U N I V E R S I T Y O F J Y V Ä S K Y L Ä
Department of Biological and Environmental Science

EVALUATION OF BIOTECHNOLOGY RESEARCH UTILISATION IN FINLAND

Master's Thesis; Biotechnology
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Author: Juhani Taskinen
Instructors: PhD, CEO Timo Törmälä
M.Sc., Assistant Leona Gilbert

Supervisors: Professor Christian Oker-Blom
Docent Pauli Seppänen

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Juhani Taskinen

UNIVERSITY OF JYVÄSKYLÄ ABSTRACT OF MASTER'S THESIS
Department of Biological and Environmental Science
Division of Biotechnology
PL 35, 40014 University of Jyväskylä

Author:	Juhani Taskinen
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Instructors:	Director Timo Törmälä, M.Sc. Leona Gilbert

Abstract:

Finland has aimed to form a fourth pillar for its industry of biotechnology and related sciences. There is reason to believe however, that Finnish biotechnology is not utilised efficiently when compared to public funding received for research and scientific impact of research results. The requirements for formation of competitive biotechnology industry have not thus been met.

The first objective of this study was to count the exact number of biotechnology patents issued to Finnish inventors, while previous research has only counted the number of patent applications, which does not necessarily correlate with the number of issued patents. The second objective was to evaluate Finland's performance in biotechnology research utilisation compared to other selected countries. Patents issued to Finnish inventors were counted from several databases of domestic patent authority and from European and American patent authorities. The evaluation was formed using calculations in which the number of issued patents was related to public funding and impact of the research results. The result of the evaluation was explained by interviewing innovation managers from Finnish universities performing biotechnology research.

Funding received for biotechnology research was found internationally competitive, as was impact of research. Finnish inventors were issued to 507 biotechnology patents, of which 218 in America. Utilisation of biotechnology research was found uncompetitive in international comparison. The main reasons for uncompetitiveness were researcher's lack of knowledge of patenting-related issues and the costs related to patenting with unavailability of easily obtainable funding for patenting. Recommendations for improvement of utilisation performance are proposed in the end of this study.

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Key words: Biotechnology, research, research funding, research quality, research utilisation, patenting, international comparison.

JYVÄSKYLÄN YLIOPISTO
Bio- ja ympäristötieteiden laitos
Biotekniikan osasto
PL 35, 40014 Jyväskylän yliopisto

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Tiivistelmä:

Suomen tavoitteena on ollut tehdä biotekniikasta teollisuuden neljäs tukijalka. On kuitenkin syytä uskoa, ettei alan tutkimustuloksia ole kuitenkaan hyödynnetty tehokkaasti verrattuna julkisen tutkimusrahoituksen määrään ja tutkimustulosten tieteelliseen merkittävyyteen. Kaikkia kilpailukykyisen bioteollisuuden synnyn edellytyksiä ei siten ole täytetty.

Tutkimuksen ensimmäinen tavoite oli laskea suomalaisille keksijöille myönnettyjen biotekniikan alan patenttien määrä. Aiemmissa tutkimuksissa on laskettu vain alan patenttihakemusten määriä, mikä ei välttämättä vastaa myönnettyjen patenttien määrää. Tutkimuksen toinen tavoite oli arvioida Suomen biotekniikan tutkimuksen hyödyntämistä verrattuna valittuihin muihin maihin. Myönnettyjen patenttien määrä laskettiin käyttäen sekä kotimaisen, eurooppalaisen, että yhdysvaltalaisen patenttiviranomaisen tietokantoja. Biotekniikan tutkimuksen hyödyntämistä arvioitiin suhteuttamalla myönnettyjen patenttien määrä julkisen rahoituksen määrään, sekä tutkimustulosten tieteelliseen merkittävyyteen. Tulosten syiden selvittämiseksi haastateltiin biotekniikan alan tutkimusta tekevien yliopistojen innovaatioasiamiehiä.

Biotekniikan tutkimusrahoituksen määrä osoittautui kansainvälisesti kilpailukykyiseksi, samoin kuin alan tutkimuksen tieteellinen merkittävyys. Suomalasille keksijöille oli myönnetty kaikkiaan 507 biotekniikka-alan patenttia, joista 218 Yhdysvalloissa. Bioalan tutkimustulosten hyödyntämisen kilpailukyky osoittautui kansainvälisesti heikoksi. Tämän todettiin johtuvan pääasiassa tutkijoiden tietämättömyydestä patentoinnin suhteen, sekä patentoinnin kalleudesta ja siihen tarkoitetun rahoituksen helpon saatavuuden puutteesta. Suositukset Suomen biotekniikan tutkimuksen hyödyntämisen parantamiseksi on esitetty tutkimuksen lopussa.

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Avainsanat: Biotekniikka, bioteknologia, tutkimus, tutkimusrahoitus, tutkimuksen laatu, tutkimuksen hyödyntäminen, patentointi, kansainvälien vertailu.

CONTENTS

1 INTRODUCTION

1.1 Motivation for the study

At Lisbon in March 2000, European Union leaders set the goal of making Europe the most competitive knowledge-based economy in the world by 2010 (Lisbon European Council 2000). One of the key determinants of success will be Europe's ability to develop more innovative business and industry. Success requires changes in attitudes towards more entrepreneurial risk taking, better availability of finance and closer links between the scientific and industrial worlds. In addition, success requires innovation, which largely depends on interpersonal, interorganisational and international connections, and positive attitudes toward making new ideas concrete. (Innovation Directorate 2003, 3)

Recent studies, the latest by the European Commission's Innovation Directorate, indicate that Finland implements the European Union's goal quite efficiently by being among the top countries in many EU charts of high technology patenting and innovation activity (Innovation Directorate 2003). Finland even tops distinctively the chart of high technology patent applications filed to the European Patent Office per population and is second in a similar chart of patent applications filed to the United Stated Patent and Trademark Office (European Innovation Scoreboard 2002, 9). This would seem to be well in concordance with Finland's aim to form a fourth pillar of its industry out of biotechnology, beside forest/paper industry, metal industry and electronics/information technology.

On the other hand, there is reason to believe that not everything is done to achieve this goal. Prime minister Paavo Lipponen stated in his speech at Helsinki University's Biocenter 3 opening ceremony on 19th of September 2002, that public investments in biotechnology research have been relatively large lately, but the results at this point have been commercially inadequate. In addition, a recent study by the Academy of Finland concerning the impact of public funding of biotechnology, noted that Finland's

current innovation protection policy has compromised, inhibited and delayed some key factors that are essential for a successful bioindustry to form (Kafatos, Beyreuther, Chua, Mach, Owen & Steitz 2002, 51). Statistics on biotechnology patent applications of Finnish inventors also indicated that Finland's success in high technology patent application charts doesn't apply to biotechnology (e.g. Statistics Finland 2002a). This study is done to clarify Finland's position in international comparison of biotechnology research utilisation, of which patenting is a central part.

1.2 Objectives and the hypothesis of the study

There is a clear contrast between Finland's position as a chart leader in high technology patent applications in general and the number of biotechnology patent applications. It will be proven in upcoming chapters that intellectual property protection, especially patenting, has a central role in forming a competitive biotechnological industry. Previous studies of biotechnology patenting activity are scarce, and have focused mostly on the number of patent applications (e.g. Statistics Finland 2002a). A large share of patent applications will never get approval however, and the number of *issued* patents is thus not the same as the number of applications. First objective of this study therefore, is *to calculate the actual number of biotechnology patents issued to Finnish inventors.*

A broader view of the state of Finnish biotechnology is achieved by comparing the situation here to other countries. The hypothesis of this study of the current state of Finnish biotechnology is divided in three parts:

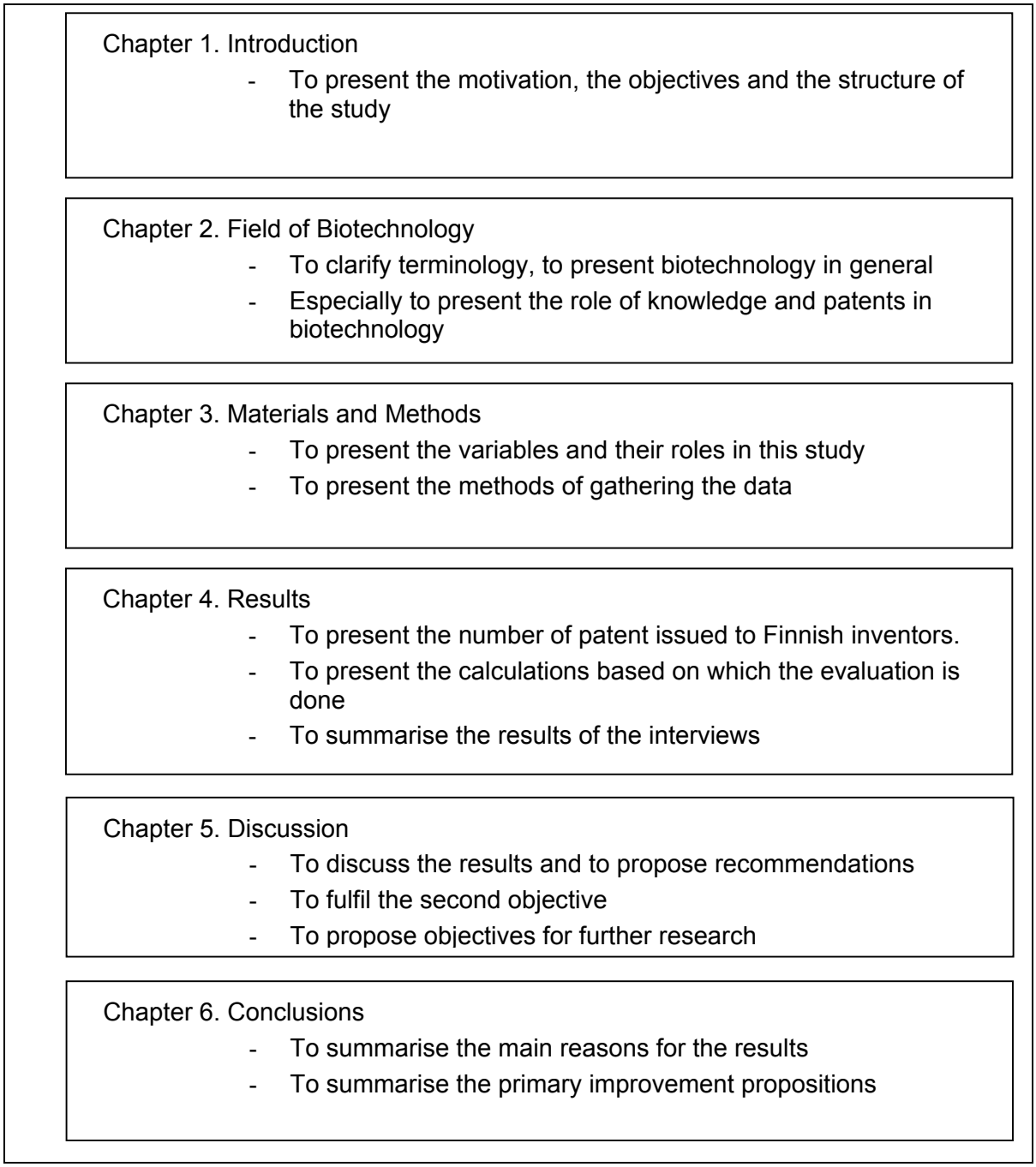
1) Public research receives good support and funding by governmental organisations
2) Finland produces scientifically important and high impact basic research
3) Research results, although high in potential, are not well utilised when compared to other countries

The second objective of this study is *to evaluate Finland's biotechnology research utilisation compared to other countries.* As it is proposed by a number of authors, intellectual property and patents are a key element in biotechnology utilisation (e.g. Mossinghoff & Bombelles 1996; Cunnigham 1999) and industry development (Ernst & Young 2002; Cooke 2001) and is crucial for already established industry as well (Tulkki, Järvensivu, Lyytinen & Schienstock 2001). *Patenting activity is thus used in this study as a measure of biotechnology utilisation.* Evaluation of utilisation is done by comparing public research funding by the received patents, impact of biotechnology research and the number of issued patents to similar figures of other selected countries. Semi-structured interviews of innovation managers of selected Finnish universities are used to gain in depth perspectives of the current situation.

1.3 Structure of the study

The structure of the study and the aims of each chapter are presented in Figure 1.

FIGURE 1. Structure of the study



2 FIELD OF BIOTECHNOLOGY

2.1 Modern biotechnology

2.1.1 From ancient to modern

Biotechnology, the use of microbes for the advantage of production in its narrow definition, has existed for thousands of years. During the millennia, biotechnology evolved rather "by accident" than as result of conscious development. The ancient biotechnology was merely a set of artisanal skills of producing different food products than any conscious method of using microbes. These skills, including brewing of beer and making of cheese, became widely known, but the actual molecular mechanisms remained unknown. (Smith 2001) Walsh (1993) classifies three generations of biotechnology, first being the above "unaware use" of microbial functions. The second generation is considered to have begun in the 20th century with major breakthroughs of biosciences leading to the developments in microbiology, biochemistry and chemical engineering; antibiotics discovered by Fleming in 1928 and the structure of DNA discovered by Watson and Crick in 1953. World War II has also been considered to have a significant impact, with the development of large-scale microbial production of antibiotics. Other technologies with great impact in development of biotechnology are recombinant DNA technology (rDNA and rDNA technology) discovered by Cohen and Boyer in 1973, and polymerase chain reaction (PCR) discovered by Mullis in 1983. Cohen and Boyer's discovery is often considered the birth of modern biotechnology, thus beginning the third generation according to Walsh's (1993) classification. The biotechnology industry thus has its origins in the early 1970s, with universities being the primary engine for technological innovation in the field (Ostergard, Tubin & Altman 2001).

2.1.2 Definition of biotechnology

Varying, and sometimes confusing, terms are often used when discussing the field of biotechnology. The terms like life sciences, biosciences, biotechnology and genetic engineering are used interchangeably especially among people uneducated in these fields. The most unspecified term is *Life Sciences (LSs)*, which refers to the scientific study of the living world as a whole. It's a new synthesis of several traditional disciplines, including biology, pharmacy, zoology and botany as well as newer, more specialised areas of study, such as biochemistry, and molecular biology. The latter are subsets of LSs and are called *biosciences*, dividing in more and more specialised areas of study. These definitions are not strictly defined however, and may thus vary depending on the context.

The term biotechnology is most typically defined according to the Organisation for Economic Cooperation and Development (OECD): "The application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services."[1] There is thus no strict definition that would form a frame specifically for biotechnology. In other words, biotechnology is rather a set of technologies of different biosciences than a separate science, which enables quite flexible definition to be done. To define biotechnology only according to OECD's definition would be limiting in study, while it makes a considerable difference between biotechnology and conventional pharmacy. The OECD's definition is therefore hereafter referred to as *molecular biotechnology*.

The scientific difference between biotechnology in pharmaceuticals and conventional pharmacy is that conventional pharmacy uses chemical synthesis in production of drugs and biotechnology living organisms, or parts thereof, to do the same. Both of these methods of production have their uses; chemical synthesis is a cheap way to produce rather small and structurally simple molecules, but it cannot produce large molecules like proteins. Living on the other hand, can produce proteins, *oligonucleo-*

[1] http://www.oecd.org/EN/document/0,,EN-document-617-1-no-1-31006-617,00.html

tides[1] and *vectors*[2] for gene therapy for example, and are therefore useful in therapeutic areas that have previously been unavailable. The pharmaceuticals, whether they are proteins, oligonucleotides or other types of biologically produced therapeutic agents, are often called *biopharmaceuticals* in contrast to conventional pharmaceuticals. While biopharmaceuticals form a central area of biotechnology, there are still, according to Robinson (2002), only 137 biotechnically-produced medicines (biopharmaceuticals) are on the market at the moment. Biopharmaceuticals are thus only a small proportion of existing pharmaceuticals that count over 5300[3] in total. On the other hand, about one third of all new therapeutic agents are biopharmaceuticals, and the trend in strengthening (Brännback, Hyvönen, Raunio, Renko & Sutinen 2001, 30).

The utilisation of research results are measured in this study by counting the number of patents issued to inventors of a certain country, in certain patent classes that essentially count as biotechnological. These patent classes include both biopharmaceuticals and conventional ones and it would be beyond the scope of this study to separate biopharmaceuticals from all the patents in the used classes. For this reason the OECD's definition of biotechnology is too limited to use in this study. Therefore in this study, *biotechnology refers to both molecular biotechnology and conventional pharmacy, unless stated otherwise.*

Table 1 provides the class codes and the definitions of the patent classes under which inventions are considered biotechnological in this study. How these patent classes are used in counting patenting activity of each participating entity is discussed in section 3.3.3. The presented patent classes are the ones of the United States Patents Classification (USPC) – system by the United States Patent and Trademark Office (USPTO)[4]. Other similar patent classification systems exist, most important being the IPC – system provided by the World Intellectual Property Organi-

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[1] Nucleotides are "building-blocks" of DNA and RNA. *Oligo-* is a prefix that indicates a chain consisting of (in this case) nucleotides.
[2] Vectors are oligonucleotides that are used to carry a gene into its' target cells.
[3] Source: Swiss Pharmaceutical Society. 2000. *Index Nominum 2000: International Drug Dictionary.* Stuttgart: Medpharm Scientific Publishers.
[4] Full definitions of USPCS classes are available over the Internet in the following address: http://www.uspto.gov/web/patents/classification/selectnumwithtitle.htm

sation (WIPO)[1]. Being the most accurate in its class definitions, the USPC system was selected for this study. A recent study by The Swedish Agency for Innovation Systems (Vinnova 2001, 7) has also used the USPC system similarly and provides the classes used here.

TABLE 1. The classes of the USPC system under which biotechnological inventions fall to, and their definitions.

424 (incl. class 514)	Drug, Bio-Affecting and Body Treating Compositions (includes Class 514) Class 514 is an integral part of Class 424. It incorporates all the definitions and rules as to subject matter of Class 424.
426	Food or Edible Material: Processes, Compositions, and Products
435	Chemistry: Molecular Biology and Microbiology
436	Chemistry: Analytical and immunological testing
530	Chemistry: Natural resins or derivatives; peptides or proteins; lignins or reaction products thereof
800	Multicellular living organisms and unmodified parts thereof and related processes
930	Peptide or Protein Sequence
935	Genetic Engineering: Recombinant DNA Technology, Hybrid or Fused Cell Technology, and Related Manipulations of Nucleic Acids

2.2 Knowledge and its protection in biotechnology

2.2.1 Environment and value of knowledge

Although there are several definitions for high technology and high-tech industries, as summarised by Chabot (1995), the most commonly considered feature of high-tech is its knowledge intensiveness. Teece (1981) stated that “economic prosperity rests upon knowledge and its useful application”. In addition, “the increase in the stock of

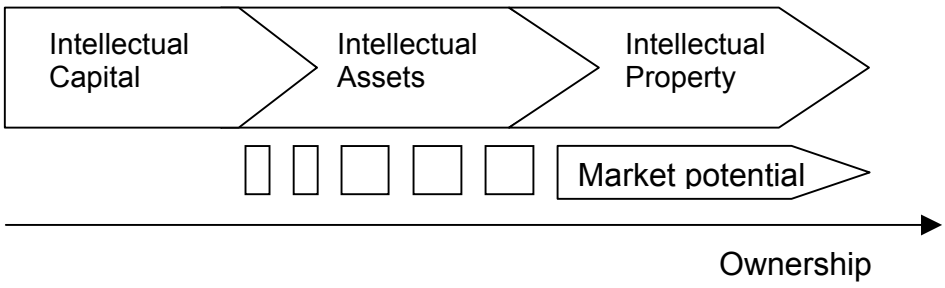
[1] Definitions of IPC classes are available over the Internet in the following address: http://www.wipo.int/classifications/fulltext/new_ipc/index.htm

useful knowledge and the extension of its application are the essence of modern economic growth" (Kuznets 1966). Therefore, biotechnology being most definitely knowledge intense and thus a high-tech field according to Chabot's summary, it is helpful to understand the environment of knowledge to understand patents and their value, as patents are one of the most tangible forms of knowledge. For this purpose Williams & Bukowitz (2001, 98) define three broad categories of knowledge:

(1.) intellectual capital (IC)
(2.) intellectual assets (IA)
(3.) intellectual property (IP)

According to the same authors, intellectual capital covers all forms of knowledge. It means for example knowledge and skills of an individual to do research, culture and values of an organisation. In addition lecture notes, spreadsheets and process maps, patents and other intellectual property rights fit here too. Intellectual capital includes thus both abstract and concrete forms of knowledge, forming an "umbrella concept" under which IA and IP fall to. Most of the knowledge counted as intellectual capital is in intangible form however (like know-how needed to do research), and it is therefore common to say that intellectual capital cannot be owned or sold (although the concrete forms of it, like patents, definitely can). Whether organisation's knowledge can be owned or not depends on the form the knowledge is in and of the level of organisation's ownership over it. Organisation's level of ownership of its knowledge forms and the market potential of these forms is presented in Figure 1, adapted from Williams & Bukowitz (2001).

FIGURE 1. Organisation's ownership level of its knowledge forms and their market potential.



The term market potential is used here to reflect the availability of the benefits that ownership produces. The higher the market potential, the more tangible form the knowledge is in and the more available are the benefits of the ownership of the knowledge. These benefits resemble the benefits of any other tangible goods; ownership grants the owner the benefit of use or selling the owned goods. In knowledge environment this means that concrete knowledge enables sale of that knowledge, whereas intangible knowledge cannot be sold. To enable sale or other commercial exploitation of knowledge, it is thus reasonable to make it as concrete and tangible as possible. The market potential thus describes how well one can take the knowledge one has and turn it into a marketable item.

Intellectual capital is an “umbrella-concept” that consists of the said intangible forms of knowledge lower in market potential, but also the more concrete intellectual assets and intellectual property. According to Williams & Bukowitz (2001, 98), intellectual assets are a subset of intellectual capital and have two distinguishing characteristics:

(1.) Intellectual assets are knowledge having a concrete form. Consequently IA can be presented to someone else without being present oneself. For example research results, an idea written on a paper or said aloud, an e-mail sent to someone, as well as reports, business processes or data, are intellectual assets. Because intellectual assets have been transformed from unarticulated abstract knowledge (intellectual capital) into more concrete, they are often referred to as “explicit knowledge.”

(2.) An organisation owns the intellectual assets, although it doesn’t own the knowledge or the people that produced them.

While intellectual assets consist of any articulated knowledge, some portions of are so valuable that the organisation owning these IA, may want to legally protect that knowledge. When intellectual assets, for example research results, get legal protection, they are called the *intellectual property* of that organisation. Intellectual property is therefore a subset of intellectual assets. Intellectual property is the most interesting form of knowledge regarding this study, while a patent is one of its forms. Different forms of intellectual property, and their uses in biotechnology, are discussed in more

detail in the next section. Of all forms of knowledge, intellectual property has the highest market potential. Higher market potential of tangible knowledge forms (IA and IP) doesn't mean that knowledge in an intangible form would be of less value for an organisation acting in biotechnology; organisation's knowledge needed to do research and human resources are without a doubt an essential requirement to create marketable products. To commercially use the intellectual capital in biotechnology however, it must be turned into marketable form. To enhance the value of intellectual capital into its best, *it should be turned into intellectual property,* most preferably into patents. (Cooper 2000)

2.2.2 Intellectual Property in biotechnology

2.2.2.1 Types of Intellectual Property

The most concrete form of intellectual capital of any entity, whether it is a person or an organisation, is its intellectual property (Williams & Bukowitz 2001, 99). This means that the knowledge of the entity has been considered so valuable that to ensure the exclusivity of that knowledge, legal protection has been applied and granted for it. These legal protection types are called Intellectual Property Rights, or IPR. The forms of IPR are presented in each country's laws and therefore may differ in details, but are commonly recognised at least in OECD countries. IPR are not of the same value in biotechnology IC protection, however. Although they all are the most tangible and the most easily utilised forms of an organisation's knowledge (see section 2.2.1), they most typically protect somewhat different domains. The comparison of the four commonly acknowledged forms of IPR clarifies the difference. In addition to Williams & Bukowitz (2001, 107), also Medd & Konski (2003, 202) have summarised and compared the forms of intellectual property protection. Table 2 presents Medd & Konski's comparison chart.

TABLE 2. A comparison of the four types of intellectual property protection.

	Patent	**Trademark**	**Trade secret**	**Copyright**
Information public	Yes	Yes	No	Sometimes
Duration	Up to 20 years	Indefinite if the requirements[1] for the protection remain	Indefinite[2]	Life of author + 70 years[3]
Subject matter eligible	Composition of matter, method of use or process of production	Words, names, numbers, symbols, devices, designs, sounds, colours	Business and technological material. Also ideas.	Tangible expression of an idea, not the idea itself; limits on non-artistic aspects.
Owner's rights	Right to exclude others from making, using, selling, or offering the invention for sale	Right to exclude others from selling similar goods or services	Right to exclude other party from using or disclosing the trade secret	Exclusive rights to reproduce, prepare derivative works, distribute, public performance of and display the work
Cost	Relatively expensive to obtain, police and enforce	Inexpensive to obtain, may be expensive to police/enforce	Relatively inexpensive	Inexpensive to obtain, may be expensive to police/enforce

Based on Table 2, the probable uses of the presented forms of IPR in biotechnology research results protection can be discussed: The most obvious method to protect intellectual assets (for example research results) [4] in biotechnology research would be to apply for a patent. According to United States Patent and Trademark Office's Description of Patent Types guide (USPTO 2000), a (utility-) patent[5] is:

> …issued for the invention of a new and useful process, machine, manufacture or composition of matter, or a new and useful improvement thereof, it gener-

[1] Rights can be lost if the mark becomes descriptive of a generic type of good or service.
[2] For as long as participants decide otherwise or knowledge becomes public
[3] For corporate works, the term is 95 years from publication or 120 years from creation, whichever is shorter.
[4] One must note that according to Williams & Bukowitz's definition of knowledge (2001), research results become IP only after legal protection is granted (see section 2.2.1).
[5] Also referred to as "patents for invention" to separate from Design Patents and Plant Patents. The common term "patent" most typically refers to Utility Patents.

> ally permits its owner to exclude others from making, using, or selling the invention for a period of up to twenty years from the date of patent application filing, subject to the payment of maintenance fees.

According to USPTO's definition, a patent can thus be granted for an invention that has met three prerequisites: novelty, utility and nonobviousness. Novelty means that the invention is new and has not been previously disclosed in any public forum. Utility means that the invention has some industrial or commercial use, i.e. that it can be used physically or as a method of doing something in some process. Nonobviousness means that the invention must not be obvious to person familiar with the art of the invention.

A patent grants the owner a right to exclude others from making, using, offering for sale, or selling the invention for the duration of the patent, which is most typically 20 years from the date of filing the application. Exclusivity doesn't solely apply for research however, while patented technologies may be used in academic, and other non-profit research. Patents provide the strongest protection for intellectual capital, albeit the scope of the patent may enable inventing around it (Teece 1998, 65). A patent is valid only in the country in which it is applied (and granted) for. Thus, to provide the best market value added a patent must be applied for in each country in which the exclusive marketing rights are wanted. Patenting in biotechnology will be discussed in further detail in section 2.2.2.2, and the use of patenting activity as a measure of intellectual capital utilisation in the section 3.3.

A trademark protects, according to Medd & Konski (2003, 201), words, names, numbers, symbols, devices, designs, sounds and colours that are used in trade with goods to identify the source of the goods and to distinguish them from the goods of others. Typical examples of trademarks are the names of products, like Viagra in pharmaceuticals or Sprite in soft drinks. A similar example is the certain blue colour of Fazerin Sininen, a Finnish chocolate brand. Trademark rights may be used to prevent others from using a confusingly similar mark, but not to prevent others from making the same goods or from selling the same goods or services under a clearly different mark. As trademarks protect the "outside", or the expression, of a product (whereas patents protect the "inside", or the composition of a product") their value in

intellectual capital protection in biotechnology is to protect the expression of the end product, for example the market name, the colour or the shape of it.

Copyright is a form of protection granted to an original work of authorship that has been fixed in a tangible for of expression. Tangible forms of expression include for example literary, dramatic, musical, artistic, and certain other intellectual works, both published and unpublished. Titles, names and short phrases are not usually copyrightable, but instead are often trademarked. As patents, also copyrights must be applied for in each country separately and require registration for enforcement against other parties. (Medd & Konski 2003, 201) The copyright protects the form of expression rather than the subject matter of the writing. For example, a paper describing pharmacology of a drug could be copyrighted, but this would only prevent others from copying the description; it would not prevent others from writing a description of their own or from making and using the drug. A copyright is thus a rather insignificant method of IC protection in biotechnology, at least when studying innovation activity.

In addition to patents, trade secrets are maybe the most applicable IA protection method in biotechnology. While trademarks and copyrights are of little use in core technology protection, trade secrets provide a way to protect the technology itself instead of just the expression of it. As in other forms of IPR, the strict definition of trade secret may also vary depending on each country's legislation. The basic idea however, is about the same as in the Uniform Trade Secrets Act (ULA) §1 in the legal system of the USA: "A trade secret is information that is not generally known and which derives independent value from being kept confidential." A trade secret can be technical (for example an invention, a production process, or chemical composition of a material) or economical (for example a contract, pricing policy or a marketing plan) (Karinkanta, 2001). A trade secret thus protects quite similar subjects than a patent.

Trade secret protects information that is not intended to be made public at least for the time being. Unlike in patents, the information protected by a trade secret does not need to be new or unique, but it must not also be public knowledge or so simple that producing the information requires only minimal inputs from people familiar with the art. Trade secret doesn't prevent the other types of IC protection of the invention at later time, whereas the publicity of a patent prevents the trade secret. Technologies

to be patented are commonly protected by a trade secret until the patent application is filed. In that case the requirements for patenting (novelty, nonobviousness, utility) are applied to the trade secret protected technology also. Trademarks and copyrights may also co-exist with trade secrets, protecting the expression or the literal material of the product. (Medd & Konski 2003; Karinkanta 2001)

There are two distinctive features of trade secrets in comparison to the other forms IPR. The first distinctive feature of trade secrets is the commercial and competitional value it must provide to the company. No strict definition to the commercial and competitional value regarding trade secrets, have been stated. However, typically this is considered to mean any knowledge that is an essential part of an organisations products or processes.

The second distinctive feature is the requirement of active measures taken to maintain the secrecy of the subject matter. The literal requirement set for the measures is that they are *reasonable under the circumstances.* “Reasonable” measures are not strictly described, but if needed for example in an infringement case, are defined by court in each case separately. If secrecy is successfully maintained and the other requirements of trade secret protection are met, the protection may last indefinitely. (Karinkanta 2001) A classic example of a well-kept trade secret is the formula of Coca-Cola, which has been kept secret for about one hundred years (Williams & Bukowitz 2001, 107). If someone resolved the formula, either by reverse engineering (i.e. by analysing the product) or theft, and published it so that the formula was therefore in public domain, the trade secret would be lost. It is noteworthy that reverse engineering is legal, as is publishing any information produced by it. (Eisenberg 2000, 3) Other legal method that would result extinction of trade secret protection is independent research. Independency generally means the entity doing the research has no associations (that would enable easy theft of the information) to the owner of the trade secret. (Karinkanta 2001)

Because trade secret protection is relatively cheap to obtain, lasts potentially indefinitely and also prevents exact features of the subject matter becoming public, it is a considerable alternative to rather expensive and limited duration patent protection. If the matter of the invention is such that no exact compositions or formulas are re-

quired to be published, a trade secret can be used to protect biotechnological inventions also. The likelihood of disclosure is thus a key issue when considering whether to protect an invention with a trade secret or a patent. (Eisenberg 2000, 3) If the invention is a drug, the exact formula as well as all other information of its chemical and physical properties must be published, which essentially eliminates the possibility for trade secret protection. Patents are thus the only form of protection applicable to new pharmaceuticals, although trade secret protection can be used before filing the patent application.

Other fields of biotechnology are less dependent of patents in their IP protection. Although these fields may vary considerably (for example monoclonal antibodies production vs. genetically modified, or GM, crops production) a common feature of them is that their end products are usually not as highly regulated as drugs. The tight regulations of drug development, production as well as use are the reason why information regarding any of these areas will become public knowledge. Even though some of other biotechnology fields, like GM crops, are tested and regulated tightly also, the information regarding these products are not needed by every doctor or user, unlike they need the information of drugs. Other inventions than drugs, or at least some parts of them may, therefore, meet the secrecy requirement of trade secret protection. Inventor, or the owner of the invention[1], of these fields, may therefore be willing to protect the invention by a trade secret rather than by applying for a patent. This is common especially if the invention is unlikely to be discovered or duplicated by anyone else because it is so specific to a particular process or product (Seppälä & Saarelainen 1998; Eisenberg 2000, 3).

Possible technology transfer, especially licensing, may be difficult if the invention in question is not patent protected. A competitor's possibility to patent the technology protected by a trade secret, thus disabling the trade secret and forcing the trade secret owner to end using the technology, may cause the licensee to be more willing to favour a patent protected invention over a trade secret protected. Same effect may

[1] The owner of the invention varies depending on the institute and the country of the institute. Ownership of inventions will be further discussed in becoming chapters.

also be caused by licensee's doubt of licensor's ability to maintain the secrecy required to maintain the trade secret. (Eisenberg 2000, 3-5)

An obvious situation where a trade secret is to be preferred over a patent is when the invention is not patentable. Such a situation may occur when the invention is for example a business method, like marketing strategy. (Eisenberg, 6) One must note however, that some business methods are patentable. An example could be as follows: "Company A invents a novel approach to solving a business problem, codifies the approach in a software application, seeks and is granted patent protection." In such a case, competitors are excluded not only from using the software (without owner's permission, of course), but also from applying the business method in their own operations. (Williams & Bukowitz 2001, 100)

Trade secrets are also preferred over a patent if it is clearly the most advantageous competitive situation to be the first in the market and the expected life cycle of the invention is short (Eisenberg 2000, 6). Such products might be for example ones highly dependent on public trends and fashions. Due to the nature of biotechnological products, publicity caused by regulations and long life cycle of many of the products, this may be a rare situation however.

In some situations trade secret protection provides advantages over patent protection as discussed above, and are thus in those cases an alternative for patents also in biotechnology. Being kept secret however, they are obviously not applicable in this or other studies concerned with utilisation activity of an entity. Patenting activity is therefore used to assess the research results utilisation activity of countries participating in this study.

2.2.2.2 Patents and patenting in detail

The World Intellectual Property Organisation, or WIPO, defines a patent to strictly mean *a patent of invention* (WIPO). USPTO uses the term *utility patent* – of the same subject. The term – patent – in this study refers to these two definitions and is *essen-*

tially defined as the following description of utility patents. USPTO issues also two other types of patent documents that must not be confused with utility patents. Short descriptions of different patent types issued by the USPTO are presented in the following (USPTO 2000).

- Utility Patent - Issued for the invention of a new and useful process, machine, manufacture, or composition of matter, or a new and useful improvement thereof. It generally permits its owner to exclude others from making, using, or selling the invention for a period of up to twenty years from the date of patent application filing. Approximately 90% of the patent documents issued by the USPTO in recent years have been utility patents.

- Design Patent - Issued for a new, original, and ornamental design for an article of manufacture. It permits its owner to exclude others from making, using, or selling the design for a period of fourteen years from the date of patent grant.

- Plant Patent - Issued for a new and distinct, invented or discovered asexually reproduced plant including cultivated sports, mutants, hybrids, and newly found seedlings, other than a tuber-propagated plant or a plant found in an uncultivated state. It permits its owner to exclude others from making, using, or selling the plant for a period of up to twenty years from the date of patent application filing.

As discussed in previous sections, patents can be considered the most useful form of IP protection in biotechnology. It has also been discussed that patent legislation varies between granting organisations (i.e. country by country), but that the main idea maintains. The European Patent Office (EPO) states about patents as follows (European Patent Office 2002, 70): “European patents shall be granted for any inventions which are susceptible of industrial application, which are new and which involve an inventive step.” Patents are not granted for “discoveries, scientific theories and mathematical methods, aesthetic creations, schemes rules and methods for performing mental acts, playing games or doing business, and programs for computers, presentations of information.” The previous is called the *utility* of an invention, and it

is the first of three general requirements set for patentable inventions (see USPTO's definition of utility patents). It means that the invention has to have some industrial or commercial use, i.e. that it can be used physically or as a method of doing something in some process.

The second requirement for a patentable invention is novelty. Novelty means that the invention is new and has not been previously disclosed in any public forum. According to EPO (2002, 72) "An invention is considered new if it doesn't form a part of the state of the art." In other words, it must not be common or publicly available knowledge. In Finnish and European patent systems this is a very strict rule and is definitely an important issue when considering whether to apply for a patent for research results that are going to be published. If a patent application is to be filed, there must not be any publicly available information regarding the subject matter of the patent application, prior to filing the application. In Europe, the rights for a patent is given to the applicant that first filed the patent application. This is called *first-to-file* principle. In the USA however, there is a *grace period* of 12 months from publishing the invention during which time one can apply a patent for it. This is caused by the *first-to-invent* principle that gives the rights for a patent to the first inventor. Therefore it is typical in USA to publish an article before filing the patent application. *It must be noted however, that publishing an article before filing a patent application in Europe disables the possibility for a patent in Europe.*

The third general requirement for a patent is non-obviousness (also called the inventive step), which according to EPO (2002, 74) means that "An invention shall be considered as involving an inventive step if, having regard to the state of the art, it is not obvious to a person skilled in the art." In other words, the invention must be such an application or process that it can't be considered as a straightforward step of some existing process.

The most distinctive feature in applying, policing and enforcing a patent is the relatively high costs involved compared to other forms of IPR (Medd & Konski 2003, 202). In 1995, patenting process cost in five different countries with different languages up to about € 35,000. This sum covers only the applying and approval process, and excludes annual payments as well as possible infringement litigations, office

actions, oppositions and other variable costs. Variable costs literally vary greatly case-by-case and any fixed sum cannot therefore be stated. In addition to said variable costs, the total sum of applying and administering a patent is essentially dependent of the number of claims, as well as of the length of the application and of the number of countries and languages in which the patent is applied for. (Ruuskanen 1995, 1) To obtain the best protection for a biotechnological invention, it is commonly patented in three essential market areas that are Europe, USA and Japan. Europe is the most expensive of these areas to apply a patent from. There is no "common European patent" that would be valid in each European Patent Office (EPO) member country without being first translated into the country's own language. To obtain good patent coverage for an invention in Europe, the application must thus be translated into as many languages as there are countries in which the patent is applied from. For the best patent protection over the three essential market areas, the total costs of applying a patent may rise above the mentioned € 35,000.

Although patenting is rather expensive as discussed above, its importance is stressed in biotechnology industry development. It has been stated that it provides the best protection for an innovation (Teece 1998, 69). Patent protection in a knowledge intense high technology field like biotechnology has even heightened importance (e.g. Teece 2002; Cooper 2000, 25). It is thus reasonable to measure patenting activity of a country in assessing its biotechnology utilisation.

2.3 Biotechnology industry

Expectations that can be considered exaggerating have been set for biotechnology industry and its role in world's economy by authors like Oliver (2000). He claims that during the next fifteen years, biotechnology "(…) will be recognised as more important than the Internet or, in fact, the whole information revolution" (Oliver 2000, 39-40). On the other hand, also respected business journals, for example the Harvard Business Review, have predicted that biotechnology will transform world economics "equally dramatic" as did the Internet (Harvard Business Review 2000). It can be be-

lieved therefore, that biotechnology industry has increasing effect in world economics in the future.

Biotechnology industry has its origins in the early 1970's, universities being the primary engine for technological innovation, and the development of rDNA-technology providing both scientific and industrial interest for the field. As discussed in this study, intellectual property and especially patents are in key role in biotechnology industry. Before 1980's, no patents were issued to inventions nowadays considered as "biotechnological." The economic motivation for biotechnology industry was provided in the 1980 with court case Diamond vs. Chakrabarty, where the US Supreme Court decided that genetically engineered life forms were patentable. Ananda Mohan Chakrabarty, a microbiologist and employee of General Electric (GE), developed at the time a type of bacteria that could ingest oil. GE applied for a patent in 1971. After several years of review, the USPTO refused the request under the traditional doctrine that life forms are not patentable. GE sued the decision and won the case in the Supreme Court. The court's decision was that "life was patentable (…) relevant distinction was not between living or inanimate things, but between products of nature (…) and human-made inventions." In 1985, the PTO ruled that the Chakrabarty ruling could be further extended to all plants, seeds, and plant tissues - or to the entire plant kingdom. This case undoubtedly helped to open the gates for the ensuing patent applications for genetically engineered biological material. (Ostergard *et al.* 2001)

While universities have a key role in innovation development of the industry, it is useful to consider the ways in which knowledge (research results) is spread from universities. This is presented in Figure 2, adapted from the model presented by the University of Kuopio (2002, 27-28). Commercialisation channels of research results are typed in **bold.** Figure 3 presents universities' role in bioindustry *value chain*, in other words universities' importance as innovation producers as proposed by Ostergard *et al.* (2001). Porter (1985) created the value chain model to depict organisations operations as a chain of value-creating activities. Figure 3 is adapted to biotechnology from Porter's model.

FIGURE 2. Flow of knowledge from the universities and the formation of business.

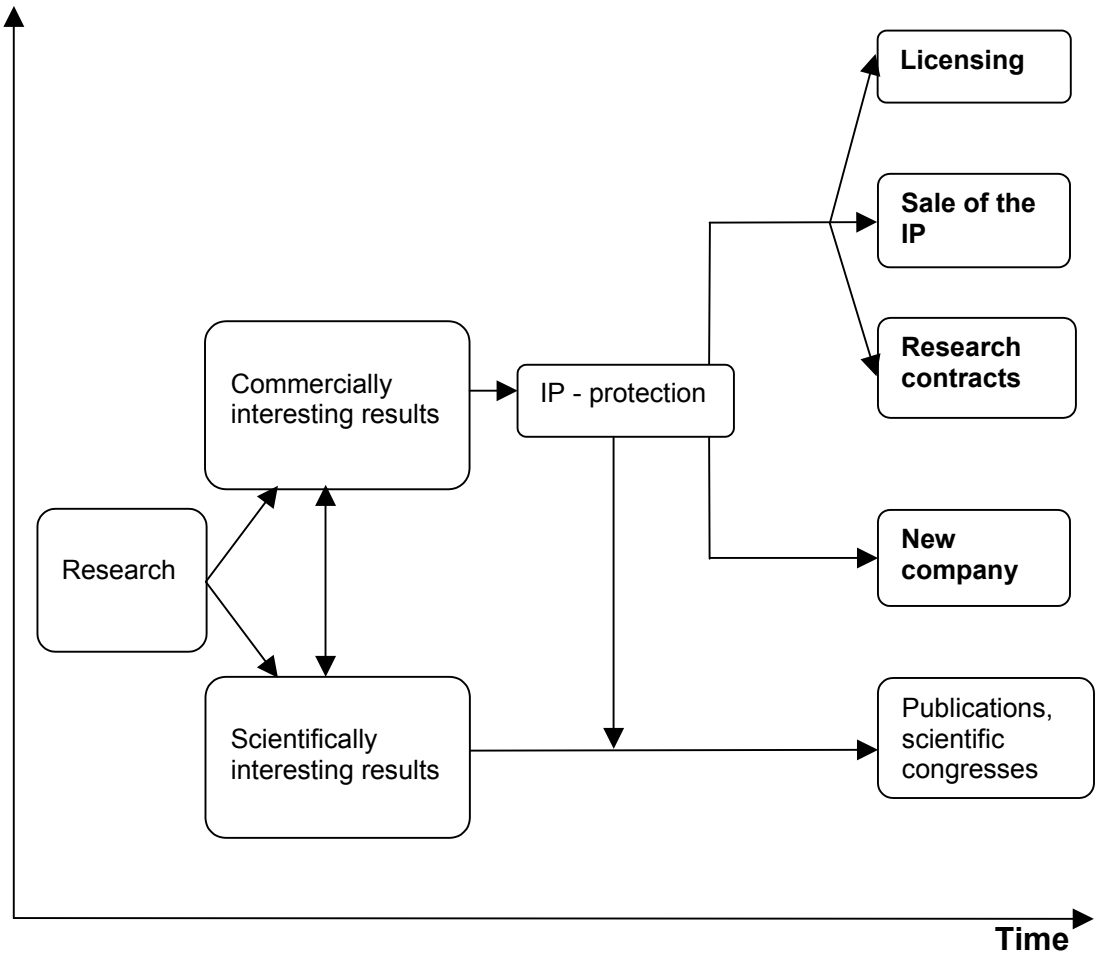


FIGURE 3. Biotechnology value chain and roles of operators in it.

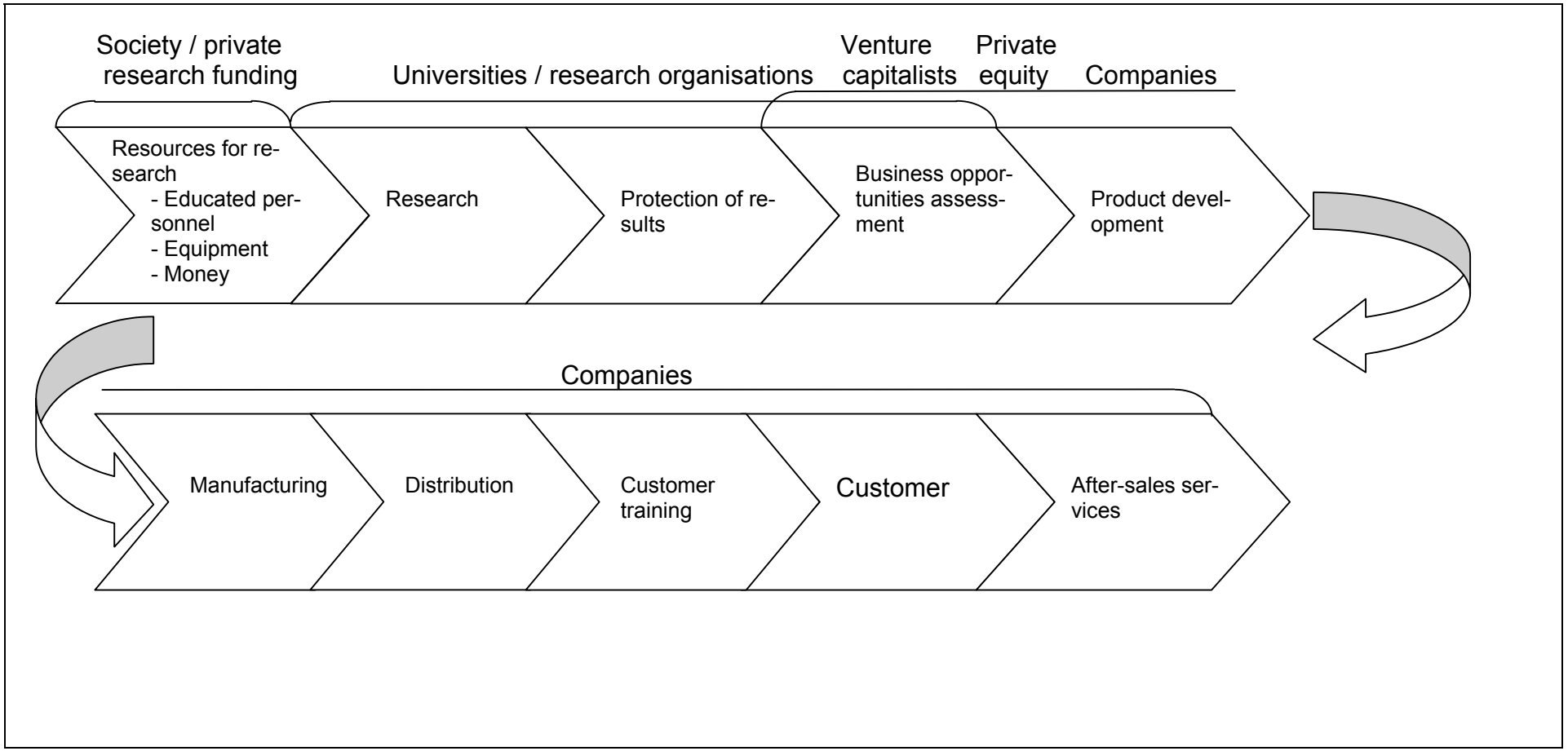


Figure 2 provides supporting evidence to other authors' (e.g. Williams & Bukowitz 2001; Cooper 2000) claims that IP protection is crucial for technology utilisation, as does Figure 3 for Ostergard's *et al*. (2001) claim that universities have an important role as innovation producers. However, efficient research and university inventions (whether patented or not) by them selves are not adequate measures for a competitive biotechnology industry to develop, but requires several other factors to be met as well. These factors, according to Ernst & Young (2002, 14) are presented in the Table 3.

TABLE 3. Critical factors for the development of modern biotechnology industry

1	Risk-tasking culture that encourages entrepreneurism
2	Competitive, free market economy in which capital investments on the front-end has the potential for reward on the back-end through market-driven product pricing mechanisms
3	Protection for intellectual property, assuring temporary market exclusivity to recoup product development investments
4	Academic support for technology transfer, promoting the licensing of basic research discoveries from university laboratories to commercial development
5	Government support not only in the form of funding for basic research, but also local and national cooperative tax incentives
6	Public regulatory system that fosters confidence in the safety and efficacy of new products

In addition, Cooke (2001) lists three critical factors that affect biotechnology industry development: 1) exploitation of basic science, 2) venture capital and 3) cluster-formation. Exploitation of basic science (i.e. commercialising it), the first on the list, is in concordance with Ostergard's *et al.* (2001) study, in which universities were stated as the biggest producers of scientific innovation, which again affect the development of the whole biotechnology industry (Tulkki *et al.* 2001). Part of the reason why the US bioindustry has its leadeship compared to Europe's, is its history of commercialising science, that begun already in 1950's. In that time, the major breakthroughs of biosciences were almost exclusively done in Europe, but were not commercialised. Since then, a similar situation has existed, where Europe produces a large share of inventions and the US commercialises the most of it. (Cooke 2001) There is resemblance between the Cooke's study and the factor three in the Table 3: Protection for

intellectual property. Exploitation (utilisation) of science is dependent on intellectual property protection and is a critical factor in bioindustry development. In addition, as discussed in the section 2.2, patenting is an essential form of intellectual property protection in biotechnology. Thus, not only is patenting of exceptional importance in innovation protection in established bioindustry, but is as well considered *essential for competitive bioindustry formation.*

The two other factors affecting the biotechnology industry development are the availability of venture capital and the cluster-formation of not only the scientists, but also of the venture capitalists. Larger clusters provide scale advantages, as well as competition, which raises effectiveness. (Cooke 2001)

Arojärvi (2002, 19-21) lists factors specific to already established biotechnology industry as follows: (A1) Centers of scientific excellence, (A2) ownership through patenting, (A3) the importance of regulatory climate and (A4) the involvement and interest of large companies. Gustafsson (2000, 21-29) presents five similar factors specific to pharmaceutical industry: (G1) global markets, (G2) international regulation, (G3) high entry barriers, (G4) evolution of industry structure and (G5) technological uncertainty. High entry barriers can be further divided into (G3a) capital requirements, (G3b) proprietary technology, (G3c) access to distribution channels and (G3d) access to skilled personnel (Porter 1983).

In the list of Arojärvi, centres of scientific excellence are mentioned first (A1). Scientific excellence is also mentioned by Ostergard *et al* (2001) and Senker (1998, 20). In addition to their role of general centres of excellence, Ostergard *et al.* stress the role of universities as *producers of innovation*: Since the dawn of biotechnology industry in the 1970's, a major proportion of the innovations of biotechnology originate from research done in universities. This role has not been diminished until these days, because the development of biotechnology industry is still largely dependent of the knowledge produced in universities (Tulkki *et al.* 2001).

Both Arojärvi and Gustafsson mentioned tight regulation of the industry as well (A3 and G2, respectively). Especially regarding drug development, regulations have lead to five consequences: a) high development costs, b) long development times, c) capi-

tal requirements imposed by the costs and time of the development, d) political approval and pricing risks (changes in regulation) and e) weakened competition due to approval policy. Development costs of new drugs have risen more than tenfold since the beginning 1970's, when the average cost of a new drug was about 54 million dollars (including the expenses of failed projects); similar costs are now estimated to be over 600 million dollars and rising. The growth rate of the costs is estimated to be about 13% per year. Long development times (up to 15 years) contribute to the costs as well, but also raise the importance of patent protection of the developed drug. As a result of high costs and long development times, new pharmaceutical companies need millions of euros of capital, thus raising the high entry barriers of the industry. Approval policies of new drugs raise the risk of development, thus contributing to heightened technology risk of the industry (G5). Regulation lowers also competition (although patents have the main lowering impact on it) while authorities often approve only drugs that are more effective than existing ones. (Gustafsson 2000, 22-24)

The role of large companies was directly mentioned by Arojärvi (A1) and indirectly by Gustafsson, according to whom biotechnology industry has global markets (G1), needs distribution channels (G3a) and capital (G3c). The three factors G1, G3a and G3c can all be found from large companies that thus have a significant role in the industry.

Evolution of industry structure (G4) was mentioned as one of the specific features of (bio)pharmaceutical industry. Evolution is caused and maintained by the development of molecular biotechnology in 1980's and 1990's, which enables manufacturing of designed drugs, and increasing calculation power of computers, which enables the calculations required to design the drug molecules. Industry structure evolution can be seen primarily in increasing number of acquisitions and mergers of companies. (Gustafsson 2000)

The most interesting point regarding this study, listed by both Arojärvi (A2) and Gustafsson (G3b), the role of intellectual property in already established biotechnol-

ogy industry,[1] is being supported by yet another study: “On average, the biotechnology industry ploughs some 45% of its annual income into R&D. That means nearly half the value[2] of the industry is embedded in its intellectual capital” (Moise 1999). Accroding to Ostergard *et al.* (2001), patenting genetically modified organisms laid the economic ground for the whole biotechnology industry. Intellectual property, especially patents, has thus become the most distinctive feature of biotechnology industry. Many authors have stated that patents are of exceptional importance in biotechnological industries (e.g. Teece 2002; Cooper 2000, 25). A comparison between Finnish biotech Small and Medium sized Enterprises (SMEs) and Finnish SMEs in general provides supporting evidence to this claim: While only 6% of SMEs in general hold patents, the percentage in biotechnology SMEs is 63% (Hermans & Tahvanainen 2002, 7). This number may seem rather small, but it must be kept in mind that also companies in supporting businesses are often counted as biotechnology companies, if they provide their services to biotechnology. Finnish Bioindustries, or FIB, is Finland's biotechnology industry association of which’s member companies 25%[3] work on the supporting fields of biotechnolgy rather than on the actual biotechnological R&D, or are subsidiaries to corporations. In the latter case the corporation is often the patent holder rather that the inventing subsidiary. The supporting fields of FIB’s members cover the areas of consulting, contract manufacturing, funding and technology transfer. The important role of patenting is in convergence with knowledge intensiveness of high technology (Chabot 1995) and with the heightened market potential of knowledge in IP form (Williams & Bukowitz 2001, 98). Teece (1998, 69) claimed that a patent provides the strongest protection for an invention. Patenting is also considered “a vital source of competitive advantage in the knowledge economy, where value is generated from protected ideas, knowledge, skills, and methods” (Lang 2001).

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[1] See also section 2.2.
[2] Value is defined here to be the same as market size.
[3] Calculated from the list of member companies of FIB available on FIB’s internet homepage at http://www.finbio.net/jasenet

3 MATERIALS AND METHODS

3.1 Funding

3.1.1 Role of funding in public biotechnology research

In addition to biotechnology development (especially pharmaceuticals) done in companies (section 2.3), also basic research in universities and research institutes is expensive. The costs include premises, educated personnel, the machinery and the materials used. As laboratories, the premises have needs that raise the costs of building as well as maintenance. If the laboratory has, or aims to apply for, a quality assurance accreditation like GMP or GLP, the costs rise even higher due to strict standard for all operations.

As discussed in the section 2.2.1, knowledge has an especially important role in biotechnology. In practice, this knowledge means that people doing the research will be highly educated, which again means that they are well paid for their work. Educated personnel can be found most easily from developed countries in which labour costs tend to be considerably high. According to Porter (1983), availability of educated personnel is also one of the entry barriers of any industry, without doubt being that in knowledge intense bioindustry as well.

Machinery is also a factor that raises the research costs of biotechnology. Even the smallest of laboratories require a large amount of equipment to do research, and that equipment generally costs a lot. For instance, one laser tube for a confocal microscope cost over € 200 000, and is thus a considerable cost for an acquiring laboratory. Such equipment is of course not needed in every laboratory but an example helps to understand the level of costs. This applies also for materials; some of them,

for example monoclonal antibodies, are commonly used especially in laboratories, and cost hundreds of Euros per milligram.

In addition to costs of physical materials, also possible patent protection of inventions requires funds to maintain. The costs of applying and maintaining a patent are discussed in the section 2.2.2.2.

To do biotechnology research, the institution requires thus relatively large amount of funds each year. Because basic research is generally done in universities and public or non-profit making research institutes, public funding is of essence to basic biotechnology research. The situation is similar in all OECD countries; consequently it is useful to evaluate each country's public R&D funding for biotechnology, to evaluate the state of their research.

In this study, public funding means all funding from all of the governmental organisations and ministries that used their resources to support biotechnology research. In Finland, these ministries and organisations are the Ministry of Education (administers Academy of Finland), the Ministry of Trade and Industry (administers The National Technology Agency), the Ministry of Social Affairs and Health, the Ministry of Agriculture and Forestry and the Ministry of Environment (Kafatos *et al.* 2002).

It must be noticed that other sources of funding are also available for public research. The two most considerable of these other forms of funding are funding from companies and scholarships admitted by foundations. These sources, especially funding from companies, may form a considerable part of funding of public research in other countries than Finland, but being kept secret, the amount was estimated only regarding Finland.

3.1.2 Collecting the data

The information regarding public research funding in Finland is based on three sources, OECD (2002) and Statistics Finland (2002a) for the year 2000, and Kafatos *et al* (2002) for the year 2001. Due to varying definitions of biotechnology of each data-source, *comparable information regarding each country's research funding was unobtainable.* For example, Statistics Sweden provided a sum for public biotechnology research funding in Sweden (Vinnova 2001, 144) that was only one third of the sum Thore (2002) provided. The difference was caused by varying definitions of biotechnology, Thore's being more close to that used in this study. The comparison of public research funding between Finland and other countries is therefore based on each county's gross expenditures on R&D. *No information regarding biotechnology's share of a country's total R&D costs was available from other countries than Finland.* Therefore a presumption is done that each government finances biotechnology research with the same 9 % than does Finland[1]. Information regarding national gross expenditure on R&D was provided by the OECD's Main Science and Technology Indicators – study. The study provided information of each country's total R&D expenditures, as well as government's share of it. Share of biotechnology funding was calculated from the government's share of total R&D expenditures, of which the said 9 % was presumed to be devoted to biotechnology.

Scholarships granted by foundations were estimated based on the information from the five biggest Finnish foundations granting scholarships for non-clinical biotechnology/medical research. The foundations were Suomen Kulttuurirahasto, Eemil Aaltosen Säätiö, Jenny ja Antti Wihurin Rahasto, Syöpäsäätiö and Sigrid Juseliuksen Säätiö. Scholarships from these five foundations represent approximately 90% of all non-clinical medical and biotechnology scholarships (Törmälä, personal notification 19.3.2003). Törmälä also estimated funding from companies, while such information is commonly trade secret protected and therefore not public. The information of granted scholarships for years 2001 or 2002 (depended of which year was published) was mainly gathered from the foundations' internet homepages, excluding the Sigrid

[1] Source: Statistics Finland 2002a

Juselius foundation, which's sum was estimated by Mrs. Eva Tallqvist from the foundation (Tallqvist, personal notification 17.3.2003). There were no major changes of granted scholarships between the years 2001 and 2002, for which reason the information regarding those years are used interchangeably.

3.2 Impact of biotechnology research

3.2.1 Measuring the impact of research

The second objective of this study, to assess Finnish biotechnology research utilisation, requires not only quantitative measurement of biotechnology patenting to be done, but also an evaluation of the impact of Finnish biotechnology science itself. The impact of the science is measured by rating the quantity and quality of each country's biotechnology research. Publication activity of research results, both the quantity and the quality, is the primary criteria based on which the impact of a science is rated, because only published results can be evaluated and criticised by the scientific community.

By counting the number of published articles (publications) the magnitude, or the quantity, of a country's research of a certain field can be assessed. Being totally numeric, this information is unambiguous and comparable between entities. It can be easily obtained too, from several databases. By qualitative measurement an entity's probability to produce utilisable inventions, or its *utilisation potential*, can be assessed: At least in technological sciences higher impact means that the more likely it is that the results include inventions that can be utilised. The scientific importance, or quality, of research is not easily evaluated however. A common belief in scientific community is that the most acceptable method to measure the scientific importance of research of an entity is a professional peer review. On the other hand, these reviews tend to be rather cursory and over-polite, and provide no numerical data that could be readily used in assessments between entities. Two bibliometric methods are

therefore developed to measure the scientific importance of research: Citation analysis, which measures the number of citations an article receives, and impact factor analysis, which measures the status of the publication forum (i.e. the status of the journal in which the article is published). The scientific importance of any research is defined by these two methods, while only published results are considered to include impact. Such methods are applicable in national and international evaluations of strictly outlined field of science, but not between different sciences, because there are severe differences in the volume, structure and culture of publishing results between sciences. (Raivio 1997; van Beuzekom 2001, 14-16 & 107) However, only a few articles may cause citation index to rise considerably, if these articles are cited often. For example, an article describing an effective cure for AIDS would without doubt be cited enough to raise the citation index of the inventor's country to top the charts. This wouldn't depict the country's state of biotechnology research as whole, while it didn't recognise the magnitude of the research. Especially when considering utilisation potential of research, the magnitude of the research has an essential role, as more research can be expected to include more patentable inventions. To assess the utilisation potential of a country's research, the *total impact* of the research is calculated. Total impact recognises the magnitude of the research, and thus describes utilisation potential better than just the citation index. Total impact is calculated by multiplying the number of publications by the relative impact of the publications (i.e. quantity by quality). This calculation is presented in the calculation (6.).

3.2.2 Collecting the data

The information regarding the magnitude and the relative impact of each country's biotechnology research was collected from an OECD study considering the state biotechnology in OECD member countries. The data has been provided by NUTEK Sweden[1], and has been collected (using Sweden as an example) as follows (van Beuzekom 2001, 107):

[1] Nilsson, A., Pettersson, I., & Sundström, A. 2000. *A Study of the Swedish Biotechnology Innovation System using Bibliometry.* NUTEK Working Paper, January.

> For the international comparison of Swedish publication volumes and relative impact factors in life science fields relevant to biotechnology, the National Science Indicators on Diskette (NSIOD) from the Institute for Scientific Information (ISI) were used (…).
>
> [For other than relative impact data] (…) bibliometric data set was constructed by downloading all papers with the word "Sweden" in the address field from the CD-ROM version of the Science Citation Index (SCI). SCI includes the most important ten to fifteen percent of all scientific journals in medicine, natural sciences and engineering, but is believed to provide better coverage of the Life Sciences than engineering (…).
>
> In order to define articles relevant to biotechnology, the journal subject categories as defined by ISI were used[1]. (…) we also limited our analysis to journals that had reached an impact factor of at least five.

3.3 Patenting activity

3.3.1 Evaluation of patenting activity

The second objective of this study, *the evaluation of biotechnology research utilisation in Finland, is based on the patenting activity* of each country participating this study. While patenting has been proven essential for competitive biotechnology industry to form (e.g. Cooke 2001; Ernst & Young 2002, 14), the patenting activity of each country is used as an indicator of utilisation of the research. To do this, public funding of biotechnology research and the total impact of the research of each country, are divided by the number of patents issued to the country's inventors, respectively.

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[1] Of all life science fields, the articles and their citation indexes in *Biotechnology and applied microbiology* – class were selected for van Beuzekom's (2001) study.

The comparisons of patenting activity between countries are based on the patenting activity of each country in the United States. There are several reasons that make this procedure not only sensible but also the only reliable method, as discussed in the following:

In this study, the number of patents should indicate the innovation activity of participating entity. The European Patent Office's (EPO) method of listing issued patents makes it impossible to determine the number of actual inventions in contrast to the number of patents issued. The reasoning begins with EPO's legal status; EPO is not under control of the European Union and therefore cannot force the member countries to adopt similar patent laws. This leads to a complex routine in applying a patent covering many EPO member countries at the same time. This means filing the patent application to EPO and naming the countries in which the said patent is to be registered. In practice this means that although EPO grants patents, its member countries (the ones the applicant names) need to register the applied patent separately. When counting the number of patents issued by EPO, each of these registrations is counted as a separate patent, because the patent is only valid in countries that register the application. When counting issued patents, each patent issued by EPO will therefore get a number of hits depending on the number of countries the applicant wants the invention to be registered in, respectively. The number of countries in which the applicant wants the EPO-patent to be registered in, is totally dependent on the applicant. One applicant may want to register his patent in just two countries, while another wants a registration from seven countries. This variation in the number of registrations causes major error when counting the patenting activity of the inventors from any single country. To dissolve the error, the one to count the issued EPO-patents should use the national patent databases of each country's patent authorities, which are not necessarily accessible.

In addition to the complex procedure of counting the EPO-patent registrations, another aspect makes it difficult to count the patents applied in Europe reliably: A patent applicant can file an application for his invention straight to the patent authorities of each country separately. This is a typical procedure, because this grants the appli-

cant a priority date[1] and the invention is granted a patent generally much faster than from the EPO. In the countries that allow double patenting[2], both the patent and the registration are counted as patents. This adds uncertainty to the exact number of inventions patented.

An example clarifies the above: An inventor from a country that allows double patenting applies for a patent for his invention in his own country and then files a second application for an EPO-patent to be registered in five other EPO-countries. If both of his applications are granted patents, and the EPO-patent is registered in all stated countries, the invention gets seven hits when counting the number of patents registered to the inventors of his country: It gets one hit from each other country that registers the patent and two from his own, because the local patent authority granted him two patents: First the applicant was issued a patent applied straight from his country and then got his EPO-patent registered in his country also.

Because of the above, patenting activity calculated by counting the number of patents granted by EPO using EPO's own databases, is unreliable. To evaluate the real patenting activity of any country, one must use databases that count the issued patents on the same requirements for each and every country. For this reason, patenting activity comparisons between countries are based on the patenting activity in the U.S. Patent and Trademark Office.

3.3.2 Collecting the data

Patents issued to Finnish inventors are counted using information from the Finnish Bioindustries or FIB, Esp@cenet - database[3], The United States Patent and Trade-

[1] Priority date is used to determine the first inventor. In Europe, the one with the earliest priority date is considered to be the first to invent, and therefore he is the one to whom the patent is granted to.
[2] Patent is issued straight by national patent authority and also registered through EPO.
[3] http://fi.espacenet.com/

mark Office (USPTO 2002a), and National Board of Patents and Trademarks of Finland, hereafter PRH[1].

In the Table 4, figures for the years 1997 and 1998 were provided by FIB (Finnish Bioindustries 1999), except the patents issued by the USPTO. Figures for the years 1999, 2000 and 2001 (fields Finland and Finland through EPO) were counted using Esp@cenet - database, selecting the sub-page “Suomesta”. Further, the field “Julkaisupäivä” was filled with the number of each year, and the field “Keksijä” with the country code of Finland, FI. From the list of results of the search with given values, the appropriate patents according to International Patent Classes were counted. The IPC-classes under which inventions were considered biotechnology – A61A-A61N, C07, C12 and G01n33 – were also provided by FIB (1999). Only inventions with biological inventiveness of given classes were counted. This excluded for example a sauna stove and several inventions of purely organic chemistry.

In the Table 4, the figures for other EPO countries for the years 1999, 2000 and 2001 were unobtainable in publicly available databases, and were therefore counted upon request by Mr. Veli-Pekka Hyttinen from PRH. He searched EUREG – data-base with the following criteria: patents in the given IPC-classes issued to Finnish inventors in the years 1999, 2000 and 2001, with priority from another EPO-country than Finland. The appropriate patents were selected among of these results, using the same criteria as in Esp@cenet searches.

All figures in the Table 4 regarding patents issued by the USPTO were provided by the USPTO (USPTO 2002a). Figures for the years 1997 and 1998 were available from FIB also, but differing slightly from the USPTO’s figures, were not selected to maintain comparability with other countries.

[1] Patentti- ja rekisterihallitus

3.4 Semi-structured interviews

Chapter 5 of this study discusses, argues and reasons out the results presented in chapter 4. Based on the results, the second objective of this study – to evaluate Finland's biotechnology research utilisation compared to other countries – is met. The evaluation is based on semi-structured professional interviews. The people interviewed were innovation managers of selected Finnish universities that produce biotechnological, or related research. Innovation managers are set to promote innovativeness in general, to advice on industrial property rights and innovations, to seek for innovative projects and to evaluate them, as well as to contribute to the technical, productional and commercial exploitation of innovations (University of Jyväskylä 2002). Due to the nature of their work, it could be expected that these people had invaluable opinions to explain the situation of patenting activity in Finnish universities. Interviewed persons were selected based on their university's research areas. Out of twenty-one Finnish universities, ten practice biotechnology research. Six innovation managers from these universities participated on these study, the rest being unreachable or had no time for an interview within the time limit, which was 5.5.2003-16.5.2003. Names, dates and universities each interviewee represented, are available in Appendix I. Interviews were done in Finnish to avoid language-related misunderstandings. The interviews took place at each interviewee's workplace, except Mr. Rantala's, which took place at the premises of Licentia Ltd. and Dr. Virtapohja's at the University of Tampere. Upon request, when citing an interviewee, no information revealing their identity is presented, but the interviewees are merely referred to as: (Interviewee 2003), if quoted from word to word.

Semi-structured interviews were selected for this study because they provide the best method to gather insights to the studied phenomenon. Only one interview session per interviewed person was needed and was relatively easy to arrange. Enough information for the evaluation presented in the chapter 5, could still be gathered. Semi-structured interview is an information-gathering method of qualitative research. Qualitative research aims to reflect "real life", depict actual behaviour and to find relationships between phenomena. Qualitative research aims to find and discover facts rather than to prove existing claims. (Hirsjärvi, Remes & Sajavaara 1997, 161) A

semi-structured interview is the most adequate tool to capture how a person thinks of a particular domain. It is a combination of faith in what the subject says about the underlying meaning, with the scepticism about what she/he is saying. (Honey 1987, 69-82) Semi-structured interview as a qualitative research method is thus well applicable to this study, as it intends to find reasons and relationships between factors that affect patenting activity in Finnish universities.

Semi-structured interview is a combination of a structured interview and an open interview. It is typical for a semi-structured interview that no strict form is set for the questions but the session proceeds along preset themes. The nature of a session is rather a discussion of a certain domain, than a step-by-step interview. (Hirsjärvi *et al* 1997, 204-205) Semi-structured interviews have advantages compared to other interview types; motivating interviewed persons is easy, order of questions can be altered and presentation of the questions is not strictly set. More focused extra questions are possible too, if need be. (Hirsjärvi & Hurme 1988, 15)

3.5 Countries and institutions involved in this study

Countries were selected for this study based on their biotechnology industry performance. Sweden is an obvious country to compare Finland to, as it has similar culture, geographic location and population only a little larger than Finland. In addition, Sweden has similar aims in biotechnology industry development as Finland.

The Great Britain (UK) was selected because it is considered the leader in European biotechnology *industry*, while the Unites States of America (US), respectively, is the world leader (Ernst & Young 2002). An illustrative example of the state of biotechnology industries in these countries is that the US is ten years ahead of UK, which again is ten years ahead of Germany, which represents European average. (Cooke 2001) One must note that these countries are the best in *development of biotechnology industry,* not necessarily in the science. Keeping in mind the European Union's and

Finland's aim to develop a competitive biotechnology industry, it was reasonable to compare Finland to the countries that have been best in industry development.

While patenting activity was one of the main indicators based on which a country's biotechnology research utilisation is assessed, the patent activity of some US-based universities are also included in this study. Information that was reliable and comparable to the countries mentioned above, regarding the funding and the scientific quality of the biotechnology research done in these universities, was not available. Patenting activity information of these universities are thus presented merely as a curiosity toward which Finland's performance can be compared. The institutions were selected among those commonly considered as top universities of the US. The universities are Harvard University, University of California, Johns Hopkins University, Massachusetts Institute of Technology and the University of Texas. Patent information of the universities was obtained from the USPTO (2002b), and was collected similarly than the activities of countries. It must be noted that the information for universities was not available for the year 2001, unlike for countries. The results should be compared to Finland's patenting performance keeping in mind that said university patents represent in sense (although not purely) public or non-profit research, whereas for Finland's performance company patents are counted as well.

4 RESULTS

4.1 Biotechnology research funding by country

For simplicity reasons, US dollars ($) and euros (€) are used interchangeably in this study, with the presumption that their exchange rate is 1:1. The changes of actual rates may cause error, for which reason the following calculations are for evaluative purposes only.

Finnish public investments in biotechnology for the year 2000 were € 115 million (Statistics Finland 2002a) and € 145 million in 2001 (Kafatos *et al* 2002, 21-23). Similar, comparable figures from other countries were unobtainable, for which reason sums of public biotechnology research funding were calculated from the total R&D investments of each country. OECD (2002) provided the sum of $ 4 459.6 million for Finnish total R&D expenditures (exps) for the year 2000, of which 70.2 % was from industry and 26.2 % from government[1]. The remaining 3.6 % was not explained. On the other hand, it is known that the share of public biotechnology research in Finland was 9 % of all public R&D expenditures (Statistics Finland 2002a). Public research funding for biotechnology in Finland can therefore be calculated from the above as presented in calculation (1.).

(1.) Total R&D exps * Share of public exps * Share of biotechnology of public exps
M$ 4 459.6 * 26.2 % * 9 % = M$ 105

The sum counted from OECD's statistics is in reasonable concordance with the sum provided by the Statistics Finland: M$ 105 vs. M€ 115. The variation probably derives from the inaccuracy of the percentages presented. Public research funding for each country is calculated similarly *with the presumption that each country uses the same share than Finland (9 %) for its biotechnology R&D.*

[1] Governmental and public expenditures mean the same here.

As discussed in section 3.1.1, company funding and scholarships are also available for public research. The information regarding company funding being commonly not disclosed, Dr. Timo Törmälä, CEO from Licentia Ltd., estimated regarding the number of probable companies financing public biotechnology research, the *company funding to be at maximum € 10 million per year.* The estimate is based on the small number of large biotechnology companies in Finland, which could finance university research.

Scholarships from the foundations granted for non-clinical medical / biotechnology research are presented in the Table 4.

TABLE 4. Scholarships of the five most considerable foundations

Foundation	Scholarships for	Sum (€)
Suomen Kulttuurirahasto[1]	All natural sciences	358 000
	Non-clinical medicine	736 000
Emil Aaltosen säätiö[2]	Non-clinical medicine & biosciences	180 000
Jenny ja Antti Wihurin säätiö[3]	Non-clinical medicine & biosciences	180 000
Sigrid Juseliuksen säätiö[4]	Non-clinical medicine & biosciences	5 600 000
Syöpäsäätiö [5]	Cancer research	3 000 000
Others[6]		1 000 000
Total, non-clinical medicine & biosciences		11 000 000

Combining all of the above, funding received by public biotechnology research in Finland (including public funding, company funding and scholarships), it can be concluded that the *total funds received were about € 160 million* in the year 2001; 145

[1] Source: Suomen Kulttuurirahasto 2003
[2] Source: Emil Aaltosen säätiö 2003
[3] Source: Jenny ja Antti Wihurin säätiö 2003
[4] Source: Eva Tallqvist. 2003. Personal notification 17.3.
[5] Source: Syöpäsäätiö
[6] Source: Dr., CEO Timo Törmälä. 2003. Personal notification 19.3.

million from public sources, ten million from companies and 11 million from foundations.

According to OECD (2002), Sweden's total R&D expenditures in the year 2000 were M$ 7 864.8, of which 67.8 % was from the industry and 24.5 % from the government. Again, the remaining 7.7 % was not explained. Assuming that the Swedish government used the same 9 % of its total R&D expenses for biotechnology, the sum for Swedish public biotechnology research funding is presented in calculation (2.):

(2.) Total R&D exps * Share of public exps * Share of biotechnology of public exps
M$ 7 864.8 * 24.5% * 9% = M$ 173

Thore (2002) estimated that Sweden's public expenses for the year 2000 would be MSek 2 100, which is about M€ 230. The variation between calculation from OECD's information and Thore's estimate probably derives from the presumption of the share of biotechnology expenses of total R&D. On the other hand, Thore's sum was an estimate in itself. In addition, the changes between the exchange rates of the currencies may add error to Thore's sum.

The United Kingdom used some M$ 27 029.2 for R&D in the year 2000, with 49.3 % share of industry and 28.9 % of government. Again, the remaining 21 % was not explained. Assuming that UK used the same 9 % of the total public R&D exps for biotechnology as Finland, the sum for UK public biotechnology research funding is presented in calculation (3.):

(3.) Total R&D exps * Share of public exps * Share of biotechnology of public exps
M$ 27 029.2 * 28.9% * 9% = M$ 703

The Unites States of America used some M$ 282 292.7 for R&D in the year 2000. Industry's share was 68.3 % and governments 26.9 %. The remaining 4.8 % was again not explained. With the assumption that 9 % of total R&D expenses were used for biotechnology, the sum for US public biotechnology research funding is presented in calculation (4.):

(4.) Total R&D exps * Share of public exps * Share of biotechnology of public exps
M$ 282 292.7 * 26.9 % * 9 % = M$ 6 834

While it is obvious that a larger country can invest absolutely more to its R&D than a smaller one, it is reasonable to relate the sums they use for biotechnology R&D to the population. Population data was provided by Statistics Finland (2002b). The biotechnology R&D expenses vs. the population in millions ratios for above countries in the year 2000 are presented in calculation (5.):

(5.) Public biotechnology R&D exps / millions of population = public funding *per millions of capita:*

Fin:	M$ 105 / 5.2	= M$ 20
Swe:	M$ 173 / 8.8	= M$ 20
UK:	M$ 703 / 59.5	= M$ 12
US:	M$ 6 834 / 285.0	= M$ 24

In addition, similar results were obtained when public funding *per capita* was related with GDP *per capita.*

4.2 Total impact of each nation's biotechnology research

Table 5 presents the national shares of the total publications in the biotechnology and applied microbiology journal NSIOD category (van Beuzekom 2001, 15). NSIOD (National Science Indicators on Disc) is the Institute of Scientific Information's (ISI) categorisation of about 5 500 natural scientific and technological reviews and about 3 000 in other sciences. Biotechnology and applied microbiology category consists of 132 journals in several languages, being slightly dominated by journals in English. Figures in Table 5 represent the shares (in percentage) of each country's biotechnology articles against all articles of the field.

TABLE 5. National shares of the total number of publications in the biotechnology and applied microbiology NSIOD journal category.

	1986	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**Mean**
Belgium	1.0	1.4	1.4	1.1	1.0	1.0	1.0	1.0	1.6	1.4	1.2	1.4	1.0	1.2
Canada	9.4	10.5	8.8	7.6	6.3	6.9	6.4	5.9	5.8	6.3	5.1	5.1	3.8	8.2
Denmark	0.6	0.7	0.4	0.5	0.5	0.6	1.0	0.9	1.0	1.1	1.2	1.1	1.4	0.8
Finland	**1.1**	**0.9**	**0.9**	**0.6**	**1.0**	**1.3**	**0.8**	**1.8**	**1.0**	**1.2**	**0.8**	**0.8**	**0.7**	**0.9**
France	7.4	7.1	7.0	6.1	6.4	6.4	6.9	5.6	6.7	6.9	6.3	7.5	7.3	5.9
Germany	5.4	6.4	6.1	6.5	6.3	6.9	7.3	6.6	6.7	6.8	7.3	6.3	6.9	6.0
Italy	1.1	1.1	1.3	2.1	1.6	3.8	2.2	4.1	2.5	2.7	2.7	2.7	2.6	2.1
Japan	10.9	10.7	11.3	11.4	12.3	12.6	12.1	13.1	12.7	11.9	10.7	11.6	12.9	12.1
Netherlands	2.2	2.1	2.7	2.1	2.9	2.8	2.6	2.9	2.9	2.8	3.1	3.1	3.0	2.4
Norway	0.1	0.2	0.0	0.2	0.4	0.2	0.2	0.3	0.5	0.2	0.3	0.4	0.5	0.2
Spain	1.8	2.2	2.2	2.2	2.4	2.8	2.7	3.6	3.6	4.1	4.9	4.5	4.8	2.6
Sweden	2.0	1.4	1.7	1.9	1.9	2.2	1.4	1.3	2.0	1.5	1.4	2.0	1.9	1.8
Switzerland	1.9	1.1	1.7	1.1	1.2	1.1	1.6	1.9	1.6	1.9	1.8	1.8	1.8	1.5
United Kingdom	12.4	10.2	8.9	7.9	10.1	11.0	9.7	8.6	9.6	11.0	8.7	8.6	8.7	9.3
United States	22.9	23.8	28.8	26.5	27.0	22.8	22.2	21.8	20.5	21.2	21.5	21.8	21.0	23.3
Other countries	19.8	20.2	16.8	22.2	18.7	17.6	21.9	20.6	21.3	19.0	23.0	21.3	21.7	20.3

Table 5 states that the average share of Finnish articles is 0.9%, Swedish 1.8%, UK 9.3% and US 23.3%.

Table 6 presents the relative impact of country's biotech publications, according to van Beuzekom (2001, 16). The relative impact of publications describes the average scientific importance of the country's research, higher value presenting higher scientific importance. Each figure in the Table 6 below represents how much each country's articles have been cited, *in relation to world average.* For example, Finnish articles have been cited 60% more than an average article. The Table 6 disregards countries that are not members of OECD, thus raising the mean of the Mean- values to higher than the word average, which is 1.0.

TABLE 6. The relative impact by country of publications in the biotechnology and applied microbiology NSIOD journal category.

	1986	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**Mean**
Belgium	0.5	0.8	0.9	0.9	1.0	1.9	1.1	1.0	1.6	1.5	1.3	1.5	0.6	1.1
Canada	1.0	1.1	1.2	1.3	1.1	1.1	1.1	1.2	1.1	1.3	1.1	0.9	1.0	1.1
Denmark	0.6	1.0	1.6	1.4	2.3	1.7	1.1	1.4	1.0	1.4	1.4	1.5	0.5	1.2
Finland	**1.4**	**2.7**	**1.6**	**1.3**	**1.1**	**1.3**	**2.8**	**1.2**	**1.4**	**1.0**	**0.7**	**1.6**	**2.3**	**1.6**
France	0.6	0.8	0.8	0.8	0.9	0.9	0.8	0.9	0.7	0.7	0.8	0.9	0.6	0.9
Germany	1.0	1.1	0.9	1.3	1.0	1.4	1.1	1.1	1.1	1.4	1.4	1.4	1.5	1.3
Italy	0.9	0.8	1.0	0.5	0.8	0.6	0.9	0.7	1.2	1.3	0.7	1.0	1.5	0.9
Japan	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.7	0.8	0.8	0.9	0.8
Netherlands	1.5	2.4	1.4	1.4	1.5	1.6	1.6	1.8	1.9	1.6	1.3	2.0	1.2	1.6
Norway	0.6	2.9	0.3	3.1	1.8	0.6	1.3	1.2	1.2	1.2	0.3	1.4	1.0	1.2
Spain	0.6	0.9	0.8	0.7	0.8	0.8	0.8	0.9	0.8	0.8	0.8	1.0	0.7	0.8
Sweden	1.4	1.8	1.5	1.5	1.2	1.5	1.7	1.9	1.7	1.7	1.6	1.6	0.8	1.5
Switzerland	2.4	1.6	2.5	2.0	2.1	1.6	1.3	1.5	1.1	2.5	2.4	2.0	3.3	1.8
United Kingdom	1.0	1.2	0.8	1.4	1.1	1.1	1.3	1.2	1.3	1.2	1.3	1.1	1.3	1.1
United States	1.5	1.3	1.3	1.3	1.4	1.3	1.5	1.4	1.3	1.3	1.5	1.6	2.0	1.4

It can be seen from the Table 6, that Finnish and Dutch biotechnology research are cited second most in the world (with relative impact of 1.6), after only Swiss articles (with relative impact of 1.8). Relative impact for Swedish articles is 1.5, UK articles 1.1 and US articles 1.4.

Combining the figures representing Finland in Tables 4.1 and 4.2, the total impact of a country's biotechnology research is calculated. Total impact can be used to describe a country's potential for patenting, while it recognises the magnitude of the research, and not just the citation activity. Total impact is calculated by multiplying the country's share of all articles (Table 5) by the relative impact of the publications (Table 6). Average total impacts of each country's biotechnological research are presented in calculation (6.):

(6.) Share of all publications * relative impact

Finland: 0.9*1.6 = 1.44

Sweden: 1.8*1.5 = 2.70

UK: 9.3*1.1 = 10.23

USA: 23.9*1.4 = 33.46

It is noteworthy that, according to Table 6, Finnish articles have the second highest *relative impact*. The *total impact*, which is used in following calculations of this study, is not as high due to the lower share of all articles.

Total impact of each country's research in relation to the population (in millions of people for the year 2001) of the country, provides a more accurate perspective to the state of a country's biotechnology research, while a country with larger population has higher potential to do research and thus to publish more. Total impacts in relation to countries' population are presented in calculation (7.). It must be noted that, while the result values are less than one, for simplicity reasons the *values are used in later calculations without the " $*10^{-3}$ " multipliers.*

(7.) Total impact / population

Fin: 1.44 / 5.2 = 2.8 $*10^{-3}$

Swe: 2.70 / 8.8 = 3.1 $*10^{-3}$

UK: 10.23 / 59.5 = 1.7 $*10^{-3}$

USA: 33.46 / 285.0 = 1.2 $*10^{-3}$

4.3 Patenting activity by participating countries and institutions

The first objective of this study was to count the number of biotechnology patents issued to Finnish inventors. The sections 2.2.3 and 3.3 discuss the role of patenting in biotechnology. This section presents the patenting activity of each country and institution involved in this study as Tables. Table 7 presents the number of patents issued to Finnish inventors. The lacking figures between the years 1997-2000 in – Finland

through EPO – means that there were no patents issued to Finnish inventors during that time. Finland joined the EPO in the year 1996 and the first patents that were applied from EPO to Finland were issued in 2001, due to EPO's long examination times.

TABLE 7. Patents issued to Finnish inventors in Finland, EPO and USPTO.

Patents issued						
Year	1997	1998	1999	2000	2001	Total
Finland	25	49	17	39	22	152
Finland through EPO	-	-	-	-	31	31
Other EPO countries	32	35	13	11	15	106
USPTO	29	49	58	36	46	218
Total	86	133	88	86	114	507

As an answer to the first objective of this study, *the total number of biotechnology patents issued to Finnish inventors is 507,* between the years 1997-2001. To gain perspective whether the figures in the Table 7 are high or low internationally, they must be compared to other countries. As discussed before however, comparable information of each country's total number of patents is unavailable. Comparisons between countries' patenting activity is therefore done based on the patents issued by the USPTO. Figures in the Tables 8 – 11 are provided by the United State Patent and Trademark Office and counted as discussed in the section 3.3.2. The origin of patents is determined by the residence of the first-named inventor (USPTO 2002).

TABLE 8. Patents issued to Finnish inventors by USPTO.

YEAR	1997	1998	1999	2000	2001	Total
USPTO	29	49	58	36	46	218

TABLE 9. Patents issued to Swedish inventors by USPTO.

YEAR	1997	1998	1999	2000	2001	Total
USPTO	109	126	135	135	133	638

TABLE 10. Patents issued to UK inventors by USPTO.

YEAR	1997	1998	1999	2000	2001	Total
USPTO	482	593	617	599	635	2926

TABLE 11. Patents issued to US inventors by USPTO

YEAR	1997	1998	1999	2000	2001	Total
USPTO	6736	8198	8671	7837	8380	39822

It is noteworthy in above Tables, that Swedish inventors were issued more patents by only the USPTO (638 in total), than Finnish inventors by all patent-issuing authorities (507 in total).

In calculation (8.), the number of patents issued for inventors of each country is divided by the population of that country. This is done to evaluate a country's patenting activity vs. population, while it is obvious that a developed country with higher population produces more patents than a country with lesser population.

(8.) Number of patents / Population (in millions) = Patents per million of population

Finland 218 / 5.2 = 42
Sweden 638 / 8.8 = 73
UK 2 926 / 59.5 = 49
US 39 822 / 285.0 = 140

When the number of *patents per million of population* is divided by the *total impact per million of population* [calculation (8.) divided by (7.)], a figure can be calculated indicating patenting activity vs. science impact ratio, regarding the population. A

higher figure means that the country has higher tendency of patenting its biotechnology inventions, disregarding the impact of the research. This is presented in calculation (9.).

(9.) Number of patents per million of population / total impact per million of population:

Finland	42 / 2.8	= 15
Sweden	73 / 3.1	= 24
UK	49 / 1.7	= 29
US	140 / 1.2	= 117

The third hypothesis of this study; that Finnish biotechnology research is not well utilised although receiving well public funding, is examined in calculations (10.) and (11.). The calculation (10.) presents the ratio of the number of patents per funding received. Calculation (11.) presents the ratio of the number of patents per million of population.

(10.) Number of patents / public funding:

Finland	218	/ 105	M€ = 2.1 $^{1}/_{M€}$
Sweden	638	/ 173	M€ = 3.7 $^{1}/_{M€}$
UK	2 926	/ 703	M€ = 4.2 $^{1}/_{M€}$
US	39 822	/ 6 834	M€ = 5.8 $^{1}/_{M€}$

(11.) Number of patents / public funding *per millions of capita*:

Finland	218	/ 20	M$ = 11 $^{1}/_{M\$}$
Sweden	638	/ 20	M$ = 32 $^{1}/_{M\$}$
UK	2 926	/ 12	M$ = 244 $^{1}/_{M\$}$
US	39 822	/ 24	M$ = 1 659 $^{1}/_{M\$}$

As mentioned in the section 3.5, biotechnology-patenting activity of selected US – based universities are presented in this study to assess Finland's patenting activity compared to universities that are commonly believed to produce high quality science. In following Tables 12 – 16, patents issued to universities of Harvard, University of California (UC), Johns Hopkins University, Massachusetts Institute of Technology and the University of Texas, are presented, according to (USPTO 2002b). Patents are counted from the same USPC – classes as for countries (Table 1.). It must be noted that information for the Tables was available only for the years 1997-2000. It must be noted as well that the following data doesn't include patents granted to inventors in the universities, but the universities themselves. This is because in the US, inventions made by university employees belong to the university, instead of to the inventor as in Finland.

TABLE 12. Patents issued to Harvard University by USPTO.

YEAR	1997	1998	1999	2000	Total
USPTO	23	37	27	17	104

TABLE 13. Patents issued to University of California by USPTO.

YEAR	1997	1998	1999	2000	Total
USPTO	119	177	165	195	656

TABLE 14. Patents issued to Johns Hopkins university by USPTO.

YEAR	1997	1998	1999	2000	Total
USPTO	25	58	72	54	209

TABLE 15. Patents issued to Massachusetts Institute of Technology by USPTO.

YEAR	1997	1998	1999	2000	Total
USPTO	27	27	29	13	96

TABLE 16. Patents issued to University of Texas by USPTO.

YEAR	1997	1998	1999	2000	Total
USPTO	47	60	53	55	215

It must be noted from the above Tables that University of California was issued more patents by only USPTO in four years, than Finnish inventors by three patent authorities in five years. If comparing Finnish patents issued by only USPTO, the University of Texas, in addition to the University of California, is issued more patents in four years than Finnish inventors in five. The Johns Hopkins University would most probably be issued more patents in five years than Finnish inventors in the same time by USPTO.

4.4 Summary of the interviews

Six innovation managers from six Finnish universities doing biotechnology research were interviewed separately to gain opinions on Finland's performance in biotechnology research utilisation. Interviews were semi-structured and were done in one session divided in two parts; in first part patenting was discussed broadly without presenting the results of this study and in the second part the results were presented. The frame of the interviews is available in Appendix II.

The first part of the interviews, questions 1. - 13., returned relatively unanimous answers. Patenting was considered an important catalyst to technology development in

general, patent databases being especially relevant as sources of information. Especially when compared to the alternative in industry, to protect the research results with trade secrets, patenting was considered an evident route for technology information to spread. Furthermore, patents were considered of exceptional importance in biotechnology, especially in drug development, by the most of the interviewees. In addition to industrial level information source, patents were considered motivators of innovation in personal level because of their monetary reward potential. Other positive sides of patenting were generally considered to include the monopoly it produced for the patent owner, which grants the owner a possibility to recoup development investments. This was considered especially important for smaller enterprises that cannot afford major losses in development. Patents were as well considered to clarify an inventor's legal status, which was considered difficult with trade secret protected inventions.

On the negative sides of patenting, the costs to apply, maintain and enforce were mentioned most often. As discussed in the chapter 2.2.2.2, only applying for a patent in more than just Finland can cost tens of thousands of euros, which most likely exceeds the resources of an individual inventor. As part of the interviewees noted however, application and maintenance costs are small compared to the possible litigation costs, especially in the US. The publicity of a patent was mentioned as well as a negative side of a patent for the patent owner. In addition, some interviewees noted the ethical issues related to drug patents and developing countries of which many have no resources to buy the needed medications. On the other hand, many of the interviewees mentioned that without patents, the most of the drugs would not have been developed at all.

Patenting was considered beneficial for the inventor as a method to enable the commercialisation of the invention, as well easing funding negotiations regarding further research; if an invention had a patent, funding organisations were more eager to support further research regarding the subject of the invention. Patents were considered beneficial for the universities as well, albeit in Finland the inventor generally owns the rights for the invention done in a university. While universities have limited means to compete with industry in salaries, the possibility for a researcher to own a patent if working in a university was considered a major advantage for a university as

an employer. In addition, the state of Finland was also considered to benefit from its inhabitants' patenting; although research is funded greatly by public funds and a researcher him/herself owns the patent, a share of the inventions will be exploited within the country, thus providing jobs for people and tax incomes for the state.

Knowledge regarding patents and patenting among university researchers in general were often depicted by phrases such as: "…next to nothing" and "…there is no such thing." This was considered the case with the vast majority of researchers, although *remarkable exceptions were mentioned to exist in all universities*. The most of these researchers had had history in industry, in addition to university. The role of the group leader's attitude and knowledge on patenting was emphasised as well; if the group leader was positive towards patenting, the rest of the group knew the benefits of patenting too.

Support for patenting in universities was mainly considered good, if by support other than financial support was meant. Universities together with TEKES and other such organisations were considered to arrange a large number of events and other education regarding patenting and research commercialisation, but the events lack participants. One example was given where only one percent of university's research personnel had ever attended such an event. This was considered the main reason why researchers' knowledge of patenting and its benefits are so low among the majority. On the other hand, none of the interviewed innovation managers had received any education on patenting during their degree-studies, although they represented wide variety of sciences and had received their degrees from different universities.

Financial support on the other hand was considered mostly inadequate, especially in relation to funding for research. Some variation among answers arose on whether the government should directly support patenting in universities. In technical universities direct government support was not as widely supported as in "conventional" universities. It was admitted however, that technical research is more often done in cooperation with companies, in which cases the companies pay patenting costs. For basic research with no industry connections, the idea of direct government support was mostly supported with cautions.

Patenting activity within universities was generally considered low in conventional universities and “quite ok”, as one of the interviewees said, in technological universities. An example of the difference between patenting activities of conventional and technological universities was provided, where within the technological university from five to ten times more patent applications were filed compared to the conventional university in the same city. The difference was explained by the difference in the nature of research done in said universities, technological university producing more applied than basic research, which again majored in the conventional university. In addition, researchers’ lack of knowledge and negative attitudes towards patenting were considered to be a key element in the conventional university’s low patenting activity. However, in all universities knowledge of patenting-related issues has been increasing lately, as well as the number of patent applications filed by researchers.

Among different sciences the universities acted on, natural and technical sciences represented, the largest share of patent applications filed by the researchers. Biotechnology and related sciences were mentioned among the most active in patent appliers of all science fields in all but one university. It became evident during the interviews that none of the universities fully exploited the utilisation potential of their research, including technological universities as well. The most often mentioned factors causing this lack of utilisation were the lack of patenting history and thus no knowledge of the benefits of patenting. This was especially common in conventional universities and among research groups, which’s members had had no industrial career history. Research groups’ industrial connections and cooperation with companies were mentioned to affect positively on patenting activity in universities. In addition, especially group leader’s attitude and knowledge was mentioned to have major impact in knowledge and attitudes among the rest of the group; patenting activity was considered distinctively high among those groups that had leader with positive attitude on patenting.

Another factor mentioned to have a negative effect on patenting activity within universities was the current law of employee inventions, which in most cases grants an inventor in a university full rights for the invention. While most researchers were considered to have but a vague idea of what benefits patenting might produce, and while

the university has no motive or resources to redeem the invention for further exploitation, the possible actions towards patenting are totally dependent on the researcher. On the other hand, transferring rights for inventions done in universities for universities was considered to include the risk that universities' resources would form a limit for obtaining good patent protection for the majority of inventions. For this reason, if the rights of an invention were transferred to universities, the inventor should have a possibility to redeem his/her invention back from the university in cases in which it is evident that university has no resources or interest to obtain patent protection for the invention.

Although the results of this study were not presented to interviewees at this point, they estimated the current situation of Finnish biotechnology patenting nearly the same as the results, albeit they were mostly a bit more optimistic than the results of this study. Based on interviewees' estimations they were asked to state probable effects that would result if current patenting activity, especially of biotechnology, did not rise in the near future. The results were considered severe and including the following implications; research funding, *especially for highly supported biotechnology,* would decline, which would result in decreasing number and size of research groups, which again would result in decreasing magnitude and quality of Finnish science.

Lastly, before the results of this study were presented, the interviewees were asked to evaluate Finland's possibility to form a fourth pillar for its industry out of biotechnology, regarding the current patenting activity. Of all discussion areas of this interview, the answers for this question varied the most; part of the interviewees saw no clear connection between the current patenting activity and the "fourth-pillar aim", whereas some considered low patenting activity clearly as a factor postponing the development of the industry. All agreed however, that it would be possible for Finland to form industry's fourth pillar out of biotechnology, *but within a considerably longer time period than anticipated*. The time period was estimated to be near twenty years from now.

All interviewees confirmed the presented results of biotechnology utilisation to be low. The results were mostly considered expected, although Finland's performance was often even lower than in interviewees' image. Otherwise the results mostly com-

plied with the interviewees' images of the funding and the potential of Finnish biotechnology. Presenting the results did not thus alter the interviewees' opinions of the reasons for the level of patenting activity or any other subject of the interview. Two main reasons for the low patenting activity in biotechnology were mentioned; researchers' negative attitudes and low knowledge of patenting and its benefits, and issues related to the costs of patenting. High costs were mentioned by themselves as factors lowering the patenting activity, as well as the lack of easily obtainable funding for an individual to cover the costs.

To improve Finland's performance in research utilisation, more funds were suggested to be invested in protection of the results. Sources of this improved funding were many, including direct government funding and "patent loans" that would be paid back after the patent began to reimburse. Secondly, instead of funding universities only based on the number of master's and doctor's degrees produced, the number of patents deriving from their research should increase funding respectively. In addition, education of patent/IPR–related issues were proposed to be improved, both among students aiming for a degree and among university staff doing research.

5 DISCUSSION

This chapter discusses the results presented in the chapter 4, thus providing the evaluation of utilisation of biotechnology research in Finland, i.e. fulfilling the second objective of this study. Reasons for Finland's performance in utilisation of research, opinions and recommendations are mostly based on the interviews of innovation managers of selected Finnish universities, as discussed in the section 3.2.1. The areas of discussions of the interviews are available at the Appendix II. The results presented in chapter 4 are discussed and improvement propositions presented first in part I, followed by the applicability of used methodology to obtain information of each area of the study and recommendations for further research in part II.

PART I

The first hypothesis of this study was that Finnish biotechnology research is well funded by public organizations, when compared to other countries. Funding was calculated from each country's government's share of all R&D expenses of the country, assuming that each country invested the same 9 % of all governmental R&D expenses in biotechnology. It can be seen from the calculations (1.)-(4.) that Finland had the smallest investments in biotechnology R&D, if population is disregarded. On the other hand, if funding is related to population, Finland shares the second place with Sweden, with precisely the same sum invested to bioresearch *per capita.* Finland and Sweden are only slightly after the US and considerably ahead of the UK. It must be noted that the share of each government's investments on biotechnology research was estimated to be the same 9 % that it is in Finland. There is reason to believe that, especially regarding UK, the share is smaller the used 9 % of all public R&D costs. This view emerged in the interviews done for this study, and can also be concluded from the country's relatively low citation index value of 1.1 (Table 6.). Had the UK government supported basic biotechnology research with same share of its all R&D expenses as Finland, the country's science would probably be scientifically more important and thus cited more. No such information was available regarding Sweden and the US and therefore it is estimated that they used 9 % share of all of

their R&D expenses for biotechnology. Based on calculations (1.) - (5.), it can be stated that the first hypothesis was right and *Finland's public biotechnology research funding is internationally competitive*.

The second hypothesis of this study was that Finnish biotechnology research is scientifically important and high in impact. Scientific importance was measured by relative citation indexes presented in Table 6, with higher values presenting higher importance of published articles. In this measurement, Finnish articles shared the second highest relative impact position with Netherlands (average value 1.6), after only Swiss articles with average value of 1.8 (Table 6). When assessing the utilisation potential of a country's science however, the magnitude of the research must be recognised, because it can be assumed that more research includes more patentable inventions. The utilisation potential of each country's science was measured by total impact (multiplying the average values of Table 5 by the average of Table 6), higher value meaning higher utilisation potential. Finnish biotechnology research received the lowest value of total impact due to the low share of all articles of the field. However, when related to population (calculation 7.), Finnish bioresearch again received the second highest value (2.8) being only slightly behind Sweden (3.1) and leading considerably UK (1.7) and the US (1.2). Thus, based on calculation 7, it can be stated that Finnish biotechnology research - when related to population – *is internationally competitive in impact*. This proves right the second hypothesis of this study; that it could be therefore expected that *there is relatively high utilisation potential in Finnish biotechnology research.*

The first objective of this study was to count the actual number of patents issued to Finnish inventors, because all previous studies had focused on patent applications and not the issued patents. No method was available to separate industrial patents from those applied by public research institutes and their employers. Thus the result, 507 patents issued to Finnish inventors by PRH, EPO and USPTO, included all patents that had a Finnish inventor, disregarding whether their research was done in industry or in a public research organisation. The result had to be compared then to the number of patents issued to inventors from other countries to assess Finland's performance. Data regarding patents issued to other countries than Finland by EPO was

unobtainable as discussed in section 3.3.2, for which reason the patents issued by USPTO were used for international comparison.

Finland's tendency of patenting its research results was measured in calculations (8.) and (9.). Calculation (8.) related the number of patents to population, while a larger developed country probably produces more patents than a country with smaller population. The result indicated that *Finland produces least patents per million of people,* of the countries that were measured. Although only a little behind UK in this calculation, Sweden (which is Finland's closest competitor and most similar in its research culture) produced nearly twice as many patents per million of people. As expected, the US held distinctively the top position of this chart with twice as many patents as Sweden. In calculation (9.), a country's patents-per-population were divided by its science's total impact, or its utilisation potential. This calculation regarded a country's size while examining its tendency of patenting research results, i.e. exploiting the utilisation potential of its research. As can be seen from calculations (8.) and (9.), Finland has had a low tendency of patenting its research results, even though the impact of the research is high related to population. While high impact of research is expected to include high utilisation potential, it is stated that *the high utilisation potential of Finnish biotechnology research is not well exploited in international comparison.*

Further information of a country's tendency to utilise its research was achieved by relating the number of issued patents to received public funding and received public funding *per capita*. This was done in calculations (10.) and (11.). As could be seen from these calculations, Finnish researchers and organisations have the lowest patenting activity per received funding of the countries participating in this study. Sweden led Finland with almost twice as high number of patents per received funding and thrice as high number of patents per received funding *per capita*. Both of these calculations were led by the US with almost seven-fold lead to the seconding UK, in calculation (11.). Based on calculations (10.) and (11.), it is stated that in relation to received funding, *Finnish biotechnology research is not well utilised in international comparison.*

Furthermore, patenting activities of selected US-based universities were presented in Tables 12 – 16, to obtain even further information of Finland's performance in biotechnology patenting. The universities were selected among those that commonly are supposed to produce academically important research. The funding these universities used for biotechnology research, or the personnel of the universities were not explored. These universities represent non-profit research organisations, for which reason they were good entities toward which Finland's performance could be compared. Based on Tables 12 – 16, there is reason to believe that Finland has not used all measures available to improve its performance in research utilisation: A non-profit research institute like a university, was issued to more patents *in four years* than a whole country including its industry *in five years* (656 patents issued to the University of California by only USPTO vs. 507 patents issued to Finnish inventors by *three* patent authorities). The contrast was even greater if Universities' patents were compared to Finland's patents only in the USPTO: the Universities of California, Texas and Johns Hopkins patented more than Finland, although their patenting activities were only obtainable from a time-period of four years.

The second objective of this study was to evaluate biotechnology research utilisation in Finland. Biotechnology and related sciences were among top innovators within Finnish universities, (considering the government inputs in biotechnology research this was expected) but as can be seen from calculations (8.) – (11.) and Tables 12 – 16, inadequate in international comparison. As an answer to the second objective, based on calculations (8.) – (11.) and Tables 12 – 16, when relating issued patents to either the utilisation potential or the funding of the research, *Finland's performance in utilising its biotechnology research results is evaluated to be low.* Finnish biotechnology research receives competitive funding and produces results with high utilisation potential, but the *potential is not exploited efficiently.*

An implication of the current utilisation of biotechnology research maintaining in the future is radical decline of funding for biotechnology. Already there have been signs of financiers' patience ceasing; e.g. former Prime Minister Lipponen considered this as an evident consequence if commercial results will not soon arise out of biotechnology (see section 1.1). Similar speeches have also been given lately by the executives of private sector's financing organisations, of which some have already can-

celled or postponed their investment plans and support for biotechnology. Similar actions were expected by the interviewees from government in five to ten years in the future. It would be beneficial for Finland to use all possible measures available to prevent this from happening, otherwise the promising future of Finnish biotechnology, both scientific and industrial, is threatened. On the other hand, as all interviewees believed, Finland has a good possibility to form a fourth industrial pillar out of biotechnology. Kafatos *et al.* (2002, 11) believed in this as well, saying that Finland "(…) has a very real chance to become one of the most successful small countries in the world in biotechnology." For this reason the *competitive support for biotechnology, both public and private, should be continued in the future.*

The two main reasons causing Finland's low performance on biotechnology research utilisation were already mentioned in chapter 4.4: Commonly there has been no history of patenting especially in conventional universities, in addition to which researchers' knowledge and negative attitudes towards patenting (partly deriving from the lack of knowledge) lower the patenting rate. The interviewees proposed two actions to be taken to improve the knowledge; including IPR/patenting education within the degree studies and offering more education to university staff. While both of these approaches are recommended, especially including IPR/patent education within degree studies, it must be noted that the problem of low level of researchers' knowledge was not caused by the lack of educational events, but instead low participation to those events. To more efficiently use the existing resources, *attracting more people to the existing events is recommended,* instead of arranging more events. To attract more people, following measures are proposed to be taken:

a.) Reviewing the location and timing of the events: See if it is possible to arrange the event together with some other event more popular among researchers.
b.) Reviewing the way in which the message is delivered to the audience: See that the speakers are "on the same level" with the audience, i.e. that they don't exaggerate the benefits or belittle the threats, and that they use language and terminology familiar with the audience.
c.) Reviewing the other measures taken to attract participants: If there are no other attractions in the event than just the information from the

speeches, some small “hooks” should be placed. These could be for example availability of coffee and other refreshments, or similar small things. If such attractions exist, their effectiveness should be reviewed.

Another aspect affecting negatively on patenting activity was the costs of patenting, together with the lack of easily obtainable funding for an individual. As Kafatos *et al.* (2002) suggested, *TEKES should consider participation on defraying patenting related costs*. In addition, a common suggestion of the interviewees was to increase the funding for patenting purposes. On the other hand, while resources for this kind of improvement are limited, it is proposed that *the focus of existing public research funding should be shifted a little towards the end of research, i.e. towards the exploitation of the results*, instead of just supporting the beginning of research. Furthermore, *it is suggested that the financier of research should require patenting of the results, in addition to requiring academic results.* This could be required in cases that evidently include commercial potential and in cases where the application for financing expects commercial applications from the research.

The interviewees’ suggestion of universities’ funding being not only based on the number of degrees produced but as well the number of patents deriving from their research, is recommended. This would add universities’ motivation to patent inventions done in their research, *especially if combined with the transferring the rights for inventions to university.* Caution should be used with this system however, while not all sciences produce patentable findings. Therefore the used of this type of funding should be limited to technical and natural sciences. The recommendation is based on the new law depicting universities’ missions, of which one expects that universities have influence in surrounding society. Patenting research results, by being a key element in commercialising biotechnology, causes some share of the results to be used in Finland, thus fulfilling the law’s requirement of social influence.

Lastly, the ownership of inventions in universities was considered to have effect on the low patenting activity of Finnish biotechnology by both the interviewees and the study by Kafatos *et al.* (2002). Furthermore, the US’s leadership in biotechnology is supposedly caused at least partially by the ownership structure of their university inventions, which makes the university the owner of the inventions. Many of the US

universities have a Technology Transfer Office (TTO) that is responsible for reviewing the invention declarations[1] (which are obligatory) submitted by researchers and, in case of commercialisable invention, filing a patent application before allowing publishing of the research. TTO's are mostly financed with revenues from existing patents, thus requiring no major financing from the university's other parts. Applying this model of invention ownership and technology transfer to Finland might raise the patenting activity and utilisation of inventions in Finnish biotechnology. Thus, as it was proposed in Kafatos's *et al.* (2002, 60) and by the interviewees, *the ownership of inventions should be shifted from the inventor to the university,* with obligation on the owner to include the inventor in a significant share of the revenues from the patent. In addition, a few *TTO's or companies with sufficient resources should be formed to serve Finnish universities to raise patenting activity and utilisation of inventions.*

PART II

The methodology of this study comprised of two parts; literal sources based on which the amount of research financing and the impact of the research were resolved, the number of patents counted, different variables calculated and finally Finland's performance in research utilisation evaluated. In addition, semi-structured interviews were done to find the reasons for Finland's performance in research utilisation.

Out of the fifty-nine sources referred to in this study, thirty-nine were published during or after the year 2000. Of the remaining twenty, twelve were published between 1993-1999. The literal sources thus represent the newest research, which adds their validity. In addition, a major share of the sources represented acknowledged authors (e.g. Porter and Teece), journals (e.g. California Management Review and Nature Biotechnology) and organisations (e.g. European Commission, OECD and Statistics Finland), which again add their credibility and reliability.

Generally, the results and recommendations in this study are in good agreement with the recommendations of the Kafatos' *et al.* (2002) study (for the Academy of Finland)

[1] keksintöilmoitus

assessing Finland's biotechnology funding. This can be considered as further proof of the accuracy of the conclusions of this study.

Criticism against the fulfilment of the first objective, counting the number of biotechnology patents issued to Finnish inventors, could be made. The sources regarding the number of patents vary somewhat, and the harmony of the criteria of counting certain patents as biotechnological cannot thus be confirmed. This may add error to the final figure. In addition, USPTO's defines the origin of a patent by only the origin of the first name inventor, which causes error if multinational research group is the applicant. However, a more reliable figure than the one presented in the results could only be achieved by counting each issued patent by hand, which exceeds the scope of this study, as discussed in the chapter 3.3.1.

Criticism against the evaluation of Finnish biotechnology research utilisation can be made too: The evaluation based partly on calculations using rather abstract variables, like the total impact of a country's research. On the other hand, the aim of this study was to *evaluate Finland's research utilisation performance against other countries* and *not* to calculate absolute figures depicting the variables. For evaluation between countries, the selected method was reliable, because the performance of every country was assessed using the same method.

In addition, the use of only the patents issued by the USPTO in measuring patenting activity can be criticised. More accurate result would be achieved if patenting in all patent systems were counted. In theory, it is possible that other countries prefer patenting in USPTO to EPO or local patent authority, in which case the their total number of patents would not radically change even if EPO and local authorities were counted as well. If the case was such, Finland's performance in patent activity in relation to the size of the country would dramatically improve, while utilisation performance could be calculated using total number of patents issued. In that case Finland's 507 patents would be very competitive against Sweden's but a little more than 638 patents that they are issued to now. This can be considered unlikely however, for which reason Finland's research utilisation performance in biotechnology can be evaluated low.

A possible source of error can be found from the presumption that each country devoted 9 % of its total R&D expenditures to biotechnology. The presumption was done because no reliable and comparable information regarding the share of biotechnology of all R&D expenditures was found from other countries than Finland. This was caused by varying definitions of biotechnology, several sources excluding some essential sciences from their definition (see also section 3.1.2).

Three subjects are suggested for further research:

1.) To study how the patented research results have succeeded in commercialisation. It must be noted that patenting only *enables* commercialisation (and thereby income) and does not produce it by itself. Therefore it would be informative to investigate patents' success in commercialisation to enable more effective commercialisation in the future. This was not studied here, while this study focused on the enabling step of commercialisation, and not commercialisation itself.
2.) To study both the inventional and patent-technical quality of the issued patents. To be able to well exploit inventions, they must be both important as inventions and protected well against competition. This was not studied here, while the aim of this study was to assess the magnitude of biotechnology research patenting, not the quality of it.
3.) To study universities' patenting performance in other sciences than biotechnology. During the interviews for this study, clues were found suggesting that university researcher's share of all high-technology patent applications was rather small. This was not studied further here, while this study focused on patenting biotechnology.

6 CONCLUSION

Finland's performance in utilising its biotechnology research results proved to be low in this study. The high utilisation potential of biotechnology research produced by high quality science has not been exploited efficiently. Implications are severe if utilisation level is not raised by active measures; research funding declines, which leads to decreasing number and size of research groups, which again results in decreased impact of the remaining science.

Main reasons for Finland's low performance were low level of knowledge of patenting and its benefits and negative attitudes of majority of researcher's towards it. The other main reason was the high costs related to patenting, together with the unavailability of easily obtainable funding to cover the costs.

Suggested improvements to raise Finland's biotechnology patenting activity were:

1.) Adding IPR/patent –related education to degree studies
2.) Review and possible refocus of IPR/patent –related education aimed at researchers
3.) Refocusing research funding from the beginning of research towards the end of it
4.) The requirement of funding organisations of patenting research results in addition to requiring academic results
5.) Basing universities' basic research funding not only on degrees produced but also on patents produced
6.) Transferring the rights for inventions done in universities to the universities from the researchers[1] and establishing a few well resourced Technology Transfer Offices responsible for application, costs and commercialisation of patents.

To succeed in formulating a fourth pillar for industry out of biotechnology, in addition to producing purely scientifically and academically valuable research, Finland should effectively protect research results to enable commercial use, or utilisation, of them.

[1] Giving the inventor the right to redeem inventions not utilised by the university

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8 APPENDICES

APPENDIX I: INNOVATION MANAGERS INTERVIEWED

Name	Date of the interview	University
Jari Rantala	6.5.2003	University of Helsinki (Kumpula campus)
Juha Kiljunen	12.5.2003	Tampere University of Technology and University of Tampere
Janne Virtapohja	13.5.2003	University of Jyväskylä
Anssi Toivanen	14.5.2003	University of Kuopio
Kristiina Heiniemi-Pulkkinen	15.5.2003	Helsinki University of Technology
Anne Grönlund	16.5.2003	University of Helsinki (Viikki campus)

APPENDIX II: FRAME OF SEMI-STRUCTURED INTERVIEWS

Interviews and questions originally done in Finnish.

Subject: The state of patenting in public Finnish biotechnology research.
(Results of the study not presented)

1. What is your experience of patenting?
2. Do you consider patenting important for technology development?
3. In your opinion, what are the good sides of patenting? What about bad sides?
4. In your opinion, do patents have any special meaning in biotechnology?
5. How would you describe university researchers' knowledge of patenting in your university?
6. In your opinion, is patenting beneficial for a university researcher/for university/ for government? If yes, how is it beneficial?
7. Is patenting currently supported in your university? Is the support adequate? Should government support patenting in universities?
8. How would you describe current patenting activity in your university?
9. How many patents are applied from your university each year?
10. Of what faculties/sectors do the patents/patent applications come?
11. In your opinion, what factors affect the patenting activity in your university?
12. What
    a. short term
    b. long term

    consequences/implications would you think current (bio)patenting activity will have?
13. How would you comment Finland's objective to develop a "fourth pillar" for its industry out of biotechnology (beside metal, forest and electronics/IT industries), with respect to current patenting activity?

(At this point, the results of the study are presented)

14. Did the presented results of biotechnology patenting activity reflect your own view of the activity?
15. Did the presented results somehow change your opinion of any of the previous subjects of this discussion?
16. In your opinion, what affects the patenting activity in your university?
17. What are your suggestions to increase patenting activity in your university?