of Graded-Index Plastic Optical Fiber (GI POF)

The biggest advantage of the graded-index plastic optical fiber (GI POF) is a much higher bitrate than that of a conventional step-index POF (SI POF). Figure 4.1 shows the refractive-index profiles of both the SI POF and GI POF. In the SI POF the light

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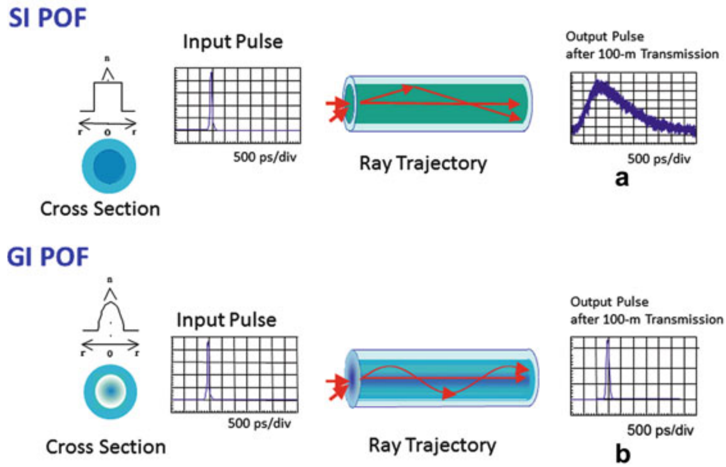

Fig. 4.1 Effect of refractive-index distribution on bandwidth of GI POF (**b**) compared to conventional Step-Index Plastic Optical Fiber (SI POF) (**a**)

going straight has a longer path than the light with many reflections. The output pulse through 100 m of SI POF is then spread enormously as shown in Figure. 4.1a. Conversely, since the GI POF has the refractive-index distribution in the core region, the light basically has a sinusoidal trajectory. The light going straight along the center axis transmits through the region with the higher refractive index, so the velocity of this light is slower. However, because the light with a sinusoidal trajectory has a longer path compared with the light moving in a straight line and very often goes through the periphery region with lower refractive index, it moves faster than the light going along the center axis. These two opposite effects are completely compensated when the refractive index profile is optimized; therefore all lights (modes) through a GI POF arrive at the end of fiber at the same time without time delay, resulting in no broadening of the output pulse as shown in Fig. 4.1b.

1.2 Overcoming Light-Scattering Loss

In the 1980s, I was at a crossroads in my research on whether it was possible to create a GI POF, which could send optical signals at high speeds greater than a gigabit. This was because our trial POF was poorly transparent, the transmission loss exceeded 1,000 dB/km, and light passed through only several meters. To achieve transmission speeds greater than a gigabit, it was necessary to add another material to the fiber and form a concentration distribution in a radial direction to form a refractive-index distribution. However, the important issue at the time was how to remove impurities to make the POF transparent. Conversely, attempting to realize high-speed optical communication by adding a separate material (an impurity?) to form a refractive-index distribution seemed a major challenge and an absurd idea.

No matter how many times we conducted our experiments, light passed only a few meters through the GI POF. The cause was light-scattering loss. The problem of light scattering consumed our time, expense, and energy. We could not assign this as a research theme for an undergraduate or masters student's thesis project because we did not know what results would be obtained, so we continued thinking about this problem. While reading a lot of literature, we came across Einstein's fluctuation theory of light scattering proposed in the early 1900s. This theory is based on micro-Brownian motion in solution, which proposes that light-scattering loss is proportional to isothermal compressibility. When we actually entered the isothermal compressibility value for the POF material polymethylmethacrylate (PMMA), the result was less than 10 dB/km, which was significantly lower than the aforementioned transmission loss of 1,000 dB/km. This meant that transmission in excess of 1 km was possible, which was how we perceived "light" at the time. However, the question then was: What is this 990 dB/km error? To find out what inhomogeneous structure caused this excessive scattering, we thoroughly investigated the light-scattering theory proposed by Debye (who later received the Nobel Prize in Physics) around 1950. We also attempted to work this theory out by ourselves. This theory was extremely useful in analyzing the relationship between the micro heterogeneous structure of polymers and light scattering. What is superior about Debye's light-scattering theory is that by defining the correlation function, the shape and size of the micro heterogeneous structures in polymers can be correlated with light-scattering loss. It became a powerful tool for me in searching for the cause of excessive scattering in polymers.

1.3 Seeing the Essence of the Problem

Using Debye's light-scattering theory, we began to conduct a detailed analysis of the excessive scattering in a 1,000-dB/km plastic optical fiber that allowed light to pass through only 6 m. While carefully reviewing and organizing past data thought to be unsuccessful, we began to see the true nature of light-scattering loss. We began to see how our former method of forming a refractive-index distribution according to differences in reactivity would form an extreme polymer composition distribution in the generated copolymer. It became clear that the more we increased the refractive-index distribution by increasing the difference in reactivity, the larger the inhomogeneous structure formed within the polymer. This large inhomogeneous structure reached more than several hundred Å, and when I applied it to Debye's light-scattering theory, I discovered it to be the cause of a very large scattering loss exceeding several hundred dB/km. This realization was the culmination of many long years of research and made me recognize that the fiber would theoretically not become transparent with processing methods that rely on monomer reactivity.

I decided to reconsider the problem from the beginning. By this time, we were able to visualize the cause of excessive scattering clearly. It did not take much time for me to come up with a new idea for a low-loss fiber. We conducted an experiment based on the completely new idea of forming a graded index using molecular size. April 1st, 1990 is still a memorable day for me. We produced an excellent transparent GI POF preform. It was the moment I emerged from a 10-year-long search for an answer to scattering loss.

People in this industry formerly believed that polymers could not be used in high-performance photonics, due to lower clarity, larger birefringence, larger wavelength dispersion of refractive indices, lower optical uniformity, etc., compared with optical glass. These were considered unavoidable problems peculiar to polymers because they are caused by aggregations of huge molecular chains. In the twenty or so years since then, however, we have seen the birth of photonics polymers with our GI POF.

Research papers written by Einstein and Debye during the early 1900s that delve into the essence of light scattering became my bibles. These papers made us realize that the latest research papers would not necessarily be useful in pursuing leading-edge research. We learned the importance of returning to fundamentals when trying to achieve a larger breakthrough.

2 New Developments in GI POF

Our laboratory was galvanized from this point on. Our course was clearly set, and all student themes were channeled in this direction. Test data on increasingly lower-loss and higher-speed GI POFs were continually produced. We soon obtained a patent, wrote numerous papers, and began joint research with industry. These achievements were widely publicized. News that an optical signal exceeding a gigabit had passed through 100 m of a GI POF for the first time was reported on August 31, 1994 on the front page of the Nihon Keizai Shimbun. The GI POFs developed by our laboratory would go on to break annual records in POF bit rate and transmission distance. The preform method (where a GI preform is created and made into a GI POF through hot stretching) was the main manufacturing method until around 2005 with a focus on interfacial-gel polymerization. However, from around 2005, we began to develop the continuous-extrusion method, and by 2008 had succeeded in 40-gigabit transmission as shown in Fig. 4.2.

This was the world's fastest transmission speed, surpassing the GI-type silica optical fiber. We achieved these results through joint research with Asahi Glass based on the "essential principle of materials" that perfluorinated polymer, used as the POF core material, has small material dispersion compared to silica (material dispersion determines the transmission band). We also developed another type of GI POF through collaboration with Sekisui Chemical to achieve a larger core and easy handling mainly for home networks. Recently, we have studied the microscopic heterogeneous and structural properties of GI POFs to improve further the data transmission properties.

After we proposed the GI POF, there was a sharp rise in research reports on GI POFs coming out of Japan and the West, and the International POF Conference began to be held annually in countries around the world. Many published papers on high-speed optical communication cited our research because of its originality.

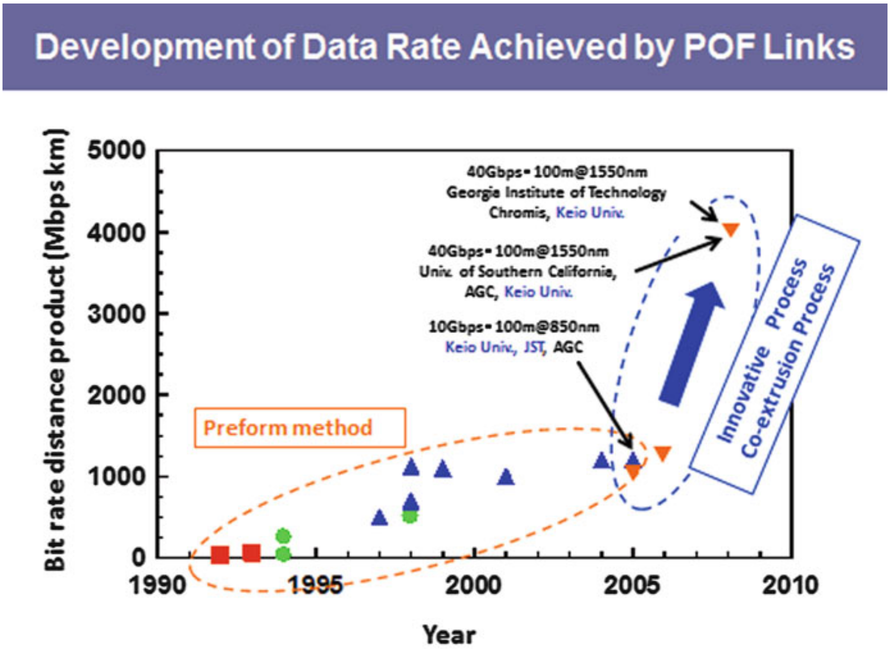

Fig. 4.2 Progress in Fabricating GI POFs

3 Progress from Light-Scattering Loss to Light-Scattering Efficiency

Research on high-resolution and large-screen displays relates back to the research into GI POF scattering loss, which has already been described. Using this knowledge, we studied light-scattering phenomena and focused our research on how to decrease light scattering. We applied what we learned to the question of how to scatter light efficiently in a prescribed direction. As a result, we have proposed the highly scattered optical transmission (HSOT) polymer, which allows double the luminance of conventional transparent LCD backlights. I obtained the basic patent for this technology and succeeded in integrating it into the LCD backlights of various laptop computers such as the Sony VAIO, Sharp, Panasonic, and Toshiba, among others.

The HSOT polymer has greatly contributed to the low power consumption of laptop computers and has been showcased in an episode of “NHK World” that aired in May 2009 as the prime candidate for future ultra-low-power-consumption LED lamps. Before this light-guide plate was released, research on the light-guide plate focused on how to make a transparent light-guide plate with little light scattering. At the time, therefore, such a proposal for a highly efficient light-scattering polymer lacked foundation. However, the HSOT polymer was the only conclusion that could come from the aforementioned series of studies on light scattering.

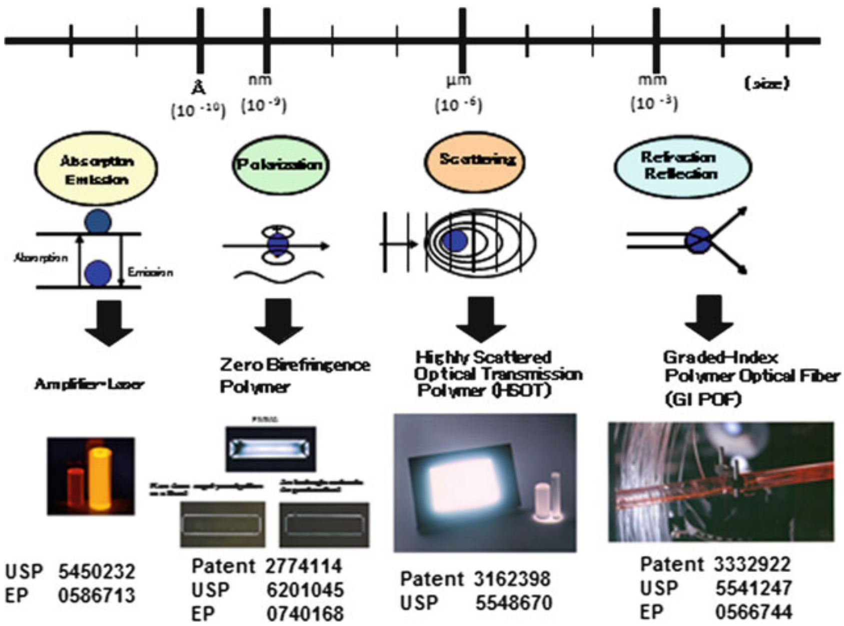

Fig. 4.3 Photonics polymers proposed by Koike Laboratory, for which basic patents have been granted

Another of our inventions, the zero-birefringence polymer, completely removes birefringence, which significantly reduces large-screen LCD performance. It is attracting a great deal of attention as a key technology for large displays.

4 From Basic Research to Developing the Technology for Practical Use

We have obtained basic patents for the GI POF, zero-birefringence polymer, and HSOT polymer. A standard for the GI POF (IEC60793-2-40 Ed.2.0) has also been established by the International Electrotechnical Commission (IEC), the world's foremost authority in the information and communication fields, through the independent proposal of Japan and the joint proposal of Japan, the U.S., and France. A foundation for global deployment has thus been established, with Japan taking a leading role. Also, the zero-birefringence polymer has made extrusion molding possible, which was difficult to do with existing films because of birefringence. It is expected to enhance the image quality of LCD films and significantly reduce costs.

Figure 4.3 shows the relationship between refraction, scattering, and polarization, which are essential light phenomena caused by differences in size of the inhomogeneous structures of polymers, and the technologies that use them-GI POF, HSOT polymer, and zero-birefringence polymer. This diagram shows how refraction and reflection occur if polymer size is measured in mm units, how scattering occurs if polymer size is measured in μm, and how polarization occurs if polymer size is measured in nm. It also shows how to control the behavior of photons and light waves. This research is based upon the essential principles of light, and is the inimitable core technology of our R&D.

Experience from over 30 years in research and development of photonics polymer materials has taught me that the key to innovation is basic research. As previously mentioned, in this age where the trend is to make materials transparent by removing impurities, the concept of the GI POF, which purposefully adds another material (an impurity), is the realization of our many years of exploring the essence of photonics polymers with deep academic insight.

In typical cases of collaborative work between industry and academia, a result tends to lack essential points because a 1- or 2-year rapid industrial result is expected. Therefore a black box often remains unresolved, and no innovation is made. An innovation cannot be achieved within a small timeframe; it takes many years, perhaps a decade, of deep searching.

5 Establishing KPRI for Realizing Face-to-Face Communication System on FIRST Program

The Keio Photonics Research Institute (KPRI) is a new research organization established within Keio University's Faculty and Graduate School of Science and Technology in April 2010 when the application of our research proposal, "Creation of a Face-to-Face Communication Industry through the Application of the World's Fastest Plastic Optical Fiber and Photonics Polymers for High-Definition Large-Screen Displays" was selected by the "Cabinet Office of Japan's Funding Program for World-Leading Innovative R&D on Science and Technology" (FIRST). FIRST is one of the largest government schemes to financially support most advanced research proposals to strengthen the science and technology of Japan. Its system has been specially designed to support selected researchers who are likely to achieve practical results that benefit Japan.

KPRI's target is to create an industry for face-to-face communication that realizes "a sense of really being there" through GI POFs with super-high bitrates, and to develop super-high-resolution large-screen displays. This could not be realized by extending conventional internet technology from Silicon Valley, and is possible only through innovations in photonics technology. For example, this technology enables the elderly in nursing-care centers to talk to their families at home as if they were actually in the same room, and to be surrounded by their warmth whenever they want. Even in an emergency, we can connect one person to another, which provides us with peace of mind and safety. This is a vision of a world that cannot be achieved with our current small-screen and keyboard culture. It will realize a society where people start to treat each other like people again by promoting a culture of real human interaction.

Figure 4.4 shows a conceptual diagram of this research and development. Developing photonics polymer core technology, which is central to this program, can be largely classified into developing ultra-high-speed plastic optical

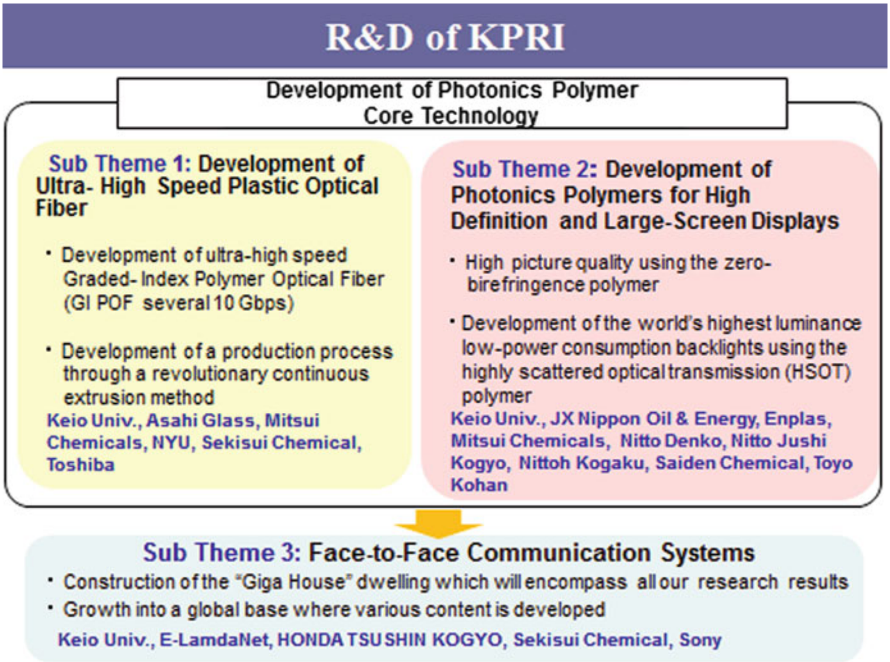

Fig. 4.4 Research and Development of KPRI

fibers and developing photonics polymers for high-resolution and large-screen displays. Research and development in both areas is being vigorously promoted, in addition to developing face-to-face communication. In the latter half of this program, we will construct the "Giga House." By directly linking the Giga House to various bases, visitors can experience first-hand the results of our research and development toward creating a face-to-face communication industry.

We hope that even after this program ends, the Giga House will become a global base where various services will be developed, and will greatly contribute to developing a face-to-face communication industry and society where people become reconnected with one another.

The NHK TV program "Professional: Shigoto No Ryugi" filmed a long documentary about our research activities over a 2-month period and broadcasted it in August 2008. On March 19th, 2010, the activities of KPRI were widely publicized on the front page of the Nihon Keizai Shimbun. Also, Nikkei Business magazine's May 3rd, 2010 edition ran a story on the history of research and development of optical technology and the activities of KPRI titled "Creation of a 10 trillion yen Industry through Optical Technology." The story appeared in a regular series called "Time to Decide and Act," which features the work and achievements of individuals in the business world.

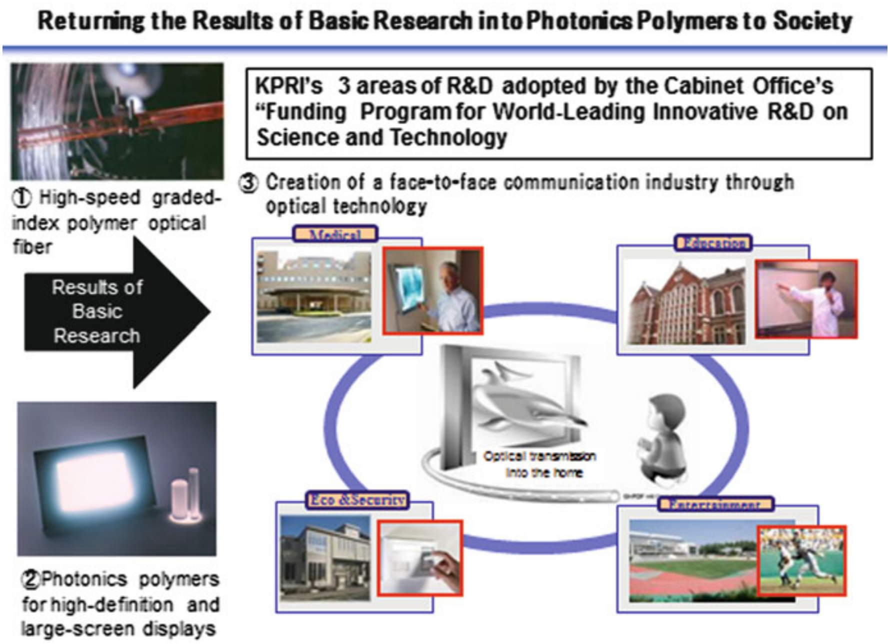

Fig. 4.5 Realizing photonics polymer technologies

6 Returning the Results of KPRI Basic Research to Society

On July 8th, 2010, the Asahi Shimbun ran a story called "Application over Basics: Money Making South Korea." The article pointed out that while the level of basic research at Japanese universities was high; Japan was lagging behind South Korea in the areas of applied research and product commercialization. In recent years, basic research has been the focus of R&D at Japanese universities, and while this has produced results, Japan has not made full use of these results in application and product commercialization.

As the Koike Laboratory has been doing thus far, we at KPRI focus on expediting industry-academia cooperation to return the results of basic research to society through product commercialization and industry creation. Under the FIRST Program we have established a framework for returning the results of KPRI's basic research to society through industry-academia-government cooperation. Currently, we are carrying out research-and-development consignment contracts with 14 companies and a university.

Meanwhile, we are also pursuing separate collaborations with a broad range of business groups such as user businesses, application vendors, and network providers, and are endeavoring to create a face-to-face communication industry through such joint development. Our work was spotlighted on June 30th, 2010 by a Nikkei Sangyo Shimbun article titled "The Changing Face of Leading-Edge Research."

Photonics polymer materials will change our society just as semiconductors created today's information society as shown in Fig. 4.5. To this end, rather than applying new technology to solve existing problems and processes, it is important that we ask new questions to come up with revolutionary technological solutions.

KPRI is resolved to bring about the creation of a face-to-face communication industry by proactively investing itself in industry-academia-government cooperation and by borrowing from the experience and knowledge of industry. The core competence of academia is mainly in basic research, and that of industry is in mass production and business. Because industry and academia play different roles, when working together each player should focus on its core competence, respecting the other's work in the collaboration to benefit society.

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Chapter 5
Translational Medicine of Stem Cells: Central Nervous System Regeneration and Modeling Neurological Diseases

Hideyuki Okano

Abstract We have been conducting research on regeneration of the damaged central nervous system, which includes (i) regrowth of the disrupted neuronal axons, (ii) replenishment of lost neural cells, and (iii) recovery of lost neural functions. In particular, we have investigated cell therapy for treating spinal cord injury. Considering the ethical issues related to fetal cells and embryonic stem cells, there is increasing interest in stem cell technology involving induced pluripotent stem (iPS) cells. Here, we wish to introduce our achievements in iPS cell-based therapy. In addition to their application for cell therapy, iPS cell technologies provide versatile tools for investigation of the pathophysiology of various diseases. Indeed, disease model mice do not always recapitulate the pathophysiology of human diseases. However, iPS cell technology can provide some solutions because neural cells at various developmental stages and a wide variety of cells with the same genetic information as that of patients can be obtained for further investigation. Through these investigations, I have had numerous collaborations with life science industries, including pharmaceutical companies, and generated various patents. Some examples of these achievements will be discussed here.

1 The Challenge of Regeneration of the Central Nervous System

It had been long believed that the damaged central nervous system (CNS) does not regenerate upon injury [1]. However, we have been challenging this dogma for many years by taking advantage of various biotechnologies, including stem cells [2–11], in collaboration with academia and various pharmaceutical companies.

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Before introducing the details of our past and on-going research, I wish to introduce the concepts of regeneration of the CNS, which include (i) regrowth of disrupted neuronal axons, (ii) replenishment of lost neural cells, and (iii) recovery of lost neural functions. Investigation of CNS regeneration is indeed an exciting and profound research field, but also provides enormous opportunities for industry-university cooperation. In fact, through investigations of CNS regeneration and stem cell biology, I have obtained 30 patents and filed 57 patents pending.

(i) Regrowth of disrupted neuronal axons
Axonal regeneration hardly takes place in the damaged CNS because of the presence of large amounts of inhibitors [9, 10], including myelin-derived proteins (e.g. MAG, Nogo-A, and OMgp) [12–17], and glial scar-derived factors (e.g. CSPG) [18, 19], and extracellular matrix-derived factors (e.g. semaphorins). In a previous collaboration with Dainippon Sumitomo Pharma Co. Ltd., we demonstrated the therapeutic effects of a specific inhibitory compound (SM-216289) against semaphorin3A (Sema3A) [20], a major inhibitor of axonal regeneration [21–23], in spinal cord injury (SCI) using a rat complete transection model. Remarkably, we found that this Sema3A inhibitor induced significant functional recovery as well as enhanced axonal regeneration at the lesion site and robust Schwann cell-mediated myelination. This evidence suggests the possibility of using Sema3A inhibitors for the treatment of human SCI patients in the future, which is being continuously investigated through the collaboration between our group at Keio University and Dainippon Sumitomo Pharma Co. Ltd. In addition to treatment of SCI, we found another application of the Sema3A inhibitor in the ophthalmological field. In collaboration with the Department of Ophthalmology at Keio University School of Medicine and Dainippon Sumitomo Pharma Co. Ltd., we showed that the Sema3A inhibitor was able to treat peripheral nerve damage of the cornea. Treatment with the Sema3A inhibitor promoted a robust network of regenerating nerves as well as functional recovery of corneal sensation through subconjunctival injections in a mouse keratoplasty model [24], suggesting a novel therapeutic strategy for treating peripheral nerve damage of the cornea.

(ii) Replenfishment of lost neural cells
It is obvious that replenishment of lost neural cells will be a very important aim of stem cell technology. In our previous studies [25–30], we found that transplanted neural stem cells (NSCs) survived and differentiated into neurons, astrocytes, and oligodendrocytes, which are three major cellular components of the CNS. Graft-derived neurons formed synapses with host neurons and integrated with host neuronal circuits. Graft-derived oligodendrocytes were shown to participate in re-myelination of host axons in SCI models [28, 30], which significantly contributes to functional recovery after SCI [30]. It is possible that graft-derived astrocytes and undifferentiated NSCs produce various trophic factors that support angiogenesis [27–29], cellular survival, and axonal regeneration of host axons including 5-HT-positive raphe-spinal tracts involved

in the locomotive functions of hindlimbs [27–29]. Thus, these findings suggest that both cellular replacement mechanisms and trophic mechanisms are responsible for the effects of stem cell therapy in SCI models. The details of stem cell therapy for treating SCI will be described in the later sections.

(iii) Recovery of lost neural functions
Considering the therapeutic applications of stem cells, it is obvious that recovery of lost neural functions is an important aspect of regeneration of the damaged CNS. For functional recovery, we are interested in rehabilitation and its combination with blockade of the inhibitors of axonal regeneration [31], and/or stem cell transplantation.

2 NSCs and Stem Cell Therapy for Treating SCI

NSCs are somatic stem cells in the CNS, which are characterized by their multipotency and self-renewal. A single NSC is capable of generating various kinds of cells within the CNS, including neurons, astrocytes, and oligodendrocytes. Because of these characteristics, there has been a strong research focus on NSCs and neural progenitor cells for both basic developmental biology and therapeutic applications for treating the damaged CNS [2].

2.1 Basic Biology and Tools for Investigation of NSCs

It is understood that (i) specific immunocytochemical markers, (ii) selective culture methods, and (iii) technologies for the prospective identification and isolation of NSCs and early precursor cells (neural stem/precursor cells, NS/PCs) have greatly contributed to the rapid progress of the investigation of NSCs [8].

(i) Specific immunocytochemical markers
Specific marker molecules for NSCs include Musashi1 (an RNA-binding protein) [32–38], nestin [39, 40], and some Sox family transcription factors [41].

(ii) Selective culture methods
The neurosphere method involves suspension culture with fibroblast growth factor-2 (FGF-2) and/or epidermal growth factor in a defined medium [42], which has been widely used as a versatile method for selective expansion of NSCs. Neurosphere culture allowed us to expand NSCs in an undifferentiated state. NS/PCs obtained by neurosphere culture have been used for transplantation into patients with SCI and Parkinson's disease. We applied neurosphere culture for efficient induction of NSCs from pluripotent stem cells including embryonic stem (ES) cells and induced pluripotent stem (iPS) cells [43–45]. Briefly, we generated embryoid bodies (EBs) from mouse ES/iPS cells in the presence of neural inducers (noggin or retinoic acid), resulting

in neurally biased differentiation of ES cells and a substantial number of NSCs. The NSCs within EBs were then expanded in the presence of FGF-2 to give rise to primary neurospheres that were subsequently passaged to form secondary neurospheres. Interestingly, when we induced the differentiation of primary neurospheres, they exclusively gave rise to neurons, but not glial cells. The majority of neurons derived from primary neurospheres were early projection neurons including forebrain type cholinergic neurons, mesencephalic dopaminergic neurons and spinal motor neurons. However, when we induced the differentiation of secondary neurospheres, they gave rise to neurons, astrocytes, and oligodendrocytes. Neurons derived from secondary neurons, including GABAergic interneurons as the major population, were different from those derived from primary neurospheres. Furthermore, tertiary neurospheres gave rise to a higher proportion of glial cells. Therefore, this in vitro differentiation system of mouse pluripotent stem cells probably recapitulates the change of differentiation potential of NSCs, which occurs in vivo [46]. Using these methods for neural differentiation of pluripotent stem cells, we generated patents, including "Process for Producing Nerve Stem Cells, Motor Neurons, and GABAergic Neurons from Embryonic Stem Cells," and "Remedy for Dysmnesia," and licensed out these patents and related technologies to various pharmaceutical companies and bio-ventures.

(iii) Technologies for the prospective identification and isolation of NSCs and early precursor cells
For the prospective identification of NSCs, combinations of antibodies against cell surface antigens [47, 48] and NSC-specific fluorescence reporters [49–56] have been used [8]. For the latter strategy, we constructed a reporter gene consisting of cDNA encoding a fluorescent protein (green fluorescent protein, Venus, Kusabira Orange, or ffLuc-cp156 [57]), which was placed under the control of the 2nd intronic enhancer of the *nestin* gene or enhancer elements of the *Musashi1* gene for specific expression in NSCs. By taking advantage of these strategies using cell type-specific promoter/enhancer elements and fluorescent reporter genes, we generated several patents for the prospective identification and isolation of NSCs ("Enriched Preparation of Human Fetal Multipotential Neural Stem Cells") and dopaminergic neurons ("Method of Concentrating and Separating DOPAMINergic Neurons") [58].

In addition to (i)–(iii), there are rapidly accumulating studies of the signaling mechanisms involved in the self-renewal and differentiation of NSCs. In the related field, we have published numerous scientific reports and generated various patents including "Numb Protein Expression Inhibitor Making Use Musashi," "Method of Detecting Activation of Notch Signal Transmission System," "Signal Transduction System Activator," "Agent for Inhibiting Proliferation of Neural Stem Cells," and "Method of Promoting Subsistence and/or Proliferation of Neural Stem Cells and Promoting Extension of Neurite, Promoter therefore, Pharmaceutical Composition Containing Neural Stem Cells, Method of Assay and Method of Screening."

2.2 Stem Cell Therapy for Treating SCI

2.2.1 Pathophysiology of SCI

The pathophysiology of SCI is known to change over time after the initial injury. SCI is initiated by primary mechanical trauma (the so called “primary injury”) and followed by a series of secondary events (the so called “secondary injury”) [8]. The secondary injury includes hemorrhage, ischemia, and hypoxia (which take place within seconds), production of pro-inflammatory cytokines and glutamate cytotoxicity (which take place within minutes), and production of free radicals and nitric oxide, protease activation, and neutrophil invasion (which take place within hours). These events characterize the strong inflammation at the acute phase of SCI. The acute phase of SCI lasts for several days after the primary mechanical trauma, which is followed by delayed events (the so called “subacute phase”) including neural apoptosis, astrogliosis, and axonal demyelination. The subacute phase is followed by an irreversible stage (the so called “chronic phase”) including severe axonal degeneration, cyst formation, and permanent loss of spinal functions. The chronic phase is considered to begin at 6 weeks in rodents and 6 months in humans after the primary mechanical trauma. This phenomenon is not observed in salamanders in which the spinal cord regrows even after tail amputation [59]. The damaged spinal cord hardly regenerates in adult mammalian animals because of limited activation of endogenous stem cells and axonal regeneration, which is why there is a need for blockade of the inhibitors of axonal regeneration, and transplantation of NSCs for treating the SCIs of humans.

2.2.2 Interventions at the Acute Phase

In the acute phase of SCI, inflammatory cells such as neutrophils, hematogenous macrophages (blood-borne macrophages), and resident microglia accumulate at the lesion site. Because pro-inflammatory cytokines such as tumor necrosis factor α, interleukin (IL)-1β, and IL-6 are major regulators of inflammation, these cytokines are likely targets for potential pharmaceutical interventions for treating SCI [60]. Among them, IL-6 induces the activation and invasion of microglia/macrophages within SCIs. Thus, in collaboration with Chugai Pharmaceutical Co. Ltd, we administered an anti-mouse IL-6 receptor antibody, MR16-1, to a mouse SCI model, resulting in improved functional recovery with reduced inflammation and astrogliosis, and enhanced tissue sparing [61]. Furthermore, we have investigated the mechanism of action of the anti-MR16-1 in more detail by focusing on the effect of temporary inhibition of IL-6 signaling in macrophages and microglia after SCI [60]. We found that MR16-1 treatment reduced the infiltration of macrophages, but increased the number of microglia at the SCI. Thus, temporary inhibition of IL-6 signaling must have induced switching of the major inflammatory cell type at the lesion from hematogenous macrophages to resident microglia, resulting in improved tissue sparing and debris clearance for promotion of neural repair after SCI. Notably, a humanized antibody against the human IL-6 receptor (Actemra; tocilizumab) is already used clinically, and our findings suggest its potential application for the treatment of SCI patients at the acute phase. Keio University and Chugai Pharmaceutical Co. Ltd have filed patents covering the therapeutic actions of blocking antibodies against IL-6 signaling during the acute phase of SCI ("Therapeutic Agent for Spinal Cord Injury Comprising Interleukin-6") in various countries.

2.2.3 Stem Cell Transplantation at the Sub-acute Phase

Considering the time course of secondary injury, the most appropriate time point for transplantation of NSCs is important. In rodent SCI models, we performed transplantation of NS/PCs at 9 days after injury, i.e., after the acute inflammatory phase and before the astroglial scar becomes prominent [8]. In mice, we found that transplantation of NS/PCs at the chronic phase did not result in functional recovery [62]. Thus, the chronic phase of SCI is not appropriate for therapeutic transplantation. The formation of large cysts and the development of glial scarring during the chronic phase might inhibit axonal regeneration (Nishimura et al. Submitted). In the case of humans and considering the time course of inflammation, it is assumed that NS/PCs should be transplanted by 4 weeks after the primary mechanical trauma. In relation to stem cell therapy of SCIs, we generated a patent entitled "Central Nervous System Neural Progenitor Cell which Induces Synapse-Forming Neurons in the Spinal Cord."

2.2.4 Non-human Primate Models of SCI

While most studies of SCI have used rodent models, it is not easy to directly correlate the results obtained in rodent models to clinical cases because of the functional and anatomic differences of the spinal cord between rodents and primates. Previously, we developed a non-human primate model of contusive SCI at the C5 level in the common marmoset. This model consisted of mild, moderate and severe contusive SCIs that were induced by dropping one of three different weights (15, 17, or 20 g) onto the C5 level from a height of 50 mm. We also developed behavioral assays to monitor the motor functions of these common marmoset models of SCI by measurements of spontaneous motor activity, as well as bar grip and cage climbing tests [63]. Using this model, we verified the therapeutic effects of transplantation of human fetal NSCs [64] and infusion of hepatocyte growth factor (HGF) [65]. By confirming the safety and utility in this non-human primate model, we initiated a Phase 1 clinical trial of HGF infusion for treatment of patients with amyotrophic lateral sclerosis in collaboration with Professor Masashi Aoki at Tohoku University and Kringle Pharma Co Ltd. [66]. We also filed a patent for the common marmoset model of SCI in both Japan and the USA ("Method of Constructing Spinal Injury Model Monkey and Utilization Thereof").

2.2.5 Sources of Stem Cells for Treating SCI

We have demonstrated that transplantation of human fetal NSCs into a common marmoset model of SCI results in significant functional recovery. However, because of the ethical controversies, we are not allowed to perform clinical trials using fetal cells. Human ES cells are also somewhat controversial. Therefore, we became interested in iPS cell-derived NS/PCs, directly induced NSCs [67], and neural crest stem cells [68] for transplantation into patients. These cells can be derived from adult tissues, including a patient's own tissue, and are therefore not ethically controversial.

2.3 iPS Cell-Based Therapy for Treating SCI

2.3.1 Brief Summary of iPS Cell Technology

iPS cell technology was developed by Professor Shinya Yamanaka, the 2012 Nobel laureate for Physiology or Medicine, and colleagues at Kyoto University. In 2006, they published a study showing that somatic cells, such as adult skin fibroblasts, can be reprogrammed into ES cell-like pluripotent stem cells by retroviral transduction of four genes encoding transcription factors, i.e., *Oct4, Sox2, Klf4*, and *c-Myc* [69]. Since 2006, we have had a close collaboration with the Yamanaka Laboratory, aiming for iPS cell-based therapy for treating SCI patients. In 2007, establishment of human iPS cells using retroviral or lentiviral transduction of reprogramming factors was reported by Yamanaka [70] and Thomson [71]. Subsequently, various methods have been published (reviewed by Okano [72] for generating integration-free iPS cells, including episomal vectors, the Sendai viral vector, and modified RNA).

2.3.2 Transplantation of NSCs Derived from iPS Cells

First, we examined transplantation of NSCs derived from mouse iPS cells into a mouse SCI model. However, the investigation was not as straightforward as we had expected. We had already established mouse ES cells [43, 44], and induced various mouse iPS cell lines into secondary neurospheres. The resultant mouse iPS cell-derived secondary neurospheres gave rise to neurons, astrocytes, and oligodendrocytes, which was irrespective of their somatic origin or method of iPS cell production [45], in a similar manner as that of mouse ES cell-derived secondary neurospheres. However, when we transplanted these mouse iPS cell-derived secondary neurospheres into mouse brains, varying tumorigenic propensities were observed depending on the somatic origin of the iPS cells [45]. These observations indicated that epigenetic memory and completeness of reprogramming were involved in the tumorigenic propensities of iPS cell-derived NSCs. Subsequently, we transplanted non-tumorigenic iPS cell-derived NSCs (primary or secondary neurospheres) into mouse thoracic contusion injury models (Th10) to examine their therapeutic effects.

Interestingly, we found that transplantation of secondary neurospheres, but not primary neurospheres, resulted in significant and long-lasting functional recovery, indicating the importance of glial cells. We found that transplanted iPS cell-derived secondary neurospheres gave rise to neurons, astrocytes, and oligodendrocytes, and re-myelination was induced by graft-derived oligodendrocytes. Conversely, transplantation of tumorigenic iPS cell-derived secondary neurospheres into SCI model mice resulted in functional recovery, but the effects were transient. Eventually, transplanted animals suffered from strong paralysis due to the effects of tumors. Thus, the safety issue concerning tumorigenicity is crucial for iPS cell-based therapy of SCI.

Human iPS cells can be induced to differentiate into NSCs in a similar manner as that of mouse iPS cells, although additional passage(s) are required to obtain both neurons and glia from iPS cell-derived neurospheres. Thus, in the case of humans, we used tertiary neurosphere instead of secondary neurospheres for the following transplantation experiments. We screened human iPS cell lines and found that NSCs derived from the 201B7 human iPS cell line were non-tumorigenic (Okada et al., submitted). We transplanted 201B7 human iPS cell-derived NSCs into mouse [29] and common marmoset SCI models (Kobayashi et al., submitted), and found that grafted cells gave rise neurons, astrocytes, and oligodendrocytes and induced functional recovery without any signs of tumorigenesis.

2.3.3 Future Direction of Cell Therapy for Treating SCI Using Reprogramming Technologies

Thus far, we have transplanted NSCs derived from mouse and human iPS cells into mouse and non-human primate SCI models, which results in functional recovery. Furthermore, using appropriate cell lines, there were no signs of tumorigenesis in transplanted animals during the time course of the observation. For clinical application in the future, there are some concerns that need to be addressed. Considering that the critical time window for transplantation is within 4 weeks after SCI (primary mechanical trauma) and establishment of human iPS cells and subsequent induction of NSCs, which produce both neurons and glia, requires ~180 days, it is essential to prepare clinical grade banks (or stocks) of iPS cells and iPS cell-derived NSCs in advance. Clinical grade cell banks would allow these cells to be transplanted into any patient within the critical period. In addition, before iPS cell-based therapy can be used in the clinic, we believe that the safety issues should be addressed as follows: (1) usage of integration-free iPS cells, (2) selection of an appropriate neural differentiation method, (3) selection of appropriate iPS cell clones by somatic origin, reprogramming, epigenetic characterization, and flow cytometric analysis, (4) pre-evaluation of tumorigenesis in vivo, and (5) elimination of graft-derived tumors [72].

3 Disease Models

There is increasing interest in iPS cell-based modeling of diseases [73]. In fact, disease model mice do not always recapitulate the pathophysiology of human diseases. Furthermore, it is extremely difficult to investigate what is taking place in vivo during the onset of disease, particularly neurological and psychiatric diseases, partly because there is poor accessibility to pathological foci in the brain. These aspects complicate the investigation of human neurology. However, iPS cell technology can provide some solutions because neural cells at various developmental stages and a wide variety of cells with the same genetic information as that of patients can be obtained for further investigation. In my laboratories, we have been characterizing various neurological and psychiatric diseases that are classified into the following categories: (1) diseases caused by disrupted gene regulation, (2) diseases caused by structural abnormalities of the nervous system, (3) diseases caused by abnormal neural functions, (4) diseases caused by abnormal metabolism in the nervous system, and (5) late-onset neurological diseases including Alzheimer's disease [74] and Parkinson's disease [75]. Characterization of iPS cells derived from pediatric neurological disorders may recapitulate disease processes, at least partially, which may contribute to drug development and future therapies.

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Chapter 6
Fostering Technology Transfer, Innovation, and Entrepreneurship from the Perspective of a Public University

Benjamin Chu

Abstract The goal of a technology transfer office should be to encourage technology transfer, innovation, and entrepreneurship. For a public university, those goals must also be aligned with the university's mission as a teaching and research institution. This chapter describes some of the activities in the University of California system and at the University of California, Los Angeles campus in fostering technology transfer, innovation, and entrepreneurship in support of research, education, and public service. These include a new proof-of-concept fund, an on-campus incubator, and a growing student internship program.

1 Technology Transfer from a Public Research Institution

The University of California (UC) system comprises ten campuses (Berkeley, Davis, Irvine, Los Angeles, Merced, Riverside, San Diego, San Francisco, Santa Barbara, and Santa Cruz) which include more than 234,000 students, more than 207,000 faculty and staff, 50,000 retirees, and more than 1.6 million living alumni. As a public institution of the State of California, the UC is committed to teaching, research, and public service as its core mission. Whereas each campus and its technology transfer office have their own specifically defined mission statements, a theme central to all the campuses and technology transfer offices is to not only maintain the UC's core mission in its technology transfer practices, but to actively complement the core mission through technology transfer.

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With a portfolio of 10,341 active inventions, 1,581 new inventions reported, 343 issued U.S. patents, and 1,285 total U.S. patent applications filed in fiscal year 2011, the UC system is highly prolific in its innovative discoveries and patenting. With 58 new startup companies formed (44 based in California), 217 new utility licenses issued, and over $200,000,000 in licensing income, the UC has certainly found success in translating technologies to the marketplace [1]. In fiscal year 2011 the University of California, Los Angeles (UCLA), received 379 invention disclosures, 47 issued U.S. patents, 52 new license and option agreements, and over $21,000,000 in licensing income [2]. In addition, 19 new startups were formed. As part of a public research institution, however, a technology transfer office should have goals beyond financial metrics by contributing to the broader research, education, and public service missions of the university.

2 Fostering Technology Transfer

A technology transfer office is often in the delicate position of balancing many competing interests and cultures. For the UCLA Office of Intellectual Property and Industry Sponsored Research (OIP-ISR), stakeholders include faculty, staff and students; licensees, industry sponsors, and investors; and federal sponsors and the people of California. The most obvious example of balancing interests would be the relationship with industry, which is motivated by profit, and the university, which is in the business of fundamental research. A successful technology transfer office must find middle ground where the interests of all its stakeholders are represented. In doing so, it must find ways to become a vehicle to encourage collaboration.

2.1 Public-Private Partnerships

Licensing deals and revenue is one mechanism by which to measure the performance of a technology transfer office, but that should not cause it to lose sight of its ability to plant the seeds of technology transfer through other means of public-private partnerships. Research collaborations beginning at the grassroots level often grow into mutually beneficial relationships. Often it begins from a scientist or engineer at the university who shares a common intellectual interest with a scientist or engineer from a company. What can a technology transfer office do to encourage these relationships?

The obvious role a technology transfer office plays is in facilitating industry-sponsored research. In fiscal year 2012, the UCLA OIP-ISR executed 483 total agreements with 226 funded industry-sponsored research agreements, totaling USD 35,465,718. As universities generally conduct early stage research, they are in many instances working on high-risk projects that may be many years from finding a place in a commercial product. Despite the high-risk nature of early stage university research, these projects hold appeal to companies that are looking toward the future and potential new products or disruptive technologies. Industry-sponsored research allows a company to leverage university expertise which may not exist within the company, university facilities, and the creativity and energy of faculty and students to explore research interests that coincide with the company's long-term business vision. Conversely, industry-sponsored research helps to support faculty, postdoctoral scholars, and students to continue to pursue their research curiosity beyond basic science and research (generally limited by federal research grants), and to direct their research toward applications which may one day benefit the public. On truly collaborative projects, expertise on both sides of the aisle can be leveraged. For instance, industry scientists or engineers with manufacturing expertise can provide insight and feedback to university researchers to better understand how university discoveries will respond and react outside of the laboratory and in real life conditions. A technology transfer office that not only helps facilitate such collaborations, but also proactively seeks to bridge these connections by identifying interesting research projects for industry or identifying potential partners for university researchers, plants the seeds for downstream licensing relationships.

2.1.1 Bridging the Gap

University research is generally a high-risk, high-reward endeavor because research projects are at an early stage, yet are focused on breakthrough discoveries. Unfortunately, there is a gap between where federal funding leaves off and where industry, venture capitalists, or corporate investors are ready to partner up. Before a company is ready to invest in an unproven technology, researchers must demonstrate some level of feasibility before a company will be willing to take on the risk associated with an early stage technology. A technology that could potentially attract millions of dollars in investment may never reach that point unless the risk associated with the technology is reduced. It may take as little as $100,000 to demonstrate a proof of concept, but so called "gap funds" or "proof-of-concept funds" are in short supply.

In 2011, the UC Office of the President initiated a new grant program called the Proof of Concept Commercialization Gap Grants (PoC Program) to bridge the gap between research and commercialization. The PoC Program supports 1-year projects which are on the brink of commercialization or licensing but have a clearly defined hurdle between research and commercialization. Research projects must addresses that hurdle. The goal is that by closing this gap to commercialization, the PoC Program will accelerate commercialization of technology and intellectual property owned by the UC by positioning the technology for licensing or leading to the development of a startup. Ultimately, the PoC Program plays into the public service mission of the UC by attracting investment, creating jobs, and translating discoveries from the UC's laboratories into commercial products and services to benefit the public and stimulate California's technology-based economy.

The PoC Program is open to all fields of research, but the intellectual property used in any project must be disclosed to the technology transfer office of the associated campus. Furthermore, the intellectual property must be assigned to the UC and be available for licensing. In this sense, a company should not leverage UC funds for a technology that is presently ready for investment. Rather, the technology must be unencumbered from any license agreements, sponsored research, or investment partners. Additionally, basic research or theoretical developments are not eligible for funding. Projects which may receive PoC funding include prototype development, commercial feasibility tests, research to demonstrate risk mitigation to potential licensees, or research to address a specific hurdle identified by industry as a barrier to attract capital. In their proposals, applicants must describe a clear path to commercial development, the market potential of the technology, and how the gap fund would lower the barrier to commercialization. Projects are reviewed mainly on their commercialization potential, meaning they must demonstrate research success and a specific deliverable, such as a demonstration, test result, or prototype, where achievement of such deliverable has the potential to result in the technology's being licensed to an established company or serve as the foundation of a startup company. Additional review criteria include: (1) exceptionality of the project as demonstrated by an innovative, well-conceived project; (2) qualifications of the personnel involved in the project; (3) resources, facilities, and infrastructure available to the researchers; and (4) benefit to California through economic development (attracting capital, investments, creating companies, and creating jobs) or by identifying new solutions to problems critical to California. Reviewers consist of both scientific peers and private investors. This enables the technologies to be evaluated on their technical merit as well as their commercial potential.

If awarded, recipients receive a one-time grant of up to $250,000. In its first round of funding, the PoC Program awarded 13 projects across the UC campuses in areas ranging from water purification to medical devices. Amounts awarded were between $100,000 and $250,000, totaling $2.7 million. UCLA received three such awards for the following projects: "In Vitro Diagnostic Sensors for Cardiovascular Disease," "Continuous Process for High Recovery Inland Desalination," and "Soft Error Mitigation for FPGA Based Systems." The UC PoC Program is a valuable program and hopefully the number of projects funded at UCLA in future PoC rounds can be increased.

3 Fostering Entrepreneurship

Over the past 5 years, 99 new startups were formed around UCLA technologies. Often startup companies bear the risk of early stage university technologies. Encouraging entrepreneurship can thus help bridge the gap between the laboratory and the marketplace. A number of initiatives at UCLA have had a positive impact on the recent uptick in entrepreneurship. These range from establishing an on-campus incubator; leveraging on-campus synergies with other departments, student groups, and the schools of law and business; establishing off-campus regional partnerships; and educational outreach.

3.1 UCLA's On-Campus Incubator

In 2009 UCLA launched the California NanoSystems Institute (CNSI) Technology Incubator to address a glaring need for affordable and accessible incubator space in a city notorious for high rents and long commute times. Perhaps one of the most difficult tasks facing UCLA's entrepreneurial faculty, staff, and students was finding physical space easily accessible from campus and affordable considering a startup company would need to manage its cash flow very carefully. Years in the making, the CNSI Technology Incubator was established to address this hurdle to commercializing UCLA technologies. It was housed in the CNSI building, which opened in 2007 as a state-of-the-art building equipped with a 260-seat theater, wet and dry laboratories, Class 100 and Class 1000 clean rooms, and eight core facilities housing electron microscopes, atomic force microscopes, X-ray diffraction microscopes, specialized optical microscopes, and high-throughput robotics for molecular screening. The CNSI Technology Incubator provides 2,000 square feet of laboratory space for startup companies that have licensed UCLA technologies.

The flexible laboratory space dedicated to company and technology incubation can hold up to ten companies. Each company gets two benches as well as access to dry and wet labs, fume hoods, and six of the core lab facilities. This access includes time on highly specialized imaging equipment such as fluorescence imaging; electron microscopy; scanning probe microscopy; atomic force microscopy; in-house expertise and training in high-throughput screening, drug discovery, and functional genomics; and access to the foundry and clean rooms. Access to the clean rooms and core facilities is on a charge basis, but eliminates the need for a bootstrapped startup company to go out and purchase capital-intensive equipment. Furthermore, despite being located physically on campus, the incubator space is designated as company space. Intellectual property developed using the incubator facilities by company employees will belong to the company, so long as university employees are not inventors. Another critically important advantage that the CNSI Technology Incubator provides is that because the incubator space leased to companies is considered company space and not university space, companies are able to apply for Small Business Innovative Research (SBIR) grants, which often require that the applicant have a dedicated company space that is not one's residence or university laboratory. The CNSI Technology Incubator is critical to opening up avenues to companies that were previously unavailable: proximity, affordable rent, access to prohibitively expensive laboratory facilities and equipment, and access to additional funding sources through SBIR grants. By making it more attractive for companies licensing UCLA technologies to stay close to UCLA, the hope is that as these companies mature, they will remain in the area thereby providing economic development and jobs to the local economy.

3.2 On-Campus Synergies

UCLA is in the fortunate position to have not only highly reputed engineering and medical schools, but also highly regarded business and law schools, in addition to a vibrant student community that proactively seeks collaborative projects across engineering, life sciences, law, and business. As is often the case with a technology transfer office, staffing levels cannot keep up with the volume of technologies coming through the door. This is where the UCLA OIP-ISR has been very fortunate to leverage the expertise from UCLA's Anderson School of Management, the UCLA School of Law, the School of Engineering's Institute for Technology Advancement, the UCLA Business of Science Center, and the Tech Coast Angels mentoring program.

The Technology and Innovation Partners (TIP) Program, offered by UCLA's Anderson School of Management in partnership with the OIP-ISR, the CNSI Incubator, the Institute for Technology Advancement, the UCLA School of Law, and the UCLA School of Medicine, is an educational program for students pursuing a Master's in Business Administration. It utilizes UCLA technologies for project-based learning. Over the course of a year, participants evaluate technologies by conducting technical and legal feasibility analyses, market feasibility, and financial feasibility. In these studies, participants try to answer some of the following questions: (1) What is the product, and what problem does it solve? (2) Who are the potential customers? (3) Which segment will use the product? (4) What is the total addressable market? (5) Why will the targeted customer use the product? In addition, a final report covers an intellectual property analysis. This involves potential prior art and freedom to operate, a high-level competitive analysis, and a developmental timeline with milestones and funding requirements. Participants take classes from both the business school and law school and work in interdisciplinary teams on real-life projects that involve UCLA-affiliated technologies. To encourage an interdisciplinary team, enrollment is open to students from the Anderson School of Management, the School of Law, and other graduate programs, generally from the medical school, engineering, or sciences. The goal is to provide a project-based educational experience that will also help accelerate entrepreneurship and commercialization at UCLA. Additionally, the researchers whose project is being evaluated gain valuable insights into the commercializability of their technologies. They often find themselves equally invested into a feasibility study with the interdisciplinary team of students.

What began as a seminar in 2003 by Professor Roy Doumani eventually evolved into a class, "The Business of Science: Exploring Entrepreneurship," offered through the Department of Molecular and Medical Pharmacology every year since 2004. The goal of the class is to expose graduate students and postdoctoral researchers to the business world, to understand how to move science from the bench to the marketplace, and to introduce academic researchers to the nuts and bolts of business. In addition, the class introduces UCLA's researchers to think beyond research careers in the laboratory and provides them with a tool set to prepare them for a career in private industry should they choose to leave academia. The class became such a success that the Business of Science Center was established with a mission "to prepare scientific, engineering, law, medical, and business graduate students for careers in the private sector; to assist university faculty and clinicians in technology transfer; and to serve as a catalyst for increased industry support and involvement on campus." The UCLA OIP-ISR has partnered with the Business of Science Center to provide UCLA technologies for Business of Science students to evaluate. The projects give students hands-on experience in analysis of patent rights, market analysis, business plan development, and understanding how to position a technology for investment.

Beginning with its first call for proposals in 2011, the Venture Competition offered by the Business of Science Center is another program at UCLA that helps their researchers and entrepreneurs move their technologies to the marketplace. Students, faculty, staff, and clinicians from the sciences, engineering, and business are encouraged to submit descriptions of innovative medical technologies. The technologies must be disclosed to the UCLA OIP-ISR and have, at a minimum, a provisional patent application filed. The technologies are screened and finalists are paired with a venture team consisting of PhD students, MBA students, postdoctoral researchers, and industry mentors. The venture team then provides a commercial assessment of the technology and presents their findings to a screening panel consisting of investors and industry executives to compete for a proof-of-concept grant and a chance to make a pitch at the Southern California Biomedical Council (SoCalBio) Annual Investors Conference. Two winning teams were chosen in the inaugural Venture Competition in 2011 and received $20,000 each in proof-of-concept funding.

3.3 Looking Outside: Regional Partnerships

For an entrepreneurial ecosystem to coalesce, a region needs to have investment capital, human capital, and innovative ideas. Los Angeles has no shortage of any of these. Most importantly, it has within its borders three renowned research institutions: UCLA, the California Institute of Technology (Caltech), and the University of Southern California (USC). In 2007 the three universities, in partnership with Entretech, a nonprofit organization that provides day-to-day support for new startups, joined forces for the inaugural "First Look LA" event. This event was designed to showcase each university's most promising technologies and emerging startup opportunities to the investment community. Hosted by USC in the inaugural year, the event has been alternating among the campuses in each subsequent year and showcases technologies along two tracks: physical sciences and life sciences. The First Look LA event brings together university researchers and entrepreneurs with venture capitalists, angel investors, and potential CEOs. The technologies showcased by the universities feature some of the universities' most promising opportunities that have never before been seen by investors. A short presentation by the researchers is followed by a question and answer period to allow investors a chance to better understand the technology and future plans, and for the researchers to understand what hurdles to commercialization they may face. Even if the presentations do not lead to a direct investment, the investment community will see what is coming down the university pipeline, hopefully planting the seeds of future investments.

Partnering with the City of Los Angeles is another way for UCLA to enable entrepreneurship and economic development, and embed itself within the surrounding community. One such example is Clean Tech Los Angeles. Clean Tech LA is a collaborative effort to bring together Los Angeles's premier academic institutions, business community, and the city to make Los Angeles a leader and a hub of clean technology research, incubation, new companies, and jobs by working together to support new research endeavors, apply for federal grants, and promote economic development. Clean Tech LA involves UCLA, Caltech, and USC as academic partners; the Los Angeles Department of Water and Power, the Community Redevelopment Agency, the Mayor's Office, and the Port of LA as government partners; and the LA Business Council, LA Economic Development Corporation, and LA Area Chamber of Commerce as business partners. Part of Mayor Antonio Villaraigosa's vision of Los Angeles as a clean tech hub is the establishment of the Clean Tech Corridor, a 4-mile stretch along the Los Angeles River in downtown Los Angeles to incubate clean technology startups and support a business cluster dedicated to clean technology manufacturing. Through regional partnerships, a strong and motivated team with aligned interests can come together to accelerate the development and adoption of early stage university technologies. For example, in 2009 the federal Department of Energy awarded a $60-million stimulus grant to the Los Angeles Department of Water and Power, in partnership with UCLA, Caltech, and USC, to modernize its aging electrical grid and develop a "smart grid" [3]. The smart grid project at UCLA, led by Dr Rajit Gadh, utilizes wireless sensors to create complex smart power meters that can be layered on top of the existing grid to make the grid compatible with renewable energy sources, respond and adjust to demand and minute-by-minute energy fluctuations, create smart climate-control systems, and switch among various energy sources depending on energy demand, availability, and pricing. Having a partner such as the Los Angeles Department of Water and Power is critical to demonstrating real-time and real-world testing and applicability of the UCLA technology.

3.4 Educational Outreach

A central component to fostering entrepreneurship is to nurture an entrepreneurial culture at UCLA. This often begins by getting students, staff, and faculty thinking about intellectual property and business. The most basic component of the UCLA OIP-ISR's educational mission is to help the UCLA community understand how to protect their intellectual property. This is done with informal presentations to the laboratories, guest lectures and seminar sessions, and speaking engagements at events on campus. For many researchers and first-time inventors, the patenting process is a very foreign experience. Through its outreach efforts, the UCLA OIP-ISR hopes to help researchers understand what is patentable material, how to work with the OIP-ISR office to apply for patents, what constitutes a public disclosure, and how to protect their intellectual property.

More advanced topics such as business development, company incorporation, or specific topics on intellectual property law are offered as focused seminars in conjunction with invited experts from patent law firms, venture capital firms, or angel investors. For example, the UCLA OIP-ISR, with invited speakers from patent law firms, has sponsored seminars on select topics such as patenting small-molecule therapeutics, proper drafting of the written description and enablement requirement, and the ramifications of intellectual property case law, such as Mayo v. Prometheus. As another example, the CNSI Incubator, with support from the OIP-ISR, sponsored a "Managing Invention Seminar Series" with topics such as "Patents 101: record-keeping/notebooks and inventorship determination," "UCLA technology transfer basics," "Licensing to start ups: a step by step review of the process," "Forming a startup around a UCLA invention: resources, guides, and tips," "Building a sturdy foundation—startup corporate structure," "Early stage founder positioning," and "Venture capital and university based startups."

Finally, the UCLA OIP-ISR offers internships and a Technology Assessment Fellows Program to graduate students for an immersive, hands-on experience in intellectual property and technology transfer. The internship program provides graduate students an opportunity to gain exposure to the university technology commercialization process, intellectual property management, marketing, and business development through interactions with licensing officers in the OIP-ISR, faculty inventors, outside legal counsel, and potential investors. Special projects are also assigned to the students. Traditionally, interns have been doctoral candidates in engineering and science, but the pool of interns has also included graduate students from the business school and law school. In these cases, the special projects might be tailored to their interests. For example, interns from the law school might focus on projects closely associated with patent prosecution, such as learning how to perform prior art searches with feature comparison charts. They also might receive training on analyzing, characterizing, and summarizing office actions from the patent office. The OIP-ISR has generally focused on having a larger class of interns during the summer months, although often the interns will continue on projects throughout the school year, but with more limited hours.

The Technology Assessment Fellows Program began in the summer of 2012 and focuses on providing students with experience in technology evaluation. Fellows are assigned projects on an as-needed basis to assess the commercial viability of new inventions, identify potential licensees or investors, develop marketing materials, generate business plans, conduct competitive analysis, and analyze the patent landscape. Whereas students in the internship program work within the office, the fellows program is a remote-based program to allow fellows to log in remotely and perform their assessments on their own time. The technology assessment report has a summary of the background of the invention, what the innovation is, potential applications, development to date, a summary of the market overview and market size, the competition, key commercialization challenges, relevant patents and publications, and finally a short marketing summary of the technology. The goal is to be able to hand the researchers a technology assessment report so that they can have a better understanding of the applications, market size, and commercial feasibility of their technology, and to get them thinking about aspects of their research that they may otherwise have not emphasized. In return, fellows gain professional experience on the business side of science. Should they choose to transition out of the laboratory, their experience from the Technology Assessment Fellows Program will also help prepare them for their own entrepreneurial endeavors or careers in consulting, business development, law, or industry-related careers.

4 Future Goals

As many of the initiatives described in this chapter are in their infancy, the goal is to grow them slowly. Undoubtedly, learning what does and does not work can enable improvement of these initiatives. The on-campus incubator is currently limited regarding how many companies it can admit. Expanding the incubator is an eagerly sought goal, whether it be finding additional incubator space on campus, or building an incubator space close to campus. It is hoped to see the proof-of-concept fund expanded to fund additional projects with multiple calls for proposals throughout the year. An expanded proof-of-concept fund can spur technology transfer by reducing commercialization risks and making early stage technologies much more attractive to commercial partners and investors. The Technology Assessment Fellows Program accepted their first class of fellows in the summer of 2012, building excitement to expand this program in the future to admit more fellows, thereby providing opportunities to graduate students to work on technology commercialization and detailed feedback to the inventors. Ultimately, by supporting and improving these current initiatives, and continually exploring new initiatives, an environment of entrepreneurship and technology transfer can be fostered while simultaneously encouraging an education and public service benefit to the university and community.

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Chapter 7
Fostering Innovation for the Benefit of Society: Technology Licensing's Role at Stanford

Kirsten J. Leute

Abstract Fostering innovation for the benefit of society is part of the mission of Stanford's Office of Technology Licensing (OTL); "To promote the transfer of Stanford technology for society's use and benefit while generating unrestricted income to support research and education." Throughout Stanford's history, researchers' drive to innovate formed Stanford into the active and prominent academic institution that it is today. To help understand the role of Stanford's OTL in this system, this chapter reviews OTL's history, policies, and practices. We provide some attributes that help OTL be successful in transferring technologies that will benefit the public, as well as examples of how OTL works with startups to move the technologies out from Stanford into companies. These companies might then produce new products that will benefit the world.

1 Stanford's Background

Stanford's history is steeped in innovation. One of the people who seeded and formed our university's ecosystem and surrounding environment is Frederick Terman, former Professor, Dean, and Provost of the university. Professor Terman had a long history with Stanford, having moved to the university when his father took a faculty position. Following in his father's professorial footsteps, he eventually became a faculty member at Stanford in the Electrical Engineering Department.

Professor Terman realized that California did not have many jobs for engineering graduates, so he helped to provide and build opportunities for such jobs, including

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making Stanford and the surrounding area a premier place to be. First, he established the "steeples of excellence" practice whereby the university recruited leading professors, which in turn attracted the notice of other important and rising academics. Second, he encouraged and helped students and former students to start businesses. One of the more famous examples is that of David Packard and William Hewlett. Third, he supported the development of the area surrounding Stanford for industry. One area developed was the Stanford Industrial Park (now called the Stanford Research Park), a high-technology park on Stanford's land.

Stanford is presently a medium-sized university with 1,934 faculty members and over 15,000 students. Of our $4.1 billion budget, $1.2 billion is for sponsored research. The vast majority of the sponsorship for research at Stanford comes from the federal government of the United States (for example, the National Institutes of Health and the National Science Foundation). It has an endowment of around $16.5 billion and part of the investment return from the endowment is used to support Stanford's operating expenses. Stanford has seven schools—Business, Earth Sciences, Education, Engineering, Humanities and Sciences, Law, and Medicine. The majority of inventions that Stanford's Office of Technology Licensing (OTL) handles come from Engineering, Humanities and Sciences, and Medicine, although we do receive a few from the other schools as well.

There are many ways Stanford transfers its knowledge and innovations to the world. Intrinsically, the education of students who go on to other endeavors is one of the main ways this happens. The publications, seminars, and presentations that the students, faculty, and other researchers give disseminate their findings. Stanford also has a faculty consulting policy where faculty are allowed to consult outside of the university 1 day per week [1, 2], using their knowledge to help companies prosper. There is also, of course, the licensing of the intellectual property owned by the university, the focus of this chapter.

2 Office of Technology Licensing

The mission of Stanford's OTL is to promote the transfer of Stanford's technology for society's use and benefit while generating unrestricted income to support research and education. We put a large emphasis on "society's use and benefit." We do not license our technologies simply to gain income. Our exclusive licenses all include diligence to make sure a technology is not shelved, and we can terminate licenses if a company is not being diligent. Our goal is to have the technology developed and people's lives improved. Although the majority of technologies do not actually become products or services, we provide the chance for it to happen.

The types of technologies we handle include patents, copyrightable material (including software), and biological material, such as cell lines, antibodies, and transgenic mice. The typical life cycle of a technology is:

(a) New technology created, often with support from government or other funding sources

(b) The technology is disclosed to OTL
(c) OTL makes the decision whether to pursue the invention, which may include starting the patent process
(d) OTL markets the invention
(e) A company is founded to license the technology (licensee), or possibly many companies are founded
(f) Licensing of the technology
(g) Monies come in to support further research and education at the university
(h) The cycle continues

This is not a self-sustaining cycle, and we do not know of a university where it is. As mentioned previously, the current amounts for sponsored research at Stanford are $1.2 billion. Last year, OTL brought in $66.8 million. OTL licenses between 20% and 25% of the invention disclosures it receives.

3 Stanford's Inventions

Our office was started in 1970 (after the era of local startups such as Hewlett-Packard and Varian). From the early days we had a number of interesting technologies. One of the first was FM Sound Synthesis developed by John Chowning. The FM Sound Synthesis technology allowed digital synthesizers to make new and interesting sounds. Yamaha saw the opportunity with this technology and licensed it from Stanford. It was the beginning of a long relationship that has lasted well after the initial patent expired in 1995.

In 1974, two researchers published an article on a method for recombinant DNA cloning. The director of OTL at the time read about the research and contacted the Stanford researcher, Stanley Cohen, about pursing patenting and commercialization of the technology. Eventually, this was done in cooperation with the University of California–San Francisco and its researcher, Herbert Boyer. Recombinant DNA went on to become a university licensing success story; it was licensed by over 400 companies, brought in over $250 million in royalties, and was used in numerous products. These included human insulin, which was developed by Genentech, a company founded in part by Dr Boyer. The benefits to humans and animals around the world from recombinant DNA technology have been enormous.

We have had inventions that were used in the DSL standards, production of monoclonal antibody drugs, microarrays, and the original algorithm for Google. The majority of our licenses are in the biotechnology field (for example, in our 2010 fiscal year, we signed 71 licenses in the biomedical space and 18 in the physical sciences). Going by the number of inventions licensed over our history, we licensed more inventions in the physical sciences. Of the 1,445 invention disclosures that OTL licensed, 560 were solely from biomedicine, 713 solely from the physical sciences, and 172 from both the medical and physical sciences areas. Large sponsored research programs from the physical sciences account for much of this discrepancy.

For example, if just one particularly large program is removed from that list, the number of inventions licensed in the physical sciences drops to approximately the same number as our biomedical innovations.

This makes sense because in the biotechnology field large portfolio licenses are uncommon as typically only a few to several patents are associated with a product. In high tech, thousands of patents often cover a single product.

4 OTL by Numbers

In our first year of existence, OTL had 28 invention discloses, signed 3 licenses, and brought in royalties of $50,000. In FY2011 (our fiscal year ends on August 31), we received 504 invention disclosures, signed 101 licenses, and brought in $66.8 million in royalties.

Working on all of these activities are 38 staff members, including our director; 20 associates and liaisons on the licensing side; 6 industrial contracts officers (handling sponsored research, material transfer agreements, collaborations, and other types of agreements from industry); a patent agent; a few accounting personnel; and IT, compliance, and administrative staff members.

When Stanford receives royalties (payments) from its licensing activities, the monies are distributed as follows:

(a) OTL takes 15% off the top—these monies pay for our activities (e.g., salaries, rent, travel, computers, and IT services). Our patent expenses are not paid for from this amount, except in the case of write-offs. Instead, the patent expenses are originally paid for by the university general fund, which OTL repays if and when the invention is licensed.
(b) After the 15%, we deduct any expenses remaining on the docket. Usually, these are the patent expenses.
(c) The remainder is divided into thirds:

  - 1/3 to the inventors
  - 1/3 to the inventors' department(s)
  - 1/3 to the inventors' school(s)

Our default for the inventors' shares is to divide it equally between the inventors unless they agree and tell us otherwise. We do not make apportionment decisions because the inventors are the ones who know who did what work, but in general we think it is easiest and creates the least conflict when each inventor receives an equal share of the inventor royalties.

Figure 7.1 illustrates OTL's income over time. Typically, it takes 10–15 years for any significant revenue to return to the university on one of its inventions. Our office first broke even for a single fiscal year 10 years after its founding. We came out of the red completely in 1985. Much of the reason we became self-

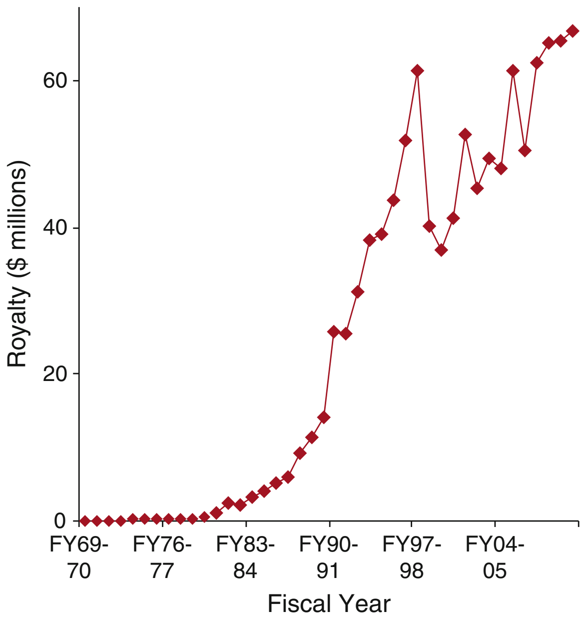

Fig. 7.1 Stanford's income from royalties, fiscal years 1970–2011

sustaining is that a few technologies, particularly recombinant DNA technology and FM Sounds, were bringing in enough income to cover all of our office expenses (e.g., salaries, resources). Historically, Stanford's Departments of Genetics and Medicine have been especially prolific in the technology development and licensing area.

Figure 7.1 shows hitting of our first revenue "cliff" in the late 1990s. This is when the Cohen–Boyer recombinant DNA cloning technology expired. We have since returned to the same levels, primarily because of a patent from Sherrie Morrison, Vernon Oi, and Leonard Herzenberg used in the production of monoclonal antibodies. That patent expires in 2015. In general, very few technologies bring in much income. At Stanford, we feel we have had three big technology transfer hits—recombinant DNA, Google, and functional antibodies—since our inception in 1970. This is out of the over 9,000 invention disclosures we have received. Naturally we hope our next big hit is already percolating among the more recent disclosures.

OTL remains self-sustaining from its 15% of gross revenue. Our operating budget in FY2011 was $5.4 million. The left-over from the 15% after our budget is covered is returned to the university. Some of this has been used to help fund the Research Inventive Fund, which provides research funds across the university.

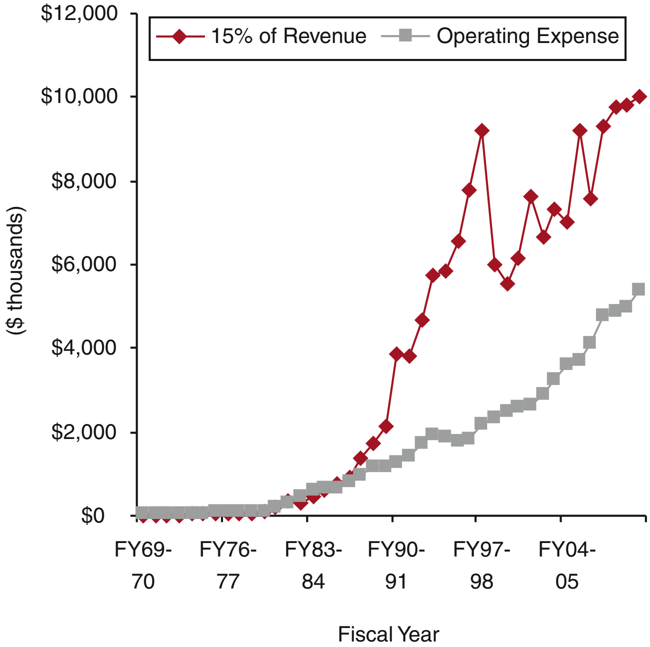

Fig. 7.2 Stanford's OTL's income (15%) versus its operating expenses over time. The difference goes back to the university to support research and education

Monies have also been given to the Research & Graduate Fellowship Fund for graduate student fellowships at Stanford. Figure 7.2 shows the comparison of our budget versus the 15% over time.

For information on other universities' statistics, the AUTM annual licensing surveys can be consulted [3].

5 Factors That Help OTL Succeed

A number of factors help OTL succeed in transferring technologies that will benefit society.

First, we try to be facilitators. Our job is part of a transition team for the technology to make its way from academia to industry. There are certain rules we need to follow (the Stanford policies and ethical practices), but we work within those guidelines to find solutions to shepherd technologies into their new homes for further growth. We try to avoid being a roadblock whenever possible.

As part of our role to foster innovation through technology licensing at Stanford, we belong to the Stanford Entrepreneurship Network (SEN) [4]. SEN brings together many of the groups around campus that work with entrepreneurs and potential entrepreneurs. Once a year, the group puts together "eWeek," a week spotlighting entrepreneurship around campus. Most members of SEN put on an event during the week that highlights the group's focus. In 2012, OTL had an open house that displayed and discussed particular inventions.

Second, we strive to be reasonable in how we handle our technologies, including the financial terms of the licenses. We want a fair deal. If the company does well, then we do well.

Third, we try to "plant as many seeds as possible," meaning we work on getting as many technologies out to industry or other developers as possible. Going back to the first point, we do not want to be a roadblock. We market all of our technologies to industry in the attempt to find a licensing partner. Still, our best leads for licensing are often through some sort of connection from our inventors. For quite a while now, we have been licensing around 20–25% of our invention disclosures. We think this is a good number considering the early stage of the technologies. Naturally we would like for it to be higher.

Fourth, we are fairly efficient. We have processes and license templates in place that we have worked on for decades. We do make changes to increase our productivity, including developing a core group of marketing people, continually updating our database, revising and improving our boilerplate agreements, and standardizing our option agreement terms and financials. When negotiating a license agreement, if we have not worked with the licensing party before, we let them know upfront which clauses we cannot change because of policies and guidelines. This can save everyone a lot of time trying to negotiate sections that do not have any wiggle room.

Startups in particular are sensitive to timing. If they have an eager investor, a startup may need to react quickly to mirror the enthusiasm of the investor to the opportunity. We will work with startups and investors on their schedules whenever possible.

Fifth, we want our licenses to be the start or the continuation of a long-term relationship with the licensing company. Through the license, we are allowing access to a Stanford asset (a researcher's "baby") and having the company nurture it into the success we all hope it will be. Like a report card from a child, we want to be kept informed of its progress. If there are any issues, we want to know about them early and work with the company on those issues before they become immense problems. But if the asset needs to return to Stanford, it is good for us to know it is coming and to prepare for what Stanford will then do with the technology.

Under the licenses, Stanford not only asks for yearly progress reports, but that developmental milestones be met. If a company isn't pursuing the technology, Stanford can terminate the agreement and find another partner to develop the technology. This is the option of last resort, but does need to remain an option because our mission is to have the technologies eventually benefit society. Our hope is that the partnership leads to repeat customers. Even if the first license doesn't yield a commercial outcome, we aim for all parties—the university, the researchers, and the company—to view the experience positively.

Finally, we seek to create an innovative environment. Stanford makes OTL's job easier by having an atmosphere where people want to create and often are willing to work together. People here want to solve problems and want to see those solutions disseminated.

An example of this is Bio-X. Opened in 2003, the center houses faculty and researchers from various disciplines in open laboratories to work on problems in biology and medicine. For example, a floor of the building could have researchers from mechanical engineering, statistics, and microbiology. More than just providing space, the program offers some funding mechanisms, interdisciplinary education, and potential to work with industry.

Connections are key to getting almost anything off the ground. Many of the researchers and business people on campus are already well connected. Others simply ask their neighbors for help. If someone needs help with connections, whether for potential financing, partners, or space for their startup, we can direct them to resources.

Stanford also has many resources for education regarding creating new technologies and starting a new business. There are formal courses but also workshops, groups, and programs in these areas. Examples include the Stanford Biodesign Program, the Stanford Technology Ventures Program, and the Center for Entrepreneurial Studies.

The resources that help sustain and grow our innovative environment have increased over the years. Some have blossomed while others have faded away. A program that has become particularly strong is SPARK, "an innovative, cost-effective way to overcome the hurdles associated with translating academic discoveries into drugs or diagnostics that address real clinical needs [5]." SPARK was started by Stanford faculty member Daria Mochly-Rosen in response to the need she saw at Stanford after she started her own company.

The SPARK mission is twofold:

1. To help academicians overcome the obstacles involved in moving research innovations from bench to bedside; and
2. To educate faculty, postdoctoral fellows, and graduate students on the translational research process and path to clinical application so that development of promising discoveries becomes second nature within our institution.

SPARK provides funding to select projects to translate them from basic research to more advanced stages where industry is more likely to pursue them. They also educate, mentor, and advise the grantees and all other interested academicians on this translational research process. A recent Nature Medicine article noted that about half of SPARK's projects have been taken up by commercial companies, and that other institutions are looking at SPARK's model [6].

Another program at Stanford that offers small amounts of proof-of-concept funding is the birdseed program. The program offers up to $25,000 in further funding for technologies that have already been disclosed to and marketed by our office, but that just need a bit of extra work to make them more attractive for licensing by industry.

6 Working with Startups

As a part of the innovation cycle, university technology transfer organizations work with startups. Many of the startups have inventor/research involvement, but some do not. For example, sometimes entrepreneurs-in-residence from local venture capital firms look around the university for opportunities to start their next business.

However, most Stanford startups do have some sort of inventor involvement. In these cases, conflict of interest issues are of primary concern. The university addresses these licensing conflict of interest issues by a multi-step process that often begins with a conflict of interest memo provided by OTL. In the memo, OTL describes the technology under consideration for license, the interested company, and some particulars of the potential license. The group reviewing the conflict then meets with the affected researcher and a plan is devised, if needed, on how the researcher's work with the company will be separate from the work occurring or to occur at Stanford. Of particular importance in this review is how any student might be affected by the researcher's relationship with the company. Once this plan is worked out, the conflict of interest review group contacts OTL on whether it can proceed with the license. The review group continues to maintain oversight of the potential conflicts.

When negotiating the license agreement, OTL will typically not negotiate with the inventor unless the inventor has left the university. The inventor is in a conflicted situation, and because the inventor receives partial remuneration from the licensing process, OTL asks that the company have a non-inventor negotiate the license.

Startups sometimes first take option agreements when licensing. These options usually last 6–12 months and are simple agreements that require little negotiation. During the option period, the startup is looking for money or may be doing some proof-of-concept experiments. For an exclusive option, the university is not allowed to license the technology to any other company. If the company succeeds in whatever it was trying to accomplish during the option period, it then "exercises" the option to begin negotiation of the full license agreement.

Some of the areas we look at closely when negotiation these licenses are:

1. Upfront payment—This is usually a combination of cash and equity. We often take equity in any startup to which we exclusively license a technology. How much equity Stanford receives is balanced against the other financial considerations in the license. Some startups are more flexible on equity than others, which often depends on their sources of capital.
2. Annual payments—Because startups are cash-poor, annual minimums may be lower in earlier years and ramp up over time and after certain milestones.
3. Diligence—Any exclusive license has diligence, but this can sometimes be a moving target, particularly with startups. We find solutions that work for our need for strong diligence and the company's changing business plan, taking into account vicissitudes of the economy. For example, we may agree to certain diligence over the first 5 years of the license agreement and then will reconvene in 5 years to determine the next set of milestones.

4. Milestone payments—Because the upfront and other early payments are usually low, we try to counterbalance some of this with somewhat higher payments, including product milestones, later in the development cycle.
5. Sublicensing—Many startups will sublicense the technology. For example, when licensing a therapeutic to a startup, the startup knows that it will not likely be able to take the potential product through clinical trials on its own and therefore will have to partner. The partnering often includes sublicensing. Depending on when the sublicensing occurs, OTL will receive some part of the remuneration received by the startup from the sublicensing partner. Often the amount is scaled down over time as the company invests more of its own effort and money into the technology.

When working with startups, as with any company, we want them to succeed. Their success is our success. Many startups are run by new entrepreneurs, so we try to help where possible. First, we understand that startups are cash-poor. We try to make our licenses affordable, but the startup needs to have some skin in the game and some ability to raise money. When working on our license agreement, we advise the startup where we can be flexible and where our policies do not allow us much, if any, wiggle room. Startups sometimes hire attorneys to assist them with their license negotiations. Although a good idea, sometimes the attorneys can be overly ambitious and cost the company a lot of money negotiating points that are insubstantial or non-negotiable. The startups sometimes need to differentiate an important point to pursue and where they can also be more flexible.

Second, we renegotiate more with startups than with other entities. As mentioned above, startups are ever evolving, sometimes even when they are past the true startup phase. We recognize that their needs and capabilities might change over time. Many times events occur that are not anticipated by the license. Our end goal remains the same—products that benefit society—so if that is being met, we can often work out a solution to the company's concerns on the license.

7 Symbiosis

Professor Terman had a vision of "close ties between Stanford students and the emerging technology industries [7]," and the fostering of this vision helped create the Silicon Valley of today. Stanford continues to see this as a great symbiotic relationship. Stanford is bordered by Page Mill and Sand Hill roads, homes to venture capital firms, the Stanford Research Park, and attorney firms. Stanford provides education to students who go to work at local companies or start their own. Stanford researchers create revolutionizing innovations that might be part of those same companies.

This synergistic relationship goes beyond these areas as well, helping Stanford to sustain and improve its amazing capabilities. As noted by President John Hennessy in a recent Fortune online interview [8]:

…think of the most money you could have charged Hewlett and Packard for their little discovery that they took out and started a company with, think of the most money. Multiply by 100,000 times and you'll begin to get an idea of the scale of their philanthropy to the university over many years.

So, we believe in that symbiotic relationship, we believe that if we're good to people they'll give back, and we can make something that works, and we won't be inhibiting the flow of technology, which I think is a really crucial thing, because in the end that's our long term contribution to society.

Stanford strives to keep this mutually beneficial relationship functioning and energized. OTL is one element in a long equation of factors that may produce the next cancer therapeutic or alternative energy solution. The better each factor works and works together with the other factors, the greater the likelihood of a positive outcome.

Acknowledgments As always, I am grateful to Stanford for its support, and in particular to my colleagues at the Office of Technology Licensing for continually sharing their years of wisdom and experience.

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Chapter 8
Managing Life Science Innovations in Public Research Through Holistic Performance Measures

Ruth M. Herzog and Christopher Wasden

Abstract Addressing the innovation gap is today considered the third task for public research organizations (PROs) in addition to their traditional tasks of research and teaching. Thus, PROs need to adapt their strategies and research management organization so that more innovative ideas from research will enter the market for the benefit of society. Innovation can thus be defined as value-creating novelties. The commercialization of research results is usually managed through technology transfer offices (TTOs), serving as an interface to industry. How PROs create value is increasingly subject to performance measurement and performance-based budgeting. Applying holistic measures will help adjust the overall strategy of the PRO in the direction of innovation and balance multiple interests and goals. Holistic performance measurement is based on the four dimensions of the decision-oriented model of research production (input, processes, output, and outcome) corresponding to the pillars of innovation. In this model, patenting is a key innovation process in academic life sciences that arises from the co-production between researchers and TTOs.

1 Introduction

Creative resources in the life sciences in academic research and in industry are not being used efficiently. This phenomenon, often described as the innovation gap or science-to-market gap [1], is very much to the detriment of the economy

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and society. The core strategy of the European Union's "Europe 2020" features the "Innovation Union" as one of seven flagship initiatives "to ensure that innovative ideas can be turned into products and services that create growth and jobs [2]." To meet the challenges of the global knowledge society, European governments and other public funding bodies increasingly demand that public research organizations, including universities (together called PROs), exploit their results from invention and discovery through technology transfer (TT). This so-called "third task"—in addition to the tasks of research and teaching—enable PROs to capitalize more fully on public funding for the benefit of society. Innovations stemming from public research will be defined in this chapter as value-creating novelties [3].

The commercialization activities arising out of public research are typically performed by a technology transfer office (TTO). In essence, the task of a TTO is to find a commercial partner willing and able to develop and further test novel ideas into product solutions that people are willing to pay for, thereby creating value. TT is defined by the Organization for Economic Co-operation and Development (OECD) as intellectual property (IP) management, whose purpose is "to identify, protect, exploit and defend intellectual property [4]."

The question how efficiently or effectively this innovation process works has to be asked for the PRO as a whole. This is because it reflects both its output and the outcome of research production. To quote the old saying: "If it isn't measured, it can't be managed," the purpose of performance measurement is thus to create transparency of results and achievements, support the defined strategy and decision making, and provide guidance for behavioral change, such as integrating innovation into research operations. Because no indicators exist either for measuring the intangible results of research or for creating multidimensional outputs from research or the quality of interaction among the players involved, a systematic attempt will be made to design a flexible and holistic concept of performance measurement. "Holistic" according to [5] incorporates:

- Focus on relevant stakeholders
- Balance between the resulting demands (as far as possible)
- Integration in a systems approach, and
- Sustainable and long term in orientation.

2 Research Production and Innovation

Holistic performance measurement of TT must take into account all dimensions at the level of the PRO. Detailed information is needed about the causal linkages of the setting in which innovation occurs, the processes of innovation, and the outcome of innovation.

PROs are an essential component in the innovation chain. Faculty and researchers produce basic novel knowledge, some of which is inventive and patentable. The bulk of these inventions occur early in the discovery phase of the innovation life cycle. Far from being a true product, they require additional research and experiments to further refine and advance these early inventions and to strengthen the patent application prior to commercialization. Today, many TTOs have created and manage a gap fund to finance such proof-of-concept studies to reduce risk and further advance their inventions in a bid to make them more attractive to industry.

One causal linkage deserves special emphasis. Patents as standard innovation indicators play a central role in the commercialization of life science inventions because only patents provide the temporary exclusivity and protection required by the pharmaceutical industry to recoup its huge investments in drug development. Thus patenting in academia deserves close scrutiny. This is because inventing and patenting are in fact two separate phenomena [6] that require different strategies and processes. Responsibilities must be clearly allocated to ascertain who is in control of which part of the innovation process.

Usually it is the researcher's decision to disclose their invention that triggers the commercialization process at the TTO. If the researcher decides only to publish and not to reveal the invention to the TTO, their invention will be lost for commercialization since it will become public knowledge and no longer be proprietary. Thus, failing to disclose inventions represents the first gap in the innovation chain. It is a myth to believe that a TT manager can just "walk the halls" and pick inventions like cherries that after commercial evaluation will be patented and successfully marketed. Researchers themselves are responsible for disclosing their invention to the TTO. Therefore, invention disclosures constitute the only direct measure of researchers' innovation activities. By contrast, the number of patents (patent applications, patents granted) reflects the output of research as a whole, including the TTO's activities. This accords with the assistant role of the TTO as described in the "assisted innovation model" [7]. The TTO forms both an integral part of the research production process and the linear innovation chain, facilitating moving inventions further along the value chain, thus closing the gap [7].

As patents are created as a result of the co-production between the researchers and their TTO, a PRO must take a twofold approach to capture the value of its investment in research and discovery: (1) ensure that all possible inventions are disclosed and (2) maintain a TTO ready and able to mine these inventions successfully. However, bearing in mind that the chances of meaningful commercial success are very low (estimated at below 1% of all invention disclosures), success can be defined as collaborations with industry, licensing to an established company, or founding a spin-off. Different inputs will yield different outputs and outcomes, just as the efficiency and effectiveness of processes will differ with expertise and experience. Although several indicators and benchmarks already exist for TT, they must be evaluated (holistically) at the level of the PRO.

The Production Model of Research: Holistic performance measures for innovation from research have been developed using the decision-oriented production model of research [8]. This approach has a twofold advantage. First, it makes it

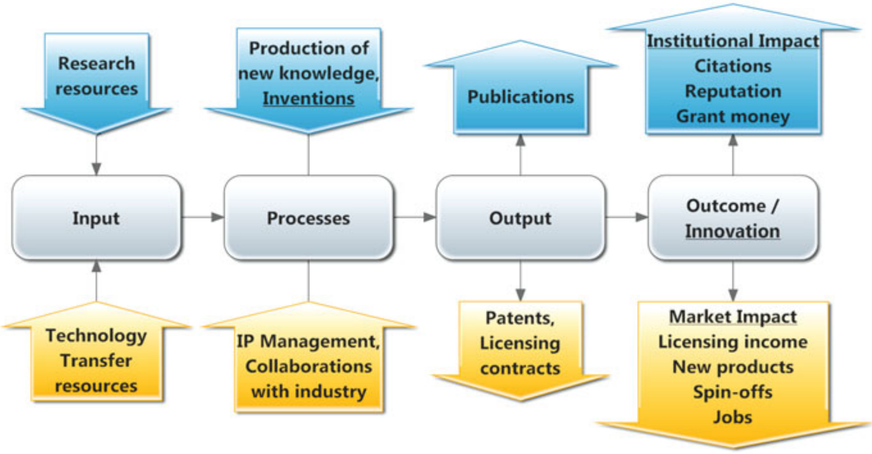

Fig. 8.1 Decision-oriented research production model aligned for holistic performance measurement along the four elements of the innovation chain. The elements in *the top row* represent the research elements and those in *the bottom row* the commercial elements leading to innovation. Both must be provided with adequate resources (input) and activities (processes) to yield the desired output and outcome. The outcome "innovation" is only obtained by achieving market impact (modified according to [3, 8])

possible to adapt performance measurement to the relevant decision-maker or stakeholder. Second, it is a tool to define the extent to which a PRO wishes to engage in innovation and take responsibility for it. The model contains four dimensions at the level of the PRO: input, processes, output, and outcome. These dimensions, if aligned sequentially, form four elements in the innovation chain (Fig. 8.1).

Input
Structure and resources (funding, personnel) available for research and TT, including the support of the commercialization process.

Processes
Research production of new knowledge includes all research activities, specifically inventions, plus all services offered by the TTO. If inventions are not disclosed to the TTO, internal innovation gaps may arise, leading to an early break in the innovation chain.

Output
Productivity and efficiency of the PRO with respect to publications, patents, and commercialization results such as licensing contracts.

Outcome
The overall impact on society can be divided into institutional impact and market impact. Only market impact can be associated with innovation (any value generated such as licensing income can be reinvested in research input).

3 Conceptual Design of Holistic Performance Measurement in Technology Transfer

The TT process is complex in nature because it must take into consideration the interdependence between input, research production, TT, the various stakeholders, and the multiple goals of a PRO. To replicate this complexity, the conceptual design of performance management needs to make use of the above-mentioned decision-oriented production model of research [8] and should contain the following elements:

- Analysis of the interests of the relevant stakeholders: government, management, and the researchers themselves
- Alignment of possible goals to respective indicators
- Examples of evaluation methods applicable to TT

3.1 Stakeholders in Technology Transfer

The most relevant stakeholders in the innovation process in the academic context are the government or other funding agencies, the PRO management, and the researchers themselves. Each of them will have a different interest in innovation, thus producing multiple, potentially conflicting goals.

The Government: The government (or other public funding bodies) funds the production of new knowledge, stipulating that funding be used sparingly and economically by maximizing desirable side effects (such as TT and international collaborations, equal opportunities, and promoting young researchers) and at the same time minimizing risks. The government might also fund specific programs to foster innovation (such as for establishing spin-off companies).

Management: The PRO's management is responsible for the overall strategy and budget from public money.[1] The management sets priorities and balances the multiple interests of the funding bodies and other relevant interest groups. The strategy is often devised together with the so-called visible scientists whose expert knowledge constitutes the most important capital of a PRO. Managing such experts, who thrive on the privilege of academic freedom, is admittedly challenging. Since the research budget is generally decreasing rather than increasing, any change in strategy will result in reallocating funds, such as for those for innovation, at the expense of other activities. Without management's support it might be difficult to pursue commercialization activities efficiently. Management might also prefer short-term visible achievements over long-term investments in innovation. As such, management might

[1] In the United States and Europe researchers have significant discretion in raising their own grant funding independently from the PRO management.

choose to establish collaborations with industry creating immediate research money, rather than investing long term in the infrastructure for TT. This is regardless of how small the investment is compared with research expenses. Ultimately, some PROs may wisely do both.

Faculty: Researchers and inventors certainly constitute the most important stakeholders in innovation. It is well known that their motivation influences the outcome of TT [9, 10]. Researchers have three ways to convey information about their work results—publish, patent or do both. However, not all researchers are equally motivated to patent. A researcher is primarily motivated by "solving the puzzle" [6], that is, answering scientific questions not necessarily connected to patenting or commercialization. Second, researchers are driven to receive recognition from their peers and to establish their reputation within their scientific community. Third, money does not seem to be the primary motivation for most researchers because most research fails to generate patentable and commercially viable inventions. Therefore, although inventors usually receive a share of about 30% of the revenues received by the PRO, this motivation is the least powerful. This share can be substantial in a very few cases, but might take a long time to materialize due to long development times.

The propensity to disclose inventions differs among researchers. Those performing basic research are less motivated to patent compared with those who are willing to invest additional time to validate their invention. This also holds true for emerging young talents who first have to build their scientific reputation. In essence, researchers will be motivated to engage in commercial activities the more they feel their resulting share will be adequate in relation to the efforts required [6]. Role models (and potentially feelings of envy) and the fact that some researchers like to "gamble" are further factors affecting researchers' propensity to patent.

3.2 Indicators and Goals in Technology Transfer

Bearing the stakeholders in mind, the most visible indicator of added value from public research is reflected in the millions of dollars in licensing revenues that some of the large American universities receive. However, this does not automatically mean that these universities and their TTOs are best in class or best in process. This is because very few extremely successful (blockbuster) inventions can generate huge licensing revenues, whereas the bulk of inventions produce only a lower income. As a result, only 16% of TTOs in the United States operate profitably, while more than 50% accrue losses [10]. Moreover, licensing revenues produced by public research constitute only a fraction of the impact and benefit to the economy and society. They reflect market success, which can be neither planned nor influenced by the TTO or PRO. Using licensing revenues as the main indicator of the quality of the TTO or outcome of research is thus not recommended [11].

The set of indicators from the annual Association of University Technology Managers (AUTM) survey represents the gold standard for measuring TTO performance in the United States and Canada [12]. The survey contains a wealth of information collected for more than 30 years and has been expanding to include other continents and countries. In fact, the European Commission (EC) published a guideline with seven key quantitative indicators with definitions matching the AUTM survey [13]. For example, these allow comparison with the United States on a country level or benchmarking with specific institutions:

- Three indicators highlight the commercial potential of public research and constitute the output of research and the prerequisites for commercialization: (1) number of invention disclosures, (2) number of patent applications, and (3) number of patents granted.
- Three indicators reflect the commercialization of public research by companies: (4) number of new licensing agreements, (5) number of spin-offs and (6) gross licensing income (in Euros or dollars) and thus measure the outcome of TT.
- In addition, one indicator was introduced that serves as a process indicator: (7) the number of new collaboration agreements with industry (excluding consortia being funded by the EC or other public money). This makes it possible to determine the focus of the transfer activities (i.e., collaboration with industry or licensing).

Care must be taken to measure performance with indicators relevant to the goals and strategy of a PRO. Measuring the wrong things may subsequently lead innovation efforts down the wrong path. Four goals in TT are usually identified: service, transfer, profit, and regional development. Each goal can be further broken down into strategic and operational goals and connected with one key indicator as follows [14].

Service: Service for the researchers as customers means focusing on the internal relationships. This is done, for example, by delivering prompt service, providing expertise in business development in specific research areas, and minimizing transaction times. The key indicator for service is the satisfaction survey conducted for a customer. Note: Because the researcher may demand services that far exceed the budget, satisfaction surveys could be conducted cost-effectively via a focused interest group.

Transfer: Maximizing transfer means maximizing marketing to industry (i.e., external relationships). For each invention the TTO assesses the most potent way of commercialization, giving preference to exclusive licenses and web-based click-licensing. Researchers should be highly motivated and hand in as many invention disclosures as possible. The number of transferred technologies represents the key indicator for transfer. Note: This is a composite indicator and not so easy to assess. Alternatively, the number of license deals can be used as a more direct indicator.

Profit: Maximizing profit involves focusing on large markets with a high potential income. It is achieved, for example, by aggressively collecting royalties and pursuing

IP infringers. The key indicator for profit is gross revenue minus direct costs. Note: Although this goal is pursued primarily by only 10% of the TTOs [9], revenues will always be an important measure of innovation.

Regional Development: Creating jobs in the region in particular is done by providing extensive coaching and teaching on how to set up a company and establishing links to science parks and investors. The key indicator here is the number of spin-offs and the number of jobs created. Note: Universities usually have a closer affinity to their region than non-university research centers.

Rather than just listing the four goals, it is preferable to identify and pursue one primary goal [14]. However, all of the above goals are essential to TT activities, and none of them can be ignored. Therefore, it is important to balance these goals and set priorities that can be changed from time to time if deemed necessary. Goals 1 and 2 are both personnel-intensive, because they require extensive marketing efforts. Although the extent to which they are pursued might be restricted by staff and budgetary limitations, marketing (internal and external) needs to be continuously improved.

3.3 Evaluation Methods and Best Practices

The above analysis on stakeholders' interests, goals, and indicators provides a systematic framework for holistic performance measurement. Making use of the concept outlined above, a PRO will first need to design a strategy geared to innovation and then start measuring performance operationally. Thus, prior to evaluation, the expectations, purpose, and goals will be laid out and provide the necessary guidance.

Strategically, after reaching agreement on what is relevant in innovation or TT, a PRO will formulate its mission statement and goals or even stipulate them in its statues or policies. The process may well create tensions and trigger discussions on the importance of traditional academic values versus engaging in entrepreneurial activities and creating added value. However, most, if not all, PROs are subject to performance-based budgeting which increasingly includes patent indicators and other innovation measures.

Operationally, a PRO will need to initiate an evaluation cycle or integrate the performance measurement of the TT activities into its own evaluation culture and make use of established evaluation methods. At the Deutsches Krebsforschungszentrum the standard process every 5 years includes self-evaluation, benchmarking with others, and external review. This process is described in more detail below.

Self-evaluation: Self-evaluation involves an analysis of the current situation, for example by summarizing TT results in a business report or plan, including an estimate of the value of the patent portfolio and a forecast of potential licensing income. A SWOT analysis is a helpful tool to visualize strengths, weaknesses, opportunities and threats and to devise action items.

Benchmarking: Benchmarking compares one's own performance with others, searching for the best processes, activities, and results. The aim is to learn from them to improve one's own processes, activities, and results. Quantitative data are available from the AUTM survey. Other data may be obtained from the literature [3, 9, 15, 16]. For a true comparison, the data must be standardized either with respect to the number of researchers potentially producing patentable results or the amount of research dollars received in relevant fields (engineering, medicine, life sciences, natural sciences, computing, and so on).

External Evaluation: External evaluation might be conducted as a peer review on site. Peer review is admittedly time-consuming and has often been criticized but it remains the oldest and the most widely accepted qualitative tool for monitoring research. If done regularly in a standardized manner, such evaluation will provide a feedback mechanism for continuous improvement and learning. For the evaluation of TT activities a mixture of the following types of experts with different professional specialties should avoid creating any bias: administrative or scientific directors of a PRO, directors of TT offices, representatives from industry and venture capital and, ideally, reputable researchers with commercial experience.

Such external evaluation may even be performed to support management in devising a strategy for TT and mapping the ensuing operational steps. Management will traditionally include visible scientists and relevant committees. Such on-site peer review will result in a written expert's opinion on topics such as (1) culture and ethos, including mission, self-image, internal and external outreach, (2) governance of the TTO, (3) business activities (IP management, collaborations with industry, and startup formation), (4) business development activities including gap or validation funding, (5) strategic orientation for the future, and (6) staffing.

For holistic performance management, it is useful to formulate a set of key questions along the four dimensions of the research production model with respect to innovations (input, processes, output, and outcome). Table 8.1 summarizes a set of key questions and indicators. Moreover, these questions may be applied to create an innovation score card as described by Levy [3].

4 Conclusions and Recommendations

In summary, this chapter has detailed the elements of holistic performance measurement for PROs to fulfill their roles of fostering, supporting, and enabling innovation and managing their "third task" activities. Although much has already been achieved there is still untapped potential for innovation from academia. Unraveling this potential is in fact highly complex. The decisive measurable first step for researchers is disclosing their inventions before publishing. The number of unreported cases is not known, but they constitute the innovation potential to be addressed. Patenting and publishing can be performed simultaneously. However, because researchers are under great pressure to publish their findings, there might not be enough time to

Table 8.1 Key questions in four dimensions to holistically measure performance and innovative activity of a PRO (modified from [3])

Dimension	Key questions	Possible indicators
Input		
Resources	Resources sufficient to create innovation? Gap funding available? Professional TTO available?	Research budget and personnel TTO budget and personnel Incentives Strategy
Personnel	TTO experience sufficient to support researchers in innovation? Licensing manager sufficiently supported by specialists and partners?	External evaluation TTO structure
Activities		
Service	Which services are offered by the TTO to the PRO and the researcher?	Customer satisfaction survey (researchers)
Outreach	Transparency of processes, successes, and activities of the TTO Internal/external connectivity of the TTO?	Customer satisfaction survey (including industry)
Output		
Productivity	How efficiently does the TTO transfer input to output?	Ratio of patents and licenses to invention disclosures or per licensing manager
Yield	How efficiently does the TTO produce results?	Ratio of licensing contracts per licensing manager Time to deal Licensing income minus costs
Outcome		
Institutional	Which services are offered by the TTO to the PRO and the researcher?	Licensing income Dependency of income on largest product Reputation Number of contacts of the TTO with researchers
Market	Transparency of processes, successes, and TTO activities	Products in the market Licensing income Number of spin-offs Reputation

exemplify promising inventions prior to patenting, thus making it difficult to produce strong patents for commercialization. TTOs are more directly involved in the innovation process and are thus a genuine organizational mechanism that closes the gap between invention and innovation. More still needs to be learned about the consequences of introducing measures, such as performance-based budgeting. It is hoped—and there is reason to hope—that fostering innovation will not lead to a decrease in the quality of basic research.

Integrating innovation as a third task into any research organization requires a holistic approach, because innovation may be perceived as counter to the tradition and culture of academic institutions. However, changes are necessary to increase innovation activities within a PRO for the benefit of society. Changes are already happening with novel therapeutic concepts, such as personalized or translational medicine. PROs have assumed responsibilities in early drug discovery formerly only vested with the pharmaceutical industry, such as establishing high-throughput screening facilities, medicinal chemistry, and early clinical trials [17]. The key aspect of this public commitment is the alarmingly decreasing number of innovative new medicines over a period of many years. This downward trend is detrimental to the healthcare system and to patients [18]. However, companies such as Genentech are still very successfully developing new and innovative drugs. There is reason to believe that their special skills in turning academia's novel ideas into novel drugs constitute the key factor for success.

Inspired by this example, many pharmaceutical companies are now creating novel collaboration models with academic institutions in early drug discovery. Both pharmaceutical companies and academia are striving to overcome cultural and organizational barriers and boundaries between them and thus are becoming more flexible in interacting with one another. Learning to integrate the best of both worlds seems like a promising way to create added value. For example, the collaborative innovation alliance between the Deutsches Krebsforschungszentrum and Bayer Healthcare can be highlighted where joint projects are performed together along defined milestones, directly feeding successful projects into the internal Bayer pipeline. This risk-and-reward sharing partnership model is based on interactions at all organizational levels in an open and mutually beneficial atmosphere of an exchange of ideas [19]. In a few years' time the ultimate measure of success of such academic institutions and industry alliances will be the introduction of innovative treatments into patient care.

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Chapter 9
Universities as Engines of Economic Growth—Entrepreneurship in Academia: A Singapore Experience

Lily Chan

Abstract In the past few decades, universities have come to be expected to directly and positively influence economic growth, a radical departure from the previous understanding of the university as primarily an education provider. How universities approach this new "knowledge economy" will vary by geography and culture, among other factors. This essay will bring to light Singapore's experience, with focus on the creation of the National University of Singapore's NUS Enterprise, a university-level cluster that aims to provide an entrepreneurial complement to the school's teaching and research functions.

1 The University as an Engine for Economic Growth

The fundamental understanding of a university's relationship to the economy has largely and radically changed within the last half century. Historically, although universities were considered a valuable source for technological innovation and scientific breakthroughs, the commercial benefit derived from their research was largely seen as secondary to the university's primary value as an education provider.

Current thinking has shifted as financial crises have, in part, caused countries to more directly promote the idea that innovation can be used to fuel economic growth. This view has been summarized by Wong et al., who write, "As argued by Etzkowitz et al. (2000) and Etzkowitz (2003) [1, 2], universities around the world are increasingly shifting from their traditional primary role as education providers and scientific knowledge creators to a more complex "entrepreneurial" university model that

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incorporates the additional role of commercialization of knowledge and active contribution to the development of private enterprises in the local and regional economy [3]."

With these developments, the view that the university is now a critical provider of not only talent, but knowledge and innovation has become embedded within the beliefs of politicians and university administrators around the world. As a result, there is increasing pressure on higher education providers to become more enterprising. Universities are now increasingly tasked not only to cultivate an entrepreneurial workforce that can adapt to the demands of a complex and competitive economy, but to also directly drive economic growth through technology transfer and the production of intellectual capital that can be licensed, patented or spun-off into companies. Thus, the promotion of entrepreneurship and innovation has been frequently incorporated as the "third pillar" of a university.

2 The Singapore Experience

Singapore itself has not been immune to the changing understanding of a university's role, although the country's unique cultural and geographical positions present their own challenges. Compared with the often-cited success stories of Silicon Valley and MIT, Singapore's pursuit of entrepreneurship has been relatively late, with impetus arising in part from the recent Asian financial crisis and the general drift toward the "knowledge economy."

Having built its post-independence success on its manufacturing and export industries, Singapore has, beginning in the 1990s, increased its focus on the commercialization of R&D and the development of intellectual capital [4].[1] Economic growth for the country has come to be seen as sustained by the skills, innovation and productivity of its people. This is a view reinforced by the fact that Singapore has no natural resources of its own.

Thus, for a country generally known for its risk-averse population and stringent educational system, the push for a more entrepreneurial society has largely been driven from the top down through government initiatives and incentives.

In 2005, the National Research Foundation's (NRF) Research, Innovation & Enterprise Council (RIEC) was formed with the mission of advising the Singapore Cabinet on national research and innovation policies, while also "encouraging new initiatives in knowledge creation in science and technology… [5]." This council has essentially helped deepen the government's commitment to fund R&D work done by both industry and higher education, thus encouraging the realization of the commercial value of research and the integration of public and private sectors to produce innovative solutions.

[1] This reflects an updated finding since 2008.

At the university level, NRF has been instrumental in promoting higher education's focus on entrepreneurship and innovation, particularly through its US$360 million "National Framework for Innovation & Enterprise." Although the initiative lays out support for everything from "creating enterprise support structures" through "innovation policy studies," its relevance to universities is particularly encompassed by its establishment of university enterprise boards and the setting up of university innovation funds (UIF).

Intended to supplement universities' existing funding for innovation and enterprise activities, UIF have provided support to university programmes in four specific categories: entrepreneurial education, platforms for start-up formation, catalysts, and events.

3 The NUS Experience: NUS Enterprise

Even prior to the UIF grant, the National University of Singapore (NUS) was actively pursuing an innovation and enterprise strategy. Indeed, in 2002, NUS Enterprise (ETP) was established in its current form to provide an entrepreneurial dimension to the university. Its three main goals include (1) embedding entrepreneurial learning as an integral part of NUS' education; (2) translating NUS' research into innovation and commercialisation impacts; and (3) serving as Asia's think tank for enterprise and innovation.

In the 10 years since its founding, ETP has developed innovative programs and services to meet the needs of aspiring entrepreneurs at all stages, be it from the inception of an idea or the establishment of a start-up, to the commercialization of new technologies. This is done through four key thrusts, largely similar to those later outlined by the UIF: experiential education, industry engagement and partnerships, entrepreneurship support and entrepreneurship/innovation research and thought leadership.

3.1 Experiential Education

NUS students learn firsthand about the challenges of entrepreneurship through the elite NUS Overseas Colleges (NOC) and innovative Local Enterprise Achiever Development (iLEAD) programs. NOC students with the academic ability and entrepreneurial drive are immersed as interns in entrepreneurial hubs around the world. At the same time they study entrepreneurship-related courses at highly prestigious partner universities, such as Stanford or the University of Pennsylvania. iLEAD represents the local version of the program, exposing students to the entrepreneurial challenges through internships at Singaporean start-ups. NOC and iLEAD programmes now exist in eight locations: Silicon Valley, BioValley, Shanghai, Stockholm, India, Beijing, Israel and Singapore.

3.2 Industry Engagements and Partnerships

INTRO, the predecessor to the current Industrial Liaison Office (ILO), was established in 1992 to handle technology transfer and promote research collaboration between NUS, industry and other partners. In 2002, the office was incorporated into NUS Enterprise. Today, ILO is a key element in the university's drive for industry engagement and partnerships, also managing NUS intellectual property, commercialising NUS intellectual assets, and facilitating the translation of new discoveries and inventions. ILO pursues various models of commercialisation, focusing on selected sub-sectors and portfolio licensing. The office, while also employing "technology scouts," experts who have worked in industry, to serve as the link between industry needs and university research capabilities.

An example of NUS's new commercialisation strategy includes the partnerships formed with accelerators and incubators, including Clearbridge. The Singapore incubator is now licensing many of NUS's technologies and, in the short span of 2 years, has incubated three medical startups from these.

3.3 Entrepreneurship Support

The pipelines provided by NUS entrepreneurial talent (NOC) and technologies (ILO) can also find support through the NUS Entrepreneurship Centre, initiated to help nurture entrepreneurs by providing the resources necessary for their start-up companies to succeed. Events, talks and business clinics are organized by NEC, while dedicated mentors provide advice and guidance on everything from funding to business planning. Physical space for start-up companies is provided through the NUS Enterprise Incubators.

NEC is instrumental in helping start-up companies reach the next stage and introducing entrepreneurs to a network of industry players. As an example, NUS Enterprise helped launch the Accelerator Workshop Series in April 2012 with the Media Development Authority (MDA), a matchmaking initiative that aims to catalyze the adoption of home-grown technology by bringing together start-up products and services with industry demands. In the first AWS call that took place, over 60 industry-start-up meetings were coordinated, with many project discussions still ongoing.

3.4 Entrepreneurship/Innovation Research and Thought Leadership

NUS Enterprise also conducts cutting-edge research on key issues of technology entrepreneurship. This includes academic entrepreneurship; innovation and intellectual property creation in the Asia Pacific; and trends, challenges, processes and success factors for start-up enterprises.

4 Results

Out of NUS Enterprise's initiatives, an impact is being felt on the local entrepreneurship scene. Proactive engagement with industry has helped move several university technologies toward the marketplace, establishing NUS as a major source for innovation in the region. Additionally, 95 active start-up companies have been founded by NOC and iLEAD graduates, each carrying forward the value derived from the immersive experience into new ventures. These start-ups have created numerous employment opportunities and attracted investment into Singapore, drawing increased interest to entrepreneurship as a viable career option for students and staff. Indeed, within a 1 km radius of NUS Enterprise, there exist more than 140 startups and 20 associated incubators/accelerators. That these facets reside so closely to the NUS campus is no coincidence; the environment established by NUS Enterprise has not only helped emerging entrepreneurs find their footing, but has also raised the potential for Singapore to become a major hub for enterprise and innovation.

5 Notes for the Region

It is important to note that the work at NUS Enterprise and in Singapore is far from complete; programmes and initiatives put in place 10 years ago are constantly being updated to adapt to new challenges in the environment. As with any innovation cluster, "success" is influenced by many factors, including the coordination of and policies by the government and university administrators, the availability of public funding and private venture capital, and the culture of a community. Thus, while universities are under increasing pressure to perform to the standards set by Stanford and the Technion it is imperative to realize that those innovation environments took decades of consistent effort to reach their level of impact.

Moreover, universities within Asia and its emerging economies are operating within a different cultural and political environment than that of California or Israel. Asia encompasses many different cultures and many different economic environments, so how this "entrepreneurial university" model is architected for success should and very likely will vary from country to country. Consequently, Asian universities must adapt the best practices of others, or forge their own, in setting their own paths for innovation and enterprise.

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Chapter 10
University Intellectual Property Exploitation: Personal Perspectives from the UK and USA

Mark Spearing

Moderator

Good afternoon, good evening everybody. It's time to start our special session. Thank you very much for joining us today, especially I would like to express our greatest thanks to the British Embassy Science and Innovation network, thank you very much. I am responsible for research coordination and administration at Keio University. I am also responsible for IT management and technology transfer for Keio University to industries. The professor over there is my boss who is General Director of this headquarters.

Today we invited Professor Mark Spearing as a speaker who is Pro Vice-Chancellor (International) at the prestigious University of Southampton in the UK. Today, his title is University Intellectual Property Exploitation: personal perspectives from the UK and USA.

As details of his background will be shown later in the lecture. He has wide and brilliant experiences in universities in the UK and USA. I expect to learn many things and share them among us. After his speech, we would like to have questions from the attendants. Now, we are ready to start. Please go ahead, Professor Mark Spearing.

Professor Mark Spearing

I would like to speak loud enough and clearly enough that I don't need a microphone. If that's not the case, please let me know. I will do my best.

Thank you very much Hatori-san and Professor Hishida for the invitation to come and join you today and to give this seminar. I am sorry; I will not be back here

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in September for the rest of the workshop on this topic. I hope I can contribute to it by the talk I will give today.

I have a very high opinion of Keio University because I had the pleasure of working with your Professor Norihisa Miki when we were together at MIT. When I found that he was coming to Keio for a position, I did some research on this place. It is very fine establishment, so I am very honored to be here today. And I would also like to add my thanks to Kevin Knappett and his team at the British Embassy for all the arrangements they have made for my visit to Keio today as well.

I am going to talk about University Intellectual Property Exploitation and I should say that I feel a little bit of a fraud in doing so because I have no professional qualifications in intellectual property exploitation. But I have worked in the university sector for a number of years. I have developed some views of how it operates and I have worked with start-up and, spinout companies. I also have a few patents to my name. Throughout my career I have consistently worked with larger companies, so I feel that I have some qualifications.

In part my invitation by Professor Hishida and Hatori to be here today came from a workshop at the British Embassy in January where I learned a lot about what was happening in Japan regarding the changing nature of the relationship between Japanese universities and industry. I think there are possibly many commonalities with what has happened a while ago in both the US and UK, so there may be some things to be learned regarding what has happened in the different cultures.

I am going to share my personal perspectives and I will invite questions. I will leave time for questions at the end and if you have some burning issue or you don't understand something I am trying to say, please stop me and I will try and answer during the talk. If I am not interrupted I will talk for 30–35 min and leave 30–25 min for questions. If I am interrupted I will just adjust…

So, where I am coming from is I have had the pleasure of working in three great universities. I did my Ph.D. and have subsequently been back on sabbatical to the University of Cambridge in the UK, spending in total 7 years there. I then spent 10 years on the faculty at MIT as a Professor in Aeronautics and Astronautics. And now I have been at University of Southampton for nearly 8 years. These are three quite different universities in two different countries, but all very, very, very successful at exploiting intellectual property and working with industry. You are probably more familiar with Cambridge and MIT. So, I will spend a little bit of time talking about the University of Southampton which you are perhaps less familiar with and unashamedly it's my employer at the moment, so I should be promoting them to you.

All three have very different models for their success and I will try and briefly describe the models and some key facets of it and make some comments and comparison and contrasting at the end.

In putting this talk together I've had input from colleagues: Prof. Phil Nelson is my colleague and fellow Pro Vice-Chancellor, responsible for research and enterprise, which is perhaps close to professor Hishida's role. Don Spalinger, you might infer from the name is an American who works at Southampton. He is the Director of Research and Innovation Services.

Tony Raven was the former Director of Research and Innovation at the University of Southampton. He now has the equivalent role at Cambridge University.

I will give some overview of the University of Southampton. I will talk about working with large established businesses and experiences in the key places and then talk about spin-out companies and the exploitation of intellectual property through creation of the company and then try and draw it together with some lessons learned at the end.

Please stay with me for maybe 5 min as I tell you something about the University of Southampton. Like all Twenty-First Century organizations, we have a mission statement. This is ours: "Through education, research, innovation and enterprise… ." This is the core of our institution's mission statement that we will provide opportunities that transform the lives of our students, our community, society and the economy. This is the mission statement of our university.

Intellectual property and its exploitation run through that mission statement. It's in the blood of our institution. It's in the blood or the DNA of MIT and actually increasingly of Cambridge, which despite its 800 years of history is a very innovative place and it has been for quite a long time. I also say we are a university with global ambitions. We are not looking just to achieve those aims of our mission statement in the UK or in the south of the UK where we are located, but we expect to have an impact globally and I think that this is probably true of the Keio University, it's certainly true of MIT and Cambridge as well.

My job as the Pro Vice-Chancellor or the Vice-President responsible for International Affairs is to see if we achieve this global ambition. Just a little bit about Southampton. We are currently ranked 75th by the QS World University Ranking. We are member of the Russell Group of prestigious research-intensive UK universities. We've got strength across a wide range of subject areas; in engineering which is where I am from but also in medicine and healthcare and in humanities subjects.

In the UK we are medium-sized university, a bit smaller than Keio, between 22,000 and 23,000 students. The majority, about 18,000 of those are undergraduates, the remainder are postgraduates.

This is a big year for us; we are 60 years old. This picture shows the Queen of the United Kingdom, presenting a Queen's Anniversary Prize for Higher Education to our Vice-Chancellor, President of the University and another colleague (Fig. 10.1). We received this honor, for our work with high performance sport We have a history of working with Formula 1 teams, Ocean Racing Yachts, including the America's Cup; more recently British Olympic athletes. The Olympics are in London this year so we are expecting more success.

Of the last 20 gold medals won by British athletes, 15 have been sports that we provided support for, including cycling and rowing and sailing and increasingly swimming. Wind tunnel aerodynamic testing and design and also hydrodynamics is our contribution.

We are underpinned by world-class facilities, super computers, a world-class clean room that's opened fairly recently. Also a Life Sciences Institute. We are making big investments, totaling £100 millions

Fig. 10.1 Celebrating 60 years of excellence

We also have a Science Park which for the current discussion is important. We have about 50 companies in this Science Park, mostly small companies and few larger ones. The key part is the taking the basic science ideas into spinouts and then turning it into something bigger and more successful.

These are just some of the facilities and achievements (Table 10.1). Ultimately it is all about people, so I put this slide in. These are some students in our wind tunnel working on an America's Cup yacht (Fig. 10.2). We are a research intensive university; we are a research-led university. Our education includes research and all of our students get an exposure to research. This is really important because fundamentally we are in the ideas business. It's about people having ideas and then following them through.

One of the most impressive things I encountered at MIT was that I would host tables at undergraduate induction. On the first evening undergraduate students spent at MIT they would be come to a large dinner at which academic staff would host a table of ten students. One thousand and fifty students came to MIT so there were about 105 of these tables, each with a member of academic staff, a faculty member on it. The main objective was to get undergraduates to talk to members of academic staff so they felt they could ask questions. As part of that, we would ask them questions and every year when I did this I would ask "so, why did you come to MIT? What do you hope to be able to do when you leave MIT?"

I was struck by the number of students who would respond "I want to have an idea to start a company or to make a product that will make me very rich," which is the very essence of "The American dream." We don't get that quite in the UK, at

Table 10.1 World-class centres and facilities

Our £3 millions supercomputer is the fastest Microsoft Windows-powered computer in Europe
Groundbreaking nanotechnology and optoelectronics research takes place in our £100 millions Mountbatten Building, equipped with state-of-the-art clean rooms
Our purpose-built £47 millions Life Sciences Building is the hub for our Institute for Life Sciences
Our extensive wind tunnel complex is used by Formula 1 teams and UK Sport for aerodynamics testing
We are hosting a new X-ray crystallography service to support and develop research excellence in chemistry, biochemistry and the physical sciences
The University of Southampton Science Park provides a home for established international companies as well as the facilities and support necessary for start-up and early stage enterprises

Fig. 10.2 Developing tomorrow's experts

Cambridge or Southampton, but actually having students who think from a very early stage that they are going to have an idea that's going to change the world, is very powerful and that helps it go through the lifeblood of the institution that you are going to do this. You are going to be thinking about having an idea whether you are an undergraduate or Ph.D. student or faculty member.

I also put this in. We own a campus in Malaysia, which is true to our ambition of going global and this will be a research-led campus. This reflects a very strong belief that Asia is a very exciting place to be with a lot of ideas coming through, plus this is an attractive place to be. This slide shows our city—we are a large port in South of England, so this is container ships in the port of Southampton at night (ESM, p.16).

We have a number of doctor training centers, Ph.D. education and increasingly in applied fields; fields that the next generation transportation system, complex system simulation. It's not just about discipline, it's about bringing several disciplines together, including the social sciences.

We work in music, we're very strong in music. This is an activity of the medieval music. I have no idea if there's any commercial outcome of this but I do believe that it is really important to open your mind to different disciplines.

These are the some of the things we are working on next generation Optoelectronics. I saw a very exciting work in Professor Koike's lab here on polymer fiber optics. This is work we are doing to a modest goal of increasing the bandwidth of the internet by a factor of 100. A lot of the very early work in fiber optics was done at the University of Southampton, at our Optoelectronics Research Centre.

We are also working through combinations of our Health Sciences activity and electronics and computer science on helping people rehabilitate people who've suffered stroke, debilitating cardiovascular injury.

Now we will get on to the main part of the talk. Remember I'll talk initially about working with big businesses, existing industry and then I'll go on to talk about start-ups and commercializing ideas in this way. We work with a number of large companies currently including Rolls-Royce who make many of the world's aircraft engines. We have a number of models and I'll talk about the models a bit later.

We are recognized as being the leading university for collaborations with industry. We are ranked second in the UK for our work with small and medium-sized companies, which are notoriously difficult to work with, for a whole variety of reasons. We are very good at this and I will try and explain some of the reasons why. A part of this is a number of partnership models and we'll expand on that later.

These are some of the companies we worked with. Many of them are global, multinational companies. You will recognize the names, Microsoft, IBM, Ford, GlaxoSmithKline. Jaguar Land Rover used to be British is now part of the Tata group, so truly international, Rolls-Royce, etcetera; a lot of companies, a lot of different sectors, although many around engineering.

We are also very good at commercializing research excellence through spinouts. This is a report, produced by a consulting firm, Library House, which is very flattering to our success in generating spin outs. This is a quote, from Doug Richards, the company's CEO, he is an American:

"Perhaps the most striking example of this is Southampton University comes third in this analysis despite being ranked over 100 places lower than both Washington and Wisconsin in the Shanghai Jiao Tong Ranking system. They are rated with Stanford and Cambridge." For some reason MIT doesn't feature on this rating. I think that's because MIT is very, very, very well funded. This is about the efficiency of spinouts.

Let me get back to big business that will give you an insight into my university, University of Southampton and its success with large companies and small companies.

These are some thoughts about why there are differences between the UK and the USA. I am very aware that things are a bit different in Japan. I have been asking questions on this visit and when I was here in January to understand a little bit more of why, so if you don't ask me questions, I'd be interested to ask you some questions around these issues.

There are lots of reasons why big companies work with universities. In my experience and that of colleagues I consult with, the single biggest reason why companies work with universities is to recruit employees. Access to cutting edge research and technology is also a key, obvious attractor. Leverage of funding is also a key consideration in deciding to work with a University. In the USA and in Europe, this notion of the leverage funding; industry only has a certain amount of money to be spent on R&D. If it can get government and universities to contribute to that, universities will by putting people in, and time in government, that makes their limited resources for R&D go further. Increasingly in the UK and USA, our industries do not have the large corporate research labs. They view these as expensive and ineffective, increasingly they are looking to gain knowledge and IP in a much more distributed way, by partnerships and acquisition (of IP) with universities as a key element of their "knowledge supply chain."

There is also symbiosis with industry wanting academia to play a role in working with government and with regulatory bodies, as a neutral arbiter to shape policy standards regulation.

On the negative side universities should not view industry as open checkbook, it does not work like that. There has to be a clear mutual benefit and understanding for the relationship to work. There is also the issue of accessing and sharing research facilities. Large research facilities are expensive and we don't have many of those left in the UK, so universities are playing a key role in managing several of the research facilities in UK and this follows a similar trend in the US. It's not the case that it will necessarily be more efficient but it means that the company doesn't have to own its own facility and incur the capital and operational costs of doing so. Fairly obviously this all amounts to outsourcing skills and a sharing of risks.

You will often hear in meetings, the reason why industry hates to work with the university. It's important for the university to work with industry so as to have access to developing technologies and to understand what the issues and the difficulties are. However there is a perception that Universities have no sense of urgency. We come looking for industry to have that open checkbook that is just a source of funding and give us the money and don't care about the results. This is an unfortunate perception that needs to be actively overcome.

Certainly, in cases where I have seen success in industry-university collaboration the student, the faculty member or the postdoc all strongly feels part of the industry team. It's really important to understand the needs of industry and Universities can sometimes over value the academic contributions and also overestimate the value of intellectual property. This leads to perhaps the most interesting contrast between MIT and Southampton and to some extent Cambridge which is somewhere in the middle. I will say a little bit more about this. At MIT—if you work with MIT as a company, MIT owns the IP, there is no negotiation, no assessment, they own it. The company that works with Southampton and pays for the research, we will give them the IP and we won't haggle over the IP issue. Two completely opposite views for two institutions that are very successful at working with industry. That's one of the conundrums behind my interest in giving this talk in this topic. It's not about IP ownership and I actually have a view that some universities are excessively focused on IP ownership. I gather Japanese universities have been under pressure to have technology licensing offices. At the University of Southampton, we don't have one, we make almost no money on licensing IP to large companies. However, one must note that IP is really important for spinouts, and I will speak more about this shortly.

Going back to working with established companies. It is important that there are no inflated egos; academic prima donnas in the team. It is also very clear that if you are going to work with a company, you must understand what the company's concerns are, what is proprietary, what is the competitive advantage that company has.

These are also cultural differences or prejudices. I won't read through the list, you can read through yourself in front of you. The key is on the academic side to acknowledge these perceptions and the genuine differences and look for ways to bridge that gap. Where I see successful partnerships between big business and universities, these differences are being bridged. They certainly don't act as barriers to the collaboration.

In the US and particularly in the UK, we have a diverse range of partnership models between companies, large and small companies and universities. The diversity of funding models means that regardless of the company and the nature of the work they want done, there's a model that fits or can be tweaked to fit.

For the long term—maybe not over the horizon but at the 5-year time horizon for commercialization, there is sponsored research, for activities where you need the answer immediately, there is the consultancy model. You pay me or you pay a research engineer in the university to work on the problem and get it done. We have knowledge transfer secondments. People from industry come back for continuous professional development. All of these activities help to build relationships. We also benefit from sponsored studentships or just acts of philanthropy. I have heard that Sony and Panasonic have made gifts to Keio to try and underpin the new buildings here, so this aspect of business-university interaction is alive and well in Japan.

This is a not a comprehensive list. It's just to say there are a lot of different ways that universities work with external organizations: research funding, visiting professorship to and from industry or to other universities, secondments, just one-off lectures. Across Southampton and it's true of the Cambridge and MIT, I see all of these happen. No one model will do the trick, there is no one answer. In the UK and US you will hear a phrase university-industry partnership is a contact sport. It's full on, it's people banging into each other all the time and it's important that happens because it's essential to maintaining a partnership, it's maintaining a relationship, it's about seeing enough of the other person. Always talking to them, always letting them know how you are feeling. It's not quite a marriage but it has some similarities. Different people work in different ways, so having lots of different ways in which that partnership can be formed and then maintained is really important. So, don't look for just one thing, always look for options that you can build on to sustain the partnership.

This is something that's really important. Traditionally, there has been this gap, the innovation gap between an academic having an idea and thinking maybe it will turn commercial and the commercialization of that product.

This gap—and you may be familiar with the concept of technology readiness levels, this might be around about 3, this becomes 7 or 8. There is this gap between 4 and 6 where it's just difficult to do. 4 is an initial demonstration, 6 is a prototype that lets you pilot the manufacturing processes and issues such as reliability. In between are the activities required to allow you to turn the idea into a real product that can be mass-produced at scale and reduced cost.

Different countries have different problems. In the UK we have a whole bunch of activities going on. There is the spinout route which is perhaps the most conventional way of bridging it, where venture capital or other investment funding is brought to bear. Although highly visible this can be quite an uncertain route.

In the UK, our research councils have well defined ranges of technology readiness levels; 3 and lower is the realm of the basic science research councils. Beyond this, at TRLs 4–6 we have the Technology Strategy Board, that used to be the Department of Trade and Industry. Their funding is generally granted at a 50:50 cost share between government and industry for activities that have a 3–5 year time horizon.

Just recently, the Technology Strategy Board and the Department of Business Innovation Skills have launched Technology and Innovation Centres which are now called Catapult Centers which are somewhat analogous but different to the German model of Fraunhofer Institutes which have proven to be quite an effective model.

Whatever the answer or the name is, it is critical to have mechanisms that bridge "The Innovation Gap." The mechanisms must take the best research, the most commercially promising research at the purely academic level, and help it through to become commercially important to the university and company.

Some keys to success: I have said that the notion of business-university interaction is a contact sport, to see enough of each other and understand each other well. When you are negotiating contracts that are enabling for the collaboration, you need to know on the university side what's the overall goal. I mentioned the issue of flexibility on IP. We give away a lot of the IP in the UK, certainly the Southampton, but what we get in return is the notion that we've made an impact.

The reputation of our university stands amongst other things on the impact that our research has had. That's not necessarily equal to revenues or share capital. As an example at the University of Southampton, colleagues in our Optoelectronic Research Centre developed the erbium fiber amplifier, which is the technology that literally enables the internet. It amplifies signals going down fiber optics every 50 km. Without that, the attenuation would prevent the internet or fiber optic communication to carry across the Pacific or the Atlantic Ocean. There has to be amplification of the signals. That work was done at Southampton. We have derived almost no revenue from it directly but we have had huge reputational advantageous because we are known as the people who did that.

It's also important to have contacts at all levels; the technical contact, the student, the engineer and the company but also the senior level, our president, our vice-chancellor, our vice-president, our deans, managers at a more senior level, the strategic relationships with our key partners. That's an important facet of the "full contact" nature of university relationships with big businesses.

This shows some of the details of our photonics cluster. This picture shows our new clean room. This shows David Payne who is the guy who invented the erbium-doped fiber amplifier (EDFA). This has been extremely successful over a period of nearly five decades. This activity alone has generated a dozen spinout companies. As a new example of industry-university interaction we are engaged in an unprecedented activity in the UK. We have partnered with a large established organisation, Lloyd's Register, it used to be Lloyd's Register of Shipping. It's moving 350 of its engineers down on to our campus into a new building. We are moving half of our engineering faculty to be close to them. The idea is this will promote the intense collaboration, commonality of interests that allows the university to work with the company. We are also keen to help small or medium-sized companies who work with Lloyd's Register to come down on to our campus.

Based on that, we are looking to cluster around our activities in marine and maritime and bring other companies in. We are a port city, we have longstanding marine engineering activities but also strength in maritime law, transportation logistics and materials issues such as corrosion and biofouling. We host the UK's National Oceanography Centre, a peer institution to your JAMSTEC. These activities cluster around the marine and maritime sector, with common interests. In order to reflect this we have created the Southampton Marine and Maritime Institute to bring these various activities together along with external partners.

Let me just pause. Are there any questions on what I have said so far?

Male Questioner 1

One question. You mentioned technology and innovation centers, do these belong to the national organization of something in UK?

Mark Spearing

The funding comes from the Department of Business Innovation and Skills (DBIS). The one I am most familiar with is the High Value Manufacturing Center, which is actually a distributed activity, so it includes seven sites at existing centers that have brought altogether.

Male Questioner 1

Who organizes these? Politician or chancellor or who?

Mark Spearing

It was a competitive process, so the interested parties bid into it, so, if you want to be part of this—and it's a two-stage process, you submit a proposal. In the high-value manufacturing TIC, there was quite a political process of bringing together groups who didn't necessarily see it as being in their best interest to work together. This was brokered by the civil servants at DBIS more than politicians.

Let me spend another 10 min talking about the spinout which is I think perhaps in some ways more interesting and perhaps less obvious than the issues associate in working with large companies. In Southampton we have had 11 spin-outs, it's 13 now, over 5 years worth about £200 million. Four have been listed on the Alternative Investment Market. Other spin-outs have become divisions of larger companies; they have spun out and then an exit strategy is applied. Several of these are based on venture capital funding, so it is critical to manage the link between university folks who are perhaps a bit naïve in venture capital ways, brokering relationships with venture capital and this is the role of the university both to maximize the potential of the intellectual property and also its people.

We do a lot of work with non-university spinouts, a lot of this through our science park and its incubation unit. Overall it's about building an ecosystem, so there is a buzz that it's in the air, it's in the water, it's in the blood. We are always looking to spin out commercial activities.

We were the first university in the UK to work with a venture capital brokering group; the IP Group. We also were a pioneer in the use of Alternative Investment Market in London for the vehicle for initial public offerings of University spin outs. We now have over 50 companies located on our science park. There are some large companies, including Cisco and Merck, with the majority being small and medium-sized companies, mostly spinouts.

Overall this provides the ecosystem and we have two fully occupied incubator units for the companies that have two or three employees and need provision of IT support etc.

So back to intellectual property. I mentioned that MIT is very aggressive in its pursuit of intellectual property. When I was there it filed 350 patents a year and its licensing office has an income of over $100 million a year, which is a big operation. It's one of the very few technology licensing offices that actually makes money for its university. A vast majority of those in the USA don't, they actually lose money. They are kind of like a luxury car, it's a prestige thing. That's the MIT model. Cambridge has one of the strictest IP models in the UK, but it's much, much more relaxed than MIT and most other US Universities.

The University of Southampton is just a pussycat by comparison. We only protect IP if there is a clear licensing of the spinout possibility. At Southampton we file less than 40 patents a year, which is about 10 % of MIT's patent activity. We only patent really certain things where we know we are going to spin the company out or where we know there is a big company who wishes to license the technology. And we are very flexible, you give away a lot of that spectrum. Overall we do very well, we've got a huge reputational benefit and we also make a significant amount of money.

Why are these long timescales for IP pay back frequently over 20 years? Frequently, after the patent has expired which is frustrating. Big wins are big, but pretty rare and clumpy.

MIT has a patent portfolio at any one time of 2,000 or 3,000 patents, each of which is maintained at the cost of tens of thousands of dollar a year. It's really expensive. When I was there, there were only three that were making money but they were making money big time, tens of millions of dollars a year each for those three that were making money.

There is potential for distortion of objectives. The impact is just not about making money. There are other things you may be able to achieve other than just revenue. Sometimes good business-university relations matter more, that's often our experience with big companies. We would like to have long-term relationship with the likes of Rolls-Royce, Microsoft and IBM. We don't want things like intellectual property to get in the way of that. If you go into the TLO model for intellectual property, you need the smoothing funding to keep the licensing operation going, to keep up the maintenance of the patent.

In the case of MIT and to some extent increasingly with Cambridge, this is paid for by their endowment. They can invest in their own technology, they can invest in their intellectual property. MIT currently has endowment that's most of $10 billion. The University of Southampton has no endowment. This also has the feature that if you go after MIT infringing one of its patents, they can protect it. They can hire better lawyers than most potential licensees which has a really big impact. At the University of Southampton, we can't and we won't do this, which is another reason for not being so protective of our own.

As I said, even in the USA, the majority of technology licensing offices lose money and lose millions of dollar a year to their university but they feel the need to persist with this route. In the UK we don't have a technology licensing office as such. We integrate that with the rest of our research and innovation services. We are very, very careful before pursuing patents.

I can say something about our experience of spinning out a companies. Firstly awareness is key. People are looking for the opportunity, it's in the blood, it's in the DNA. At the University of Southampton, we have Research & Innovation Services. Some academic or student has an idea and they approaches RIS. Their idea is screened, we have a quite experienced management board with people from VCs or experienced entrepreneurs that play a key role here. If it is promising to file the IP, and obtain Proof of Concept funding which we have a bit of in the university. With this the concept can be refined, tested and the business case prepared.

Often we identify an experienced CEO, sometimes a friend of the university to come in and run the company in the initial stage. The case for investment is present to the University investment fund committee. Southampton Asset Managemented is a holding company for our spinouts. Typically first round funding is sought from the IP group, first round funding is the order £0.5 million or 50 million yen.

They build a team. At 18 months we go to second phase funding which is probably four or five times first phase funding, i.e. £1–2 million pounds, equating for pre money valuation of 3–5 million. At around 2–3 years another round of funding, getting bigger all the time, depends on the topic.

Somewhere around 5–6 years, we're looking to exit either through Initial Public Offering on the Alternative Investment Market or a trade sale often to a rival.

We are looking to exit at about 5 year and realize a return on our investment. Our experience is that it's very much about the quality of management and having something very early on in the process that is exciting to the potential customer, an early demonstration of focus on that to get through to that 3–5 year point.

Increasingly—so that's kind of traditional, we are in a little bit of recession at the moment so we are not seeing nearly as much IP activity, there is not nearly so much venture capital around the UK. We are increasingly seeing what we call soft spin-outs where there isn't the need to have venture capital funding. It's a low capital need, often bootstrap from immediate sales, particularly from services, so we've got a couple of these going quite successfully at the moment.

Dezine Force which uses Microsoft's increasing market for the set of applications, high performance engineering products to help particularly small and medium-sized enterprises do engineering design.

Plexus Design which offers cost-modeling services initially for Rolls-Royce but it's doing this—it provides a services comparing costs of different manufacturing routes and different design choices all sources of cost to the company.

Both of these are doing rather quite well without any venture capital funding. They have turnovers of over £1 million a year after 3–4 years.

We also at Southampton—unusually we have consulting units. These are units staffed by professional engineering that provide a very important interface between academic activity and industrial needs. They are basically service companies providing consulting. They have the same sort of feel of things like Stanford Research Institute and Georgia Tech Research Institute in the US, but we've kept them in the university. And it could be spun out, we could keep it inside. We've been running these for 40–50 years. They provide very important revenue stream for the university but also a bridging mechanism that allows us to get to know companies well. They sort of fit into the gap between small companies and the University.

Okay, I am going to wrap up. These are some of the things I think I have learned from my personal 20 odds years with a number of institutions. There are some quite different models out there. Actually, the model doesn't matter, all of them can be successful. You have to understand the institutional or perhaps to a great extent the national culture and the American dream is something in America that MIT benefits from but you don't see in the UK. I am sure you don't see it in Japan in the same way, it's something different in the UK.

Cultural factors are really important both institutional and national. Some of these I think really do matter. These are the value based on conducting research within the faculty. It doesn't end with a paper. Nobel Prize is nice but there are other ways it has an impact. And it's important that the system rewards how people are hired, what students expect, that all matter.

Value placed on behaving entrepreneurially. In all three of the universities I have been drawing on from my experience, there is a value. Everyone knows who is being successful of having ideas, translating ideas that are recognized by big companies or they are spinning out. It matters. It's in the institutional values. It's not suppressed, it's out there.

Universities must show creativity in allowing student and staff to be involved with industry. Secondment models, leaves of absence that go and start the spin-out. These things really matter, that they support people doing it. If this support is not there, then the entrepreneurial culture will not develop.

Cultures can change. UK universities have become much more overtly entrepreneurial over the last 30 years. When I was an undergraduate, maybe starting to introduce people to Cambridge in the middle of 1980s, it was sort of whispered, so and so spends a lot of time at his spinout or his consulting companies. We don't see enough of him in the lab or in his office. That's changed. People talk in much more positive terms about people having corporate involvement.

There has been I think in the UK quite a strong cultural change. I think it happened in the US but probably a generation earlier. So, I suspect from what I see that that's the journey that Japan has got and is moving quite quickly on in terms of that entrepreneurial culture.

These are just some slogans. Education really matters but enterprise also gives a root to economic impact. All of the places I have mentioned and this would apply to other Universities, start with a really strong science base, strong university, good people, competitive to get into. All of these things make a strong university that makes it much more likely that there will be impact—entrepreneurial impact on large companies. Thank you very much for your attention. We welcome any questions.

Male Questioner 2

Thank you for your wonderful talk and I have a couple of questions. First, I want to ask you as a young professor or a young faculty member. It is sometimes really difficult to find a good partner in industry because I don't have any good contacts. Do you have any kind of system to promote that kind of cooperation with industry?

Mark Spearing

Yes. When I arrived at MIT, I was an even younger assistant professor. It felt to me to be important to work with industry, so I had a motivation. I thought as an engineering academic I should be working with industry. That was my attitude. I really, really, really wanted to work with The Boeing Company. Boeing is a major player in the aerospace industry and I worked in composite materials which are very important to the aerospace industry. I even had a little bit of access to Boeing because there were links between MIT and Boeing.

At first when I went to visit Boeing in Seattle, I thought that they will open their checkbook. I was a new assistant professor at MIT. I must be good and they would want to work with me! No! There seemed to be almost complete disinterest. I was taken to dinner by two senior executives of Boeing; the vice-president of engineering and the head of materials and structures. They delighted in telling me how they had just completed the Boeing 777, this was 1994, the 777 was just flying, and it was the first Boeing plane with significant composite material content in the airframe's primary structure. They delighted in telling me—these two senior people—how they were not going to have any composite materials, on their next aircraft. In their view it was too expensive. At the time I felt that the door was shut on me, but I went back and senior colleagues said, "No, no, you've got to persist." They don't really mean it. They will keep doing this. I went to Boeing seven times before I eventually was awarded a research contract. Back then it was $45,000 for 1 year. It was not even enough to fund a Ph.D. student and I had to scrape around to fund a student. I had a Master's student and had had a bit of funding from somewhere else. I was being tested basically. I had to go around, I had to find the right people, they had to see that I was persistent, that I kept coming back, that I was willing to engage in that full contract. It took me six times before I made it succeed. By the time I left after 10 years at MIT, I had received over one million dollars of funding from Boeing, leveraged by other funding from other agencies. I had been part of two major research programmes, and saw my research translate into the company's products. I was very much part of the Boeing team and I was very proud. I received an award for being a valued member of the Boeing team, it felt really good. I gained my rewards from persistence, and also from listening. Throughout they were telling me what they were really interested in. I would go away, I would think what I would do and go back. Frequently their interests would have changed. So I kept chasing. Eventually they became familiar with me, and perhaps they became familiar with my suspicious accent, and perhaps they became more confident that I wasn't going to leak their secrets to Airbus. Persistence I think would be the biggest message to anyone. For anyone who has got an idea that they believe in; you've got to keep going!

Male Questioner 3

If you have a university spinout, if it succeeds, there is no problem, however if it fails, after significant investment, and with many employees, what happens? Will the government or some other agency step into support it after a point?

Mark Spearing

Thank you for the question. The default position is that market forces are allowed to have there way, and failing companies are allowed to fail and f necessary be wound up or become subject to bankruptcy proceedings. I would take this opportunity to make a couple of other points. Firstly I would observe how individuals are treated in these circumstances and I think that the UK has moved quite a long way in this area. If you read Charles Dickens, the consequences of going bankrupt were that the individual would be consigned to the debtor's prison and might never return. This is no longer the case, but bankruptcy still has a considerable stigma in the UK. Anecdotally, in the USA, it is often stated that the average entrepreneurial millionaire has gone bankrupt three times before they make it. This is probably an exaggeration, but the point is that it is not viewed as an entirely negative outcome and to some extent individuals are judged to deserve a badge of honor. They pick themselves up off the floor and are being persistent and trying again. So long as they can articulate the lessons learned from that failure, in the USA there is actually considerable admiration of people who fail and are willing to go back at it. I believe that the UK is on a journey towards that type of view.

In terms of financial protection, it is important to choose the right financial model for a startup. Any startup has some element—usually quite a large element—of risk and you need to look very carefully and how that risk is managed financially. Certainly, the venture capital funders are very conscious of that. In the first stage of a start up there might be one venture capital investor involved. In our case we work with the IP Group preferentially. But in the second and third rounds of funding they will usually look for typically three, maybe even five, investors as they want to be diversified. That's the key.

Male Questioner 3

You have a very strong evaluation committee group or something, is that right?

Mark Spearing

Yes. For our university that's an important part of the process. We have an entity which we call Southampton Asset Management which is formally a legal company of which I am a director. The majority of directors are external to the university.

The chairman and several directors are entrepreneurs and other members come from venture capital community and are familiar with the financial issues associated with start ups.

In the UK there is a television program called the Dragon's Den where people come in with an idea that they are looking for funding for. It's on television. They have five wealthy individuals who invest real money in front of a television audience. It's a great program, it's great television. It feels a bit like that when the directors of Southampton Asset Management meet with a potential spin out. When our Research and Innovation Services (RIS) see something that's on the cusp of being ready to spin out, the academic or the students involved will come to the board meeting and will present their ideas for 10–15 min and field some questions from the board. We will then come to a decision. Unlike the Dragon's Den it is usually not just one decision about whether to invest or not, the intention is to provide guidance. There will often be several iterations so as to get the value proposition and the core team for the spin out into a position so that they are as credible as possible for obtaining initial funding and success as a company.

This is a really important part of our process. It also usually as an outcome of such meetings that decisions are made regarding investing in patent protection on behalf of the University. It seems to be a good policy for our University. Obviously there are other models that also work well.

[Multiple Speakers]

Male Questioner 4

Thank you for a wonderful presentation. My name is Kazukiro Ishida. From the student's opinion, I have a question about why does industry want to work with universities. You said the main point is for industry to identify future employees.

I have some friends who did research with a company as part of their degree studies, but now, after university but none of my friends are working that company now. So, it is difficult for me to agree with your opinion, but I am not sure is it common in the United States or in United Kingdom.

Mark Spearing

This is a good point. It is certainly not every Ph.D. student working on a company-relevant research project who goes to work for the sponsoring company. This would not work from either perspectives. Students may well want to go to other companies, or stay in University research for longer, and the company will often not want to hire all the students it sponsors. Nevertheless, in my experience, the potential to have first access to bright students working on relevant topics is a major motivation for many companies sponsoring research at Universities. In addition the sponsoring of research gives the company visibility on campus, and other students, not directly involved with the company may be more inclined to seek employment there as a result. I do not have accurate numbers for the fraction of industry-sponsored Ph.D. students who subsequently work for the company that sponsored them. I would estimate that it is significantly less than 50 %. Nevertheless, where it does occur, it is a particularly effective method of knowledge transfer to the company.

Moderator

Last question.

Female Questioner

I am a researcher from the University of Hokkaido. Thank you for very interesting lecture. Please could you say a little bit more regarding your views on Technology Licensing Offices. If you do not have a TLO, how do you protect your IP or seek commercial opportunities?

Mark Spearing

Just to be clear, it is important you have people within the university who looks out for such opportunities, but calling it a TLO, and therefore putting all the emphasis on technology and licensing, implies that's the most valuable part. In my experience in the UK this is a mistake. There are other ways that intellectual property can be exploited so that it has a benefit and generates revenues for the University. The focus on patent filing, generates substantial costs, which are often not recovered by licensing or spin out equity. That said, the TLO model works well for MIT but their TLO could well be the first and biggest TLO anywhere. It's very powerful and they operate at a scale whereby they have a better chance of backing enough of the rare big winners to cover the costs of the much more common patents that only generate costs.

Female Questioner

My question is I see that your university fund is more focused on the industrially-relevant research. So do you have a problem of explaining to the society how to balance between the basic research and applied research?

Mark Spearing

No, but we are successful. So at the moment we are the sixth largest recipient of basic science and engineering research funding in the UK and we also do very well on citation statistics. However, I think in most economically developed countries and developing countries is just not enough. Some of those ideas have to follow through to make a difference to society to keep them relevant.

Actually in a way that's why in UK and US, the big research labs have ceased being really so prevalent because they struggle to justify their impact to the company. Many of the best ideas at Bell Labs and IBM got commercialized by other companies or IBM didn't invest in it. The staff who had the idea went out and founded their own company and IBM did not benefit. Thank you.

Female Questioner

You mentioned about the collaborate investing issue about collaborating with SMEs can be difficult.

Mark Spearing

Sure. SMEs are difficult I think the world over to work with because they have people doing multiple things. If you are in an SME, we have several jobs and in a large company they have a collaboration manager, someone whose job is to manage a relationship with the university. If you are an SME, that's less likely, so being able to devote the time to the collaboration. Also their timescales tend to be particularly short. SMEs more likely are living quarter to quarter and they make a budget per quarter. If money starts to be tight, we are the first thing to get cut down.

I think there are two contributions. In the UK as a whole there are programs such as Knowledge Transfer Partnerships and Knowledge Transfer Secondments and Kevin who is in-charge of Knowledge Transfer Partnerships, which provide leverage to government funding.

It's preferentially beneficial to SMEs and that's being—and the way those work is a university person, a knowledge transfer associate gets seconded into the company. They are not on the company's budget but they are there. And so it's the university person kind of responsible for the relationship, not the company person. The company person has to manage the person in the next office which is not easy to balance with managing the collaboration.

The other thing that we at Southampton I think are very good at, we have these consulting units which provide a particularly good software professional engineers. They could work to industry timescales where they need to contact the approrpiate Ph.D student at a specialist facility, they can draw it in. But we can provide dedicated professional engineers who can work on the company's problem full-time and they are not like academics who perhaps have to go and teach a lecture or go to a conference and they are not there, just come to us and we will deliver!

Those two mechanisms are really important for Southampton and the UK.

Female Questioner

What is your motivation—I mean, university people's motivation to work with small companies? I mean I am a business course student and at the same time I running my own small company so I want to know more about this topic.

Mark Spearing

I think there are multiple and different motivations for working with small companies. At the most basic level, whether it is a small company or a large company, if I consult for you, you pay me, so it's a business transaction. For many of us though it's something a bit more than that. Certainly as an engineer I like solving problems and this is true with many of my colleagues. I derive satisfaction from actually, making a difference—I have worked in industry as well as the places that I mentioned and I have worked a lot with small and medium sized companies. Actually, going in there and providing advice, analysing their problems, even helping design products, you see it makes a difference. It turns into a commercial success, it creates jobs, which has a really good feeling. Often with small companies the ability to make an immediate difference than with larger companies As an engineer I can state with certainty that most people get into engineering not because they want to write papers, but that they want to do something that's going to make difference.

If you had the chance to work on a product—I've been around big companies. I have been around The Boeing Company and felt the buzz when a new aircraft comes out. You see that tens and thousands of people who worked on it, it's this huge feeling of creation, of triumph. You've made something, it works, it's a success. That's really a big motivator to many of us. I mean I am not saying we wouldn't want to get paid for the work we provide but equally sharing in that success is a significant motivation. There's something else. It's maybe a little bit more subtle. I know that by working with industry, gaining experience—even as an academic the going into companies, going site visits, I will learn things at the periphery of my interests that I can then bring back to inform my research, to inform my teaching, and be able to motivate students, my undergraduates because I can say, "Hey, I was at this or that company and I saw something really cool. Equally I will be able to say that I was at Keio University and boy, there is a really cool electric car or plastic fibers that's about to become big."

Moderator

Any other questions? We are running out of time. Thank you very much for this interesting lecture. Additionally, I would like to say we are going to publish the proceedings of this lecture. I therefore am happy to announce that this event is concluded. Thank you very much.

Mark Spearing

Thank you very much.

END

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Biographies

Editor

Koichi Hishida, Ph.D.

Director General, Headquarters for Research Coordination Administration; Professor, Department of System Design Engineering, Faculty of Science and Technology, Keio University. Koichi Hishida received his M.S. (1978) and Ph.D. (1982) degrees in the Department of Mechanical Engineering at Keio University, where he specialized in experimental fluid mechanics and heat transfer. He has researched heat transfer enhancement in mist flow and turbulent structure in dispersed two-phase flow and developed dynamic flow measurements based on laser techniques such as laser Doppler velocimetry with particle sizing and particle image velocimetry combined with laser induced fluorescence and infrared shadow techniques. He is currently a professor (since 1997) in the Department of System Design Engineering, Keio University. His current research includes experiments on turbulent modification of two-phase flow (particle laden and bubble flows), heat transfer controlling, and development of laser-based instrumentation for micro-nano scale flow measurements. He is now associate editor of *Experiments in Fluids* and an advisory board member of *Measurement Science and Technology* (IOP) and *Fluid Dynamics Research*, and an organizing committee member of several international conferences including Application of Laser Technique to Fluid Mechanics, Turbulent Shear Flow and Phenomena, and ICMF. He was elected as a Fellow of the Institute of Physics as a chartered physicist (CPhys FinstP) in 1999. He has published more than 150 articles in major international journals. Prof. Hishida has also held the post of Director-General of Headquarters of Research Administration and Coordination at Keio University since 2008

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Authors

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Project Professor, Graduate School of Science and Technology, Keio University, Japan. Kenichi Hatori obtained a master's degree in electronics from Gunma Graduate School of Engineering, Japan in 1975. After that, he had worked as a patent examiner, an appeal examiner, Vice Director of Patent Examination Department and Director of Automation Division and so on of Japan Patent Office for almost 25 years since 1976. He also served as the first director of the Intellectual Property Department of AIST, one of the most major public research institutes in Japan from 2001–2003. He was appointed as Professor of Keio University in 2007. At Keio, he had led the intellectual property division as Director of Intellectual Property Center from 2007–2011, and as Director of Headquarters of Research Administration and Coordination from 2011–2012 under the following missions: 1) to manage intellectual property derived from Keio's research results, 2) to promote technology transfer from Keio to industries for the benefit of society and 3) to educate students in a class of practical intellectual property management and research/technology contract. He was appointed as Project professor of Graduate School of Science and Technology, Keio University in June 2012. He has been involved in Keio Leading Graduate School Program to develop a new generation of highly advanced doctoral students with double degree among science and humanities. He has been appointed as one of expert member of university-industry collaboration commission of Ministry of Education, Culture, Sports, Science and Technology – Japan (MEXT) since 2009

Takafumi Yamamoto

CEO & President, TODAI TLO, Ltd. (CASTI). Takafumi Yamamoto is CEO and President of TODAI TLO, Ltd., a technology licensing organization of the University of Tokyo. Mr. Yamamoto is a pioneer in the technology transfer business in Japan. After graduating from the Faculty of Economics of Chuo University in 1985, he entered Recruit, Ltd. as a planner of new business development and technology transfer from universities to industries. He established this innovative business scheme with the cooperation of Mr. Niels Reimers, the first director of the Office of Technology Licensing (OTL) at Stanford University, who also became involved with other technology transferring organizations such as M.I.T., UC Berkley, and UCSF. Mr. Yamamoto established the Technology Management Division at Recruit, Ltd. in 1998 and joined TODAI TLO as CEO in July 2000. He is also a board member of UNITT (AUTM Japan) and was appointed an expert member to the Prime Minister's IP Strategy Headquarters

Robert Kneller, J.D., M.D., M.P.H.

Professor, University of Tokyo. After graduating from Swarthmore College with a major in physics and a minor in economics in 1975, Robert Kneller earned an M.D. from Mayo Medical School (1984) and a J.D. from Harvard Law School (1980). Dr. Kneller is also board certified in general preventive medicine, having completed his residency and public health studies at Johns Hopkins University. He developed his medical career in pediatrics and preventive medicine during the 1980s and also worked in China as an NIH epidemiologist. He worked in the U.S. National Institutes of Health (NIH) from 1988 to 1997. In 1998 after a 1-year Abe Fellowship, he became a professor in the University of Tokyo's Research Center for Advanced Science and Technology (RCAST). His research and teaching focus on intellectual property and startups and their importance in the development of scientific discoveries, particularly biomedical discoveries and discoveries from universities. His publications include *Bridging Islands* (Oxford), which compares the environments for new science-based companies in Japan and the U.S. and their importance for innovation, and also a study of the origins of the 252 new drugs approved 1998–2007 by the U.S. FDA, which shows the importance of new companies for the discovery of innovative pharmaceuticals

Yasuhiro Koike, Ph.D.

Professor, Councillor, Keio University, Director, Keio Photonics Research Institute. Yasuhiko Koike earned his B.S. (1977), M.S. (1979), and Ph.D. (1982) in engineering from Keio University, where he started his academic and research careers. He became a tenured professor at Keio in 1997. Prof. Koike was a researcher at AT&T Bell Laboratories from 1989 to 1990. He received an honorary doctorate from Eindhoven University of Technology in 2007. He has been an Affiliate Professor at the University of Washington since 2009. The main areas of Prof. Koike's research interests lie in such areas as photonics polymers represented by graded-index polymer optical fiber (GI POF), highly scattered optical polymer transmission (HSOT), polymer optical amplifier and polymer fiber laser, and zero-birefringence polymers, among others. His awards include the International Engineering and Technology Award of the Society of Plastics Engineers, the 42nd Fujiwara Award (youngest prize winner), the Award of the Society of Polymer Science, and the Medal with Purple Ribbon bestowed by the Japanese Emperor

Hideyuki Okano, M.D., Ph.D.

Professor, Department of Physiology, Keio University School of Medicine, Dean, Keio University Graduate School of Medicine. Hideyuki Okano received an M.D. in physiology from Keio University in 1983 and served as research associate at the Keio University School of Medicine and the Osaka University Institute for Protein Research. After obtaining a Ph.D. degree from Keio University in 1988, he held a post-doctoral position at Johns Hopkins University Medical School. He was appointed as a full-time professor at the Tsukuba University School of Medicine in 1994 and the Osaka University School of Medicine in 1997, and returned to the Keio University Medical School in 2001 as a tenured professor of physiology. He has been Dean of the Keio University Graduate School of Medicine since 2007. Dr. Okano has conducted basic research in the field of restorative medicine including, neural stem cells and iPS cells, spinal cord injury, developmental genetics, and RNA binding proteins. He is the recipient of a number of awards and honors including the Medal with Purple Ribbon in 2009

Benjamin Chu, Ph.D.

Technology Transfer Officer, UCLA Office of Intellectual Property and Industry Sponsored Research. Benjamin Chu earned his Bachelor of Science in Electrical Engineering with the Biomedical Option in 2002 and Doctor of Philosophy in Biomedical Engineering in 2006, both from the University of California, Los Angeles (UCLA). Dr. Chu joined the UCLA Office of Intellectual Property and Industry Sponsored Research (UCLA OIP-ISR) in 2007. As a Technology Transfer Officer, Dr. Chu is responsible for managing a portfolio of UCLA intellectual property, reviewing invention disclosures for patentability and commercial potential, securing patent rights, marketing technologies to industry, facilitating the commercialization of UCLA technologies for the public benefit, negotiating and drafting licensing and inter-institutional agreements, and guiding UCLA faculty and students through the patenting and commercialization process. In his role at UCLA OIP-ISR, Dr. Chu works closely with faculty in engineering and physical sciences on commercializing technologies in nanotechnology, wireless communications, semiconductors and solid state devices, polymer and CNT electronic devices, materials science, medical devices and diagnostic tools, Clean/Green tech, MEMS and bioMEMS, and regenerative medicine

Kirsten Leute

Senior Licensing Associate, Stanford University Office of Technology Licensing. Kirsten Leute's education includes a bachelor's degree in biology from Wellesley College and a master's degree in Business Administration from Santa Clara University. Her specialities lie in the areas of international business and management of technology and innovation. In 2003, Ms. Leute passed the U.S. patent bar exam and is U.S. Patent Agent No. 55375. At OTL, Ms. Leute handles a diverse caseload of over 275 biotechnology and high technology inventions. She also has rich experience in software, trademark, and copyright licensing. Having started at OTL in 1996, she also worked as a technology manager at the Deutsches Krebsforschungszentrum (German Cancer Research Center), Heidelberg, Germany, in 2004. Ms. Leute was Vice President for Communications of the Association of University Technology Managers (AUTM) in 2007–2008 and was an editor of the *AUTM Journal*. She is currently Co-Chair of Membership for Women in Bio, San Francisco Bay Area. She is also a past board member of Women in Licensing Bay Area (WiLBA)

Ruth M. Herzog, Ph.D., M.A., CLP

Head of the Office of Technology Transfer, Deutsches Krebsforschungszentrum (DKFZ, German Cancer Research Center). Ruth M. Herzog received a diploma in biology in 1986 from the University of Bonn and a Ph.D. in molecular tumor biology in 1991 from the University of the Saar. After building her business career in sales and marketing in oncology at Hoffmann-La Roche from 1991 to 1997 she joined the DKFZ to reorganize its technology transfer operations. In 2011 she earned an M.A. in economics and management from the Technical University of Kaiserslautern and became a Certified Licensing Professional (CLP). As head of DKFZ's Office of Technology Transfer (OTT) Dr. Herzog has rich experience and knowledge in technology transfer (including benchmarking technology transfer operations), licensing, intellectual property management, and business development, especially in the cancer field. She has also participated in the establishment of a technology transfer network in Europe (ProTon Europe), where she led work package licensing for 2 years. As an active speaker Dr. Herzog has presented to audiences at ProTon Europe and German biotechnology days and other meetings and has organized workshops, e.g., for the annual AUTM meeting in 2011. She is teaching intellectual property management courses regularly within the DKFZ and externally. She is a member of AUTM, LES, ASTP, ProTon Europe, TechnologieAllianz, and the Helmholtz Committee for Technology Transfer and Intellectual Property, which she chaired for 3 years

Lily Chan, Ph.D.

Chief Executive Officer, NUS Enterprise. Lily Chan leads NUS Enterprise at the National University of Singapore (NUS), with the vision to inject an enterprise dimension to NUS teaching and research involving the University's students, staff and alumni. The Enterprise Cluster comprises several divisions for entrepreneurship support, experiential education, and technology exchange. As the Chief Executive Officer, she spearheads strategies and initiatives to promote industry collaboration and business ventures for the University. Prior to joining NUS in 2006, she held the position of Managing Director, Investments, of Bio*One Capital Pte Ltd, an investment arm of the Singapore Economic Development Board with a focus on expanding the growth of the biomedical science industry in Singapore. She brings with her more than 20 years of industry experience, from initiating start-ups and venture investments, to active Board involvements in many startup companies. She has also been on several national-level committees on enterprise and innovation

Mark Spearing, Ph.D.

Pro Vice-Chancellor, University of Southampton, Southampton. Mark Spearing is currently serving as Pro Vice-Chancellor (International) at the University of Southampton. His portfolio includes international relationships in research and education, internationalization of the curriculum and the campus, and the recruitment of international students. He is a member of the Board of Southampton Asset Management and has been closely involved in the University's spin out and other commercialization activities. Previously Professor Spearing was Head of School and Professor of Engineering Materials in the School of Engineering Sciences at the University of Southampton. From 1994 to 2004, he was a professor of aeronautics and astronautics at the Massachusetts Institute of Technology. At MIT he was Head of the Materials and Structures Division and Director of the Technology Laboratory for Advanced Composites. Dr. Spearing is a recipient of the AIAA Outstanding Teaching Award (in 1995, 1997), Award for Outstanding Undergraduate Advising, DAaA, MIT (in 1999, 2000), Best Patent Award, Draper Laboratory (2003), Royal Society Wolfson Merit Research Award (2004), and others

Speakers of the Symposium "Fulfilling the Promise of Technology Transfer: Fostering Innovation for the Benefit of Society." Participants, at the Keio University Library (Old Building), September 28, 2012