Wageningen University – Department of Social Sciences

MSc Thesis – Management Studies Group

Anticipating industry convergence on the basis of publicly available data

The case of probiotics

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Management Summary

Industry convergence plays an important role in shaping market and industry segments. It is described as the blurring of boundary between two or more distinct industries. The convergence of demand structures, technology platforms and regulations by formerly different industry sectors leads to the occurrence of industry convergence. The study of industry convergence would be an important tool for innovation management since the world of innovation is also influenced by these three main characteristics of industry convergence. The emerging of industry convergence not only provides an opportunity for the new field of business but also provides some difficulty for firms to enter this new industry segment. Due to limited absorptive capacity, firms might lack of the essential knowledge and expertise. Therefore, the aim of this study is to anticipate the convergence at the earliest stage in order to allow firms to be able to prepare for all the challenges and downsides of the new segment.

Food industry is an interesting sector in this study and a good example of industry convergence in this sector would be the concept of functional foods. Probiotics are the main case in this study. Probiotics are applicable in many industries i.e. food, pharmaceutical and personal care products.

Monitoring tools which are used to foresee or detect industry convergence are publicly available data. Patents and scientific publications are selected since they are easily accessible and provide systematic scientific and technological data. By analysing publications, it is possible to detect the interesting knowledge fields from each industrial perspective. On the other hand, patents are a good source for detecting the advanced technologies from the most dynamic firms. The weighted average year (WAY) is used to calculate the time lag between publications and patents in order to explain the time series event of the convergence process.

Our preliminary finding is that the Food & Agriculture industry is strongly active in both filing patents and publishing scientific publications in the field of probiotics. The majority patenting and publishing behaviour in our samples are firms have mainly filed or published within their own core competences except for the Chemicals sector. Firms in the Chemicals sector file their patents with respect to commercial applicability. They filed their patents in the area of Food & Agriculture and Pharmaceuticals since these two subject areas are related to the interest of their customers. From the development over time of the share of subject area across all industrial sectors between patents and scientific publications, the result shows that the total share of the subject area is proportional to the application of probiotics. Food & Agriculture area controls the majority of share followed by the Pharmaceuticals area. It can be implied that the new product in the field of probiotics is mainly related to Food & Agriculture areas with the additional application in the Pharmaceutical area.

The most interesting result which has been found in this study is that there is the occurrence of intra-firm collaboration and joint collaboration. Even though these industry sectors are not the dominant industry sectors, they represent to certain degree of the fading boundaries in the field of probiotics. Firms are more interested not only to share upon knowledge and expertise but also to share risks in

introducing new products to the market. However, the correlation between these firms and technological complexity is relatively low. These firms are normally not filed their patents in the high technological complexity areas.

The expected ideal time series of the convergence process start with the cross-scientific knowledge and is followed by the convergence of technology. This process is found in this study; however, the time lag between knowledge and technology convergence is not outstanding i.e. the weighted average year of patents and publications are quite close to each other. The reason might be the interest in the field of probiotics is just started from the year 2000. It implies that most of the active firms are continuously seeking for knowledge and at the same time starting to protect their inventions in the form of intellectual property e.g. patents.

The further step that should be taken into account in order to access the full time series event of convergence is the relationship of patents and the new hybrid products on the market. A new monitoring tool should be constructed in order to test whether certain patents lead to new hybrid products in the market.

Preface

The writing of the thesis is an important part of the course at Wageningen University and Research Centre in which students are working on a specific research topic. By doing a thesis, students are enabled in bringing their knowledge into practice, learning how to solve problems and most importantly working independently.

During the 6 month period working on thesis, the study at hand focused on the analysis of industry convergence in the case of probiotics. This study basically deals with detecting trends of industry convergence of the food, pharmaceutical and related sectors on the basis of patents and scientific publications.

The author would like to thank Dr. Stefanie Bröring and Frances Fortuin who gave the guidance during working on this study. Dr. Stefanie Bröring is an expert in this research, she always gives nice comments and guidance in each step of this study. Frances Fortuin is always a good supporter and gives helpful recommendations. I also would like to thank Dr. Monique Vingerhoeds and Dr. Greer Wilson who also supported this study. Monique Vingerhoeds is employed by TI Food and Nutrition (TIFN). TIFN is not only provided access to Thomson Innovation but also provided support. Dr. Greer Wilson is a Science Consultant without them this study could not be accomplished. I also would like to thank Mr Ard Ellens, European and Dutch patent attorney, and Mr Olav Schmitz, Senior patent information specialist, both from Nederlandsch Octrooibureau, who gave a good introduction to the world of intellectual property.

Moreover, I would like to thank my family who always stay beside me and support me when I confronted with some difficulties. I also would like to thank all of my friends who always give good advices and be patient in teaching me how to use Microsoft Excel properly and efficiently. There are more people that I am not mentioning here but who were of high value for this study. I would like to thank them for their help and support.

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List of Abbreviations

Appx Appendix

B2B Business-to-Business

EU European Union

GPS Global Positioning System

IPC International Patent Classification

LAB Lactic Acid Bacteria

NFF Nutraceuticals and Functional Foods

OECD Organization for Economic Co-operation and Development

P P-value (refers to the signifiance different value)

PDA Personal Digital Assistant

R Correlation coefficient

R&D Research and Development

SBUs Strategic Business Units

SIC Standard Industrial Classification

SPSS Statistical Package for the Social Sciences

WAY Weighted Average Year

WHO World Health Organization

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1 Introduction

1.1 Problem Definition: Probiotics as a Case for Industry Convergence

Industry convergence is described as the blurring of boundaries between industries. In the past, this phenomenon could mainly be observed in the telecommunications, the information technologies and the electronics industry. Recently, many new industry segments have emerged from this phenomenon such as the occurrence of 'nutraceuticals' from the convergence of the food and pharmaceuticals industry. The blurring of boundaries is triggered by the convergence of demand structures and technological platforms as well as a trend towards the same regulation being employed by formerly different industry sectors (Bröring, 2005). As a result of convergence, the new industry sector has emerged. Due to limited absorptive capacity (Cohen and Levinthal, 1990), it is rather difficult and challenging for firms to share or use knowledge and technologies that are not within their competences. In other words, the emergence of industry convergence likes a sword i.e. it not only give a new opportunity for firms but at the same time it also provide some treat for firms. Some firms have made considerable attempts to cross the industry boarders, and failed (Gambardella and Torrisi, 1998). Normally, firms that are facing the difficulty in entering the new product markets are not triggered by a weak commitment to technology but rather by the inability to connect to the new 'value networks' (Gambardella and Torrisi, 1998). The value networks refer to special suppliers, customers, which are important for production and commercialization of the new products (Gambardella and Torrisi, 1998). Therefore, it remains important for firms to detect the trends of convergence at the earliest possible stage in order for them to identify business opportunities and the required competences, to source the essential knowledge and experiences beyond their own expertise and also search for new value networks (Curran, et al., 2010). Anticipating convergence will allow firms to be able to prepare for all the challenges and pitfalls of the new segment in advance.

The question remains 'how to foresee or detect the occurrence of convergence at the earliest time?'. Scientific publications and patents can be a good monitoring tool for foreseeing or detecting the blurring of industry boundaries. Both scientific publications and patents are easily accessible and provide systematic scientific and technological data. Publications can be used to detect the new field of knowledge which some firms or research organizations are interested. Patents can be used as a proxy for the innovative activity and demonstrating a positive correlation between the most dynamic firms and leadership in specialized technological subsidiaries (Wilkinson, 1998). In addition, most big companies always protect their invention by patenting. This might enhance the possibility to foresee the technological development. According to Wilkinson (1998), Nestlé is responsible for 7% of patents in the milk industry and 8.5% of all patents in the diversified food sector. General Foods Corporation filed the patents in diversified food sector in the period 1969-1988 which accounts for 8.7% of diversified foods sector. Unilever and Procter & Gamble each are responsible for over 7% of the patents in the chocolate, confectionery and non-alcoholic drinks sectors. Unilever alone is responsible for over half of the patents generated within the oil and fat industry (Wilkinson, 1998). Even though there are many shortcomings

of using patents as monitoring the trend of technological knowledge e.g. the patent information is never up to date since it is published one and a half year after filing. Patents are still be an achievable monitoring tool for foreseeing the overview of how far technological areas and firms from different industry segments are already interwoven at any given point in time (Curran, et al., 2010).

The world of food industry are more and more cross scientific research by which many food companies try to use the technological developments from other industries thus creating the phenomenon of industry convergence (Curran, et al., 2010). A good example is the concept of functional foods. Probiotics are the case in this study since it is classified into the group of functional foods. Probiotics are also provided a broad application for the different end uses, thus there is a possibility to detect the convergence. In addition, they allow for a comparison with the case of phytosterols which has been analysed initially by Bröring (2005) and was further refined by Curran, et al. (2010). According to Siezen and Wilson (2010), there have been over 2000 patent applications of probiotics filed and some 524 granted in the USA and Europe since 1981. The high number of patent applications might imply that the application of probiotics is not only restricted to the food industry but also to other industrial sectors such as the personal care sector or the pharmaceuticals sector (Siezen and Wilson, 2010). In addition, probiotics are also used in animal and fish feeding in order to enhance growth by replacing banned additive antibiotics or growth hormones (Siezen and Wilson, 2010).

In short, this study would be an important tools for innovation management since the world of innovation also influenced by the three main characteristics of industry convergence i.e. technologies, markets and regulations.

1.2 Conceptual Design

1.2.1 Research Objective

The objective of this research is:

"To foresee or detect the trend of convergence by using publicly available data including patents and scientific publications in the case of probiotics"

After analysing types of research written by Verschuren and Doorewaard (1999), this study could be described as *theory-testing* research. In theory-testing research, the existing views are tested, adjusted if necessary and/or refined (Verschuren and Doorewaard, 1999). In this study, the monitoring concepts developed by Curran, et al. (2010) are refined and tested in order to anticipate the industry convergence in the case of probiotics.

1.2.2 Research Issue

The central research question of this study is:

"How publicly available data, including patents and scientific publications, help to foresee or detect the trend of convergence in the case of probiotics?"

Sub-questions that together should answer the central research questions to meet research objective can be formulated as follows:

Q.1 Can one detect the trends of convergence in patents and scientific publications before and/or during the product emergence?

Q.2 Is the convergence in the case of probiotics different from the case of phytosterols in terms of:

a) the publication and patent behaviours,

b) the dominant industry and cross-sectoral applications and

c) the pattern of convergence?

Q.3 How does the probiotics landscape develop in time?

1.2.3 Research Framework

In this study, the research framework is divided into four sections which included literature reviews, empirical studies, results and conclusions (Figure 1).

The first section is the *literature review*. This section provides an in-depth understanding on the industry convergence, intellectual property, probiotics and their application. An understanding of this information is of paramount importance in getting into the nature of convergence and intellectual property especially patents. Furthermore, the review on probiotics and their applications will introduce us to the world of probiotics. By reviewing this literature and Curran, et al. (2010), the theoretical framework can be refined.

During the *empirical study*, the scientific publications and patents were analysed for monitoring the trends of convergence. The data analysis is mainly based on the case of probiotics. The question *'Can one detect the trends of convergence in patents and scientific publications before the product has emerged on the market?'* can be answered. After analysing the industry convergence in the case of probiotics, the comparison between the case of probiotics and phytosterols is made to answer the question *'Is the convergence in the case of probiotics different from the case of phytosterols in terms of the publication and patent behaviours, the dominant industry and cross-sectoral applications and the pattern of convergence?'* The next question on *'*How does the probiotics landscape develop in time?*'* can

be answered by analysis of the landscape maps in the field of probiotics and the main indication/application areas of probiotics.

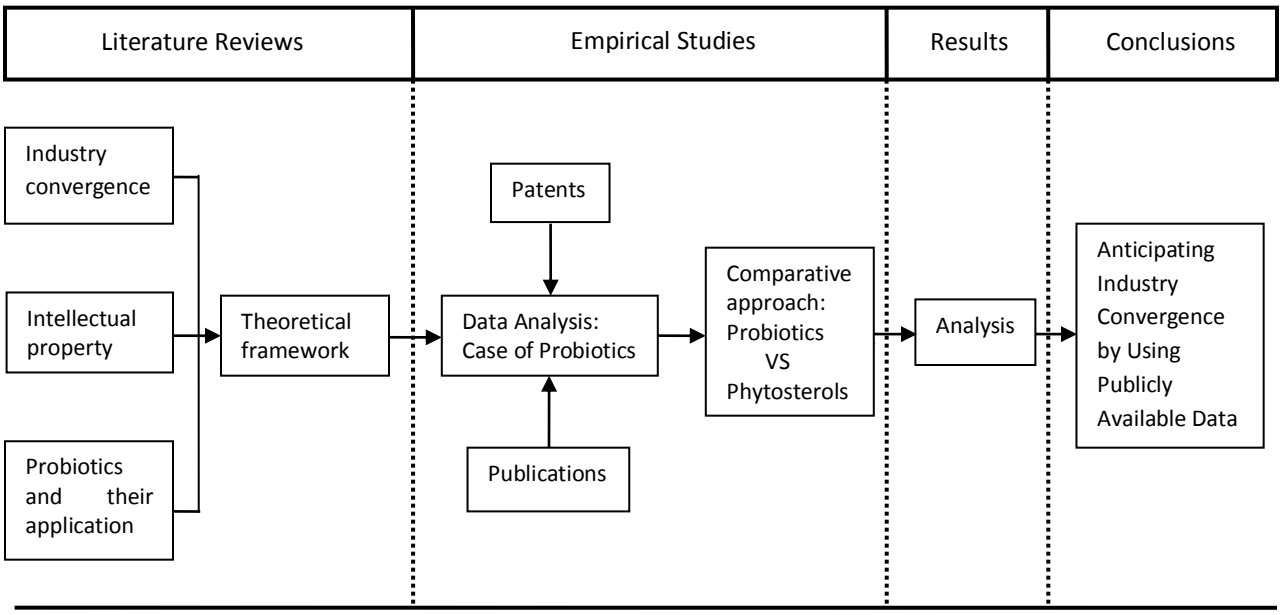

Figure 1: Research framework.

1.2.4 Definition of Concepts

Industry Convergence: Convergence can be seen as a process and a product. During the *process* of convergence two or more industry-sectors build an intersection and thereby a new inter-industry segment is emerging as a *product* of convergence (Bröring, 2005).

Intellectual Property: Intellectual property concerns the legal rights associated with creative effort or commercial reputation and goodwill (Bainbridge, 1999).

Patent: Patent is a legal grant by a government for any new inventions which are susceptible to industrial application, which are new and which involve an inventive step (Bainbridge, 1999).

Probiotics: World Health Organization (WHO) defines probiotics as the living microorganisms that when administered in an adequate amount confers a health benefit to the host (Vasiljevic and Shah, 2008).

Phytosterols: Phytosterols are plant-derived sterols that are structurally similar and functionally analogous to cholesterol in vertebrate animals (Ostlund, 2002).

1.3 Research Design

1.3.1 Research Material

In order to perform the research, there are several methods employed. A large part of this study will be conducted on the basis of:

Published material: journal articles, books, dissertation

Publicly available data: patents and scientific publications from Thomson Innovation

The literature review is comprised of the published materials which have been searched using Wageningen University's digital library. The most used resources are the Web of Science and Scopus. The hard copy of the textbooks as well as the electronic books (e-books) that are relevant to the industry convergence and intellectual property are also included and taken from Wageningen University's library.

In the latter stage on the empirical study, the scientific publication and patent data on probiotics are accessed from Thomson Innovation. Thomson Innovation is a single and integrated solution that combines intellectual property, scientific literature, business data and news with analytic, collaboration and alerting tools in a robust platform (Thomson Innovation, 2010). Thomson Innovation has the world's most comprehensive collection of patent data, from major patent authorities, specific nations and proprietary sources exclusive to Thomson Reuters. Thomson Innovation also makes a cross searching scientific literature easy and interesting (Thomson Innovation, 2010).

In order to obtain all relevant information from Thomson Innovation, it is very important to use an appropriate search term and technique during data mining. These data are analysed in order to investigate the correlation between industry sectors and subject areas. Moreover, the comparative approach between two cases, probiotics and phytosterols has also been performed during the empirical study.

1.3.2 Research Strategy

Desk research and Grounded theory approach strategy are two research strategies that will be used in this study. Desk research strategy is characterized by the use of existing materials, articles and literature produced by others. These materials will provide a broad knowledge about the theories (Verschuren and Doorewaard, 1999). Desk research is used to gather the information on the industry convergence, intellectual property and probiotics and their application. Part of this study is carried out according to the grounded theory approach. The grounded theory approach is used to gain the theoretical insights with only the minimum of prior knowledge and through continuously correlating the phenomena (Verschuren and Doorewaard, 1999). Part of the research technique that is often associated with the grounded theory approach is the method of continuous comparison (Verschuren and Doorewaard,

1999). Among many types of the continuous comparison method, the secondary theoretical comparison is applied in this study. The secondary theoretical comparison allows researchers to compare a phenomenon with theories formulated by other researchers (Verschuren and Doorewaard, 1999). In this study, the comparative approach of a phenomenon of the industry convergence in the case of probiotics with the theory formulated by Curran, et al. (2010) in the case of phytosterols is carried out.

2 *Characterizing Industry Convergence*

2.1 Definition of Convergence

When attempting to define an inclusive definition of convergence from existing literature, the perception of the term can be rather vague (Katz, 1996). The Organization for Economic Co-operation and Development (OECD) provides a commonly used definition of convergence as "blurring of technical and regulatory boundaries between sectors of the economy" (Hacklin, 2008). A broader definition of industry convergence defined as a blurring of "boundaries between industries by converging value propositions, technologies and markets" is provided by Choi and Välikangas (2001). Many articles have taken the definition of convergence from Pennings and Puranam (2001). The general definition of convergence could be described as the impact of blurring boundaries between industries, which in turn poses challenges to firms and forces them to face the new technologies, consumers and needs (Pennings and Puranam, 2001).

2.2 Typologies of Convergence

The two basic types of convergence proposed by Greenstein and Khanna (1997) are convergence in substitutes and convergence in complements. In other words, the new industry segment either replaces the former segments or complements them at their intersection (Bröring, 2005; Curran, et al., 2010).

2.2.1 Convergence in Substitutes

When there is a redundancy between the previously separate industries resulting in one competing with the other, the situation normally leads to the occurrence of convergence in substitutes (Bröring, 2010; Curran, et al., 2010). This type of convergence occurs when different and interchangeable products share features and provide the same function for the end-users (Weaver, 2007). For example, the mainframe and minicomputer (PC) industries are converged overtime as the computing power of PCs increased (Weaver, 2007). The integration of telecommunications, media and consumer electronics are another example of partially substitutive convergence. This convergence happens from a merger of technologies, distribution platforms and markets. However, this example is not a total convergence in substitutes by large industries but rather by a number of many small sub-segments (Bröring, 2010).

2.2.2 Convergence in Complements

Complementary convergence occurs when there are synergistic effects between two previously separate industries and the results are more than the sum of its parts (Weaver, 2007; Bröring, 2010; Curran, et al., 2010). Previously unrelated products are bundled together and form a new combined and integrated class of product (Weaver, 2007). This new segment of product normally provides added value for the end users (Weaver, 2007). This type of convergence does not lead to a phasing out of the formally distinct industry (Bröring, 2010).For example, the mobile phone manufacturers integrate all types of portable technology amongst which are digital cameras, digital music players, Global

Positioning Systems (GPS), Personal Digital Assistant (PDA) (Weaver, 2007). Another example of complementary industry convergence is the occurrence of 'nutraceuticals'. This new segment is driven by the integration of different technologies and market demands (Bröring, 2010).

Besides these two basic types of convergence categorized by Greenstein and Khanna (1997), Pennings and Puranam (2001) also derived other model types of convergence (Weaver, 2007). The classification by Pennings and Puranam (2001) basically depends on the supply and demand side (Wegberg, 1995). Convergence on the supply side occurs when the two different industries increasingly use the same knowledge base. On the other hand, convergence on the demand side occurs when the market boundaries become blurred both within and between the two distinct industries (Wegberg, 1995).

2.3 Patterns of Industry Convergence

There are different levels and sources of convergence which occur in almost any combination (Bröring, 2010). The different patterns of industry convergence are differentiated with regard to the implications of the firms that are involved (Bröring and Leker, 2007). According to Bröring (2010), the patterns of industry convergence are distinguished into input-side and output-side. This pattern of industry convergence from Bröring (2010) follows the work of Malhorta and Guota (2001) in distinguishing the industry convergence. The overview of input-side and output-side convergence is shown in Figure 2.

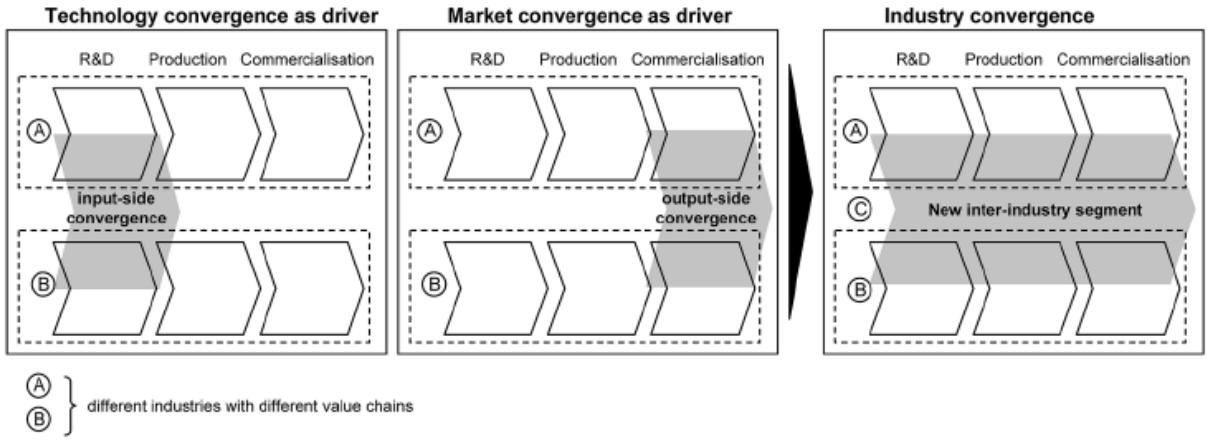

Figure 2: Input-side and output-side convergence and resulting in industry convergence (Bröring, 2010).

2.3.1 Technology-driven Input-side Convergence

The patterns of technological developments and technological competencies vary significantly between industries (Bröring, 2010). When new technology areas arise and are applied across industry, the difference in technological developments and competencies might decrease (Bröring, 2005). This finally leads to a blurring of industry boundaries. The input-side convergence refers to the converging trends of technologies and technology-platforms (Pennings and Puranam, 2001; Bröring, 2010). Another possibility is that both distinct industries start to develop a new technology platform hence enhancing

convergence between these two different industries (Bröring, 2005). In other words, the technology-platforms grow together and start to fuse (Bröring, 2010). The fusion or technology platforms or technology convergence can be further differentiated into substitutive and complementary convergence (Bröring, 2010). The substitutive aspect of technology platforms occur when the different technologies become similar and lead to a replacement of the conventional approach (Bröring, 2005). The complementary of technology platforms is contradictory to substitutive technology convergence by which the different technologies come together to create a new functionality (Bröring, 2010). The input-side convergence is different to output-side convergence by which the convergence of production platforms is not always visible for the end consumer (Bröring, 20005).

There is an argument by Gambardella and Torrisi (1998) on the possibility that the technological convergence initially leads to a convergence in the end-markets. They argued that the technology convergence does not always lead to the convergence in end-markets as the commercialisation to the distinct end-users is too different. For example, the telecommunications equipment is sold to buyers (carriers) and PCs or consumer electronics as the different end-users. These two users are different in term of size of the market and their demands for the product. Therefore, the commercial services and distribution between these two groups are entirely different (Gambardella and Torrisi, 1998).

2.3.2 Market-driven Output-side Convergence

The output-side convergence is caused by converging demand structures of the different industries (Bröring and Leker, 2007). In short, this output-side convergence occurs when customers treat products of different industries in the same way. It occurs when the products which originally do not stand in the competition between two industries start to become substitutes (Pennings and Puranam, 2001; Bröring, 2005). Market convergence can be seen as a result of an increasing trend towards convenience, one-stop-shopping and multifunction products (Bröring, 2010). Most of the time, the market-driven output-side convergence seems to reinforce the initial trends of technology-driven input-side (technology platforms) (Bröring, 2005). This can be seen in personal computers and televisions leading to the development of laptop computers with a DVD-player. This new product is not serving the computer industry but the consumer electronics sector (Bröring, 2010). The substitutive and complement relation can also be observed in the market-driven output-side convergence. The rise of PDAs is a case of substitutive convergence since PDAs leads to the total replacement of the two previously industries, mobile phones and handheld computers (Bröring, 2005). The second case occurs when there is a convergence which leads to one evolving on top of the other two markets but does not lead to a crowding out effect (Bröring, 2005).

2.3.3 Regulations, Standards and Institutions Convergence

Convergence of regulations is a third dimension of convergence (Bröring, 2010). In new industries, there are different rules since both industry standards and regulations have not yet emerged (Bröring, 2005). In addition, the usage patterns and market behaviours are unknown and speculative in the fast growing

development of new technologies and applications (Bröring, 2005). Therefore, the industrial standards are missing which finally results in the lagging behind of rapid technological developmment (Bröring, 2010). Convergence is possible when there is deregulation and privatisation (Bröring, 2010). The deregulation is often a result of policy makers' desire to induce competition by lowering the entry barriers for new competitors that bring alternative technologies or business models into the industry (Lei, 2000; Weaver, 2007). In the telecommunication sector, the regulation has initially blocked convergence (Bröring, 2010). Later on deregulation has been a driving factor in the telecommunication industry leading to the convergence between data communications and traditional fixed telephony (Katz, 1996; Weaver, 2007). In some case, the legal uncertainty or the missing of industry standards leads to options for innovation (Bröring, 2005).

In short, the development of new inter-industry segments occur when both technology-driven input-side and market-driven output-side are converged (Bröring, 2010). In most cases, the industry convergence is triggered by the technology convergence, whereas market convergence is reinforcing the process of industry convergence (Bröring, 2010). The emergence of this new inter-industry or newly emerged value chain might either lead to substitution or complementary of the old industry segments.

Technologies, markets and regulations are three main dynamic characteristics of industry convergence influencing innovation (Pennings and Puranam, 2001). Therefore, these three dynamics characteristics are important tools for the innovation management. The different patterns of industry convergence determine the impact of industry convergence on innovation (Bröring, 2005). The relevance of drivers for innovation depends on the extent to which industries converge (Bröring, 2005). Table 1 summarizes the influences of technologies, markets and regulations and standards on the industry convergence. With the respect to innovation management, the substitutive and complementary convergence is necessary to specify the trends of convergence (Bröring, 2010). In the case of total substitution convergence, the innovation seems to keep up with the trends of convergence (Bröring, 2010). In the case of complementary convergence, firms may take the opportunities of industry convergence or may choose to focus on the existing sector which does not require any adaptation (Bröring, 2010). In short, the occurrence from the convergence of technology, market and regulation and standards leads to the development of a new inter-industry segment (Bröring and Leker, 2007).

Table 1: Industry convergence as a special situation for innovation (Bröring, 2010).

Convergence of technologies	Convergence of markets	Regulation and standards
• Application of new technologies across industry boundaries	• Demand structures converge	• Missing industry standards
• Fusion of existing technologies owned in different industries to form a common one	• Substitute products arise from another industry	• Regulation for the new 'converged' sector is only about to emerge
➢ New areas of technological knowledge become relevant for innovation	➢ New areas of market knowledge become relevant for innovation	➢ Legal uncertainty in defining the options for innovation

The case of industry convergence is mainly discussed in respect to telecommunications, information technologies and electronics as shown in Figure 3. Recently, the food industry and the pharmaceutical industry find themselves affected by a convergence process as well (Bröring, 2005). The world of industry convergence is more cross scientific research thus allowing the food industry to employ technological developments from other industries in the life sciences (Hacklin, 2008; Curran, et al., 2010). The convergence between these industries has led to the concept of functional foods (Bröring, 2010).

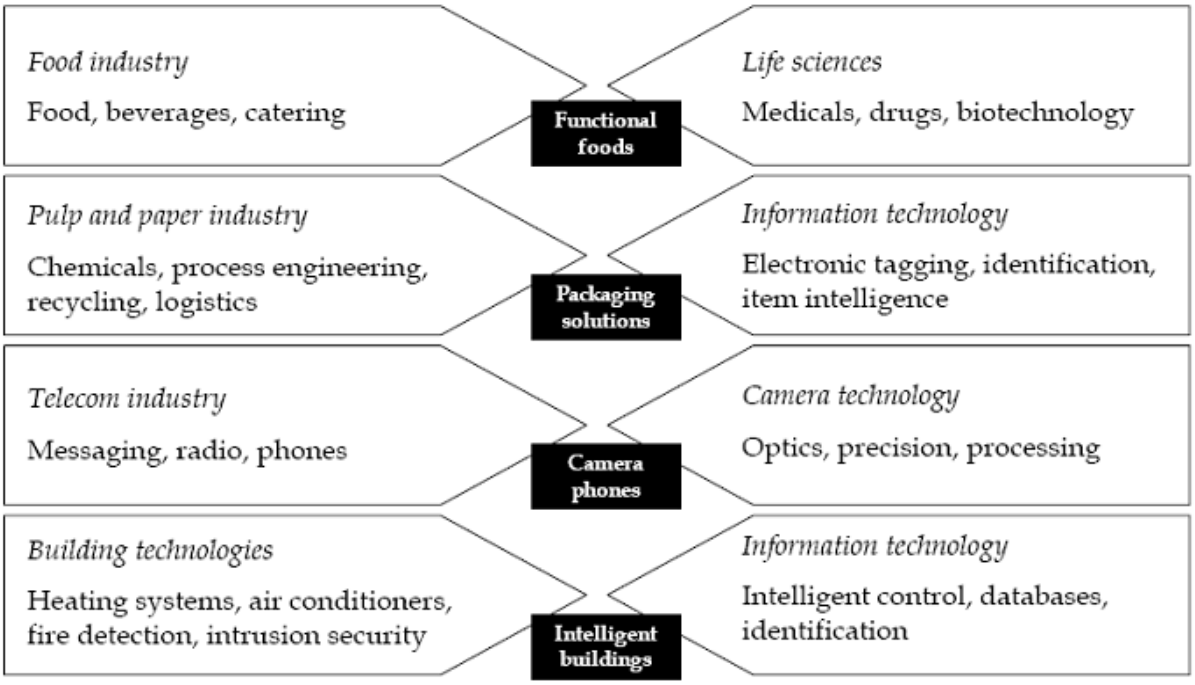

Figure 3: Examples of convergence between industries (Hacklin, 2008).

To summarize the process of industry convergence, in the first stage, the process of convergence is triggered by the outside environment such as the invention of a new technology (Hacklin, 2008). In the second stage, the unrelated industries are converged which results in changes to the industry boundaries, market structures and corporate strategies. The third stage occurs when the unrelated industries start to relate from a technological, product or market perspective. Finally, the industry structures may stabilize or new processes of convergence may evolve (Hacklin, 2008).

3 The Use of Patents to Study Innovation

3.1 Definition of Intellectual Property

Countries with innovative local industries have laws to promote innovation by regulating the copying of inventions, identifying symbols, and creative expressions (Hefter and Litowitz, 1999). This law concerns legal rights associated with creative effort or commercial reputation and goodwill (Bainbridge, 1999). The intellectual property law prevents others from copying or taking unfair advantage of work or reputation from others (Bainbridge, 1999). The owner of intellectual property has the right to prevent the unauthorized use or sale of the property (Hefter and Litowitz, 1999). The law includes four separate and distinct types of intangible property which referred to as intellectual property: patents, copyrights, trademarks, and trade secrets (Bainbridge, 1999; Hefter and Litowitz, 1999). These four types of intellectual property are not exhaustive; there are still other rights (Bainbridge, 1999). For example, the rights associated with plant and seed varieties protection (Bainbridge, 1999). All four types of intellectual property are protected on a national basis thus the scope and requirements of the protection will vary from country to country (Hefter and Litowitz, 1999). The main focus on this study is the requirement of the protection within the European Union (EU). The following details in this chapter are mainly focus on patents. The details for other forms of intellectual property i.e. copyright, trade secrets and trademarks are shown in Appendix 1.

3.2 Patents

A patent is a legal grant by a government. Governments establish patent systems and grant patents in order to encourage innovation, technical development and economic prosperity (Knight, 1997). A patent may be granted in respect of new invention capable of industrial application (Bainbridge, 1999). After the invention is granted, the invention is disclosed to public so that others can learn from it (Knight, 1997). The right to exclude others from making, using or selling the invention lasts up to 20 years (Knight, 1997; Bainbridge, 1999).

According to the Patent Act 1977s 1(1), the European patents require the following conditions to be satisfied for a patent to be granted for an invention (Bainbridge, 1999):

- The invention is new
- It involves an inventive step
- It is capable of industrial application

*European patents shall be granted for any **new inventions** which are susceptible of **industrial application**, which are **new** and which **involve an inventive step*** (Bainbridge, 1999).

Depending upon the business or individual need, there are several types of patents. The patent seekers base the type they need on the kind of protection that a particular patent offers and on what subject matter it covers (Anonymous, 2009). Patents can be granted for a new product or for a new industrial process (Bainbridge, 1999). The explanation of the different types of patents is illustrated below:

- Utility Patent

When most people talk about patents, they are referring to utility patent since the utility patent is one of the most popular types of patents and is the most one often applied for (Knight, 1997; Anonymous, 2009). The utility patent includes new machines, new compositions of matter, new manufactures, or new methods or processes of making machines, compositions of matter or manufacturers (Knight, 1997). This may include an upgraded form of something that has already been invented (Anonymous, 2009). The utility patent protects the invention from other individuals and business and keeps them from making and selling the invention for up to 20 years (Anonymous, 2009).

- Design Patent

Design patents is typically the kind of patent a business or individual applies for protecting their new and/or original ornamental designs that will be manufactured (Knight, 1997). This type of patent keeps other businesses and individuals from creating or making a profit from the design for at least 14 years from the patent date (Anonymous, 2009).

- Plant Patent

Plant patents refer to asexually reproduced, new and distinct variety of plant (Knight, 1997). This may include cultivating different types of plants to create mutants or hybrids and also newly found seedlings (Anonymous, 2009). This patent protects the owner by keeping other individuals or businesses from creating the type of plant or profiting from the plant for at least 20 years from patent date (Anonymous, 2009).

There are many advantages in using patent information. According to Dulken (1992), he indicated the following advantages of patent information:

- Patents provide a currency of data since the details of an invention have to be kept in secret before an application is submitted to the Patent Office. Therefore, the publication of a patent application is often the first time that the information is published.

- Patents provide an exclusivity of information. About 85% of the information in patents is never published elsewhere.

- Patents provide a full and practical description by which an expert in the same branch of industry could recreate the invention.

- It is easily to compare many patents since there is a standardized in patents' layout.
- Some patents are published with search reports such as the literature search on the subject matter of the invention hence providing supplementary information.
- There is an availability of translations of patents.

3.3 The Role of Patenting as an Incentive for Food Companies to Innovate

The innovation process describes activities and the results which lie between the conception of an idea and its introduction to the market (Ernst, 2001). When the technical requirements of an idea are realized by research and development (R&D), this technical success might lead to a patent application. Consequently, patents can be regarded as the result or output of technically successful of R&D activities (Ernst, 2001).

The value of patents can be classified according to the two major functions of patents (Ernst, 2003):

- A granted patent protects the owners of the patent from imitation for a certain period of time. Hence, patent protection supports the internal use of technology by which patents are supported R&D activity i.e. the technology assessment within the company. In additions, patented technology can be used externally to achieve important operational and strategic benefits. For example, the owners of the patent can sell their patent or access to their technology by setting up a cross-licensing or R&D alliances. The inventors with a strong patent portfolio can have access to important technological know-how from external sources by collaboration.
- Patent data are not only useful for tracking technological changes but also can be used in four important areas of technology management. First, analysing patent information provides relevant information about the R&D strategies of competitors and also helps to assess the competitive potential of technologies. Second, patents can be allocated to sub-fields of interest such as to business units, products, technological field or inventors. Hence it enables a more precise competitor analysis. Third, patent data can be used to identify and assess to external generation of technological knowledge. Fourth, patent information can be used for storing relevant knowledge as a core element of knowledge management and as a tool for human resource management in R&D.

To conclude, patents are often considered to be the best source for the timely recognition of technological changes in comparison with other information sources (Ernst, 1997; Ernst, 2003). It can be used to forecast technological developments by indicating the growth pattern of a technology and the technological skills that are occurring (Bröring, 2005; Curran, et al., 2010). The prior indication of the growth of technology can be predicted by looking at the volume of patent registrations in certain technologies (Twiss, 1992). Normally, there is a typical period between the registration of a patent and

the appearance of products that incorporate that knowledge in the market (Twiss, 1992). Patent data can also be used to predict which firms are about to enter or leave a technology, the age and type of each firm's technological base and the relative technological strengths of the firms (Ernst, 1997). Patents afford a detailed identification of technologies that are used within R&D projects and are suitable for the analyses involving long time-frames (Fai and Tunzelmann, 2000). Analysing patent data reveal the ownership of patent and the range of technological interests of the firms (Fai and Tunzelmann, 2000).

3.4 The Limitation of Patents

On the limitations side of patents, it has been argued that patents are subjected to a longstanding debate regarding its bias and shortcomings (Hagedoorn and Cloodt, 2003). Firstly, there is a difference in patenting behaviour in the propensity to patent of individual organizations or even whole countries (Curran, et al., 2010; Hagedoorn and Cloodt, 2003). The differences in patenting also occur between large and small companies (Hagedoorn and Cloodt, 2003). Normally price is the major reason for differences in patenting behaviours between the different size companies (Ellens, 2010 – personal communication). For example, after a large company has filed an international application, they tend to extend the protection of their invention into national or regional applications. This situation might not be affordable to small sized companies.

Secondly, the differences in patenting behaviour cannot only be found when comparing industries or technology areas but are also caused by the different types of inventions. For example, product inventions are more likely to be patented than process inventions (Curran, et al., 2010).

Thirdly, some companies might choose to secure their inventions by other means of protection rather than by filing a patent (Ernst, 1997). Therefore, low or entirely missing patent activity may not be interpreted as a sign of low R&D activity. It means that not all new technology inventions are published. This would reduce the meaning of fullness of patent data as a measure of R&D activities and hence as technological forecasting tool (Ernst, 1997).

Lastly, patents only allow a temporally immensely delayed perspective on the R&D landscape because of the 18 month time period between the priority date of application and the date of publication (Fabry, et al., 2006). However, patents are generally accepted as one of the most appropriate indicators that enable researchers to compare the inventive or innovative performance of companies (i.e. new technologies, new processes or new products) (Hagedoorn and Cloodt, 2003). In addition after the 18 months delay, patents provide a very prompt insight into the research strategy of a company (Fabry, et al., 2006).

All of these aspects imply the shortcomings feature in the use of patents for foreseeing the technology convergence.

An interesting quotation stems from the Austrian economist Schmookler: "*We can choose whether we wish to use patent statistics with prudence and to learn what we can learn from them, or not to use them and to do without all the information that they alone can provide*" (Fabry, et al., 2006).

Even though patents have many limitations, it is still promising to use patent information in such a way that patents provide certain valuable information. Therefore, patents and scientific publications are chosen in this study in order to foresee the industry convergence in the case of probiotics.

4 *Theoretical Framework*

4.1 Patents and Scientific Publications as Monitoring Tools for Convergence

There are three aspects for identifying the full-scale industrial convergence: scientific analysis, patent analysis and additional sources analysis (Curran, et al., 2010). Firstly, monitoring scientific publications will reflect trends of technological knowledge bases convergence (Curran, et al., 2010). Secondly, patent analysis will reflect the overview of how far technological area and firms from different industries are already interwoven at a given time (Curran, et al., 2010). The usefulness of patent data for technological forecasting purposes is affected by differences in the propensity of patents included, differences in countries, industries, companies and over time (Ernst, 1997). Thirdly, the analysis of other additional sources which includes collaboration projects, press releases and general business media will reflect the complete industry convergence (Curran, et al., 2010).

In Figure 4 the trends of convergence can be tracked by measuring the distances between sector A, B and C (Curran, et al., 2010). The areas of A, B and C represent the publications in the respective areas i.e. industry sector and scientific field. When looking at the patents, the areas refer to patent data in certain industry sectors or subject areas. On the contrary, when looking at the scientific articles, the areas refer to the scientific publication in certain industry sectors or subject areas. According to Curran, et al. (2010), the case of convergence occurs when the distance between each sector gradually decrease until a substitutive of complement area of convergence is formed. In other words, the closer the distance between two areas, the more likely the convergence is formed. The case in Figure 4 shows that A and B are converging. The degree of convergence is proportional to the distance between two areas i.e. B and C are more clearly distinguishable than A and C due to the larger distance. Once there is a convergence between A and B, the consequence would be sector A and B file or publish the publications together.

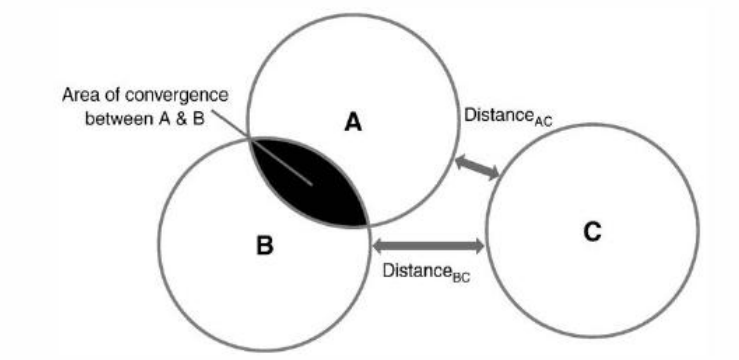

Figure 4: Measuring convergence through the distance between scientific fields or industry sector A, B and C (Curran, et al., 2010).

The distances can be calculated by combining the following different factors (Curran, et al., 2010):

1) In scientific publications, *co-authorship* with people or organizations from all converging fields will indicate a cross-disciplinary collaboration, alliances and networks.

   - The collaboration can be accessed on the basis of co-authorships of articles or on precise information on collaborative projects, changing researcher affiliations and broadened research agendas.

   - When research becomes more interesting across industries, the authors will begin to cite journals and scholars from the other research area and use keywords that were formally part of the other area. Hence, the collaboration can be accessed through the *citation analysis* and *co-citation analysis* or on *journals topics* and *keywords*.

2) In patents, convergence can be found through the growing overlap among the *SIC* codes (Standard Industrial Classification) and the *IPCs* (International Patent Classification) and also through an increase in patent citations between different classes.

   - Additional proxies for monitoring convergence from patent database are *co-applicant* and *assignee data*.

4.2 Theoretical Model

The theoretical model combines the relationship between publicly available data and convergence. Publicly available data are independent variables; while convergence is a dependent variable. The theoretical model shown in Figure 5 helps to provide the answer to the central research question.

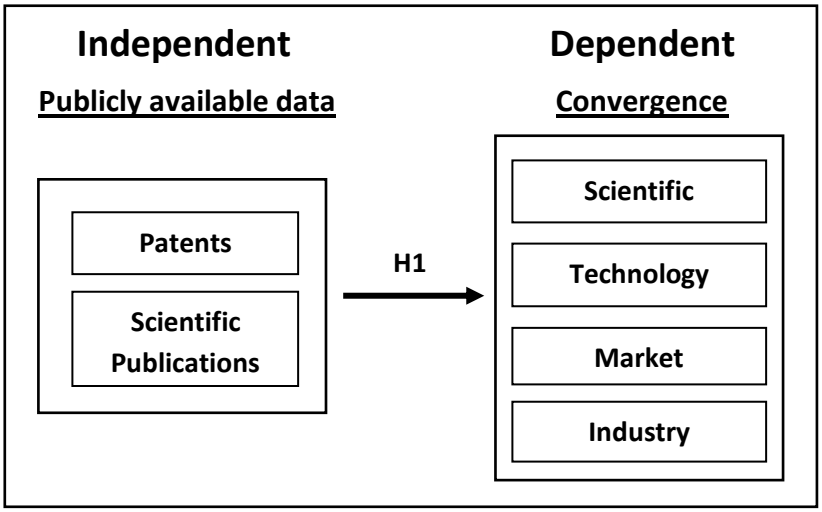

Figure 5: Theoretical model (Adapted from Curran, et al., 2010).

Literature reviews show that scientific publications and patents are said to be the major determinant of the industry convergence. Analysing scientific publications and patents will reflect the trends of scientific and technology convergence respectively. Market convergence appears to be the most difficult to assess but it can be assessed by using publicly available data. This assessment involves collecting data on companies' product portfolios and expert interviews in order to construct an overview of actual products or services in the market or the general customer trends (Curran, et al., 2010).

The remark for the theoretical model in Figure 5 is there is no clear relationship between dependent and independent variables since the three research questions in this study is independently related to each other. This point could be the remark for building the future research questions by which the dependencies between two variables should take into consideration.

4.3 Hypothesis

The hypothesis as detailed in the following is derived from the theoretical model described in Figure 5.

Hypothesis: Convergence starts with the convergence of knowledge and follows by the convergence of technology

This hypothesis is based upon the assumption on the idealized time series of convergence by Curran, et al. (2010) (Figure 6). The simplified and idealized process of convergence evolves when scientific knowledge, technologies and markets have converged (Curran, et al., 2010). The ideal process of convergence starts with the cross-citations from one to another which eventually develop further into research collaborations. This leads to the occurrence of technology convergence. Later on the new product-market combinations will emerge which resulted in market convergence. After the decreasing of distance between basic scientific knowledge, the applied science and technology development will follow. Finally, the industry convergence occurs when firms start to merge with each other.

Therefore, this hypothesis aims to test the time series of convergence events whether the convergence starts from scientific convergence, technology convergence, market convergence and finally end up with the emergence of industry convergence in the case of probiotics. In order to accept this hypothesis, the convergence should be firstly found in scientific publications and then later on in patents.

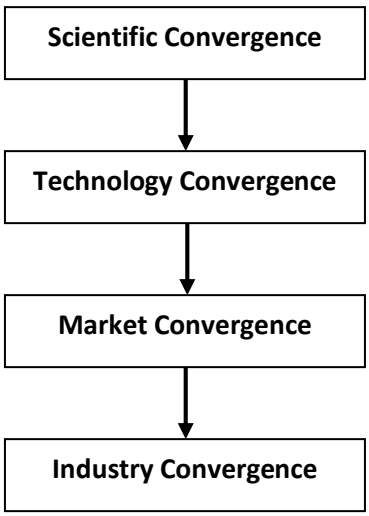

Figure 6: The occurrence of convergence events (Curran, et al., 2010).

5 Methodology

5.1 Research Design

5.1.1 Research Strategy and Routes to Data Collection

Desk research is used to gather the background information on the industry convergence, intellectual property and probiotics. In desk research strategy, secondary data are often used in order to get a more complete picture. Apart from using desk research strategy, a part of this study is carried out according to the grounded theory approach. The monitoring concept for industry convergence is refined from the work of Curran, et al. (2010) on anticipating industry convergence by using publicly available data. A central feature of grounded theory is its method of constant comparative analysis (Glaser & Strauss 1967). The grounded theory has been described by Glaser and Strauss since 1967 (Cutcliffe, 2000). Glaser and Strauss (1967) provide an initial definition of grounded theory as the theory that will:

"….. fit the situation being researched and work when put into use. By fit we mean that the categories must be readily (not forcibly) applicable to and indicated by the data under study; by work we mean that they must be meaningfully relevant and be able to explain the behaviour under study".

In this study, the monitoring concept for industry convergence from Curran, et al. (2010) is used in the field of probiotics in order to investigate whether this monitoring concept is also applicable to other industries. Furthermore, as well as testing the applicability of the monitoring concept from Curran, et al. (2010), secondary theoretical comparison is used as the comparison of converging behaviours between the cases of phytosterols and probiotics. The purpose of comparison is to investigate whether any newly found converging phenomenon in the field of probiotics have similar or different characteristics as those phenomenon previously found in field of phytosterols.

The combination between desk research and grounded theory approach strategy will enable an in-depth analysis of industry convergence by using publicly available data.

5.1.2 Data Sample

During the empirical study, patent and scientific publications are gathered using Thomson Innovation. Probiotic* is the search term that used in this study. The time frame of data collection is ranging from year 1990 to 2009. The data is searched within US Grant, GB App, US App, WO App, EP Grant, EP App, JP Grant, JP App, CN App, KR Grant, KR App, DWPI database. One important remark for the comparative approach between probiotics and phytosterols cases is the different in time frame of data collection. The data in the case of phytosterols were collected from 1897 to 2008. The limitation of Thomson Innovation is the publication data are available from 1990 onward. However, the patents publishing trends (Figure 7) shows that the incrementally increase of filing patent starts from the year 2000. This means that there will not be too much different if the time frame started at 1897 or 1990. There are only two applications from pre 1990.

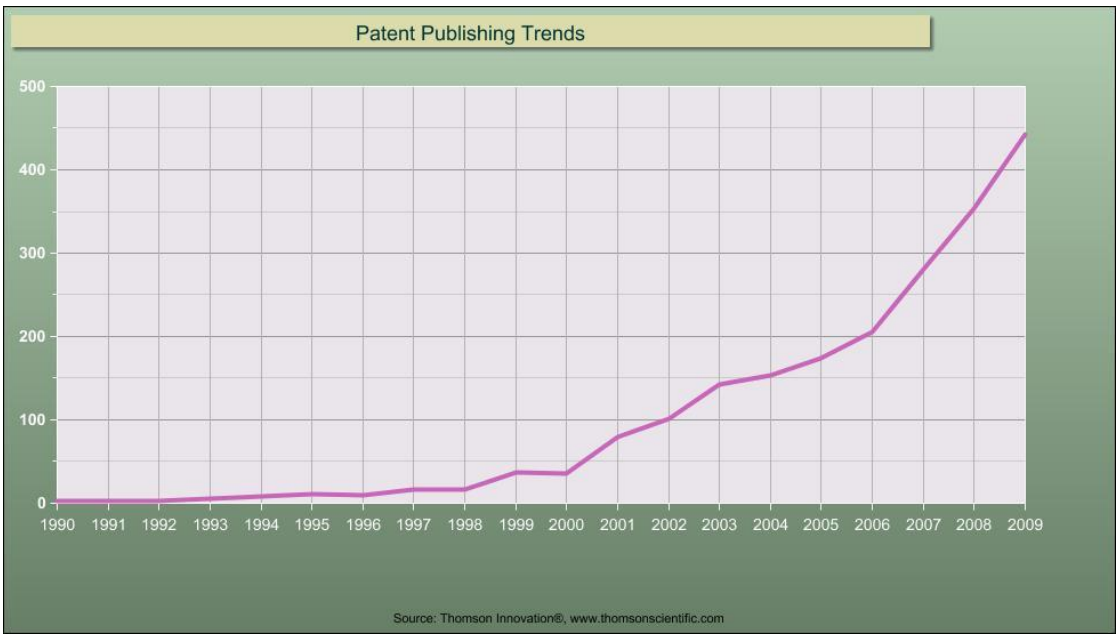

Figure 7: Patent publishing trends.

Entering probiotic* as the search term in title, abstract and claims, gives 2082 references to patent families and 8245 documents to scientific publications.

After collecting 2082 patents, the non-companies and duplicate entries are excluded. The duplicated entries will show up when company files patents for both national and international application. In this case, the granted patent will present at both applications. After that all the subsidiaries i.e. parent and daughter companies are combined. This leads to *527* patents filed by *44* firms.

The sampling method for scientific publications is slightly different than for patents. After collecting 8245 documents, non-English publications are excluded resulting in 7858 documents to scientific publication. Only the top 50 organizations with the highest numbers of publications from the 7858 documents were included. The 1566 remaining (19%) are assigned to subject areas. Excluding all non-companies and duplicate entries and including subsidiaries from the top 50 organizations led to 574 documents submitted by 20 organizations. However, the publications which submitted by companies in patent samples are also included. After including publications from the companies that presented in patents data, this leads to *629* publications submitted by *37* companies.

Therefore, the representative data samples for patents and publications are 527 patents (25%) and 629 publications (8%) of the total publications.

By using this sampling strategy, it allows us to track the same organizations both from patents and publications.

5.2 Methods for Data Analysis

The method of data analysis is refined from the work developed by Curran, et al. (2010).

5.2.1 Industry Sector and Subject Area Classification

There are two important steps in data analysis: industry sectors and subject areas classification.

Firstly, firms are assigned into one of the following industry sectors:

- Personal Care – firms who are selling or conducting R&D on probiotics used in cosmetics and personal hygiene.
- Food & Agriculture – firms who are either active in agricultural applications or selling food, feed and food ingredients under their brand names.
- Pharmaceuticals – firms who specialized in developing, producing and marketing drugs licensed for use as medication.
- Chemicals – firms who produced probiotics and selling it in the business to business (B2B) market.

The Standard Industrial Classification (SIC) codes are used as a tool to facilitate the industry classification for each firm in our samples. SIC is a United States government system for classifying industries by a four-digit code (U.S. Securities and Exchange Commission, 2008). Each firm is assigned into each industry sector according to SIC codes. SIC codes should be converted into one of the industry sectors mentioned above. In some cases, many companies have filed a patent together. Table 2 shows the alphabetical codes that are used during industry sector analysis. In addition, the alphabetical codes must be converted into special numeric codes for further analysis in Statistical Package for the Social Sciences (SPSS). The numeric codes for industry sectors present in Table 2 help to facilitate the data analysis and data interpretation by which each digit in numeric codes has its own meaning:

- First digit - indicates number of company (e.g. 1=one company, 2=two companies, etc.)
- Second to fourth digits - indicate types of industry sector (1=PC, 2=FA, 3=PH, 4=CH, 5=R)

  For example: 1100 means *one* company in *Personal Care sector*

  2120 means *two* companies in *Personal Care* and *Food & Agriculture sector*

  3224 means three companies in *Food & Agriculture, Food & Agriculture* and *Chemicals sector*

Table 2: Coding system for industry sectors.

Industry sectors	Abbreviations	Alphabetical codes	Numeric codes	Types of collaborations
Personal Care	PC	A	1100	No collaboration (One firm with one Strategic Business Units (SBUs))
Food & Agriculture	FA	B	1200	
Pharmaceuticals	PH	C	1300	
Chemicals	CH	D	1400	
Personal Care and Food & Agriculture	PCFA	AB	2120	Joint collaboration (Joint patent application between two or three firms from same/different sectors)
Personal Care and Pharmaceuticals	PCPH	AC	2130	
Food & Agriculture and Food & Agriculture	FAFA	BB	2220	
Food & Agriculture and Chemicals	FACH	BD	2240	
Food & Agriculture and Pharmaceuticals	FAPH	BC	2230	
Pharmaceuticals and Chemicals	PHCH	CD	2340	
Food & Agriculture, Food & Agriculture and Chemicals	FAFACH	BBD	3224	
Personal Care and Food & Agriculture	Intra-PCFA	IAB	1120	Intra-firm collaboration (One firm with many SBUs and filed patent for different application)
Personal Care and Pharmaceuticals	Intra-PCPH	IAC	1130	
Food & Agriculture and Food & Agriculture	Intra-FAFA	IBB	1220	
Food & Agriculture and Chemicals	Intra-FACH	IBD	1240	
Food & Agriculture and Pharmaceuticals	Intra-FAPH	IBC	1230	
Pharmaceuticals and Chemicals	Intra-PHCH	ICD	1340	
Personal Care and Food & Agriculture, Pharmaceuticals	Intra-PCFA,PH	IAB,C	2123*	Joint collaboration between firm and intra-firm collaboration
Research organization	R	R	1500	-

*Exception

Secondly, our samples from patents and scientific publications are analysed regarding to the subject areas. The subject areas are classified into four groups as follows:

- Personal Care – subject area related to cosmetics and personal hygiene.
- Food & Agriculture – subject area related to food and agricultural products.
- Pharmaceuticals – subject area related to drugs for use as medications of certain diseases.
- None of the three – subject area not related to the first three areas.

The first three areas represent the core businesses of the industry sectors – Personal Care, Food & Agriculture and Pharmaceuticals area – and the last area represents the remaining subject areas which are not included in the first three subject areas. The subject areas for patent data are assigned according to the International Patent Classification (IPC) code. For scientific publications, the subject areas are assigned by looking at the key words from title and abstract of each publication. After assigned alphabetical codes for subject areas, the codes are converted to numeric codes for SPSS analysis (Table 3).

The numeric codes for subject areas present in Table 3 help to facilitate the data analysis and data interpretation by which each digit in numeric codes has its own meaning:

- First digit – the first digit for subject areas always starts with "8" in order to separate industry sectors and subject areas when these two codes are combined.
- Second digit - indicates the sub-group of Food & Agriculture area (0=no sub-group, 1=FA1, 2=FA2)
- Third to fifth digits - indicate the subject areas (1=PC, 2=FA, 3=PH, 4=NO)

  For example: 80100 means the patent or publication in *Personal Care* area

  82200 means the patent or publication in *Food & Agriculture* area with *Functional food* areas as a sub-group.

Table 3: Coding system for subject areas.

Subject areas	Alphabetical codes	Numeric codes
Personal Care	PC	80100
Food & Agriculture	FA	80200
Dietary and nutritional supplement	FA1	81200
Functional food	FA2	82200
Pharmaceuticals	PH	80300
None of the three	NO	80400
Personal Care and Food & Agriculture	PCFA	80120
Personal Care and Pharmaceuticals	PCPH	80130
Food & Agriculture and Pharmaceuticals	FAPH	80230
Personal Care, Food & Agriculture and Pharmaceuticals	PCFAPH	80123

5.2.2 Weighted Average Year (WAY)

The weighted average year (WAY) calculation of scientific publications and patents in each of the industry sectors and subject areas leads to the average age of patents and scientific publications from the respective sector or area. The WAY calculation enables us to assess the process of convergence (Curran, et al., 2010). The fundamental of this calculation is based on the number of documents per year multiplied by the published year (year of publication) and divided by the total number of documents in each industry sectors or subject area (Curran, et al., 2010):

$$WAY_{(p,s)} = [\Sigma_i(n_{i(p,s)} * y_{i(p,s)})]/[N_{(p,s)}]$$

By which;

$WAY_{(p,s)}$ = weighted average year of patent or publication in certain subject area or industry sector

$_p$ = patent or publication

$_s$ = subject area or industry sector

n_i = number of patents or scientific publications in each year

y_i = year

N = total number of *p* in *s* in all *i* years

5.2.3 Landscape Map

A map is one of the analysis tool provided in Thomson Innovation. The landscape map is generated on the basis of patent data. The map provides an overview of the applications in the field of probiotics over time. After gathering all the patents in the field of probiotics from year 1990 to 2009 (2082 patents), the analysis starts by using 'ThemeScape' function in the 'Analyse' tool. It is important to set criteria especially the 'patent field options' and 'stopwords' in 'Map set up' option before producing the map. Firstly, the patent field options use in this study are Title (English), Title (DWPI), Abstract (English), Application Number, Application date (Time Slice), Publication Number, Publication date and Assignee/Applicant. The map is basically produced by clustering the similar field options from each patent together. Secondly, it is important to edit the stopwords in the Map set up option. These words are ignored during map creation. The stopwords that use in this study are presented in Appendix 2. Then it is possible to create a meaningful map.

5.2.4 SPSS Analysis

SPSS analysis facilitates the correlation analysis between industry sectors and subject areas. The first correlation analysis involve with the investigation of the overall correlation between industry sectors and subjects areas from the four main industry sectors i.e. Personal Care, Food & Agriculture, Pharmaceuticals and Chemicals sector. The analysis is done by inserting the subject areas of patent data from these industry sectors from year 1990 to year 2009 in SPSS input. Then using the 'Bivariate correlations' option to analyse the data. Pearson correlation is used to test the correlation coefficient. The second correlation analysis involves with the investigation of the overall correlation between firms from collaboration and the technological complexity of subject areas. The procedure is similar to the first correlation analysis except the data range. In this case, the patent data from firms with collaboration and subject areas from year 1990 to 2009 are inserted into SPSS input.

5.3 Operationalisation of the Theoretical Model

The dependent and independent variables for the theoretical model as shown in Figure 5 are mentioned in detail in this section. Indicators used to test the hypothesis and answer the research questions are highlighted in Table 4.

5.3.1 Dependent Variables

The dependent variable in this study refers to the pattern of convergence. According to Curran, et al. (2010), the idealized time series of convergence events can be classified into four series:

I. Scientific convergence – The distinct scientific disciplines begin to cite each other and collaborate

II. Technology convergence – The distance between applied science and technology development decreases

III. Market convergence – The emerging of new products

IV. Industry convergence – The fusion of firms or industry segments

5.3.2 Independent Variables

The independent variables in this study refer to the publicly available data. The publicly available data are used to anticipate the convergence event in the case of probiotics:

I. Scientific publications – The scientific publications are included journals, articles, and reviews. By analysing the scientific publications (i.e. organizations and keywords in title and abstract), the convergence of knowledge or scientific can be detected.

II. Patents – The details in patent (i.e. assignee/applicant, IPC code, title and abstract) will be used to detect the technology convergence.

Table 4: Operationalisation of theoretical model.

Operationalisation of Independent Variables			
Variables	**Indicators**	**Sub-questions**	**Remarks**
Publicly available data • Scientific publications • Patents	**1.** Industry sector – SIC code (Personal care/Food&Agriculture/Pharmaceuticals/Chemicals) **2.** Subject area – Key words (Personal care/Food&Agriculture/Pharmaceuticals/None of other three) **3.** The cross-sectoral applications (Yes/No) **4.** The publication and patent behaviours **5.** The dominant industry (Personal care/Food&Agriculture/Pharmaceuticals/Chemicals) **6.** The pattern of convergence: knowledge convergence occurs earlier than technology convergence (Yes/No)	**Q.1** Can one detect the trend of convergence in patents and publication before and/or during the product emergence? **Q.2** Is the convergence in the case of probiotics different from phytosterols case?	**H1:** Convergence starts with the convergence of knowledge and follows by the convergence of technology
Operationalisation of Dependent Variable			
Time series of convergence events	**7.** Landscape map • The overall probiotics landscape • The probiotics landscape specific to the drug-like application **8.** SPSS analysis	**Q.3** How does the probiotics landscape develop in time?	The technological development of probiotic applications can be detected by tracking the time slices of patent data in landscape map annually.

6 The Case of Probiotics

The increasing cost of health care, the steady increase in life expectancy and the desire of the elderly for improved the quality of life are the driving factors for research and development on the area of functional foods (Vasiljevic and Shah, 2008). The bioactive components from fermented foods and probiotics take the centre stage among other functional compounds due to their long tradition of safe use, established and postulated beneficial effects. Probiotic food is predicted to grow at an exponential rate, with the potential for market growth estimated at US$ 120 million per month (Senok, et al., 2005).

6.1 Definition of Probiotics

The terms ‘probiotics’ was initially used as an antonym of the word ‘antibiotic’ (Vasiljevic and Shah, 2008). It derived from the Greek language meaning ‘for life’ (Lourens-Hattingh and Viljoen, 2001; Vasiljevic and Shah, 2008). Many authors used different definitions of probiotics, the most disputed definition was defined by Parker (Vasiljevic and Shah, 2008). He defined probiotics as organisms and substances which contribute to intestinal microbial balance (Vasiljevic and Shah, 2008). This definition was disputed by many authors because ‘substances’ include chemicals such as antibiotics (Lourens-Hattingh and Viljoen, 2001; Vasiljevic and Shah, 2008). Late 1980s and 1990s there were many different definitions of probiotics but the most frequently cited definition is that of Fuller’s in 1992 (Vasiljevic and Shah, 2008). He defined probiotics as a live microbial feed supplements which beneficially affects the host animal by improving its intestinal microbial balance (Vasiljevic and Shah, 2008). This definition is more applicable to animals than to humans (Vasiljevic and Shah, 2008). Later on, the definition of probiotics was recommended by FAO/WHO on 2002. The suggested definition describes probiotics as live microorganisms that when administered in adequate amounts confer a health benefit on the host (Reid, 2008; Senok, et al., 2005; Vasiljevic and Shah, 2008). Some of the definitions of probiotics are listed in Table 5.

Table 5: Some of the descriptions and definitions of probiotics commonly cited over the years (Vasiljevic and Shah, 2008).

Year	Description	Source
1953	Probiotics are common in vegetable food as vitamins, aromatic substances, enzymes and possibly other substances connected with vital processes	Kollath
1954	Probiotics are opposite of antibiotics	Vergin
1955	Deleterious effects of antibiotics can be prevented by probiotic therapy	Kolb
1965	A substance secreted by one microorganism which stimulates the growth of another	Lilly and Stillwell
1971	Tissue extracts which stimulate microbial growth	Sperti
1973	Compounds that build resistance to infection in the host but do not inhibit the growth of microorganisms in vitro	Fujii and Cook
1974	Organisms and substances that contribute to intestinal microbial balance	Parker
1992	Live microbial feed supplement which beneficially affects the host animal by improving microbial balance	Fuller
1992	Viable mono- or mixed culture of live microorganisms which, applied to animals or man, have a beneficial effect on the host by improving the properties of the indigenous microflora	Havenaar and Huis int'Veld
1996	Live microbial culture or cultured dairy product which beneficially influences the health and nutrition of the host	Salminen
1996	Living microorganisms which, upon ingestion in certain numbers, exert health benefits beyond inherent basic nutrition	Schaafsma
1999	Microbial cell preparations or components of microbial cells that have a beneficial effect on the health and well-being of the host	Salminen, Ouwehand, Benno and Lee
2001	A preparation of or a product containing viable, defined microorganisms in sufficient numbers, which alter the microflora (by implantation or colonization) in a compartment of the host and by that exert beneficial health effect in this host	Schrezenmeir and de Vrese
2002	Live microorganisms that when administered in adequate amount confer a health benefit on the host	FAO/WHO

6.2 The Use of Probiotics

Traditionally probiotics have been found in yoghurt. Recently a number of carriers for probiotics have been examined including mayonnaise, edible spreads, cheese or chess-based dips and meat (Shah, 2007; Vasiljevic and Shah, 2008). Furthermore, probiotic organisms can also be incorporated into milk, sour milk, fruit juices, ice cream, single shots and oat-based products (Vasiljevic and Shah, 2008).

There are two most commonly used probiotics in commercial products: lactobacilli (members of lactic acid bacteria, LAB) and bifidobacteria (Lourens-Hattingh and Viljoen, 2001; Reid, 2008; Saarela, et al., 2000; Saxelin, et al., 2005; Senok, et al., 2005; Siezen and Wilson, 2010; Vasiljevic and Shah, 2008). Table 6 shows the overview of commercially used strains and their claimed probiotic effects (Siezen and Wilson, 2010).

Table 6: Examples of commercial probiotic strains and products (Siezen and Wilson, 2010).

Species/strain	Brand name	Producer	Claimed effect in humans/animals
Bacillus coagulans GBI-30, 6086	GanedenBC30	Ganeden Biotech	Improves abdominal pain and bloating in IBS patients. Increases immune response to viral challenge
Bifidobacterium animalis ssp. *lactis* BB-12	BB-12	Chr. Hansen	Reduction in *Strept. mutans* in mouth; IBS amelioration in a multispecies trial
Bifidobacterium animalis ssp. *lactis* HN019 (DR10	Howaru Bifido	Danisco	Reduced prevalence of atopy and eczema in the first 2 years of life
Bifidobacterium breve Yakult	Bifiene	Yakult	Ulcerative colitis amelioration
Bifidobacterium infantis 35624	Align	Procter & Gamble	Irritable bowel syndrome treatment
Bifidobacterium longum BB536	BB536	Morinaga	Treatment of allergy, Especially Japanese cedar pollinosis
Escherichia coli M-17	ProBactrix	BioBalance	Irritable bowel syndrome treatment
Escherichia coli Nissle 1917	Mutaflor	Ardeypharm	Enterocolitis, remission of ulcerative colitis
Lactobacillus acidophilus DDS-1	DDS-1	Nebraska Cultures	Alleviation of traveller's diarrhea; vitamin production
Lactobacillus acidophilus LA-5	LA-5	Chr. Hansen	Alleviation of acute diarrhea
Lactobacillus acidophilus NCFM	Howaru acidophilus	Danisco	Improvement of intestinal health, treatment of vaginal/urogential infections
Lactobacillus acidophilus GAL-2	Ghenisson 22	GHEN Co	Improves digestive health in poultry
Lactobacillus brevis KB290	LABRE	Kagome	Improvement of bowel movement, enhances NK activity and interferon-a activity
Lactobacillus casei DN114-001	Actimel, DanActive	Danone	Acute diarrhea treatment; Infection prevention; gut development
Lactobacillus casei CRL431	CRL431	Chr. Hansen	Immune stimulation, Alleviation of acute diarrhea
Lactobacillus casei F19	Cultura	Arla Foods	Improvement in bowel function
Lactobacillus casei Shirota	Yakult	Yakult	Alleviation of acute diarrhea
Lactobacillus paracasei St11	Lactobacillus fortis	Nestlé	Natural defence/immune system, gut health
Lactobacillus johnsonii NCC533	LC1 range	Nestlé	Immunomodulation; pathogen inhibition
Lactococcus lactis L1A	VERUM HÄLSOFIL	Norrmejerier	Immune stimulation; improves digestive health; reduces antibiotic associated diarrhea

Lactobacillus plantarum 299v	GoodBelly, ProViva, TuZen	NextFoods, Probi, Ferring	Iron absorption
Lactobacillus reuteri ATTC 55730	L. reuteri Protectis	BioGaia Biologics	Diarrhea prevention and mitigation; eradication of *H. pylori* infection; amelioration of gingivitis.
Lactobacillus rhamnosus GG	Vifit and others	Valio	Immune stimulation; alleviates atopic eczema; prevents diarrhoea in children and many other types of diarrhoea
Lactobacillus rhamnosus LB21	Verum	Norrmejerier	
Lactobacillus rhamnosus GR-1 & *Lactobacillus reuteri* RC-14	Bion, Flore, Intime, Jarrow, Fem-Dophilu	Chr. Hansen	Vaginal colonization and prevention of vaginitis
Lactobacillus acidophilus NCFM & *Bifidobacterium bifidum* BB-12	Florajen3	American Lifeline, Inc	Reduction of *C. difficile*– Associated disease (CDAD)
Lactobacillus acidophilus CL1285 & *Lactobacillus casei*	Bio-K+ CL1285	Bio-K+ International	Improves digestive health; prevents Antiobic Associated Diarrhea (AAD; inhibition of pathogens
Lactobacillus acidophilus MNFLM01 & *Enterococcus faecium*	LAB-MOS	Alltech	Lowers pathogen numbers in Lamb intestine
Lactobacillus helveticus R0052 & *Lactobacillus rhamnosus* R0011	A'Biotica and others	Institut Rosell	*Helicobacter pylori* inhibition

From the holistic approaches of the benefits of probiotics, it is expected to drive further innovations and the directions for such innovations are many (Saxelin, et al., 2005). Firstly, the attention continues to focus on the general probiotics cultures that are targeted to large consumer groups to maintain or enhance the general wellbeing (Saxelin, et al., 2005). These food products will be marketed with physiological claims or claims to reduce the risk of disease (Saxelin, et al., 2005). These claims are still under discussion by the European Union directive. Secondly, the use of probiotics will be more targeted such as in the dietary treatment of certain diseases such as vaginal infections (Saxelin, et al., 2005). This will lead to the new target group in pharmaceuticals (Saxelin, et al., 2005). Besides the possible applications of probiotics in foods and pharmaceuticals, probiotics are also commonly applied in personal care products or cosmetics, e.g. as skin products – lotions and cream and animal and fish feed, e.g. as enhancing growth by inhibiting or reducing the pathogenic bacteria that some animals or fish carry (Saxelin, et al., 2005).

Probiotics can be a good example of two recent developments of industry convergence – the emerging sectors of Nutraceuticals and Functional Foods (NFF) and Cosmeceuticals sectors due to the broad applications of probiotics in foods, pharmaceuticals and cosmetics. The emerging of NFF sector started in Japan since the early 1990s by which there is an intersection between pharmaceutical and food

industry sectors (Curran, et al., 2010). This sector can occur by both input-side and output-side convergence. The target group of the NFF sector is customers who seek to purchase foods with added health-benefits as one-stop shopping. Therefore, firms do not only need knowledge and technological skills formally unimportant to them, but also find themselves competing with others in the nutrition and disease prevention markets. In Cosmeceuticals, there is a hybrid between cosmetic and pharmaceutical sectors aiming at enhancing both beauty and health (Curran, et al., 2010). The health benefit in the Cosmeceutical sector appears to be more disputed than NFF sector. Thus, the broader the health claims marketed with the Cosmeceuticals, make it more likely there will have to undergo inspection by drug administration such as Food and Drug Administration. This leads to a convergence of regulations and standards (Curran, et al., 2010).

6.3 Market and Future Trends for Probiotics

Recently, functional foods with probiotics are well established in the European market (Saarela, et al., 2000). The products with probiotics emerged about 20 years ago, the product range has increased and is well known to consumers (Saarela, et al., 2000). In order to succeed in promoting the consumption of functional probiotic products, it is important for the food industry to satisfy the demands of the consumers concerning the safety and sensory properties of products (Saarela, et al., 2000). It has been estimated that there are approximately 70 probiotic-containing products marketed in the world and the list of products has been continuously expanding (Vasiljevic and Shah, 2008).

As mentioned before probiotics are normally incorporate into dairy products, and the consumption of functional dairy products across West Europe, United States and Japan has risen by 12% since 2005 (Vasiljevic and Shah, 2008). In Japan, probiotic products are very popular as reflected in more than 53 different types of probiotic-containing products on the market (Vasiljevic and Shah, 2008).

Probiotic-containing products are one of the most successful categories of functional foods (Saxelin, et al., 2005). The growing demand for healthy foods is stimulating innovation and new product development in the food industry internationally (Saarela, et al., 2000). The example of a completely new category of probiotic products is the daily-dose drinks in small bottles with a market volume of more than 1,000 million kg and over Euro 1.2 billion annually in retail sales in Europe (Saxelin, et al., 2005).

7 Patent and Scientific Publication Analysis

The results of publicly analysis in the case of probiotics are shown in this section. Firstly, the general descriptive analysis for the sample behaviour is shown. After the description of the sample behaviour, the next section will describe how the research questions are answered by using the weighted average year and correlation analysis.

7.1 Description of Patent and Publication Behaviour in the Sample

After patent and scientific publications were analysed according to industry sectors, they were further analysed in regard to subject areas. The four main industry sectors and subject areas mentioned in Section 5.2.1 are found in our patent and publication data and also other categories of industry sectors and subject areas are detected during data analysis. There are the industry sectors that come from the collaboration between two or more similar or distinct industry sectors filed and submitted patents and publications together. The same trends are found when analysing subject areas. Firms do not always file their patents within their core businesses i.e. in three main areas (Personal Care, Food & Agriculture and Pharmaceuticals). Some firms are likely to further extend their interest into other new areas which are basically the areas that occur from the combination of the three main areas. The results from this analysis on the overall of patenting and publication behaviours are shown in Tables 7 and 8.

Table 7: Patents by industry sectors and subject areas.

Subject areas	Industry sectors										Subject area across all industry sectors of sample
	PC	FA	PH	CH	Intra-PCFA	Intra-PCFA,PH	PCFA	FAFA	FAPH	FACH	
PC	95.5	0.0	0.0	0.0	14.7	25.0	84.6	0.0	0.0	0.0	7.2
FA	0.0	61.2	13.0	37.7	41.2	0.0	0.0	100.0	0.0	50.0	44.2
PH	0.0	12.6	66.7	35.3	26.5	75.0	0.0	0.0	60.0	0.0	24.7
NO	0.0	6.3	10.1	4.7	5.9	0.0	0.0	0.0	20.0	0.0	6.3
PCPH	4.6	0.0	1.5	0.0	0.0	0.0	7.7	0.0	0.0	0.0	0.6
PCFA	0.0	0.4	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.4
PCFAPH	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
FAPH	0.0	16.4	7.3	21.2	8.8	0.0	7.7	0.0	20.0	50.0	14.6
FA1	0.0	2.1	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
FA2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
No. of patents	22	286	69	85	34	4	13	2	10	2	527

*PC, FA, PH & CH sector represent a group from single firm
Intra-PCFA sector represents a group from intra-firm collaboration
PCFA, FAFA, FAPH, and FACH sector represent a group from joint collaboration between two firms
Intra-PCFA, PH sector is an exception group (i.e. joint collaboration between single firm and intra-firm)

Table 8: Scientific publications by industry sectors and subject areas.

Subject areas	Industry sectors														Subject area across all industry sectors of sample
	PC	FA	PH	CH	IPCFA	Intra-PCFA, PH	PCFA	PCCH	FAFA	FAPH	FACH	PHPH	CHCH	FAFACH	
PC	80.0	0.2	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
FA	0.0	25.2	4.4	29.3	45.5	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	23.9
PH	0.0	37.4	84.4	27.6	36.4	100.0	0.0	100.0	0.0	50.0	0.0	100.0	100.0	0.0	38.2
NO	20.0	21.0	8.9	32.5	18.2	0.0	0.0	0.0	100.0	50.0	40.0	0.0	0.0	100.0	22.7
PCPH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCFAPH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FAPH	0.0	14.5	2.2	10.6	0.0	0.0	0.0	0.0	0.0	0.0	40.0	0.0	0.0	0.0	12.2
FA1	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
FA2	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
No. of publications	5	420	45	123	11	2	7	2	2	2	5	1	1	3	629

*PC, FA, PH & CH sector represent a group from single firm
IPCFA sector represents a group from intra-firm collaboration
PCFA, PCCH, FAFA, FAPH, FACH, PHPH, CHCH, and FAFACH sector represent a group from joint collaboration between two or more firms
IPCFA, PH sector is an exception group (i.e. joint collaboration between single firm and intra-firm)

By focusing on the dominant industry sectors in the patent data, most of industry sectors are filing their patents in the subject areas that close to their SBUs (Table 7). Firms in Personal Care (95.5%), Food & Agriculture (61.2%) and Pharmaceuticals (66.7%) sector show slight activity in filing their patents in subject areas beyond their core competencies. The firms in Chemicals sector file their patents in Food & Agriculture (37.7%) and Pharmaceuticals (35.3%) area which account for two thirds of their patents.

For the subject area across all industry sectors in patents data, almost half of the patent data are related to Food & Agriculture (44.2%) area. For the rest, there are only 24.7% from Pharmaceuticals, 14.6% from Food & Agriculture and Pharmaceuticals (FAPH), 7.2% from Personal Care, 6.3% from the rest (None of the dominant three areas) and 1.3% from Dietary and nutritional supplement (FA1) area. The patents which are filed in Personal Care and Pharmaceuticals (PCPH), Personal Care and Food & Agriculture (PCFA), Food & Agriculture and Pharmaceuticals (PCFAPH) and Functional foods (FA2) area are accounted less than 1% of the total patents.

There are 65 patents out of 527 patents (12.3%) filed by intra-firms collaboration (i.e. firms with many SBUs) and joint collaboration (i.e. collaboration between two or more firms from similar or different industry sectors). These types of industry sectors are called as a special sector. Firms with two SBUs i.e. Personal Care and Food & Agriculture sectors are filed the highest number of patents (52.3%) compared to others firms from collaboration. This industry sector (Intra-PCFA) is basically filed their patents in the three main areas i.e. 14.7% from Personal Aare area, 41.2% from Food & Agriculture area and 26.5% from Pharmaceuticals area. For others industry sectors in the special sector, they always file their patents close to one of their industry sectors. These types of industry sectors are not the dominant industry sectors but they represent the occurrence of industry convergence in the field of probiotics.

The scientific publications in respect to the industry sectors and subject areas are also analysed (Table 8). Both Personal Care and Pharmaceuticals sector are interesting in their core knowledge. The Personal Care sector published 80.0% of their scientific publications in Personal Care area and Pharmaceuticals sector published 84.4% of their scientific publications in Pharmaceuticals area. However, Food & Agriculture sector are more interested in other areas which are beyond their core business. In this case, Food & Agriculture sector submitted publications accounted for 37.4% in Pharmaceuticals area. They published 25.2% and 21% of their publications in Food & Agriculture and none of the three areas respectively. One remark is they published 14.5% of their publication in special area (i.e. Food & Agriculture and Pharmaceuticals area). This implies that Food & Agriculture industry are interested in the application of probiotics at both Food & Agriculture and Pharmaceuticals area. For the Chemical sector, they are interested in three areas almost equally i.e. Food & Agriculture (29.3%), Pharmaceuticals (27.6%) and the rest (32.5%).

By focusing of the subject area across all industry sectors, Food & Agriculture (23.9%), Pharmaceuticals (38.2%) and the rest area (22.7%) are three main areas that are interesting by firms in our samples. For the rest, only 1.9% of publications are related to Personal Care are, 12.2% from Food & Agriculture and Pharmaceuticals (FAPH) area, 0.5% from Dietary and nutritional supplement (FA1) area and 0.6% from

Functional foods area (FA2). Among the share of subject area across all industry sectors, Pharmaceuticals area controls the highest share.

There are 36 publications out of 629 publications (5.7%) are also filed by intra-firms collaboration (i.e. firm with many SBUs) and joint collaboration (i.e. two or more firms from similar or different industry sectors). Firms with two SBUs i.e. Personal Care and Food & Agriculture sectors (Intra-PCFA) file the highest number of patents (30.6%) compare to other firms from collaboration. This industry sector basically filed their patents in the three main areas i.e. 45.5% from Food & Agriculture area, 36.4% from Pharmaceuticals area and 18.2% from none of the three dominant subject areas. For others industry sectors in the special sector, most of them are submitted their publications close to one of their industry sectors.

The growth of scientific publications and patents are also analysed in the last twenty years i.e. from year 1990 to year 2009 with respect to industry sectors and subject areas. Firstly, the growth of scientific publications and patents in respect to industry setors is shown in Figure 8. Food & agriculture sector is the most active industry sector for both filing patents and publishing scientific publications. There is a strong increase in the number of patents and publications from year 2000 onward. Unlike the increasing growth rate of patents and publications by Food & Agriculture industry, Pharmaceuticals, Chemicals and Personal Care industry show rather low increase in the number of both publications. The Personal Care industry shows not only a very slight increase in the number of patents and publications but also it would seem has no tendency to change.

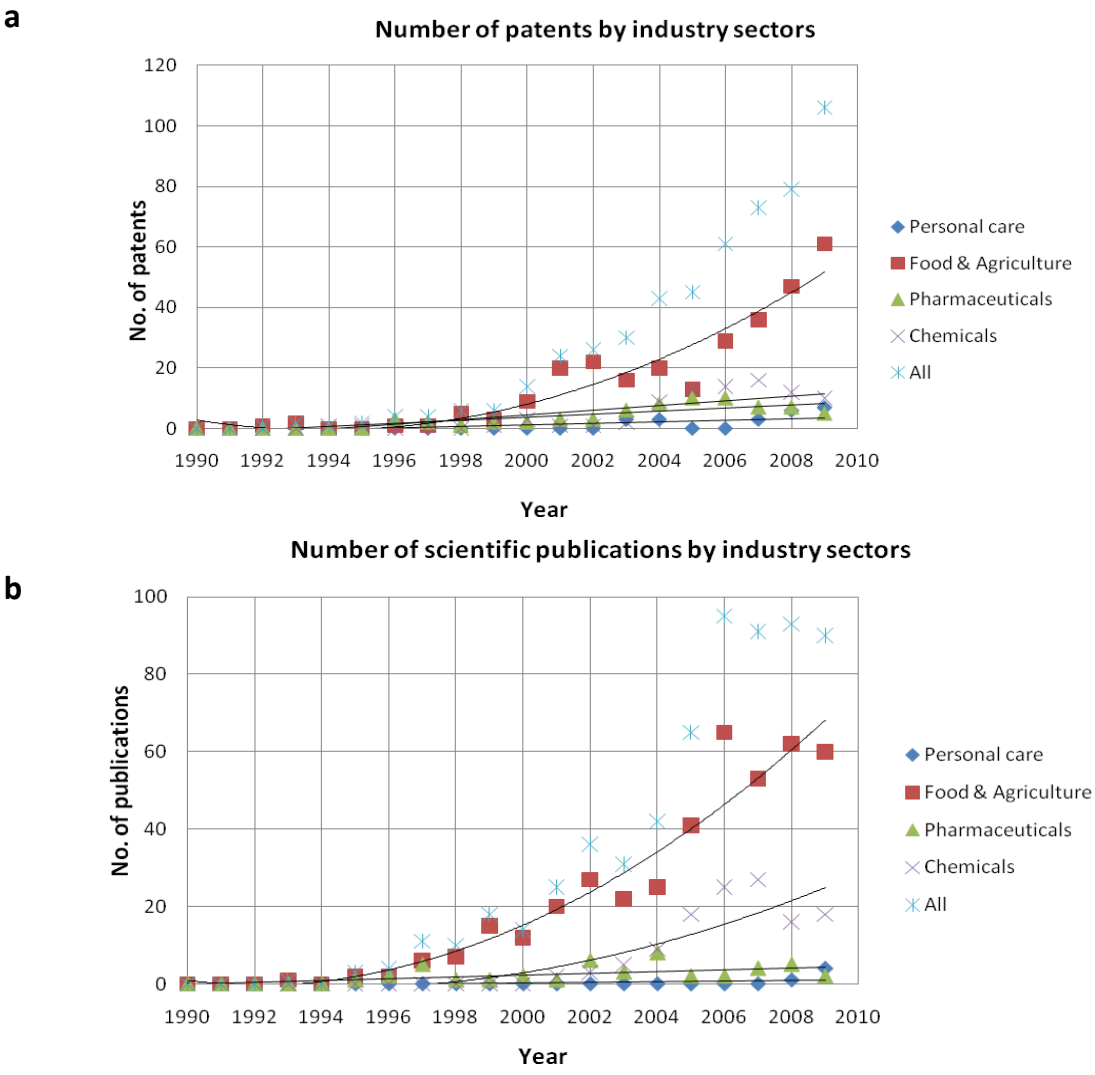

Figure 8: a) Number of patents by four main industry sectors. b) Number of scientific publications by four main industry sectors.

Secondly, the growth of patents and scientific publications with respect to subject areas is shown in Figure 9. The growth of patents and scientific publications with respect to subject areas is increasing overall sections starting from year 2000 onward. By looking at the growth of patent documents (Figure 9a), Food & Agriculture area shows the largest increase among all sections (looking at the formula for the respective linear fits, Trend line), and followed by Pharmaceuticals, none of the three and Personal Care area. On the other hand, Pharmaceuticals area shows the biggest increase in number of scientific publications, followed by none of the three, Food & Agriculture and Personal Care area (Figure 9b). The same trend from both Figures is Personal Care section which shows the least increase in number of patents and publications with indication to change. This is also found when looking at the growth of

patents and publications in respect to industry sector. The reason is that there are only a few companies in Personal Care sector interesting in the field of probiotics. Most of the probiotics applications are related to Food & Agriculture and Pharmaceuticals section.

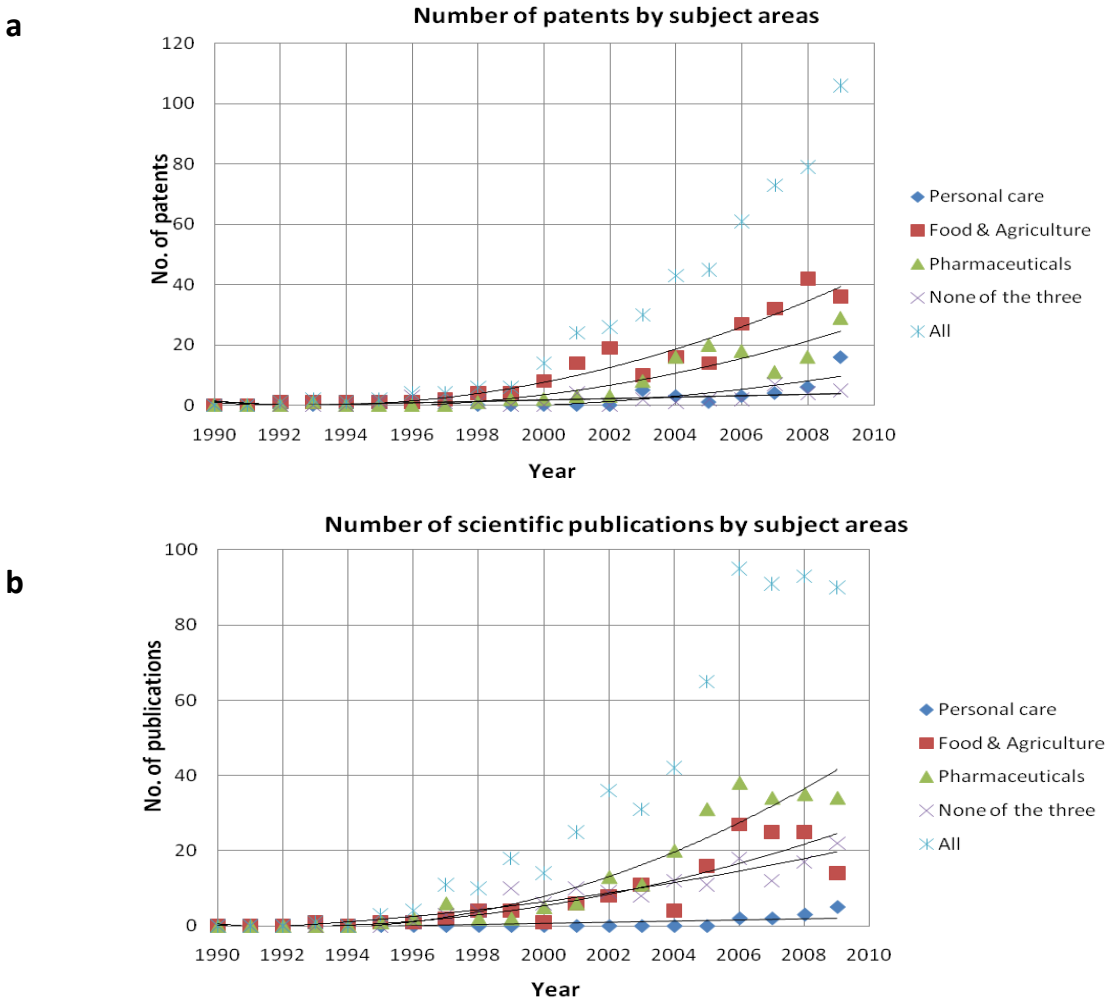

Figure 9: a) Number of patents by four mains subject areas. b) Number of scientific publications by four main subject areas.

Figure 10 shows the result of patents and scientific publications filed and published by the special industry sectors besides from the four main industry sectors. There are two forms of the new sectors which are found in this study. The first form of the industry sector occurs when there are many SBUs within one firm. This type of industry sector is called the intra-firm collaboration. The second form occurs when two or more firms from similar or different industry background filed or published patents or publications together. This type of industry sector occurs from a joint collaboration.

Figure 10a shows that the most increasing industry sector that filed patent in the field of probiotics is the firm that has two SBUs i.e. Personal Care and Food & Agriculture sectors (Intra-PCFA). The trend of patents filed by the new industry sectors are not that high when compared to patents filed by a single company (i.e. the four dominant Industry sectors – Personal Care, Food & Agriculture, Pharmaceuticals and Chemicals). However, the overall trend of patents filed by these new industry sectors is slightly increased both from intra-firm collaboration and joint-collaboration. The trends of these new industry sectors are increasing from year 2003.

The same trend is found in scientific publications (Figure 10b) by which there are both intra-firm collaboration and the collaboration between two or more distinct companies that are interesting in the field of probiotics. However, the number of publications by the new industry sectors is less than the number of patents by the new industry sectors.

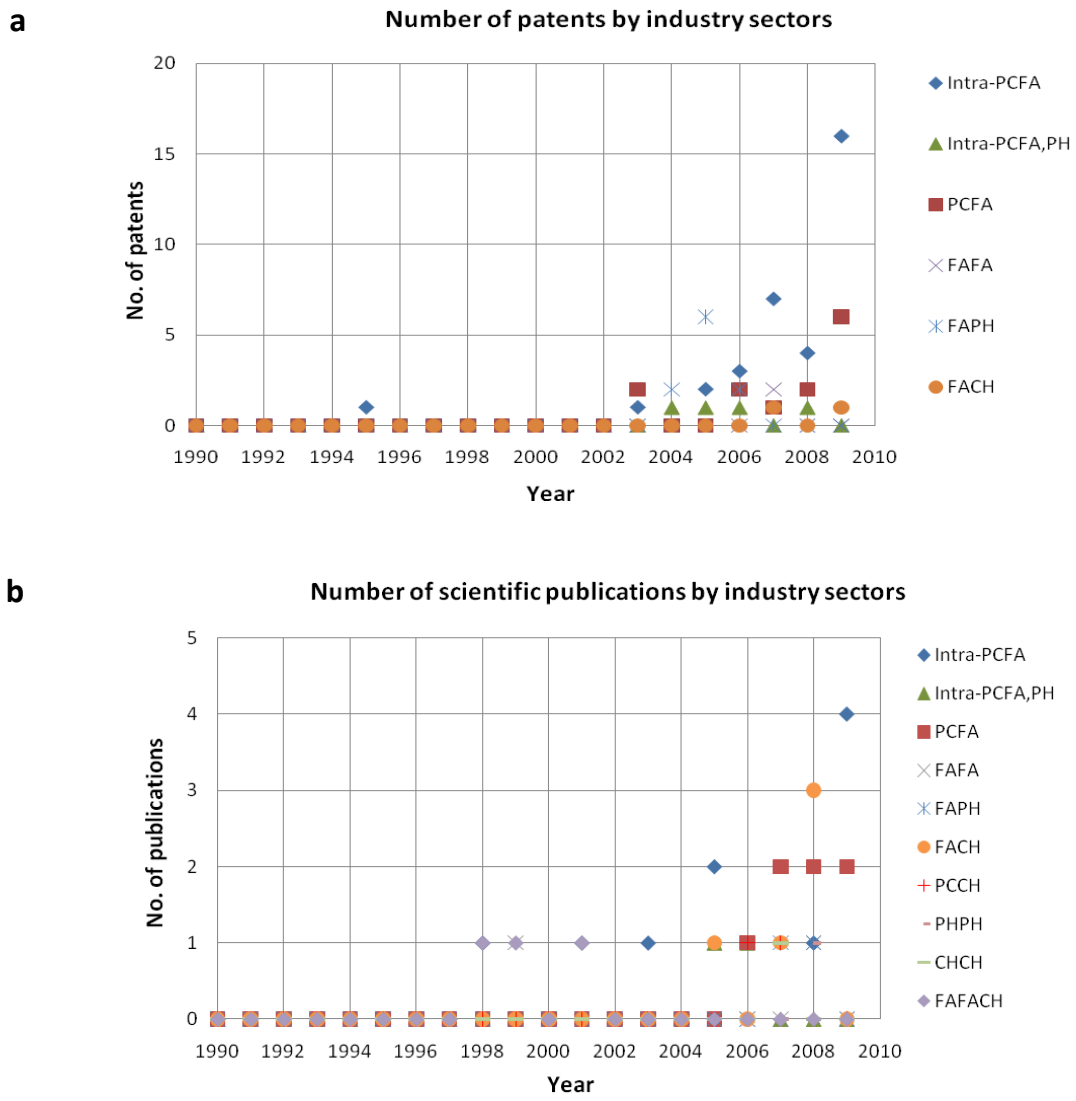

Figure 10: a) Number of patents by other industry sectors. b) Number of scientific publications by other industry sectors.

To summarize the growth of patents and publications in respect to industry sector and publications, nearly all of the curves (Figure 8, 9 and 10) share a common direction but with varying steepness (to be seen in the linear formula) i.e. the number of scientific publications and patents is higher in proportion to the increase in publications year.

7.2 Using Publicly Available Data to Detect Convergence in Probiotics

The purpose of this study is to answer the central research question on 'How publicly available data, including patents and scientific publications, help to foresee or detect the trend of convergence in the case of probiotics'. In order to meet this objective, there are three important sub-questions. By analysing patents and scientific publications, calculating the weighted average year and analysing the correlation between industry sectors and subject areas, the objective is accomplish. The following details are described as the series of three research sub-questions.

RQ1 *Can one detect the trends of convergence in patents and scientific publications before and/or during the product emergence?*

From the descriptive analysis (Table 7 and 8), there is not only the single industry sectors (Personal Care, Food & Agriculture, Pharmaceuticals and Chemicals sector) who has filed or published the publication but also the intra-firm collaboration and joint collaboration between distinct industry sector. The latter type of industry sector implies that there is the blurring between industry boundaries or the trend of convergence in both patents and scientific publications. This trend is not significantly important at a certain moment since the number of intra-collaboration and joint collaboration sectors is still too low. However, in the near future the trend of convergence in probiotics will enormously important due the changing in the market demand and the emergence of the new inter-industry segment. However, it is important to foresee the convergence process by using the weighted average year calculation. WAY calculation of scientific publication and patents in each of industry sectors and subject areas have been performed in order to reduce the complexity of the results to a singer number i.e. weighted average year of each industry sector and subject area (Table 9 and 10).

The assumption is the weighted average year of scientific publication for each of the sectors and each of the subject areas lies earlier than the weighted average year of patents. Our hypothesis on the time series event of convergence will be accepted when this assumption is proved to be true. The results on WAY calculation show that not all industry sectors or subject areas have the weighted average year of publications earlier than weighted average year of patents. The time lag between both scientific publications and patents in Food & Agriculture are different i.e. 0.3 years for industry sector and no time lag (0 year) for subject areas. From both descriptive analysis and the weighted average calculation, the trend of convergence is possible to detect by analysing patents and scientific publications. However, the further step that relating to the patents and product in the market should be done in order to answer this research question properly and also to be able to detect the full time series of industry convergence (Section 4.3, Figure 6).

Table 9: Weighted average year of scientific publications and patents according to industry sector.

	Industry sectors														
	Select.*	PC	FA	PH	CH	Intra-PCFA	Intra-PCFA,PH	PCFA	FAFA	FAPH	FACH	PCCH	PHPH	CHCH	FAFACH
Art.**	2005.3	2008.8	2005.2	2003.0	2006.3	2005.7	2005.5	2007.7	2003.5	2007.5	2007.2	2006.5	2008.0	2007.0	1999.3
Pat.**	2005.6	2007.0	2005.5	2004.3	2005.6	2007.4	2005.8	2007.3	2007.0	2005.0	2008.0				
Lag** (year)	0.3	-1.8	0.3	1.3	-0.7	2.3	0.3	-0.4	4.5	-2.5	1.2	-	-	-	-

**Art. refers to scientific publications
Pat. refers to patents
Lag refers to time lag between scientific publications and patents
*Select. refers to industry sector in data sample i.e. 527 patents and 629 publications

Table 10: Weighted averaged year of scientific publications and patents according to subject area.

	Subject areas										
	Select.*	PC	FA	FA1	FA2	PH	NO	PCFA	PCPH	FAPH	PCFAPH
Art.**	2005.3	2007.9	2005.2		2002.8	2005.5	2004.5	2007.0		2006.0	
Pat.**	2005.6	2007.1	2005.2	2006.6	2007.0	2005.8	2004.2	2006.5	2006.0	2006.0	2003.5
Lag** (year)	0.3	-0.8	0	-	5.8	0.3	-0.3	-0.5	-	0	-

**Art. refers to scientific publications
Pat. refers to patents
Lag refers to time lag between scientific publications and patents
*Select. Refers to subject area in data sample i.e. 527 patents and 629 publications

RQ2 Is the convergence in the case of probiotics different from the case of phytosterols?

By comparing the results between the case of probiotics and phytosterols, there are many similarities and differences between these two cases:

a) Publication and patent behaviours

In both cases, most of firms have filed and published in the subject areas that are closely related to their core business except Chemicals sector. In the case of probiotics, Chemicals industry filed their patents in another two areas i.e. Food & Agriculture and Pharmaceuticals area. In contrary, Chemicals industry filed their patents in Personal Care and Food & Agriculture area in the case of phytosterols.

The growth of patents and publications in respect to subject area is increased in both cases. However, there is a strong increase overall sections in the case of phytosterols. The growth in probiotics is also increasing but with less steepness for all sections. The degree of steepness is related to the number in front of 'x' value from the linear equation. This can be seen in the formula for the respective linear fits as shown below in Table 11.

Table 11: The comparison of linear formula from the number of scientific publication and patents by subject area between two cases.

Subject area	Publications		Patents	
	Probiotics	Phytosterols	Probiotics	Phytosterols
PC	y = *0.1519*x – 303.08	y = *0.157*x + 1.333	y = *0.4346*x -867.06	y = *5.557*x – 3.866
FA	y = *1.2857*x – 2563.3	y = *12.98*x + 21.66	y = *2.0008*x – 3988.9	y = *5.563*x – 0.2
PH	y = *2.1579*x – 4302.7	y = *3.690*x + 2.2	y = *1.2406*x – 2474.1	y = *3.551*x + 1.466
NO*	y = *1.085*x – 2162.2	y = *5.557*x + 33.13	y = *0.2353*x – 468.91	y = *1.478*x + 4.466

*NO refers to None of the other three

b) The dominant industry and cross-sectoral application

The dominant industry sectors who filed the highest number of patents between two cases are different. In the case of phytosterols, Personal Care sector seems to be the most active industry while Food & Agriculture sector is the most active industry in the case of probiotics. This result implies that the market demand and the application of both cases are different. Phytosterols are mainly applied into personal care products while probiotics are mainly applied into Food & Agriculture products. Chemicals sector in both cases filed their patents in other areas. The interesting subject area for Chemicals sector mainly relate to their customers. For Chemicals sector in the phytosterols case, their customers are clustered in Personal Care and Food & Agriculture sector. In contrary, Food & Agriculture and Pharmaceuticals industry are the major customers of Chemicals industry in the case of probiotics. One important remark is that both cases share a common on the cross-sectoral application. Some industries filed their patents and published in other application areas. In the case of phytosterols, this cross-sectoral application could be found in Personal Care and Food & Agriculture sector. In the case of probiotics, this phenomenon could be seen in Food & Agriculture and Pharmaceuticals sector.

c) Pattern of convergence

The other interesting result between these two cases is the weighted average year between patents and publications data. Time lag between weighted average year of scientific publications and patents will determine the pattern of convergence. Time lag can be calculated by subtracting WAY of scientific publications with patents. The positive value implies that the pattern on convergence starts with the knowledge convergence and follows by the technology convergence. The negative value implies in the other way around. The overall time lag between two cases is almost similar by which the weighted average year of scientific publications lies earlier than the weighted average year of patents (Table 12). The slight difference is there is a negative time lag in Personal Care industry in the case of probiotics. Even though the overall pattern of convergence between two cases is quite similar, the time lag of phytosterols case is higher than the case of probiotics.

Table 12: The comparison of the difference between the weighted average year of patents and publications between two cases.

Time lag	Industry sector				Subject area			
(year)	PC	FA	PH	CH	PC	FA	PH	NO*
Probiotics	-1.8	0.3	1.3	-0.7	-0.8	0.0	0.3	-0.3
Phytosterols	11.6	0.8	3.0	-3.0	11.9	8.0	24.7	16.9

*NO refers to None of the other three

RQ3 How does the probiotics landscape develop in time?

a) The overall probiotic landscape

The purpose of analysing the landscape map is to see the annual development of the probiotic landscape in the last two decades. The expected outcome from the map is to see the development of probiotics in time shifting from one area to the other. The result of probiotic landscape is quite scattered over the years (Appendix 3). The maps show that probiotics become more interesting to firms from year 2001 onward as the density of the red dots in each map increases. There is no shift detected toward specific areas.

b) The trend on drug-like applications

The results from description of patent and publication behaviour (Section 7.1) show that the Food & Agriculture sector is the dominant industry in the application of probiotics, followed by the Pharmaceuticals sector. Figure 11 shows the overall development of probiotics in Top5 technological areas. The IPC codes have classified the patent into certain technological areas. From Figure 11, A61K refers to the class of 'Preparations for medical, dental, or toilet purposes' and A61P refers to 'Specific therapeutic activity of chemical compounds or medicinal preparations'. A23L and A23K are basically related to food area by which A23L refers to 'Foods, foodstuffs, or non-alcoholic beverages' and A23K refers to 'Fodder'. For C12N, this classification refers to 'Micro-organisms or enzymes; compositions'. From the graph, there is an increase in the development of all technological areas by having food area as

the majority. This result can be related to the result shown in Section 7.1 by which Food & Agriculture area controls the highest share across all industry sectors.

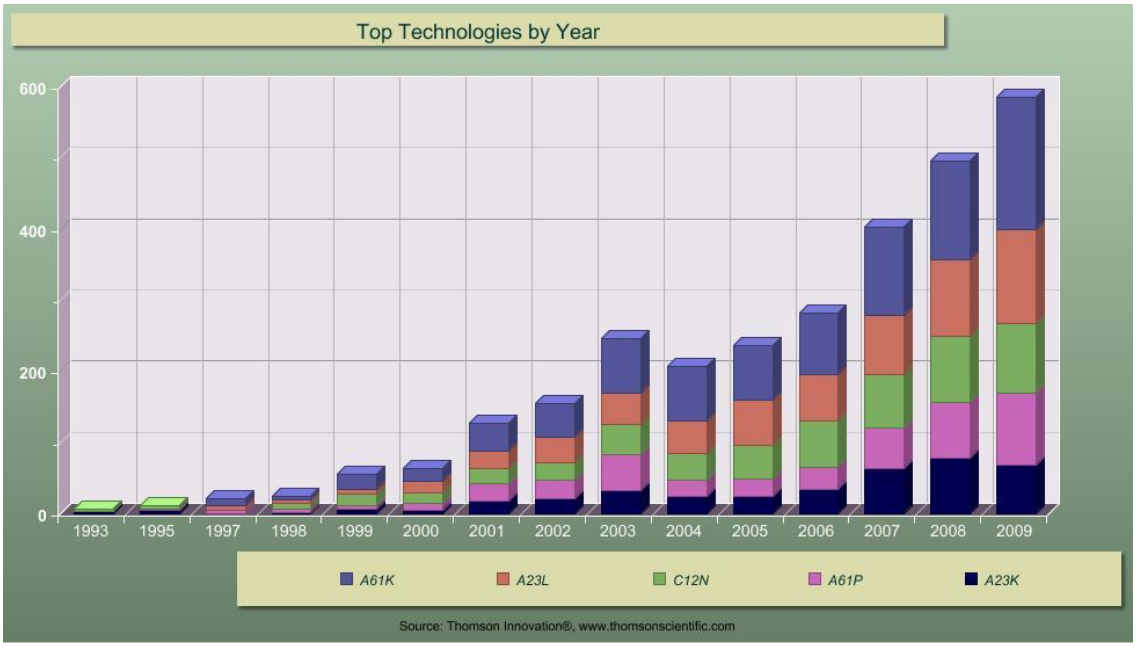

Figure 11: The top technology by year for patent data.

The results from landscape map (Appendix 4) show that there is an increase in the number of patents in the medical or veterinary science area (i.e. A61 in IPC code) in time. The number of patents in this field starts to increase enormously from year 2000. From the maps, the A61 applications are more intended for medical area (disease, bowel, inflammatory, prevention and treatment). However, there is the development of the A61 applications to other areas such as food, animal feed and personal care area in the maps. It implies that there is an increase in the trend of more drug-like application in Food & Agriculture and Personal Care sector over time. In other word, many industry sectors such as Food & Agriculture and Personal Care are interested to apply probiotics in their products with the additional purpose to promote the health benefit such as in the treatment or prevention of certain diseases. Therefore, this situation could be one of the reasons why there is a cross-sectoral application in some industry sectors.

The statistical analysis on the correlation between industry sector and subject area have been performed. The correlation coefficient (R) indicates the correlation between industry sector and the application of probiotics in certain areas. Appendix 5 shows the overall correlation matrixes from patent data in the four main industry sectors i.e. Personal Care, Food & Agriculture, Pharmaceuticals and Chemicals sector.

From Table 13, there is a higher chance that firms in Personal Care sector are filed their patents in Personal Care area (R=0.996) with statistical significance (P=0.000). The same outcome is found in Food & Agriculture sector, firms in this sector normally file their patents in Food & Agriculture area (R=0.948; P=0.000). However, the chance of firms in Food & Agriculture sector that filed their patents in Food & Agriculture area is not highly distinguished from other areas i.e. Food & Agriculture and Pharmaceuticals (FAPH) (R=0.934) and Pharmaceuticals area (R=0.855) with the statistical significant (P=0.000). For Pharmaceuticals sector, there is a higher chance that firms will file their patents in Pharmaceuticals area (R=0.925; P=0.000). The correlation for Chemicals sector is quite different from other sectors. All three subject areas has higher chance that firms in this sector will file their patents i.e. Food & Agriculture area (R=0.930), Pharmaceuticals area (R=0.863) and Food & Agriculture and Pharmaceuticals area (FAPH) (R=0.851) with the statistical significance (P=0.000).

The overall correlation analysis from all four industry sectors implies that there is a positive correlation between industry sector and the area of application.

Table 13: Summary of correlation for patent data in Personal Care, Food & Agriculture, Pharmaceuticals and Chemicals industry.

Industry sector	Correlation	Subject area							
		PC	PCPH						
PC	Person Correlation	.996**	.537*						
	Sig. (2-tailed)	.000	.015						
		FA	PH	NO	FA1	FA2	FAPH	FPCFA	PCFAPH
FA	Person Correlation	.948**	.855**	.881**	.461*	.292	.934**	.292	.063
	Sig. (2-tailed)	.000	.000	.000	.041	.211	.000	.211	.793
		FA	PH	NO	FA1	PCPH	FAPH		
PH	Person Correlation	.499*	.925**	.059	.448*	.311	.549*		
	Sig. (2-tailed)	.025	.000	.806	.048	.182	.012		
		FA	PH	NO	FA1	FAPH			
CH	Person Correlation	.930**	.863**	.491*	.240	.851**			
	Sig. (2-tailed)	.000	.000	.028	.308	.000			

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

It is also important to focus on the technological complexity of the application of probiotics in other industry sectors. The interested industry sectors are the industries which come from the intra-firm collaboration and joint collaboration. Appendix 6 shows the overall correlation matrixes between the frequency of collaboration and technological complexity. The technological complexity refers to the degree of complexity of the subject areas. In this case, the more subject areas (i.e. the multiple applications of probiotics – e.g. subject area FAPH) within one patent, the more complexity of the technology will be. From Table 14, there is a negative correlation between firms from collaboration and technological complexity of subject areas. Firms in these sectors are normally filed their patents in a low technological complexity areas. The correlation coefficient for Intra-Personal Care and Food & Agriculture (Intra-PCFA) is relatively high for Personal Care area (R=0.854; P=0.000). The correlation coefficient of other industries is also high in the low technological area – Personal Care and Food & Agriculture sector (PCFA) with correlation coefficient at 0.978 (P=0.000) in Personal Care area, Food & Agriculture and Food & Agriculture sector (FAFA) with correlation coefficient at 1.000 (P=0.000) in Food & Agriculture area, Food & Agriculture and Pharmaceuticals sector (FAPH) with correlation coefficient at 0.944 (P=0.000) and Food & Agriculture and Chemicals sector (FACH) with correlation coefficient at 0.688 (P=0.001) for both Personal Care and Food & Agriculture and Pharmaceuticals (FAPH) areas. For the collaboration between intra- Personal Care and Food & Agriculture sector and Pharmaceuticals (Intra-PCFA, PH) sector shows a high correlation in Pharmaceuticals area (R=0.840; P=0.000). In short, the overall frequency of firms from the collaboration filing their patents in the high technological complexity is low.

Table 14: Summary of correlation between collaboration industry and technological complexity.

Industry sector	Correlation	Subject area					
		PC	FA	PH	NO	PCFA	FAPH
Intra-PCFA	Person Correlation	.854**	.716**	.907**	.608**	.080	.953**
	Sig. (2-tailed)	.000	.000	.000	.004	.738	.000
		PC	PCPH	FAPH			
PCFA	Person Correlation	.978**	.218	.218			
	Sig. (2-tailed)	.000	.357	.357			
		FA					
FAFA	Person Correlation	1.000**					
	Sig. (2-tailed)	.000					
		PH	NO	FAPH			
FAPH	Person Correlation	.944**	.835**	.358			
	Sig. (2-tailed)	.000	.000	.121			
		FA	FAPH				
FACH	Person Correlation	.688**	.688**				
	Sig. (2-tailed)	.001	.001				
		PC	PH				
Intra-PCFA,PH	Person Correlation	.459*	.840**				
	Sig. (2-tailed)	.042	.000				

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

8 Discussion of Results

After the investigations that have already presented on Chapter 7, this chapter provides further discussion on the significance of patents and scientific publications as the indicators for convergence.

In our sample Food & Agriculture industry is strongly active in the field of probiotics for both filing patents and publishing scientific articles. The Personal Care sector is the least active in this field. The reason is that the application of probiotics mostly relates to Food & Agriculture area and less to Personal Care area. The benefits of probiotics are basically related to health benefits of the host, which makes ingestion of the probiotics beneficial. Therefore, there is a limitation of applying probiotics in personal care products unlike applying probiotics in food and pharmaceutical products.

By looking at the relationship between industry sector and subject area of patents and scientific publications, most of the industry sectors are filed or published in their own core competences. For Chemicals sector, they file their patents in Food & Agriculture (37.7%) and Pharmaceuticals (35.3%) area which are accounted for two thirds of their patents. Most patents are granted on the basis of commercial applicability. Patents are related to the invention of technological knowledge. The technological knowledge will be one of the key success factors for a company to employ this knowledge and introduce new products. However, the case of Chemicals sector is quite different since the purpose of their commercial applicability is to sell their invention e.g. new probiotic strains to other industries. In the case of probiotics, firms in Chemicals sector normally sell their products to Food & Agriculture sector as an ingredient development and to Pharmaceuticals sector as a chemical substance for drug development.

There is an interesting result of the development over time of the share of subject area across all industry sectors between patents and scientific publications. The share of subject area can be related to the application of probiotics and existing products in the markets. Among all industry sectors in our sample, the share of Food & Agriculture shows the highest values. It implies that other industries are interested in this area. For the share of subject area across all industry sectors in scientific publications, pharmaceuticals area holds the majority share. Pharmaceuticals area is the most popular among other areas in the publications since this area normally require the deeper scientific knowledge. From the majority share of subject area between patents and publications, it relates to our expectation by which the total share of subject area is proportional to the application of probiotics. In this case, it implies that most of the new products in the market related to probiotics belong to Food & Agriculture areas with the additional application in Pharmaceuticals area.

The interesting results from analysing the industry sector are the occurrence of intra-firm collaboration and joint collaboration. There is the phenomenon of one firm with many SBUs or multi-firms filing or publishing one patent or publication. These types of industry sectors are not the dominant industry sectors but they represent to certain degree of the fading boundaries in the field of probiotics. The existence of collaboration implies that firms are more interested to share knowledge or expertise.

Furthermore, they are more willing to share a risk in introducing new products to the market. Regarding the cross-sectoral application of firms in our samples, it implies that companies have seen the possible application of their product lines in other sectors and they are interesting enough to keep their invention in the form of intellectual property i.e. patents.

Besides from discussing the relationship between industry sectors and subject areas from patents and publications, the further argument is the time series event of convergence. In order to accept our hypothesis, the trends will emerge in scientific publication first and later can be seen in patents. The expected event is almost true for all industry sectors and subject areas. Even though the expectation is met, the time lag between patents and scientific publications is not outstanding (i.e. WAY of patents and publications are quite close to each other). The reason might be the interest in the field of probiotics is just started in the latter year. The patents and publications in this field are started to increase from year 2000. This phenomenon has resulted in the weighted average year of scientific publications are more or less similar to the weighted average year of patents. It can be implied that a new company who wants to enter this field might face a high entry barrier. Most of the active companies in this field are continuously seeking for knowledge and at the same time starting to introduce the new products into the markets. Therefore, the time lag between scientific publications and patents are not that different for both industry sectors and subject areas perspective. Personal Care and Chemicals industry are the two exceptions since WAY of publications is higher than WAY of patents. The sample size of Personal Care sector from patents and publications are quite small. There are only two industries represent the Personal Care sector. Another possible reason is firms in this sector have different strategy compared to the others. Their strategy might start with filing the patent before publishing their new knowledge in order to avoid other companies employing their invention. In other word, the research might gives some attractive results and companies want to delay the publication in order to develop their own intellectual property. Therefore, the results from WAY calculation from Personal Care sector and Personal Care area are not totally represented and go along with the overall result among other sectors and areas. For Chemicals sector, most of the companies in this sector are less active to possible market applications of probiotics. Their competences are mainly focused on the topics such as methods for analysis or processing of probiotics. These kinds of competences are not patentable and have no value as an internal knowledge.

For the development of probiotic landscape map over time, it is found that the development of probiotics is scattered among many areas in the map. It implies that there is no specific area of interest by firms in our samples. The interesting area might show up by the partner company as a result from cross-sectoral application or by the market demand at a certain period of time. In addition, the increase in drug-like application in Food & Agriculture and Personal Care industry also implies the occurrence of cross-sectoral application. The reason could be the benefits of probiotics themselves are not restricted only in promoting health benefits but also in preventing certain diseases or treating the gastrointestinal track problems. Therefore, these firms are interested to apply probiotics in their products for the special medical purpose.

9 Conclusion

9.1 Limitations and Shortcomings of the Study

The aim of this study is to anticipate the industry convergence on the basis of patents and scientific publications. The monitoring concept done by Curran, et al., 2010 is refined and tested. The concept is reliable for monitoring the phenomena of blurring industry boundaries and demonstrating the applicability not only to phytosterols case but also to probiotics case. This monitoring concept partly can detect the trends of convergence both in patents and scientific publications. There are intra-firm collaboration and joint collaboration which occur by firms in our samples. These firms have filed and published articles together. By looking at the correlation between these industry sectors and subject areas, the overall frequency of these firms is low in filing their patents in high technological complexity areas.

There are both the differences and similarities between the case of probiotics and phytosterols in the behaviours of filing and publishing publications and also the occurrence of convergence process. Firstly, most of industry sectors in both cases file and publish their publications related to their core competences. The result from correlation analysis is also proved this finding by which there is a positive correlation between industry sector and the area of application. In the case of phytosterols, Personal Care industry is the most active among other sectors while in the case of probiotics Food & Agriculture is the most active sector. Secondly, the expected outcome is the convergence occurs as the time series event by which it starts from the knowledge convergence, followed by the technology convergence and end up with the new products on the market. In both cases the assumption is verified to be true since the weighted average year of scientific publications is lower than the weight average year of patents. However, the difference between these two cases is the time lag of probiotics is less than the time lag of phytosterols which is mainly due to the difference in the patenting and publishing trend.

It is also important to see the development of probiotic applications over time. The results from landscape maps show that the development of probiotics is quite scattered in many areas in the map. It means that firms normally have no specific interest area but rather focus on the market demand. Besides from the overall development of probiotic applications, there is an increase in drug-like application in Food & Agriculture and Personal Care industry which implies the cross-sectoral application of probiotics.

Even though the monitoring concept is applicable in this study, the concept cannot be fully employed due to some limitations. Firstly, the area of probiotics might be too extensive and lead to a high number of hits from data mining. A potential problem of these extensive data might impact the data analysis in such a way that the significant results might not be obtained but rather generic conclusions from the evaluation may result. However, the sampling method can be adjusted regarding the purpose of the study. The different sampling strategy will result in different aspect of results and thus data analysis. Secondly, there is the limitation in accessing to certain databases. In order to assign subject area in

scientific publications, CAS (the division of the American Chemical Society responsible for SciFinder®) is used in previously work by Curran, et al. (2010). In this study, this program is not available. The subject areas in scientific publications have been assigned by analysing key words from the title and abstract of each publication from Thomson Innovation. Lack of the computer-aided data mining techniques complicates the data interpretation. Thirdly, it is difficult to detect whether knowledge and technology convergence lead to the industry convergence which is finally resulted in the emergence of new hybrid products on the market. In other word, there is no monitoring tool for relating certain patents with the new products.

The shortcomings of this study are basically related to the sample sizes. Firstly, the number of firms from Personal Care sector who active in the field of probiotics are small. This might affect the results in such a way that the data samples are too small. The results of subject areas from Personal Care sector might not be a good representative for the whole sector since the data comes from only two companies i.e. L'Oreal and SCA Hygiene. The other shortcoming of this study is the small number of patents and scientific publications during year 1990-2000. The overall trend of number of patents and publications start to increase from year 2000 onward. This phenomenon might affect the data interpretation on the correlation analysis between industry sectors and subject areas. In addition, it also might affect the data interpretation for the convergence process by which the weighted average year between these two documents is slightly different.

9.2 Suggestions for Further Research

Firstly, IPCs is used as a tool for assigning the subject areas for each patents. The method for assigning subject areas for scientific publications should be set up. For example, CAS is used in the study of industry convergence in the case of phytosterols. The computer-aided data mining techniques are very useful in order to gather all the necessary data from the large amounts of the available information from patents and scientific publications and save time for data handling and analysis.

Secondly, there is an increase in number of applicant/assignee in patents who come from intra-firm collaboration and joint collaboration of two or more distinct industry sector. It might be useful to further tracking the trend of these sectors and their patenting behaviours since these industry sectors imply the occurrence of industry convergence.

Thirdly, there is some limitation in using WAY calculation such as when the samples are not equally distributed throughout the industry sectors or subject areas. For example, there is no data for WAY calculation from patent data in some areas. In this case, the time lag between WAY of patents and scientific publications could not be compared since there is no WAY calculation from patent data. A further approach for predicting the time-dependent shifts in overlap between scientific and technological fields and industries should be refined in order to reduce the limitation of the weighted average year calculation.

Fourthly, WAY calculation can be used as a tool to test the convergence event. However, in order to cover all three steps of convergence, it is important to relate the patents and the emergence of new hybrid products on the market. It means that the new monitoring tool should be constructed in order to test whether certain patent lead to new hybrid products on the market or not. In other words, this type of analysis will look after the fact (i.e. ex-post analysis) that there is a new hybrid product on the market. The aim of this ex-post analysis is to track back the intellectual property behind the hybrid products. After ex-post analysis, the further study could be focused on the type of convergences in different industry sectors i.e. convergence in substitutes or convergence in complements. However, it is required the assessment to the relationship between patents and new products in the market.

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Appendices

Appendix 1: Forms of Intellectual property – Copyrights, Trademarks and Trade Secrets

Appx 1.1 Copyrights

There are two main different points between patents and copyrights. Firstly, patents are used to protect ideas which have been reduced to practice, while copyrights are used to protect the expression of the idea (Knight, 1997). Secondly, patents are used to protect others from practicing an invention, while copyrights are used to prevent others from strictly copying a work (Knight, 1997). If someone performs one of the acts that are restricted by copyright without the permission or license from the copyright owner, the copyright owner can sue for the infringement of their work (Bainbridge, 1999). Copyrights are used to protect written work such as literature, drama, music and computer software (Knight, 1997; Bainbridge, 1999). Moreover, copyrights are used to protect other expressions of ideas such as choreography, drama and pantomime (Knight, 1997). The owner of the copyright has the exclusive right to do certain acts in relation to the work (Bainbridge, 1999). For example, the owner has a right to make a copy, broadcast or sell copies of their work to the public during their life time plus ninety years after the death of the owner (Bainbridge, 1999).

Appx 1.2 Trademarks

Trademarks might not be a good reflection of inventions or creative works but they are of importance in an industrial and commercial sense (Bainbridge, 1999). Trademarks are any word or symbol used by manufacturers to identify and distinguish their products from goods made or sold by others (Knight, 1997; Bainbridge, 1999). They are often related with business image, goodwill and reputation (Bainbridge, 1999). According to Knight (1997), trademarks are an effective way for manufacturers to distinguish their products from competitive products in the marketplace. Most of the time customers rely on many marks as indicating quality, value for money or origin of goods (Bainbridge, 1999). Trademarks must be obtained from individual countries and fees are required in order to register the trademark (Knight, 1997). The application fees for patents are higher than for trademarks application. The period of trademarks protection is 5 years but can extended. Trademarks should not mislead the consumers or so called trademarks infringement.

Appx 1.3 Trade Secrets

Trade secrets provide a critical information and know-how of a business which is kept out of the public domain (Knight, 1997). Trade secrets can be more effective than patents in slowing down competition since it is a non-disclosure agreement (Knight, 1997). However, the owner of the trade secrets must take

extra precautions to maintain security of the trade secret by which the trade secrets are only kept within the organization (Knight, 1997).

The usage of each type of intellectual property is different according to industry segment. According to Ellens (2010, oral communication), he mentioned that among the types of intellectual property mentioned above, patents and trademarks are the most important in the food industry. By looking closely to the use of patents and trademarks regarding the size of the company, small companies are more often using trademarks to protect their invention. The reason is trademarks are in general cheaper than patents. Large food companies normally use the complementary between patents and trademarks to protect their invention. Patents and trademarks can be considered as a tangible asset and perception for the food company.

Appendix 2: Stopwords

These stopwords are used for producing Landscape map in Thomson Innovation. The aim for inserting these stopwords is to prevent these words appearing in the map.

a	aber	abhängig	abhängige	abhängigen
abhängiger	abhängiges	abhýngig	abhýngige	abhýngigen
abhýngiger	abhýngiges	able	about	above
accordance	according	across	actually	aforementioned
after	again	against	agent	agents
all	alle	allein	alleine	allem
allen	aller	alles	allow	allowing
allows	almost	alone	along	already
als	also	alt	alter	although
always	am	among	an	and
andere	ändern	anders	ang	angegebene
angegebenen	angegebener	angegebenes	anmelder	anmelderin
anordnung	anordnungen	another	anspruch	ansprüche
ansprýche	anstatt	any	anybody	anymore
anyone	anything	anywhere	applied	après
april	aprýs	aq	are	area
areas	aren't	around	article	articles
as	ask	asked	asking	asks
aspect	assignee	assignees	at	atome
atomes	au	auch	auf	auffinden
aufgabe	aug	august	auprès	auprýs
aus	ausser	ausserdem	aussi	autant
autre	autres	aux	avant	avec
away	ayant	b	back	backed
backing	backs	based	be	became
because	become	becomes	bedeuten	been
before	began	behandlung	behind	bei
beide	beinahe	being	beings	beispiel
beispiele	beispielsweise	bekannt	bekannte	bekannten
bekannter	bekanntes	bereich	beschrieben	besitzen
besser	best	beste	besten	bester
bestes	bestimmung	better	between	beyond
beziehungsweise	big	billion	bis	bon
bonne	bonnes	bons	both	but

by	bzw	c	ca	came
can	cannot	can't	caractérisé	caractérisée
caractérisées	caractérisés	caractýrisý	caractýrisýe	caractýrisýes
caractýrisýs	case	cases	caused	ce
ceci	cela	celle	celles	celles-ci
celles-là	celles-lý	celui	celui-ci	celui-là
celui-lý	certain	certainly	ces	ceux
ceux-ci	ceux-là	ceux-lý	cf	ch
chacun	chaque	chaques	characterized	cher
chere	chère	chers	chýre	circa
claim	claimed	claims	clear	clearly
co	combine	combined	come	comme
composées	composés	composition	compositions	composý
composýe	composýes	composýs	comprenant	comprise
comprising	compsn	concern	concerning	concerns
connu	connue	connues	connus	consisting
constitué	constituer	constitués	constituý	constituýs
contain	contained	containing	contains	content
continue	copyright	corresponding	corrresponds	could
couldn't	d	dafür	danach	dann
dans	daraufhin	darf	darstellung	darum
das	data	d'au	davon	de
december	defined	deg	delete	dem
dementsprechend	dementsprechende	dementsprechenden	dementsprechender	dementsprechendes
den	denen	denn	denotes	der
deren	dérivé	dérivés	des	describe
described	describes	describing	desdits	deshalb
dessen	deswegen	determining	deux	dezember
did	didn't	diese	diesem	diesen
dieser	dieses	differ	different	différent
différente	différentes	differently	différents	diffýrent
diffýrente	diffýrentes	diffýrents	disclosed	discloses
do	does	doesn't	doing	done
don't	down	downed	downing	downs
drei	dritte	dritten	dritter	drittes
du	dudit	due	d'un	d'une
durch	dürfen	during	dýrfen	dýrivý
dýrivýs	e	each	early	efficiently
eigentlich	ein	eine	einem	einen

einer	eines	einfach	einige	einiger
einiges	einmal	einrichtung	eins	either
élément	éléments	elle	elles	else
elses	elsewhere	embodiment	en	enables
end	ended	enden	ending	ends
enough	ensemble	enthaltend	entre	entsprechend
entsprechende	entsprechenden	entsprechender	entsprechendes	er
erfindungsgemäss	erfindungsgemäß	erfindungsgemässe	erfindungsgemäße	erfindungsgemässen
erfindungsgemäßen	erfindungsgemýss	erfindungsgemýsse	erfindungsgemýssen	erfindungsgemýý
erfindungsgemýýe	erfindungsgemýýen	ersetzt	erste	ersten
erster	erstes	erzeugen	es	esp
especially	essentiel	essentielle	essentielles	essentiels
est	et	étaient	était	etc
êtes	être	etwa	euch	even
evenly	éventuellement	ever	every	everybody
everyone	everything	everywhere	example	excellent
except	f	face	faces	fact
facts	fähig	faire	faisant	fait
faites	far	favoriser	feb	februar
february	felt	few	fig	find
finden	finds	first	folglich	follow
followed	following	fonction	fonctions	for
formed	formel	formeln	forming	formula
formule	formulée	formulées	formules	formulierung
formulierungen	formulýe	formulýes	four	fragen
frau	from	full	fully	für
further	furthered	furthering	furthers	fýhig
fýr	g	gave	geändert	geänderte
geänderten	geänderter	geändertes	geben	geendet
gefragt	gefunden	gegeben	gegen	gehen
geht	gemacht	gemeinsam	gemeinsame	gemeinsamen
gemeinsamer	gemeinsames	general	generally	generell
genutzt	gesagt	get	gets	getting
gew	gewesen	geworden	geýndert	geýnderte
geýnderten	geýnderter	geýndertes	gibt	ging
give	given	gives	gleich	gleiche
gleichen	gleicher	gleiches	go	goes
going	good	goods	got	gotten
grand	grande	grandes	grands	great

greater	greatest	gros	groß	grosse
große	grossen	großen	grosser	großer
grösser	größer	grosses	großes	group
groupe	grouped	groupement	groupements	groupes
grouping	groups	groups	groý	groýe
groýen	groýer	groýes	gruppe	grýsser
gut	gute	guten	gutes	gutter
h	haben	had	hadn't	has
hasn't	have	having	havn't	he
he'd	he'll	her	here	herein
here's	herr	herself	herstellen	herstellung
herstellungsverfahren	he's	heute	high	higher
highest	him	himself	his	hoch
höchst	höchste	höchsten	höchster	höchstes
höher	how	however	hýchst	hýchste
hýchsten	hýchster	hýchstes	hýher	i
i'd	identify	identiques	if	ihr
ihre	ihren	ihrer	ihres	ii
iii	i'll	i'm	image	important
improve	improved	improving	in	include
includes	including	increase	increased	increasing
indeed	independently	insbesondere	instead	interest
interested	interesting	interests	interresse	into
invention	inventions	Involves	is	isn't
it	it'd	it'll	its	it's
itself	iv	i've	ix	j
jahr	jahre	jährlich	jamais	jan
januar	january	je	jede	jeden
jeder	jedes	jedoch	jemals	jemand
jeweils	joli	jolie	jolies	jolis
jpo	jul	juli	july	june
jung	jünger	jüngste	jüngster	jüngstes
juni	just	jýhrlich	jýnger	jýngste
jýngster	jýngstes	k	kann	keep
keeps	keine	kg	kind	klein
kleine	kleinen	kleiner	kleines	knew
know	known	knows	komponente	können
konnte	kýnnen	l	la	là
ladite	lang	länge	länger	längsten

laquelle	large	largely	lassen	laßen
lässt	läßt	last	later	latest
laýen	le	least	ledit	l'élément
lequel	les	lesdites	lesdits	lesquelles
lesquels	less	let	let's	letzte
letzten	letzter	letztes	leur	leurs
level	like	likely	little	lon
long	longer	longest	lorsque	low
lower	lý	l'ýlýment	lýnge	lýnger
lýngsten	lýsst	lýýt	m	ma
machen	made	mag	main	maintain
make	making	man	mann	many
mar	march	märz	mass	masse
maße	matériau	matériaux	matière	matières
matiýre	matiýres	matýriau	matýriaux	may
maybe	maýe	me	meaning	means
mehr	mehrere	mehreren	mehrfach	meist
meiste	meisten	meister	meistes	mélange
member	members	men	mentioned	method
mich	might	million	mindestens	mise
mit	mitglied	mittel	mittels	mm
möchte	mode	modefizierten	modifiziert	modifizierte
modifizierter	modifiziertes	mogen	mögen	möglich
moins	mol	more	most	mostly
moyen	moyens	mr	mrs	much
muss	muß	mussen	müssen	müßen
müßte	müßte	must	mustn't	muý
my	mýchte	mýgen	mýglich	mýlange
mýrz	myself	mýssen	mýýen	mýýte
n	nach	nächste	nächsten	nächster
nächstes	nachweis	named	necessary	need
needed	needing	needs	nehmen	neu
neue	neuen	neuer	neues	neuest
neuesten	neuste	never	new	newer
newest	next	nh	nicht	nichts
nie	niedrig	niedrige	niedrigen	niedriger
niedriges	niemals	nm	no	nobody
nombre	nombres	non	none	noone
normalerweise	not	nothing	nötig	nötiger

notwendig	nouveau	nouveaux	nov	novel
november	now	nowhere	nr	number
numbered	numbering	numbers	nummer	nutzen
nýchste	nýchsten	nýchster	nýchstes	nýtig
nýtiger	o	oberen	object	objects
objekt	objekte	objet	objets	obtain
obtained	obtaining	obtenu	obtenue	obtenues
obtenus	obwohl	oct	october	oder
of	off	offen	oft	often
öfter	ohne	okt	oktober	old
older	oldest	on	once	one
only	ont	open	opened	opening
opens	optionally	or	order	ordered
ordering	orders	other	others	ou
où	our	out	over	own
oý	p	par	part	parted
particularly	partie	parties	parting	parts
per	percent	perhaps	peut	peuvent
piece	place	places	platz	plätze
plýtze	poids	point	pointed	pointing
points	portion	position	possible	pour
pouvant	ppm	präparate	präparates	preferable
preferably	préférence	préférences	premier	première
premiýre	preparation	préparation	prepared	present
presented	presenting	presents	principe	problem
probleme	problems	produce	producing	produisant
produisent	produit	produits	provide	provides
prozent	prozentig	prýfýrence	prýfýrences	prýparate
prýparates	prýparation	pts	puisse	punkt
punkte	Purpose	put	puts	q
qu	quality	quantité	quantitý	que
quelle	qu'elle	quelles	qu'elles	ques
qui	quil	qu'il	quils	qu'ils
quite	quon	qu'on	r	range
rapporte	rather	really	relate	relates
relating	représente	représentent	representing	represents
reprýsente	reprýsentent	respect	result	resulting
revendication	revendications	revendique	revendiquent	richtig
richtige	richtigen	richtiger	richtiges	richtung

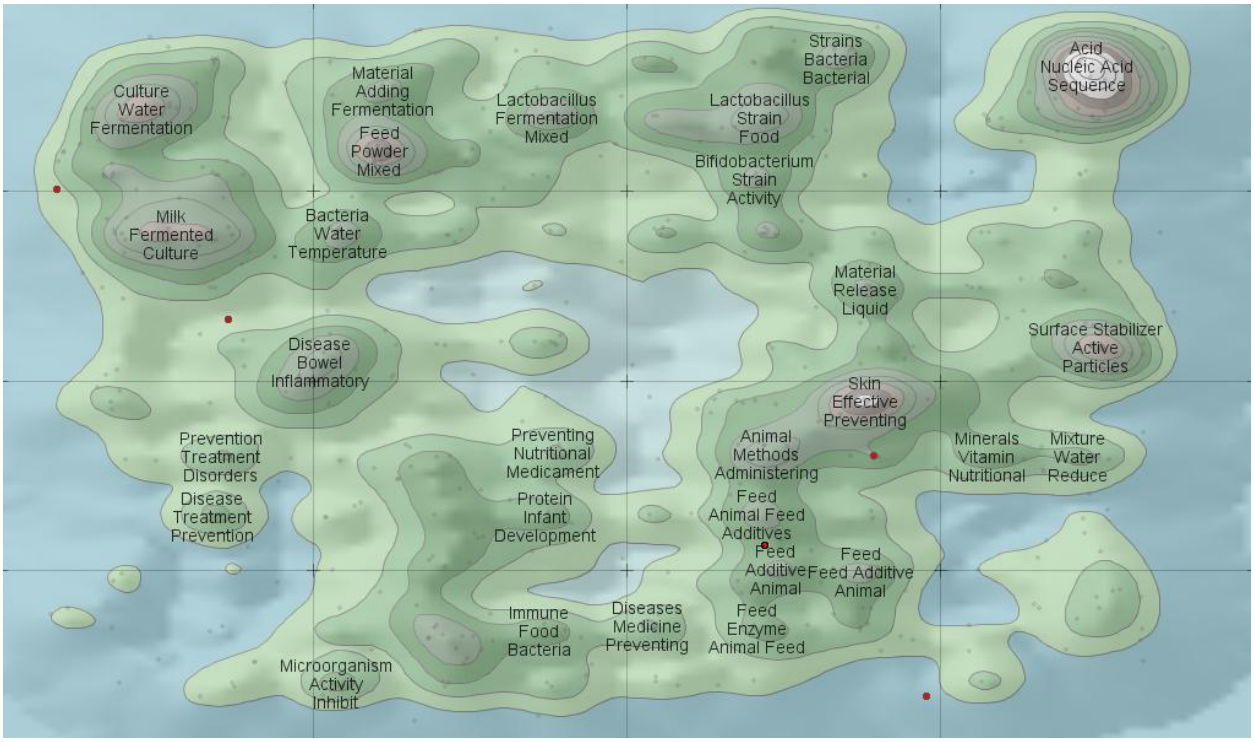
right	room	rooms	s	sagen
sagt	said	same	sample	sans
saw	say	says	schliesslich	schließlich
schlieýlich	se	second	seconde	seconds
see	seem	seemed	seeming	seems
sees	sehr	sein	seine	seinen
seiner	selected	selon	sep	sept
september	ses	several	shall	she
she'd	she'll	she's	short	should
show	showed	showing	shows	sich
sicherlich	side	sides	sie	significant
significantly	signification	significations	since	sind
small	smaller	smallest	so	soit
soll	sollen	sollte	soln	some
somebody	somehow	someone	something	somewhere
sonst	sont	state	states	statt
stattdessen	step	steps	still	study
stuff	sub	subsequent	subsequently	substance
substanz	substanzen	substituées	substitués	substituiert
substituierte	substituiertes	substituýes	substituýs	such
sup	sur	sure	système	systýme
t	take	taken	tant	tel
telle	telles	tels	test	testing
than	that	that's	the	their
them	themselves	then	there	thereby
therefore	therein	thereof	there's	these
the've	they	they'd	they'll	they're
thing	things	think	thinks	this
those	though	thought	thoughts	three
through	thus	title	titre	to
today	together	too	took	toward
traitement	treating	turn	turned	turning
turns	two	u	über	überall
um	un	unabhängig	unabhängige	unabhängigen
unabhängiger	unabhängiges	unabhýngig	unabhýngige	unabhýngigen
unabhýngiger	unabhýngiges	und	under	une
unes	unit	units	uns	unter
unteren	unterscheiden	unterscheidend	unterscheidende	unterscheidenden
unterscheidender	unterscheidendes	until	up	upon

us	use	used	useful	uses
using	usually	v	value	various
verbesserte	verbindung	verbindungen	verfahren	verschieden
verschiedene	verwendung	very	vi	via
viel	viele	vielen	vieles	vielleicht
vieux	vii	viii	viiii	vohergehende
von	voneinander	vorhergehend	vorhergehenden	vorhergehendes
vorrichtung	vorrichtungen	vous	vs	w
want	wanted	wanting	wants	war
waren	warum	was	wasn't	way
ways	we	we'd	weg	weight
weil	weiss	weiß	weiter	weitere
weiteren	weiterer	weiteres	weiterhin	weiý
welche	welchen	welcher	welches	we'll
we'lls	wenig	weniger	wenigstens	wenn
went	werden	were	we're	weshalb
we've	what	what'll	what's	when
where	wherein	whether	which	whichever
while	who	whole	whom	who's
whose	who've	why	wichtig	wie
wieso	will	wir	wird	wirkstoff
wirkung	wissen	with	within	without
wobei	wollen	wollte	won't	word
worin	work	worked	working	works
would	would'nt	would've	wt	wurde
wurden	x	xi	xii	xiii
xiv	xv	y	ýber	ýberall
year	years	yes	yet	ýfter
ýlýment	ýlýments	ýndern	you	you'll
young	younger	youngest	your	you're
yours	you've	ýtaient	ýtait	ýtes
ýtre	ýventuellement	z	zeigen	zu
zuletzt	zum	zur	zusammensetzung	zwei
zweite	zweiten	zweiter	zweites	

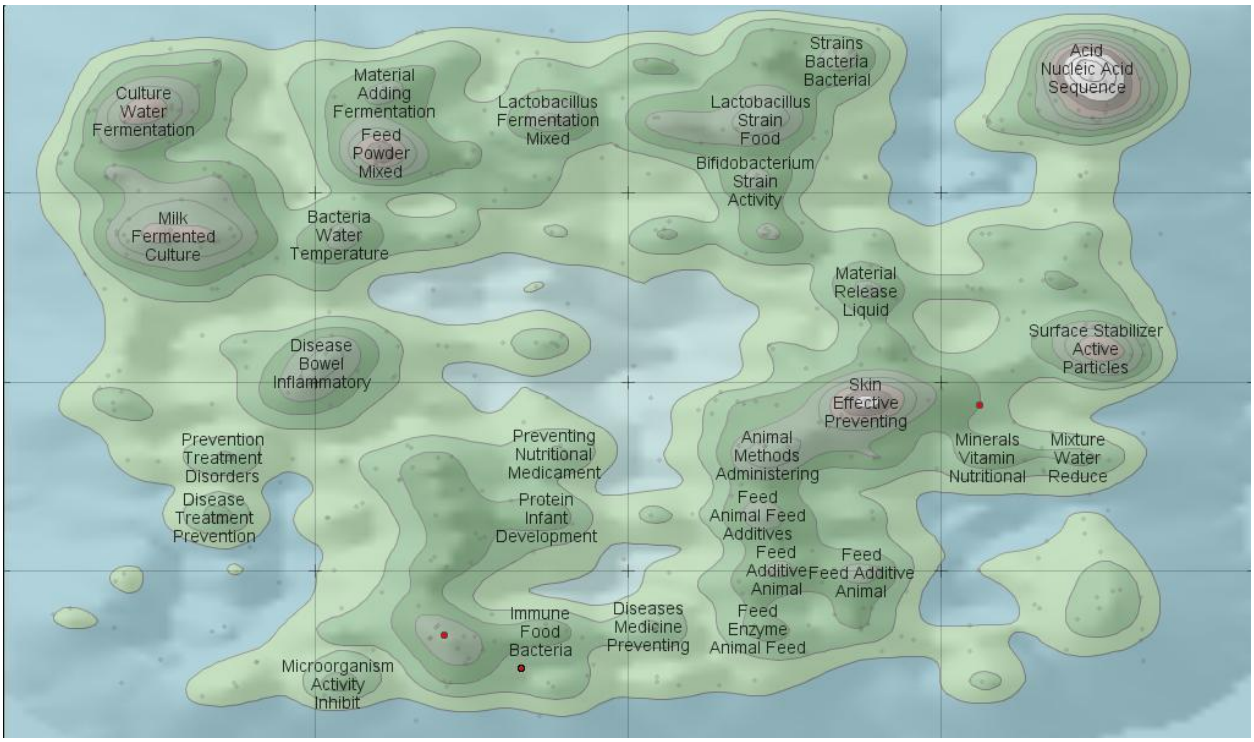
Appendix 3: The Overall Development of Probiotics Landscape

The following maps are showing the development of the application of probiotics from year 1990 to 2009. The small red dots represent the patent documents in certain areas on the maps. The clearer picture on the development of probiotics landscape can be seen from the attached DVD.

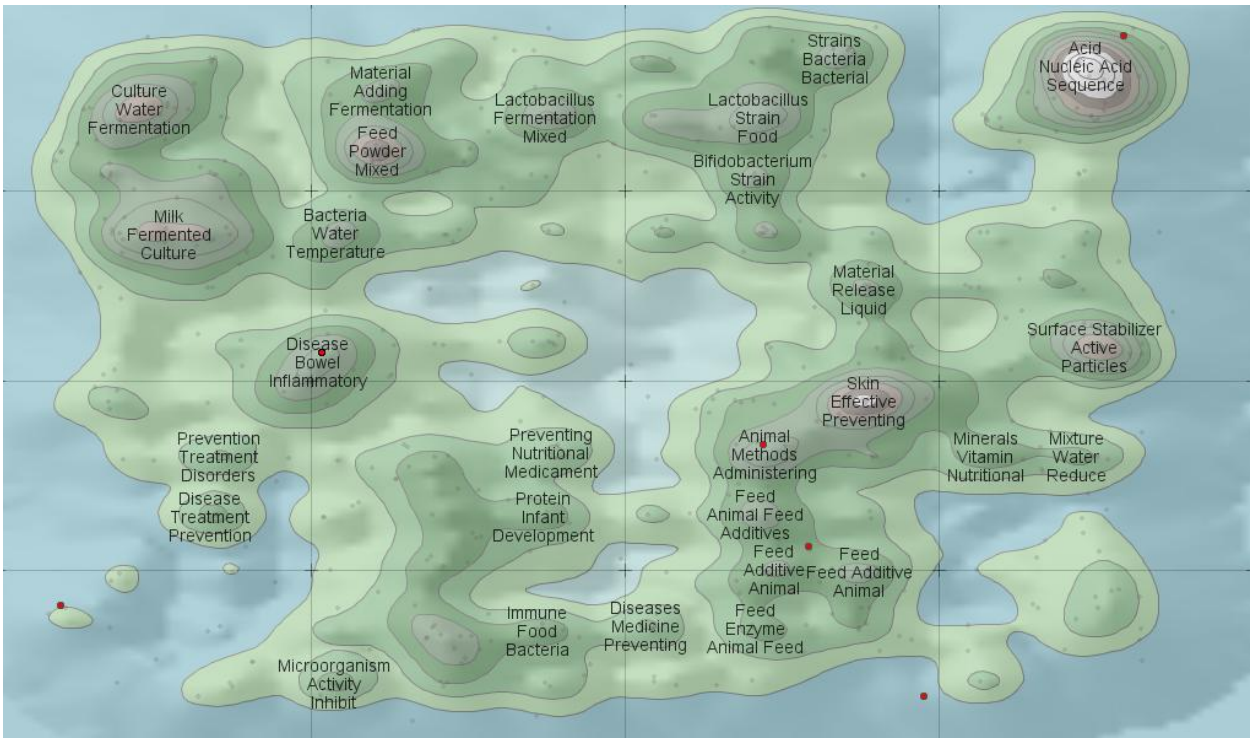
- Year 1990



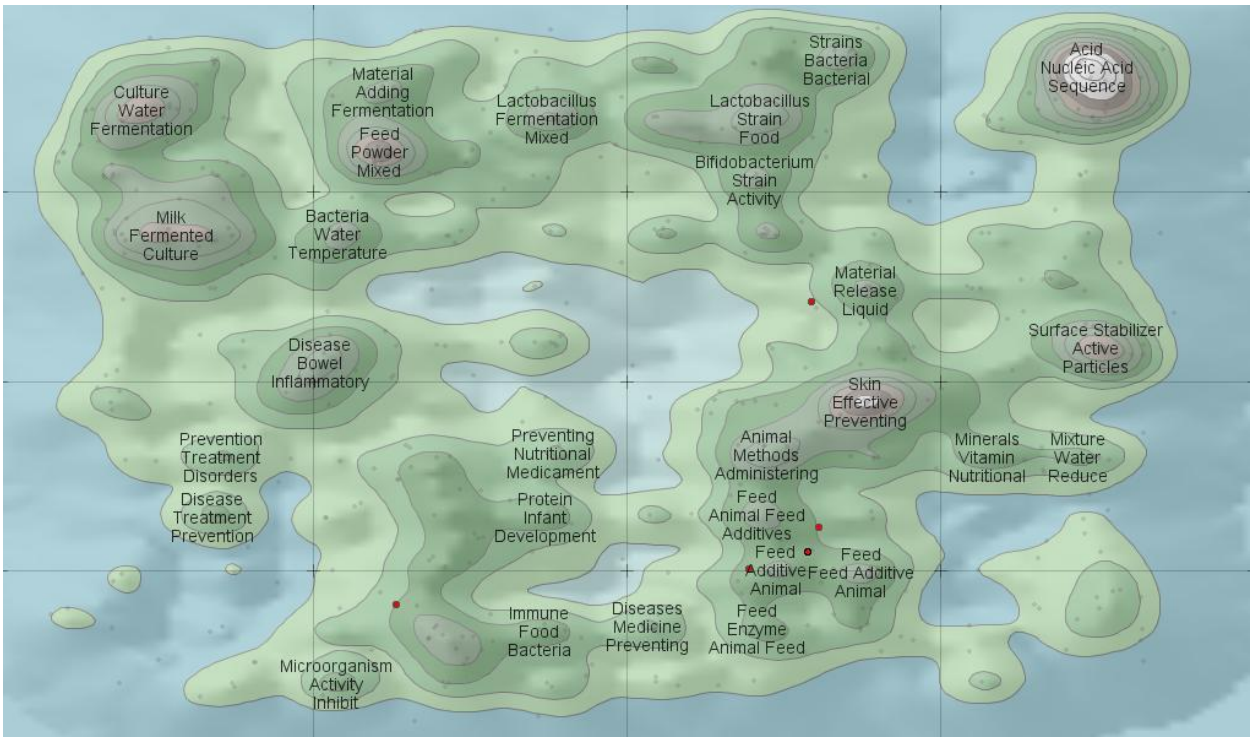
- Year 1991



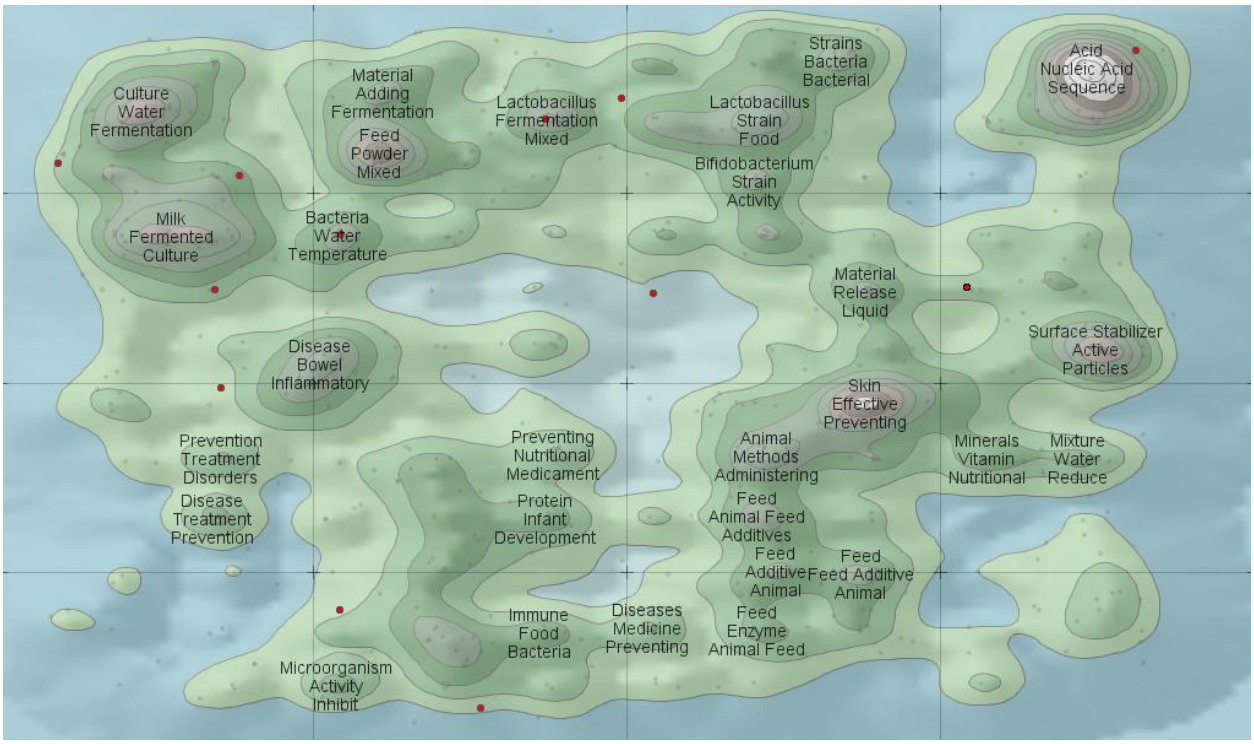
- Year 1992



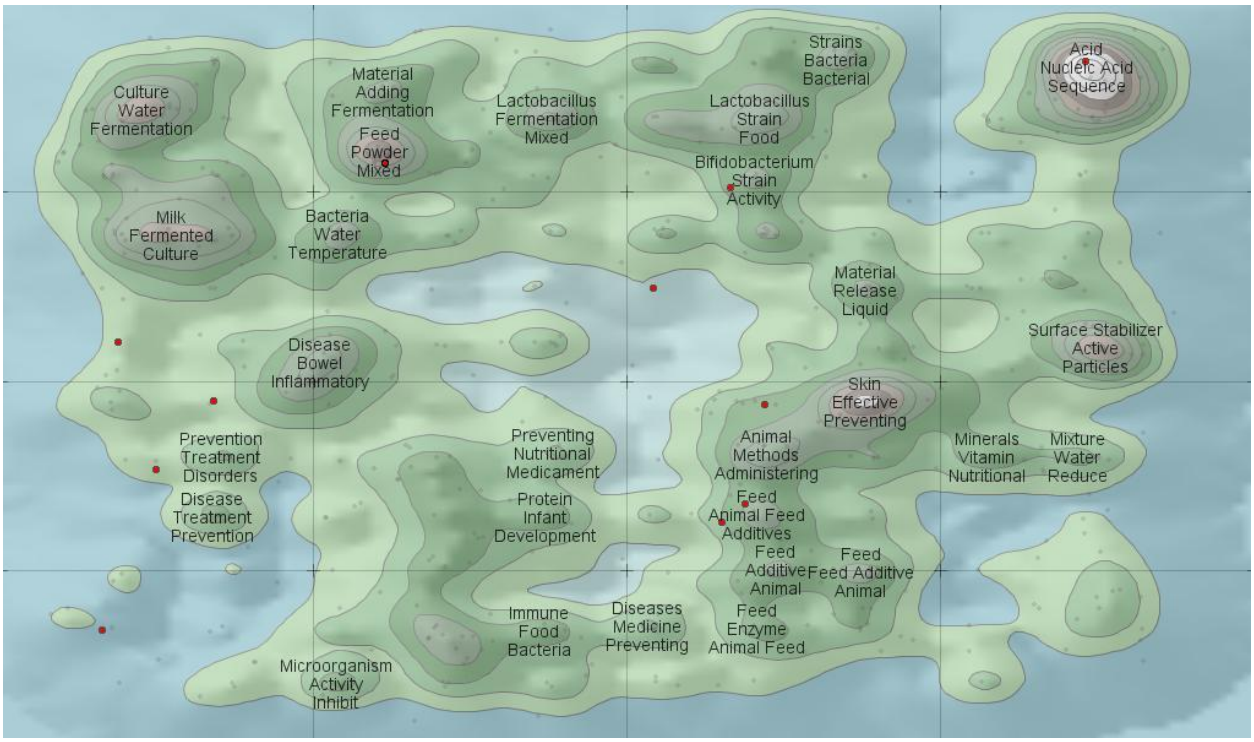
- Year 1993



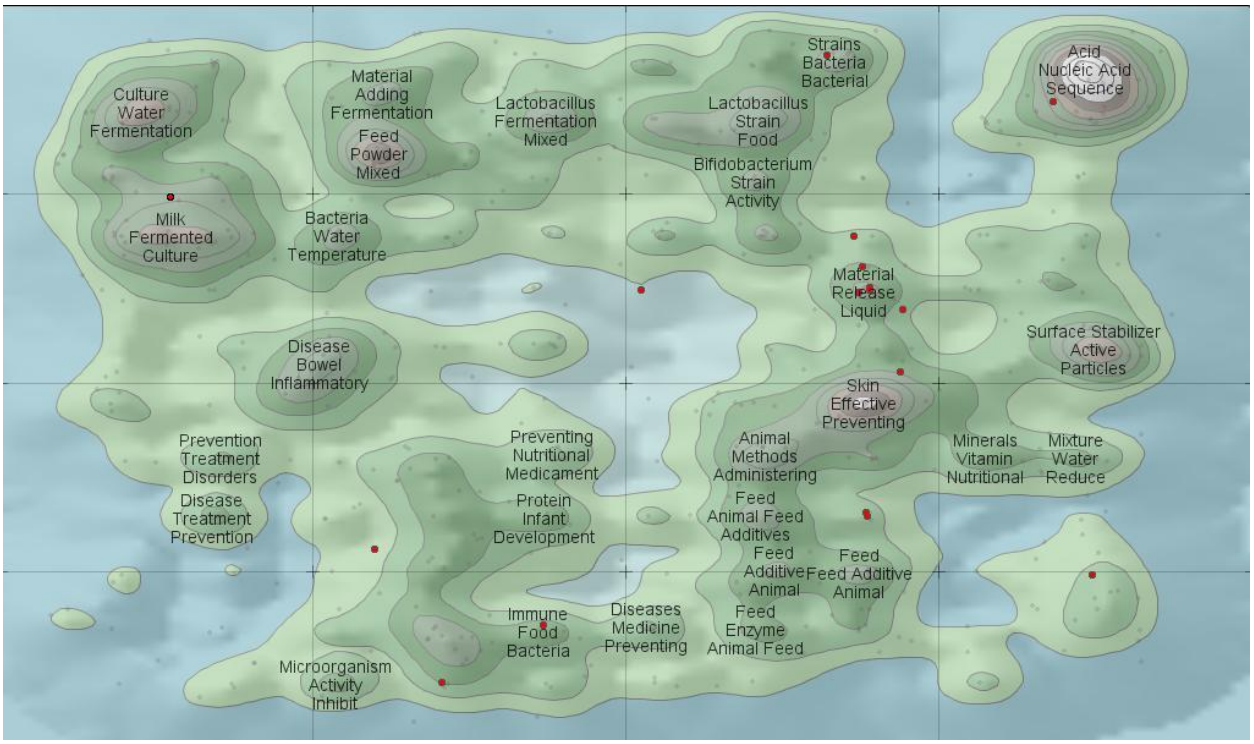
- Year 1994



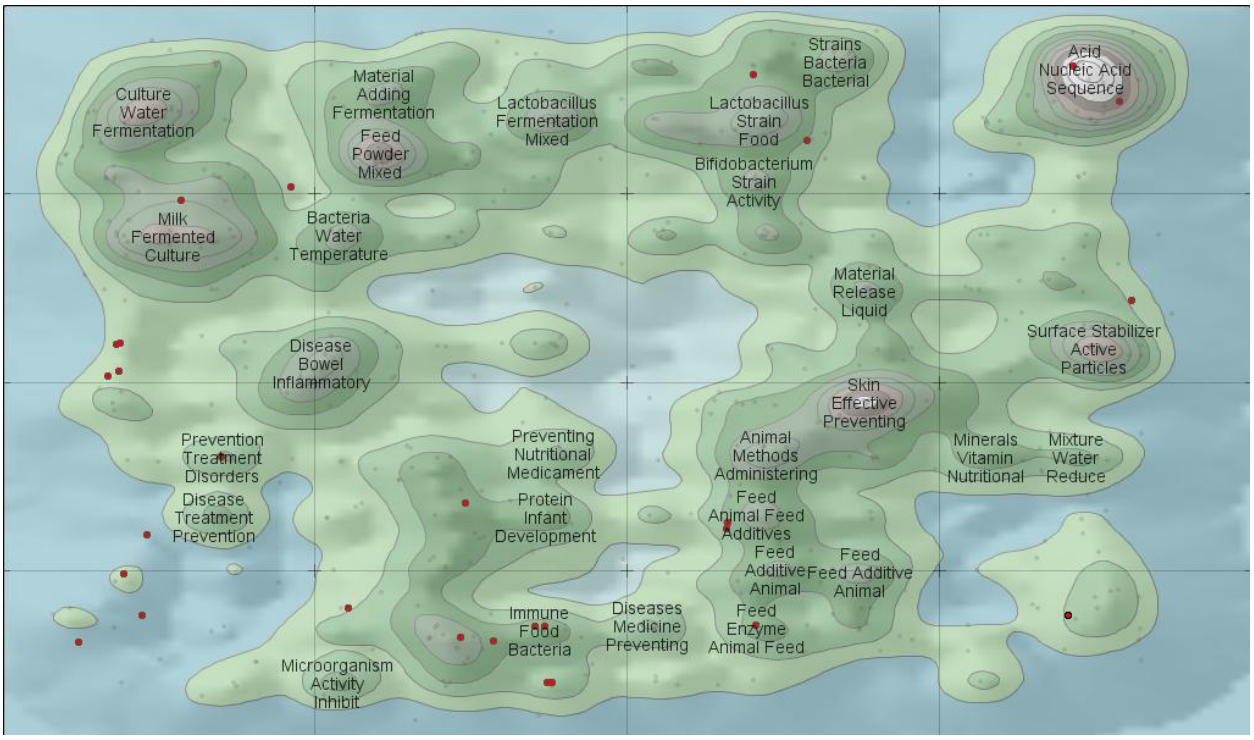
- Year 1995



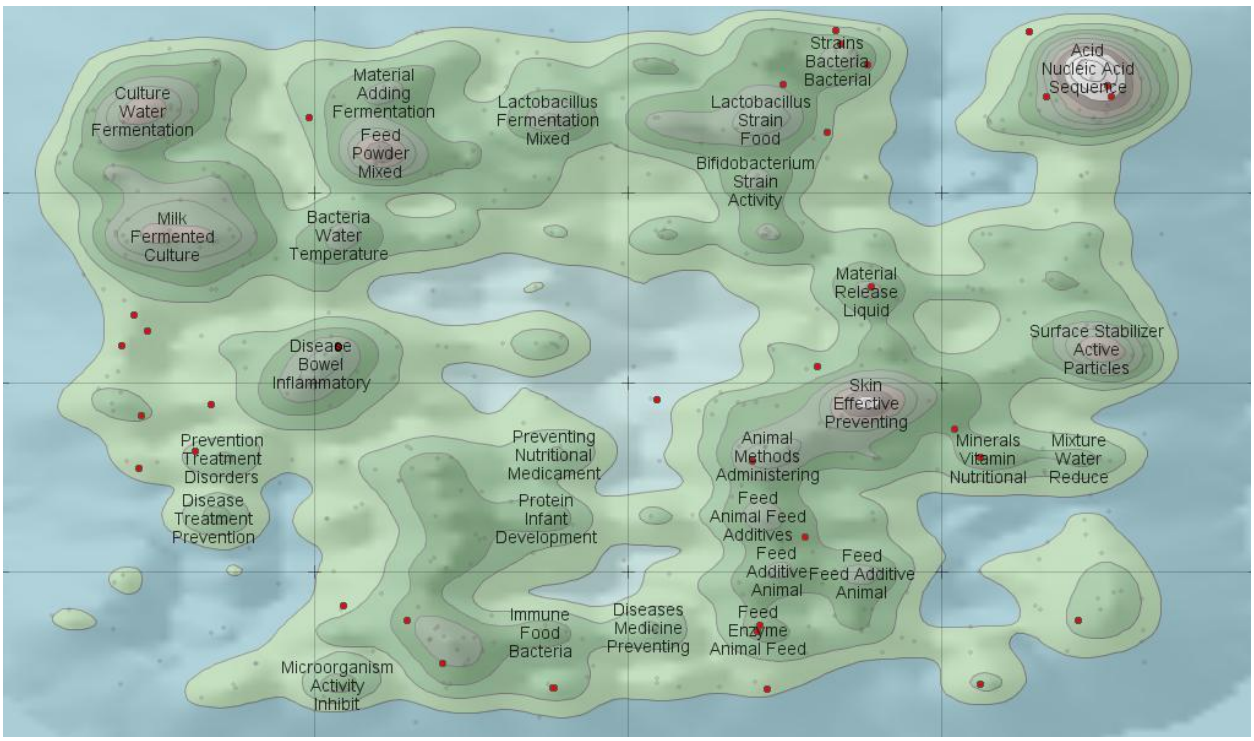
- Year 1996



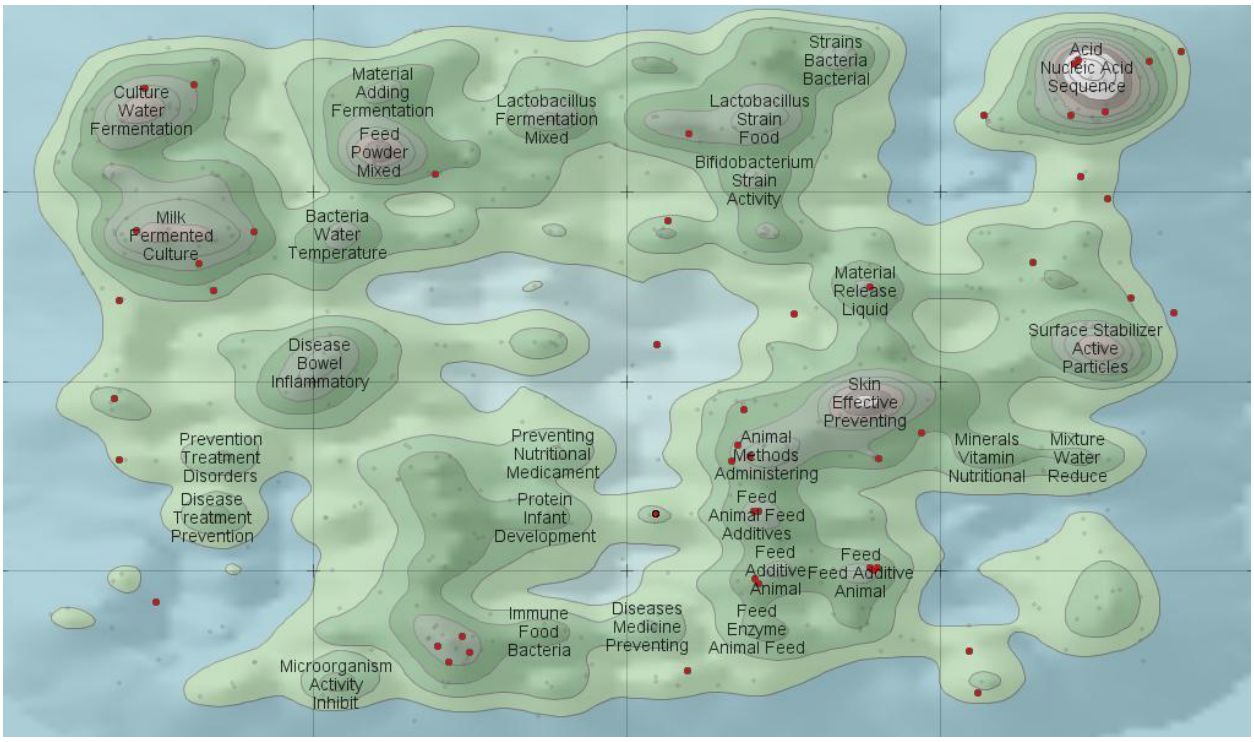
- Year 1997



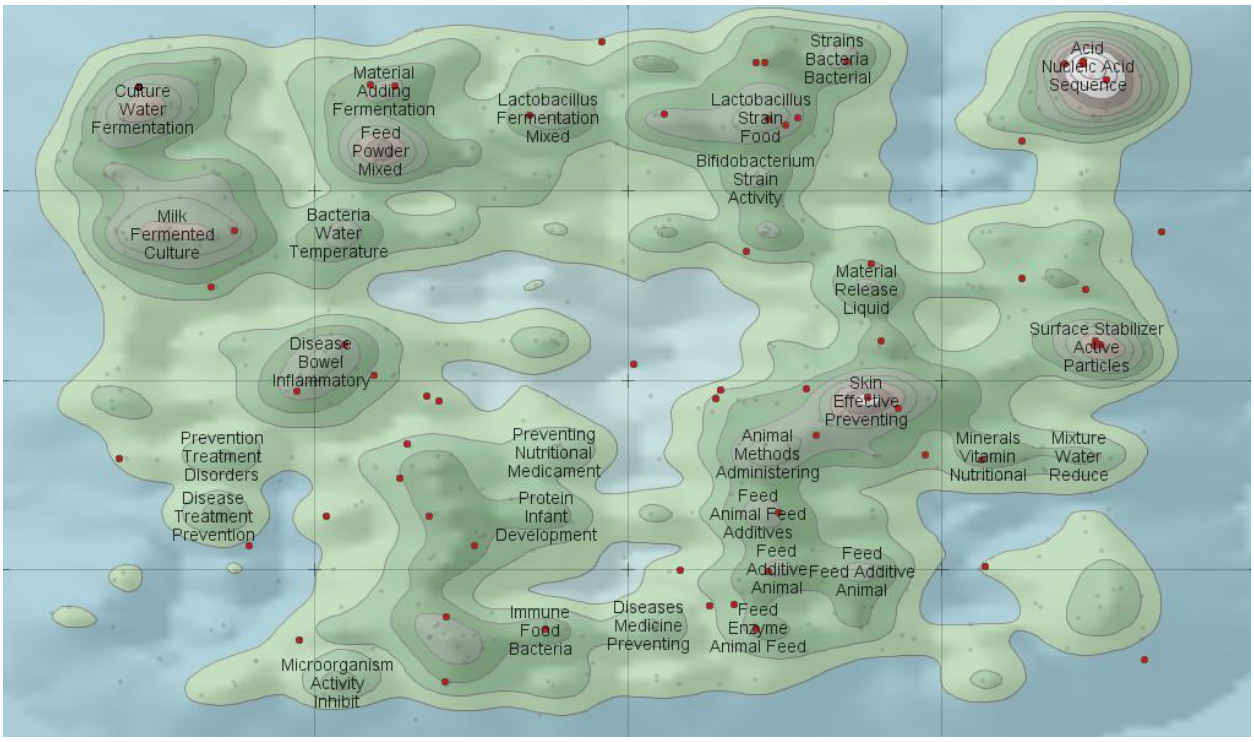
- Year 1998



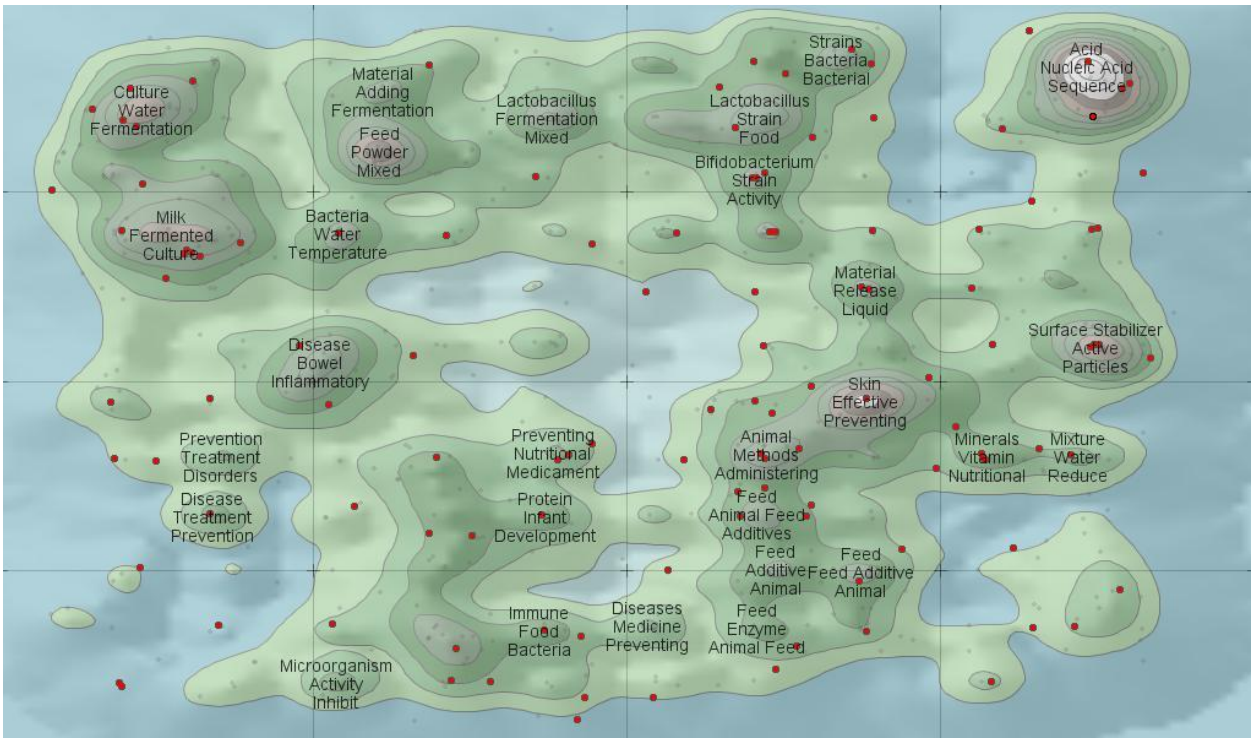
- Year 1999



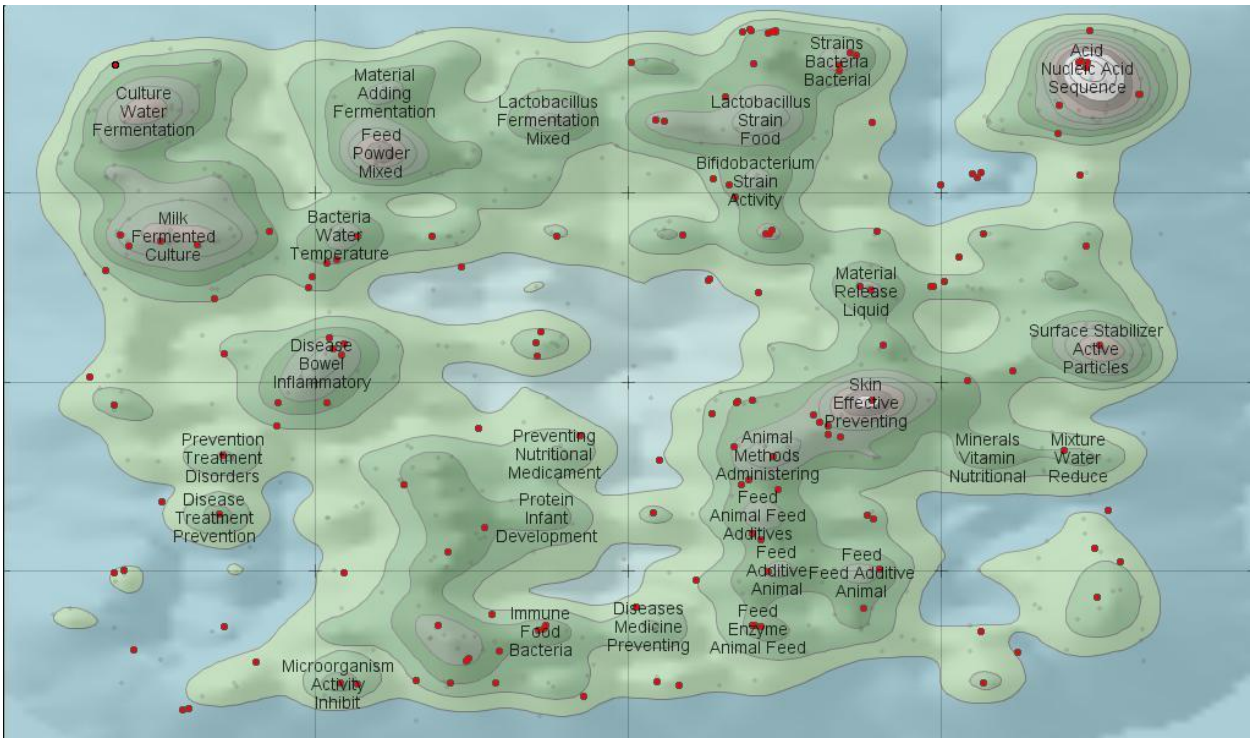
- Year 2000



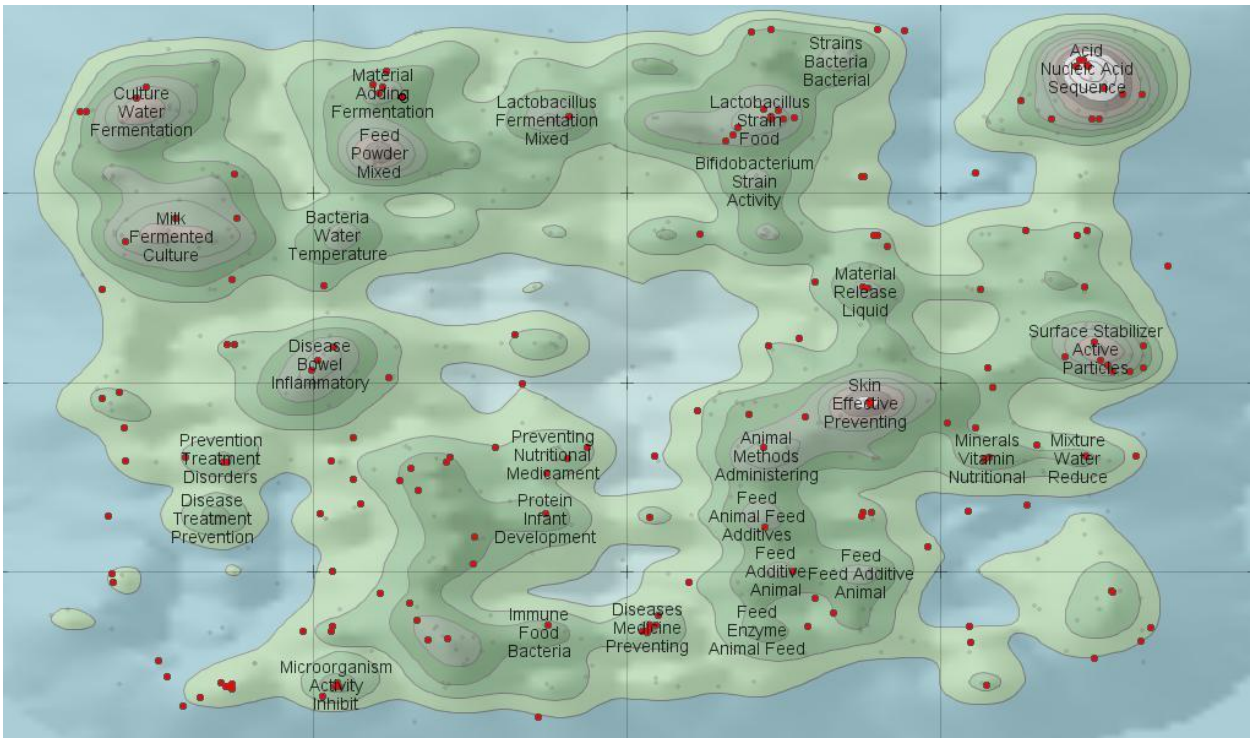
- Year 2001



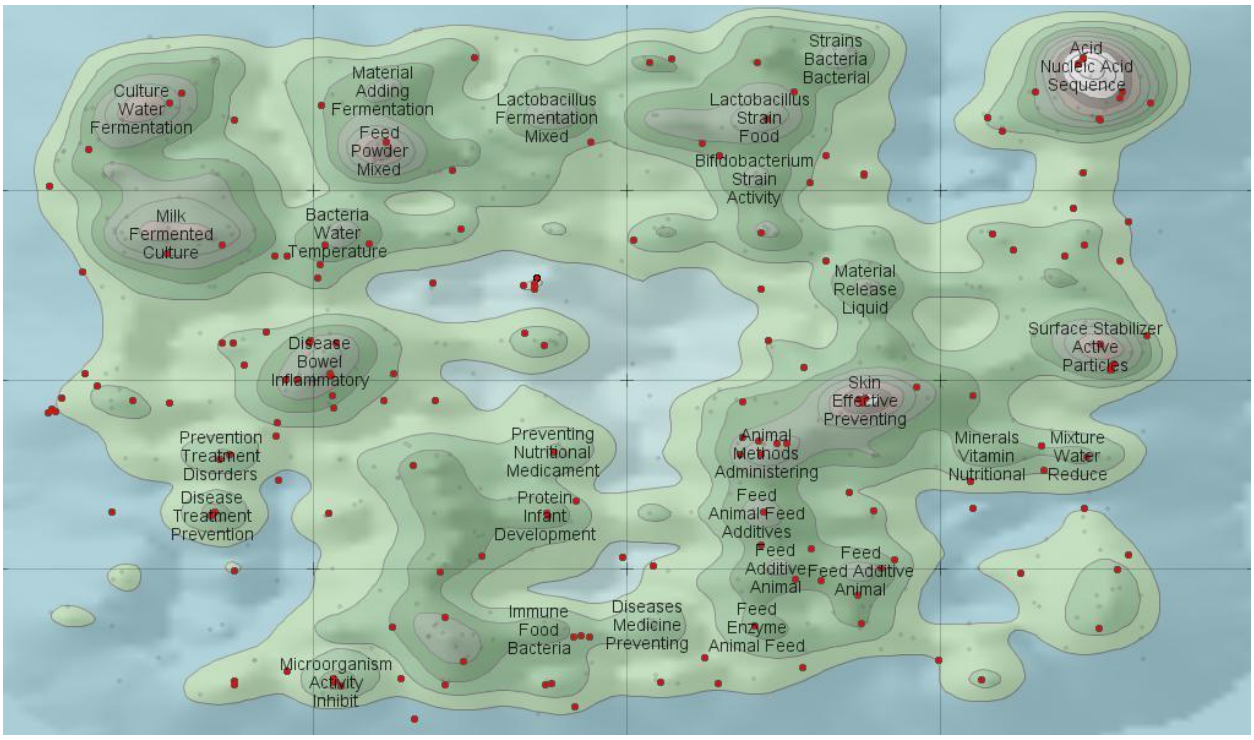
- Year 2002



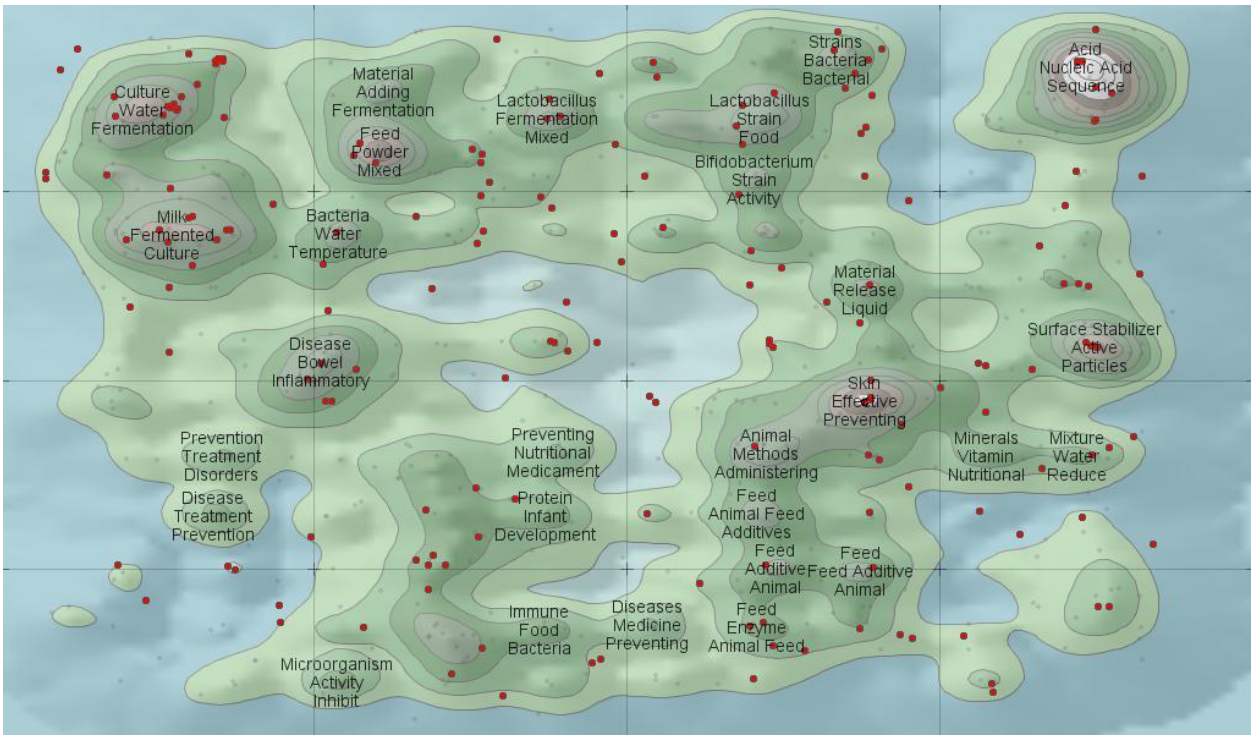
- Year 2003



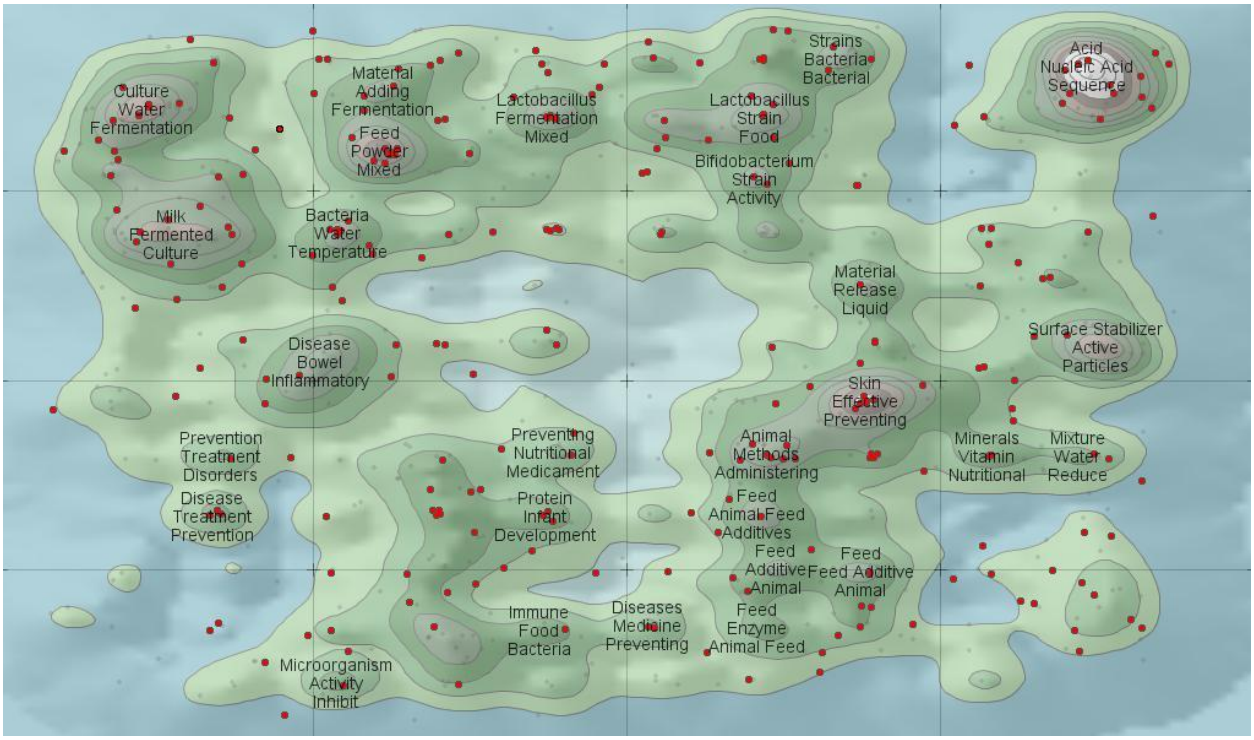
- Year 2004



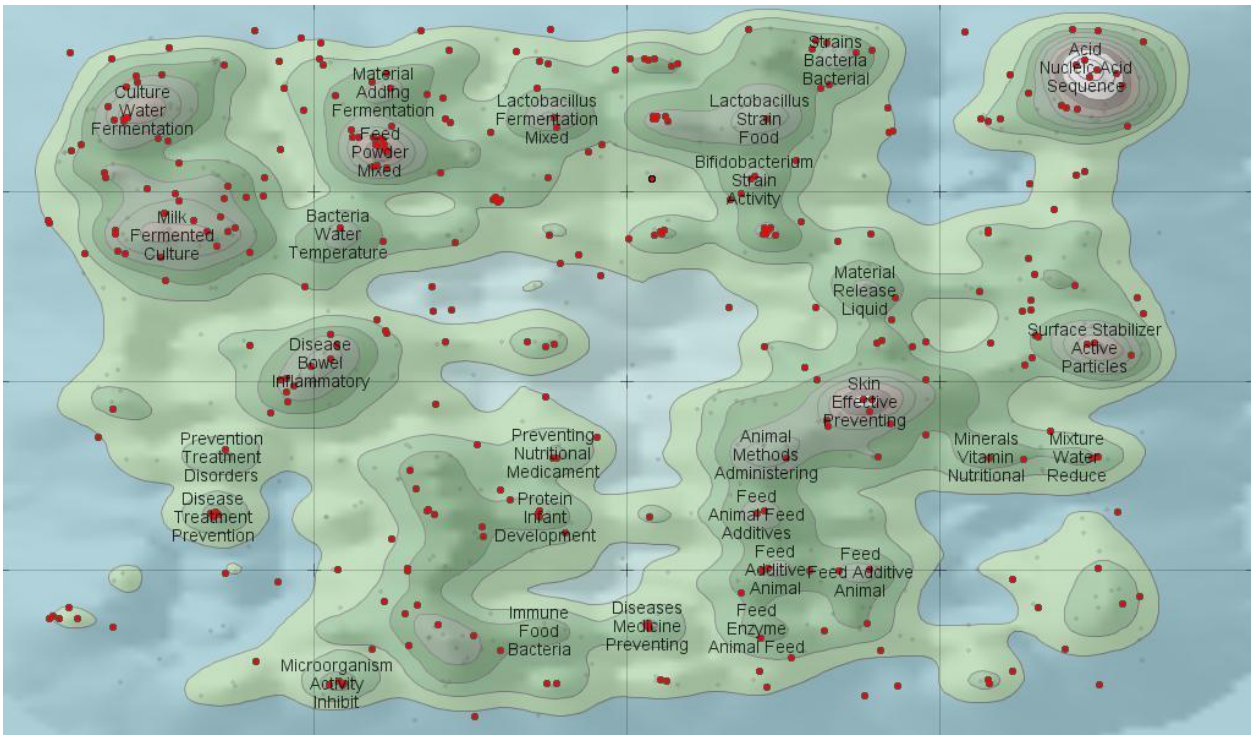
- Year 2005



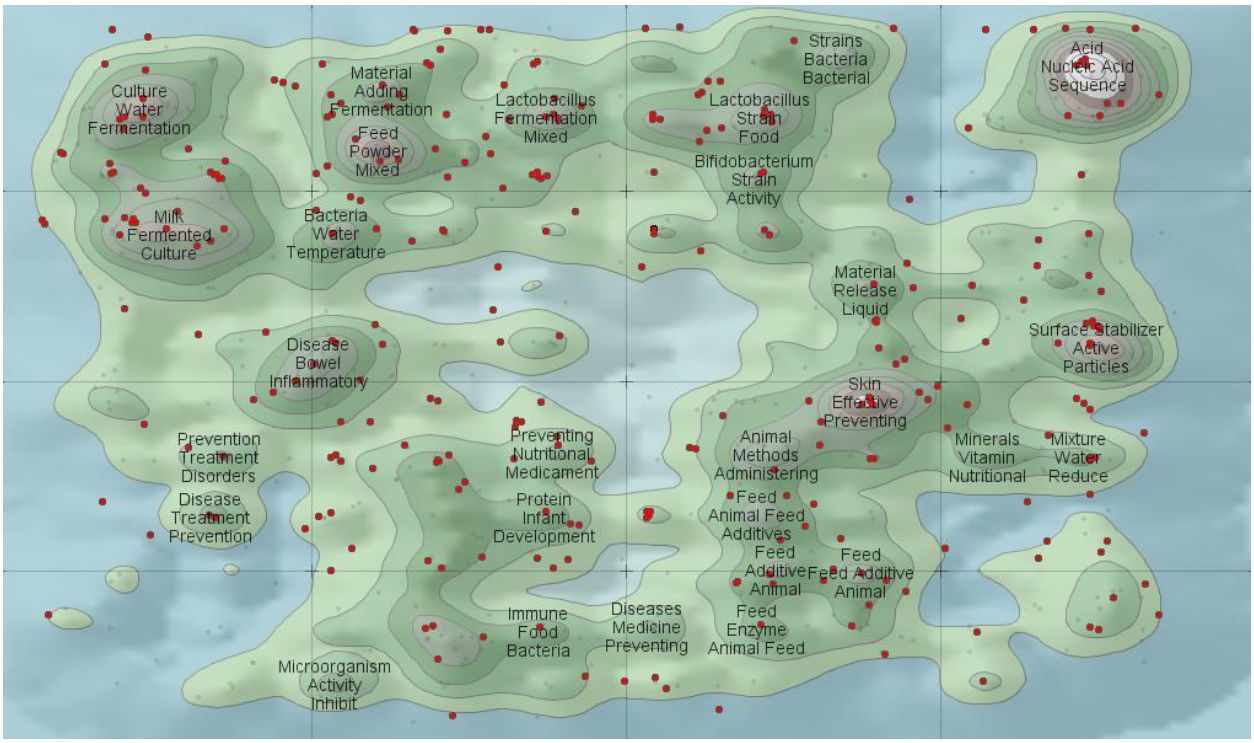
- Year 2006



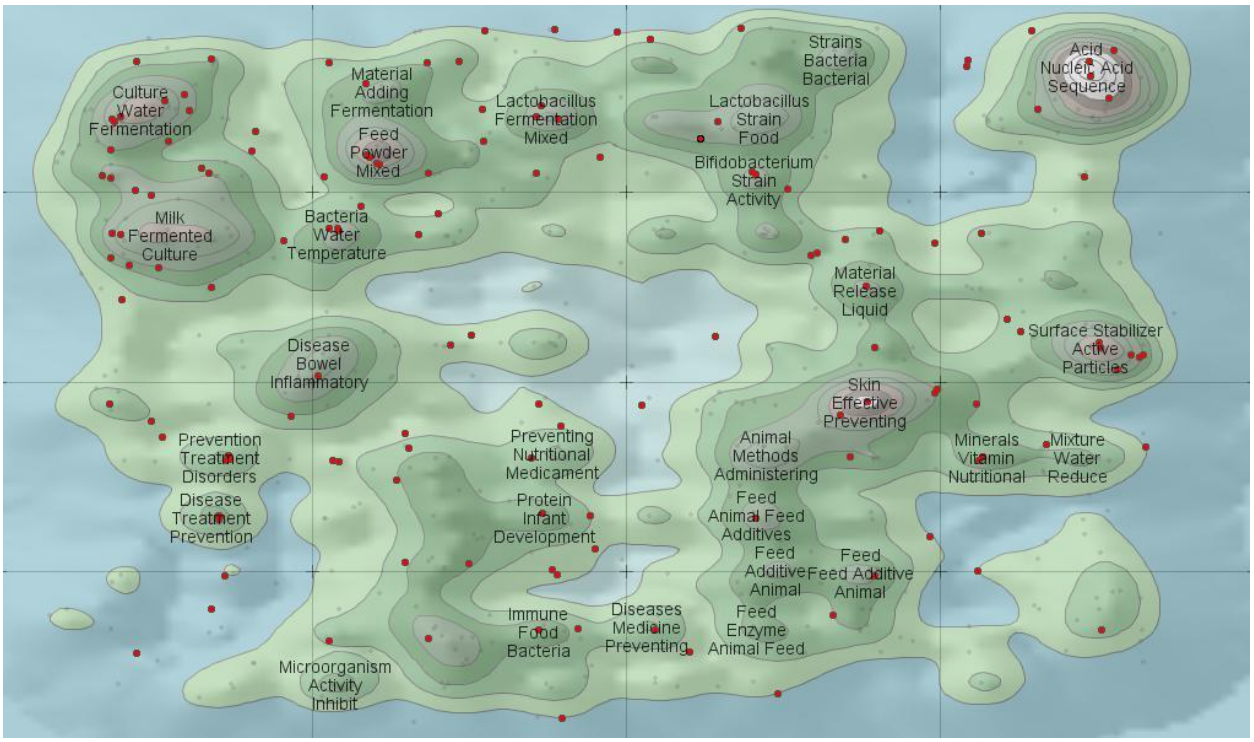
- Year 2007



- Year 2008



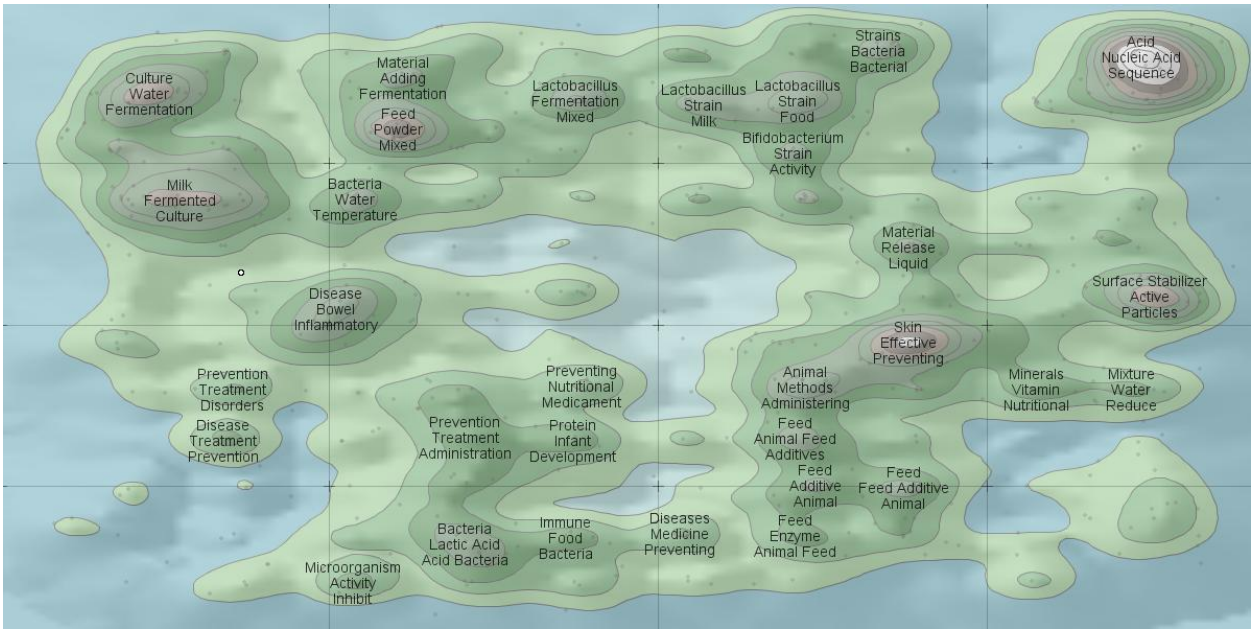
- Year 2009


Strains
Bacteria
Bacterial
Acid
Nucleic Acid
Sequence
Culture
Water
Fermentation
Material
Adding
Fermentation
Lactobacillus
Fermentation
Mixed
Feed
Powder
Mixed
Lactobacillus
Strain
Food
Bifidobacterium
Strain
Activity
Milk
Fermented
Culture
Bacteria
Water
Temperature
Material
Release
Liquid
Surface Stabilizer
Active
Particles
Disease
Bowel
Inflammatory
Skin
Effective
Preventing
Prevention
Treatment
Disorders
Preventing
Nutritional
Medicament
Animal
Methods
Administering
Minerals
Vitamin
Nutritional
Mixture
Water
Reduce
Disease
Treatment
Prevention
Protein
Infant
Development
Feed
Animal Feed
Additives
Feed
Additive
Animal
Feed
Feed Additive
Animal
Immune
Food
Bacteria
Diseases
Medicine
Preventing
Feed
Enzyme
Animal Feed
Microorganism
Activity
Inhibit

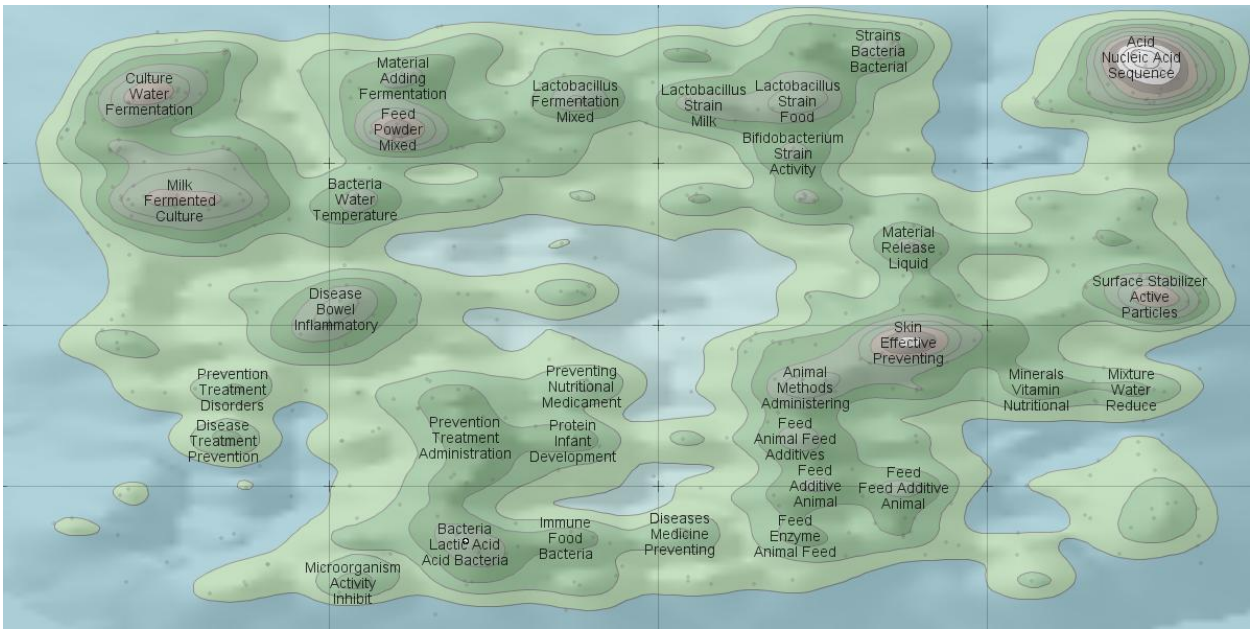
Appendix 4: The Development of Probiotics Landscape for Drug-like Application

The following maps are showing the development of the application of probiotics in IPC code A61 (drug-like application) from year 1990 to 2009. The small white dots on the maps represent the patent documents in medical or veterinary science area. The clearer picture on the development of probiotics landscape for drug-like application can be seen from the attached DVD.

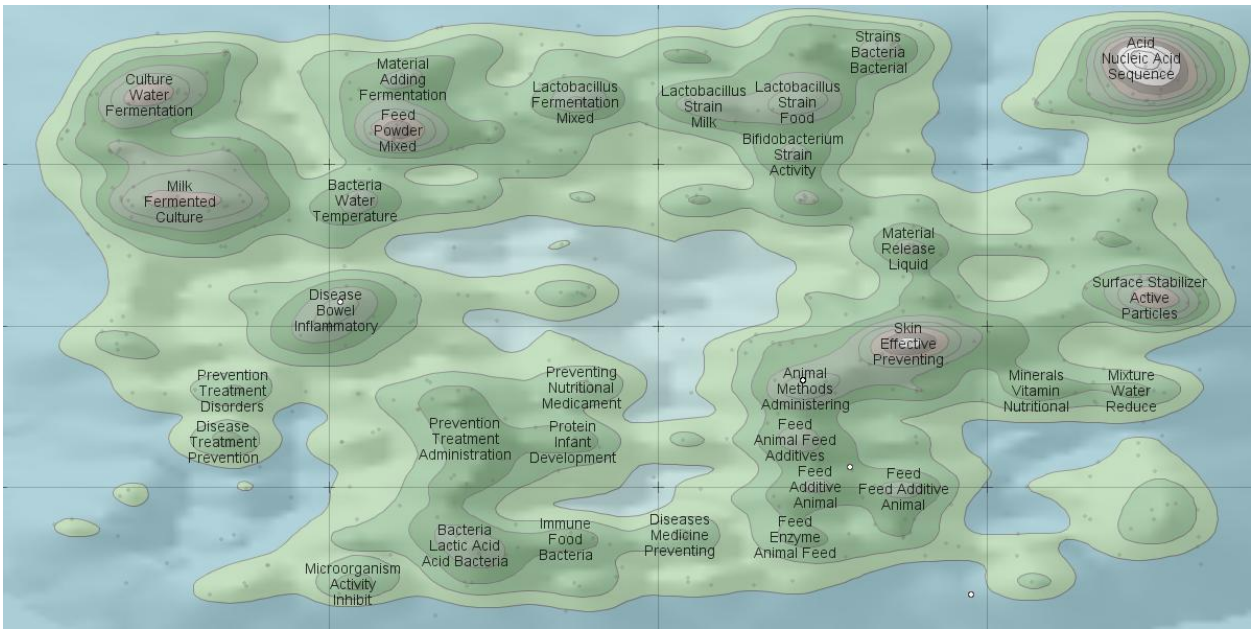
- Year 1990



- Year 1991



- Year 1992



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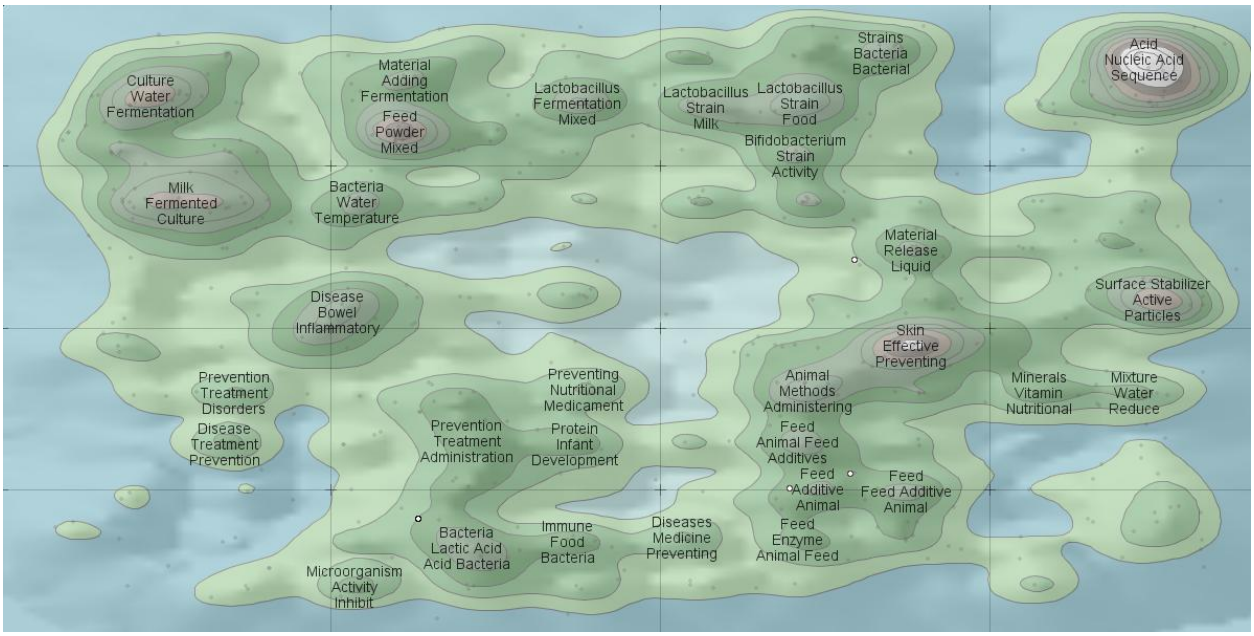

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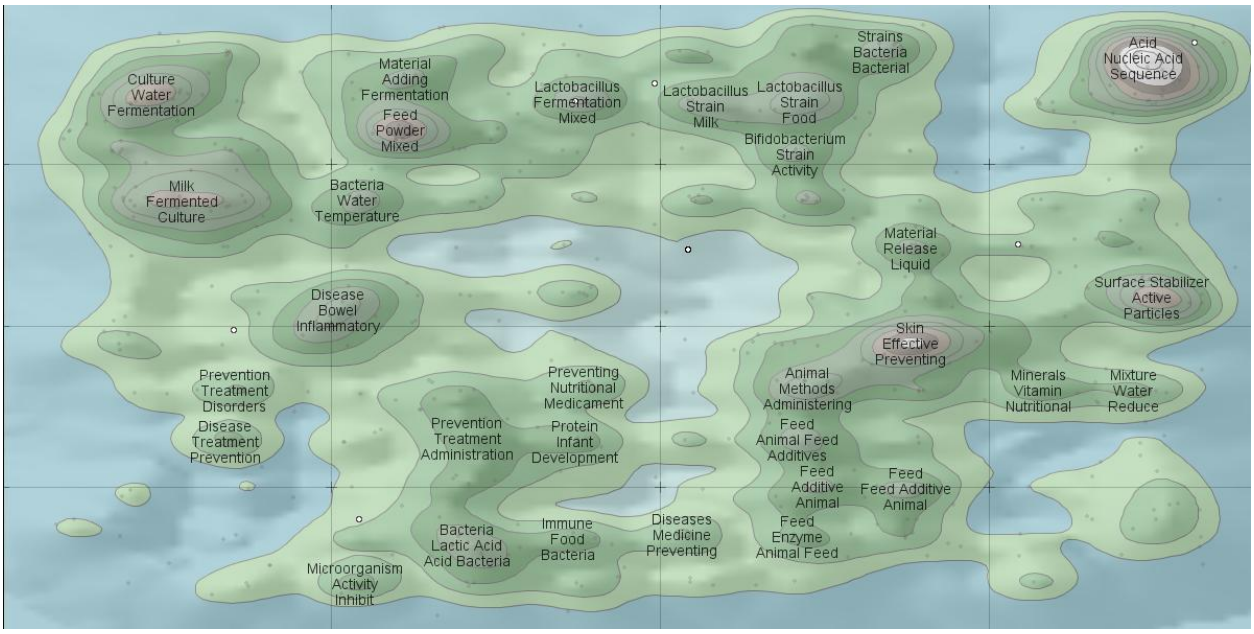

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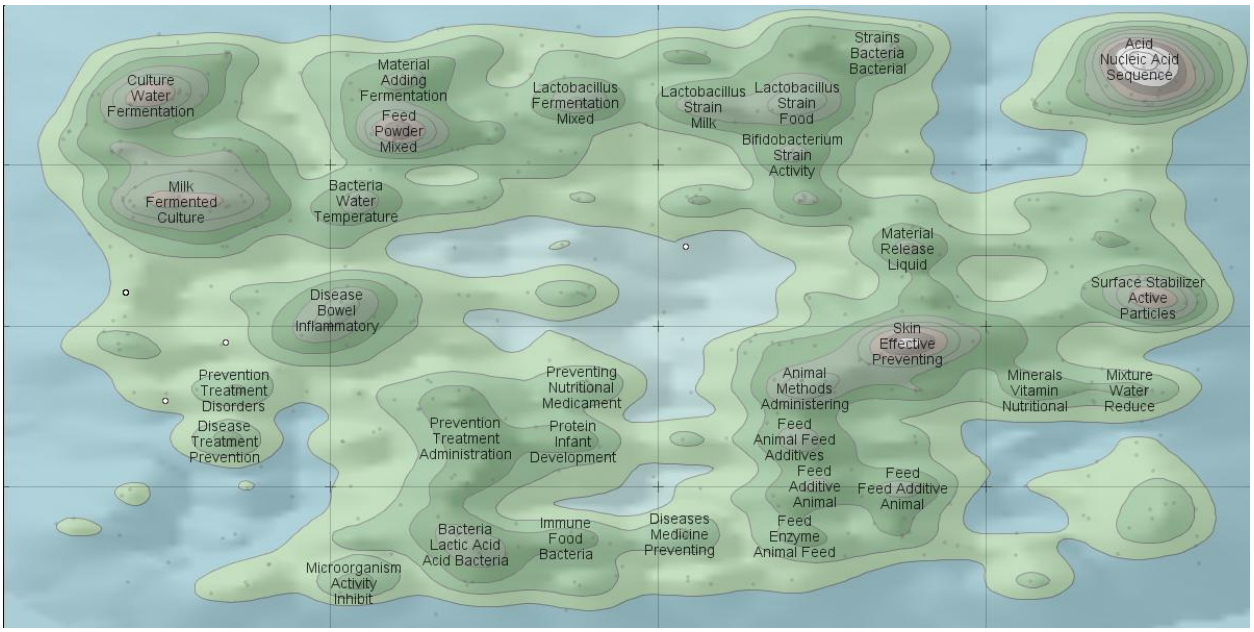

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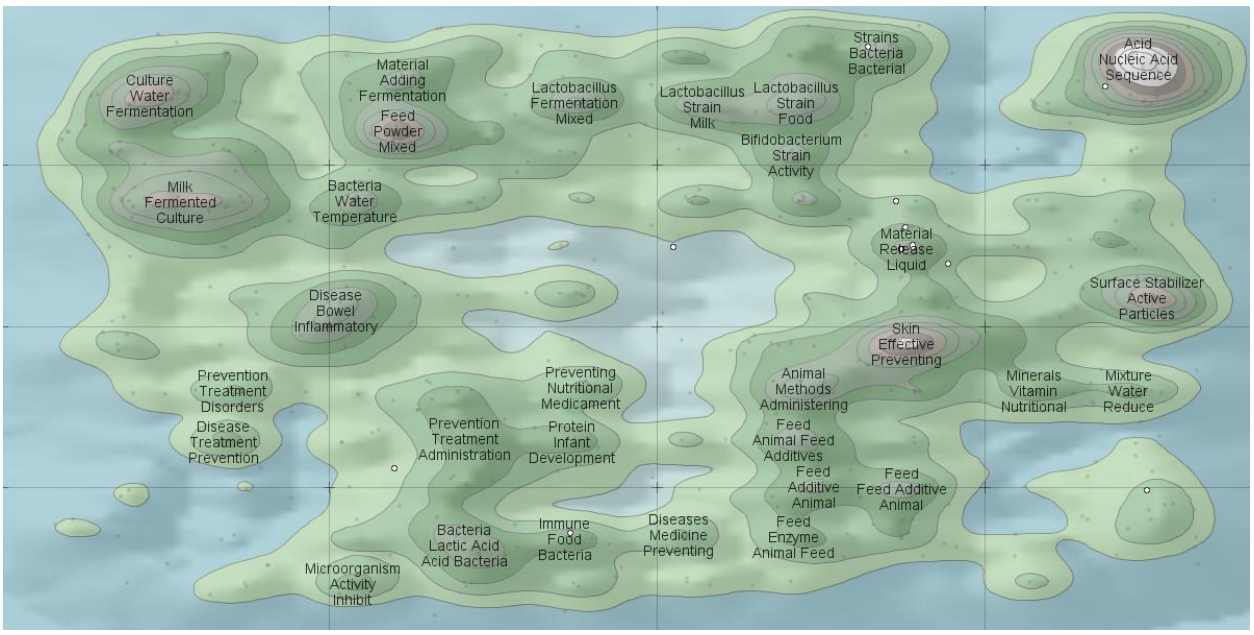

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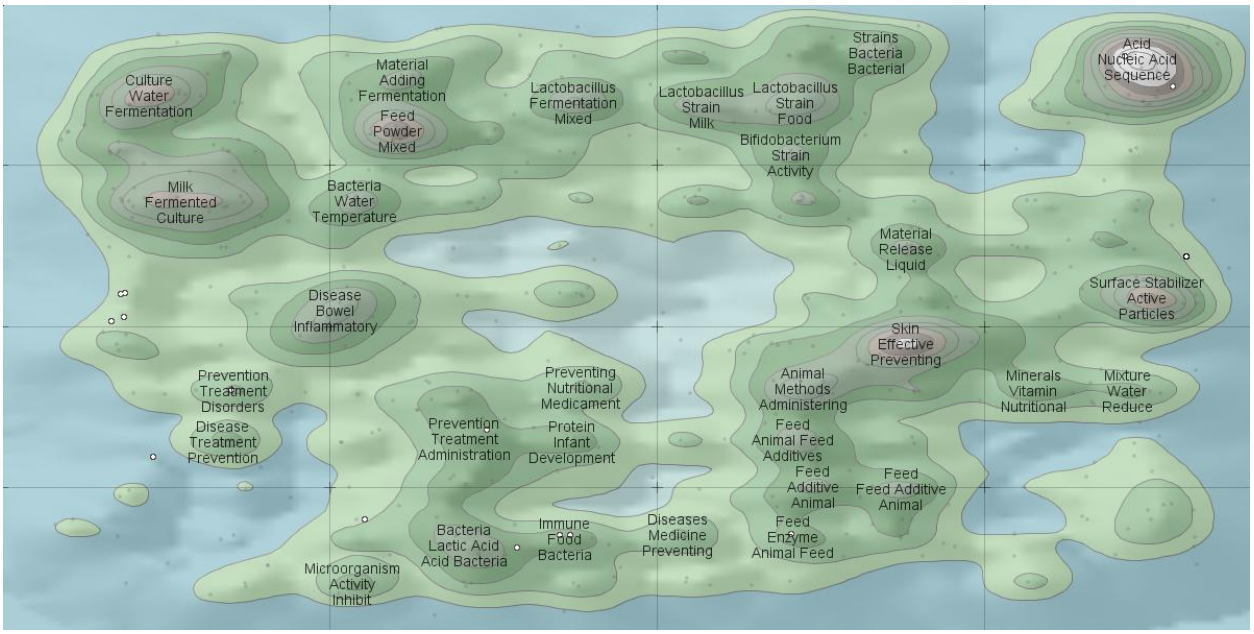

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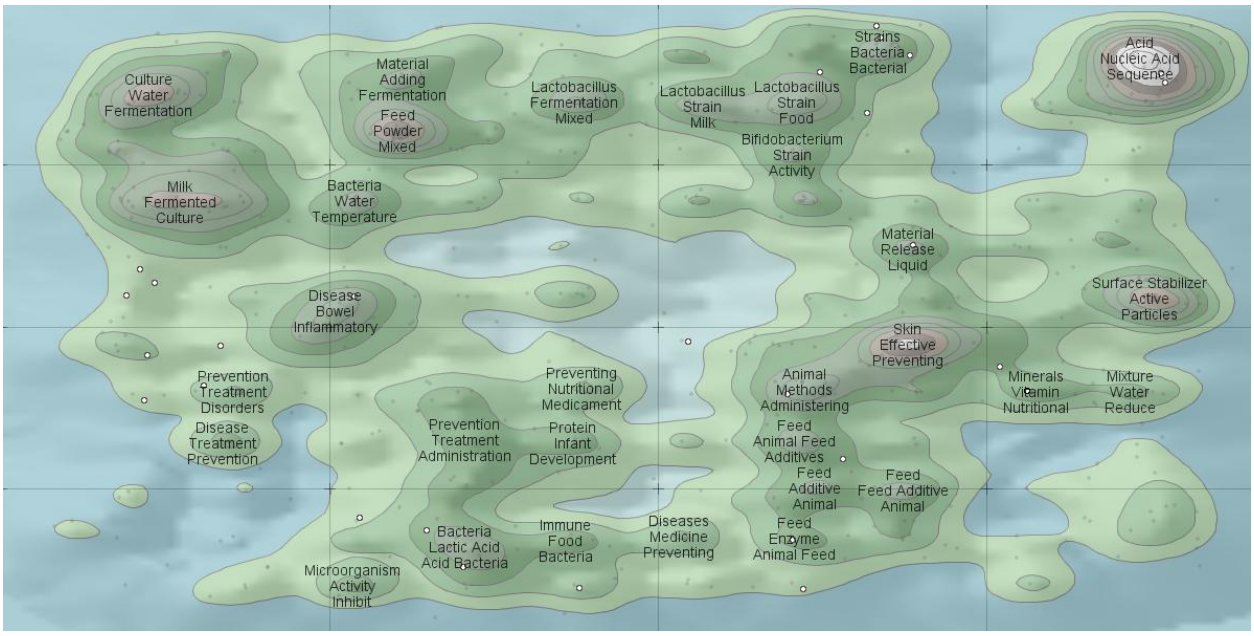

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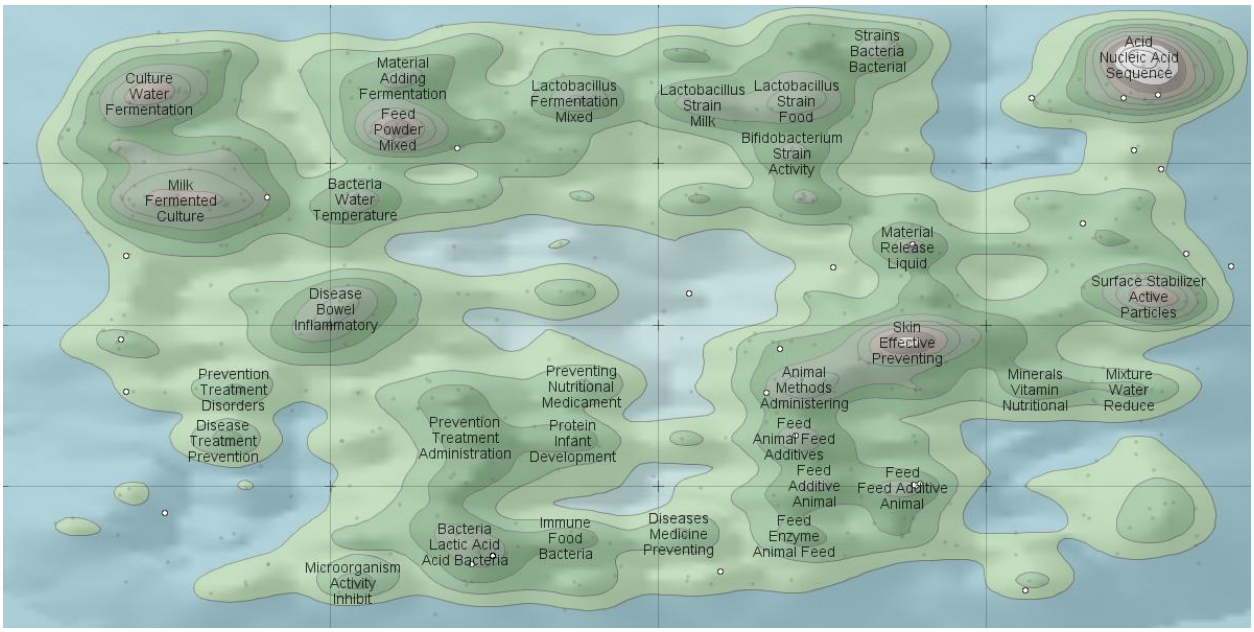

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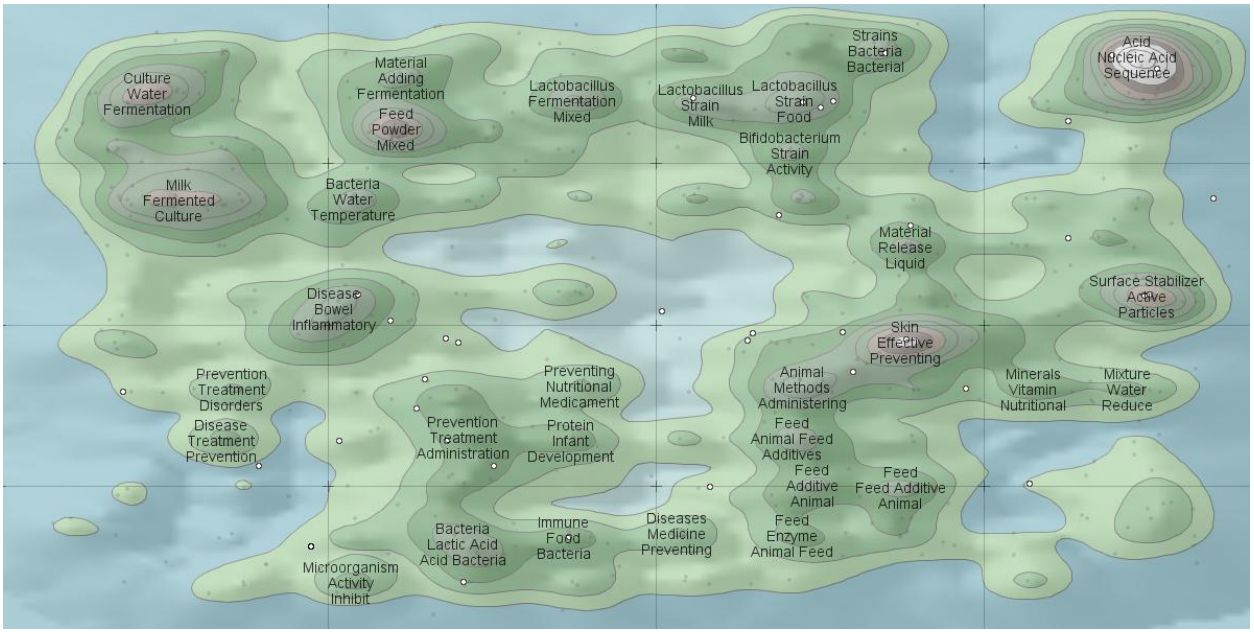

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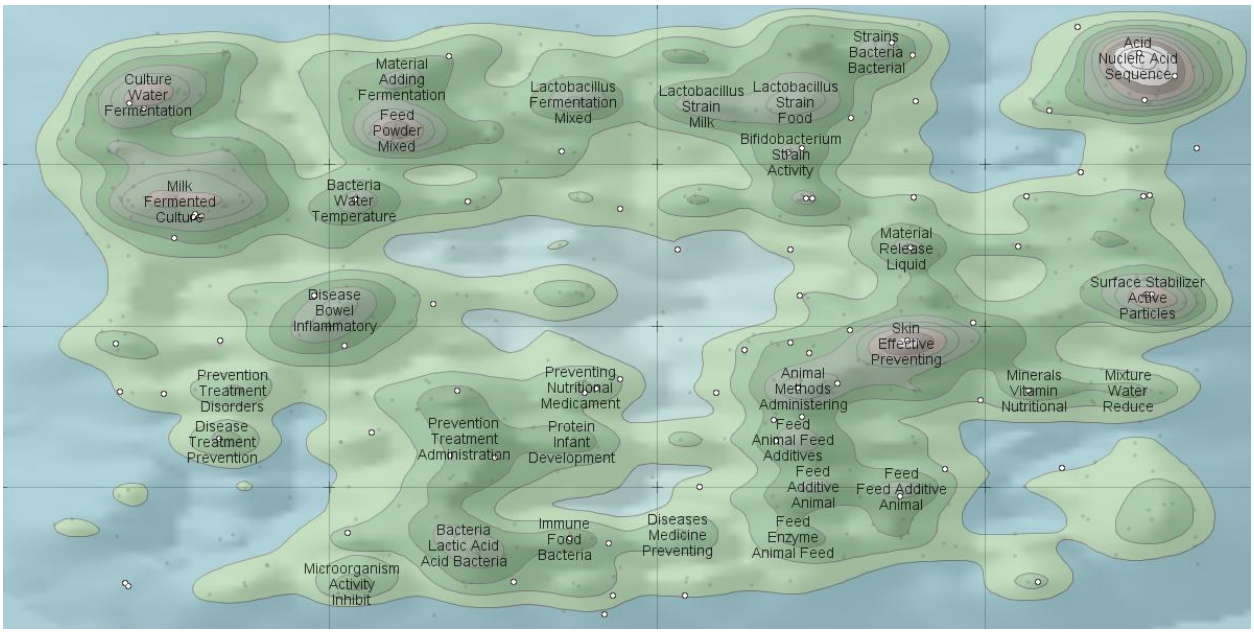

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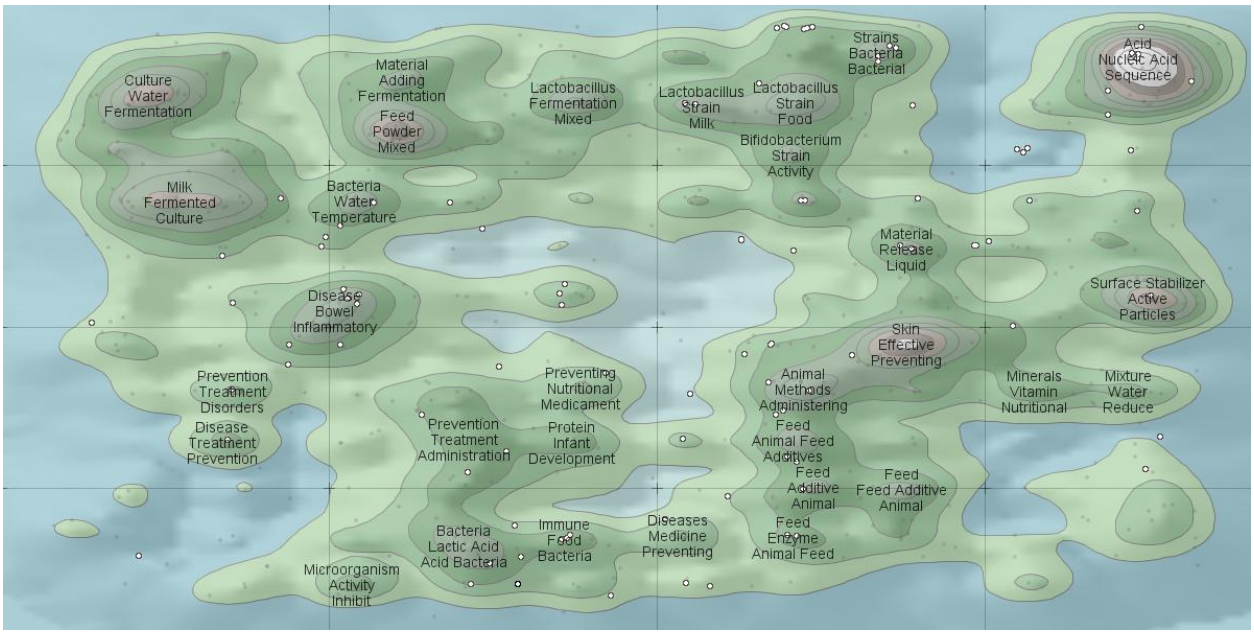

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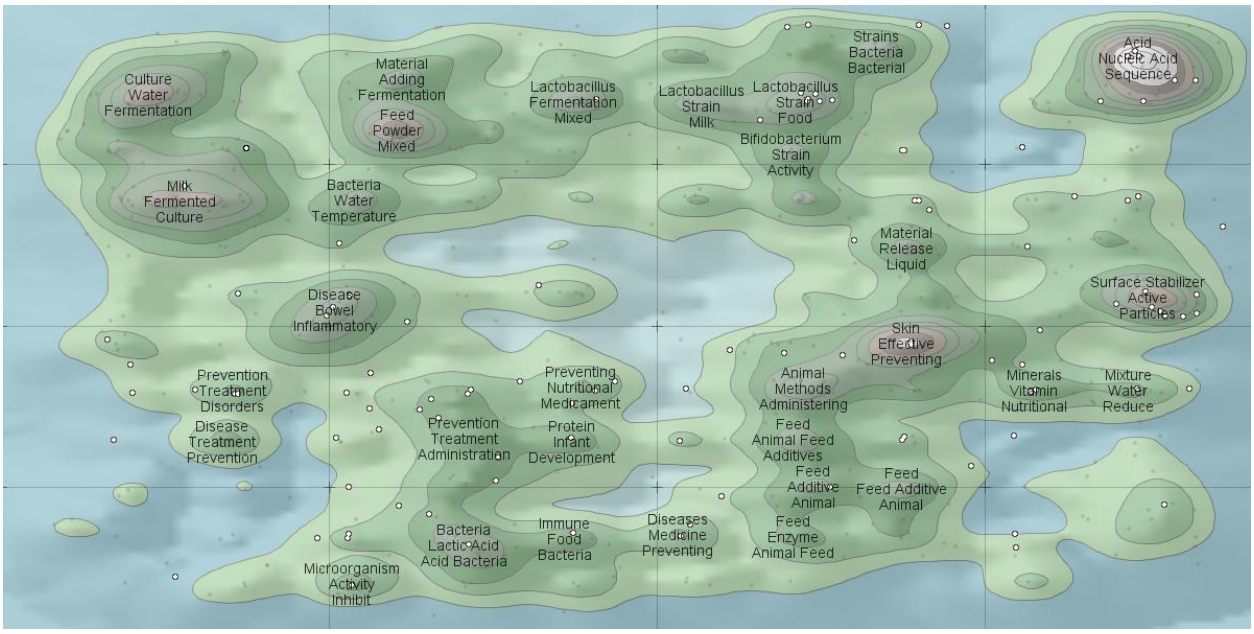

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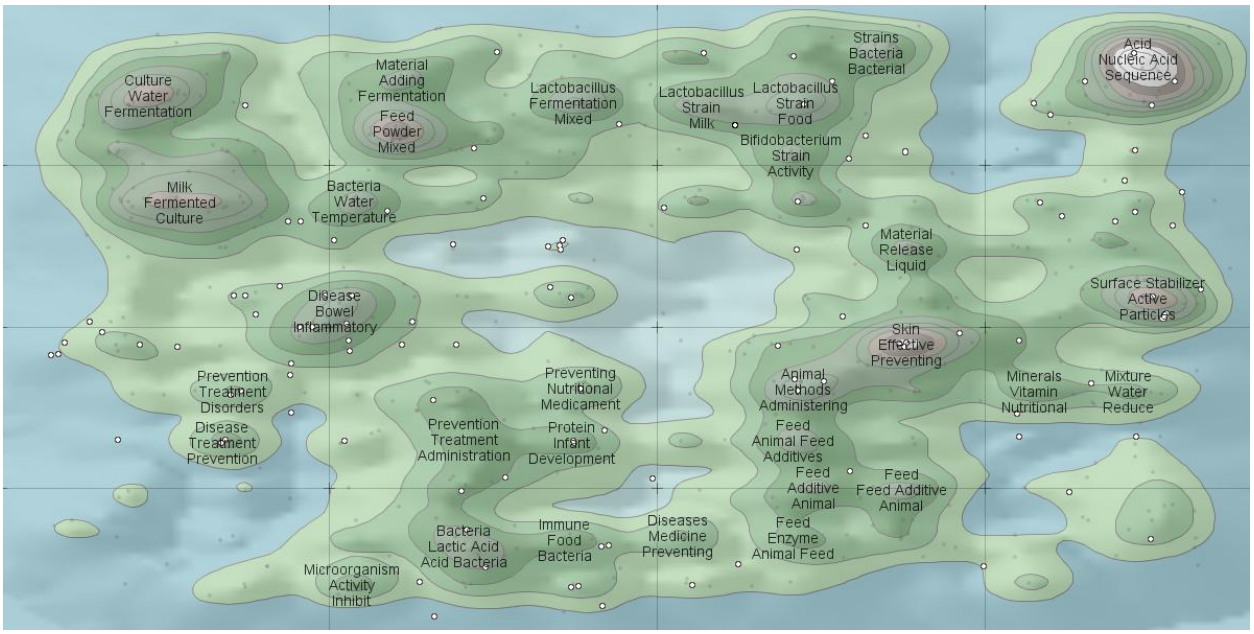

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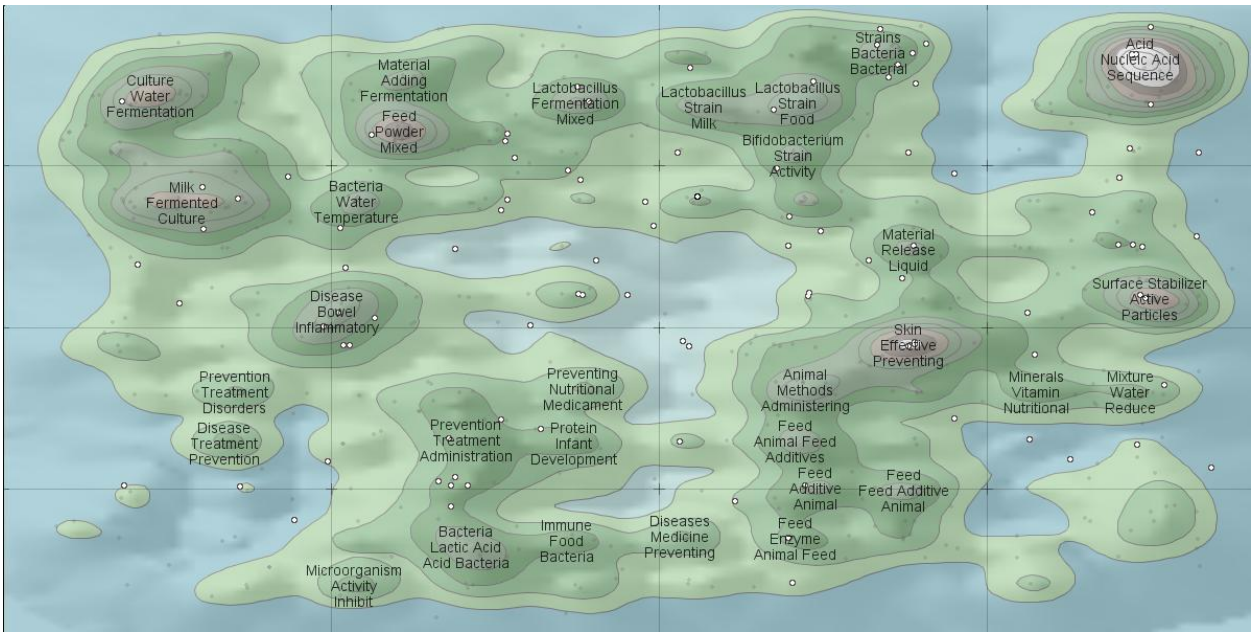

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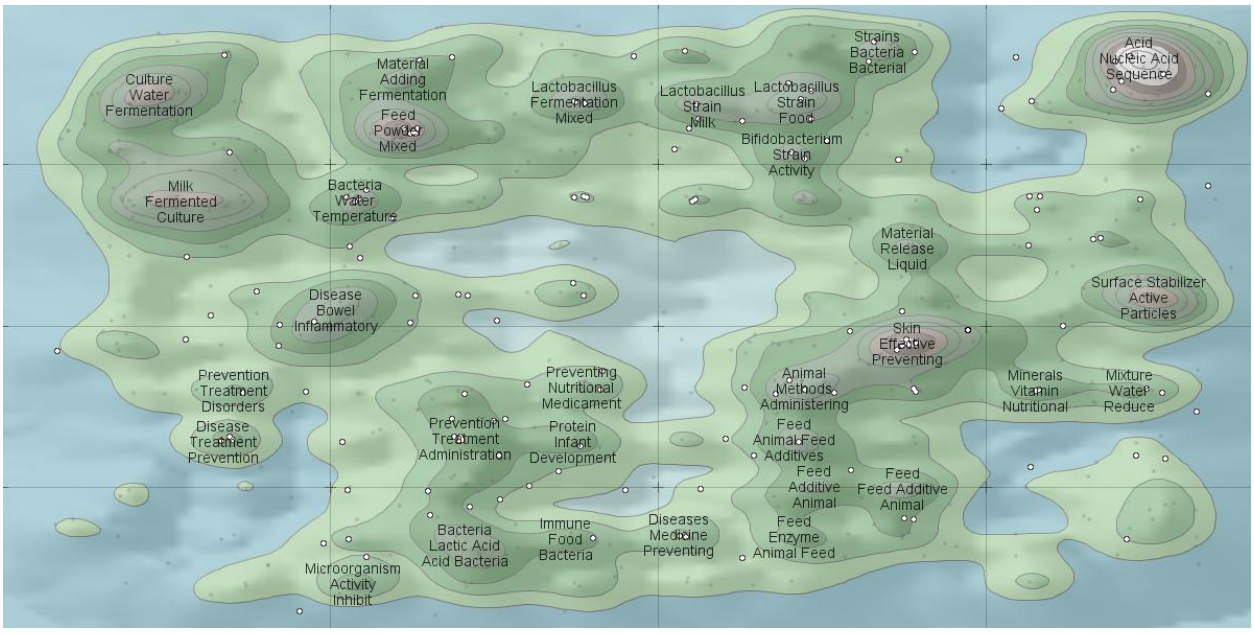

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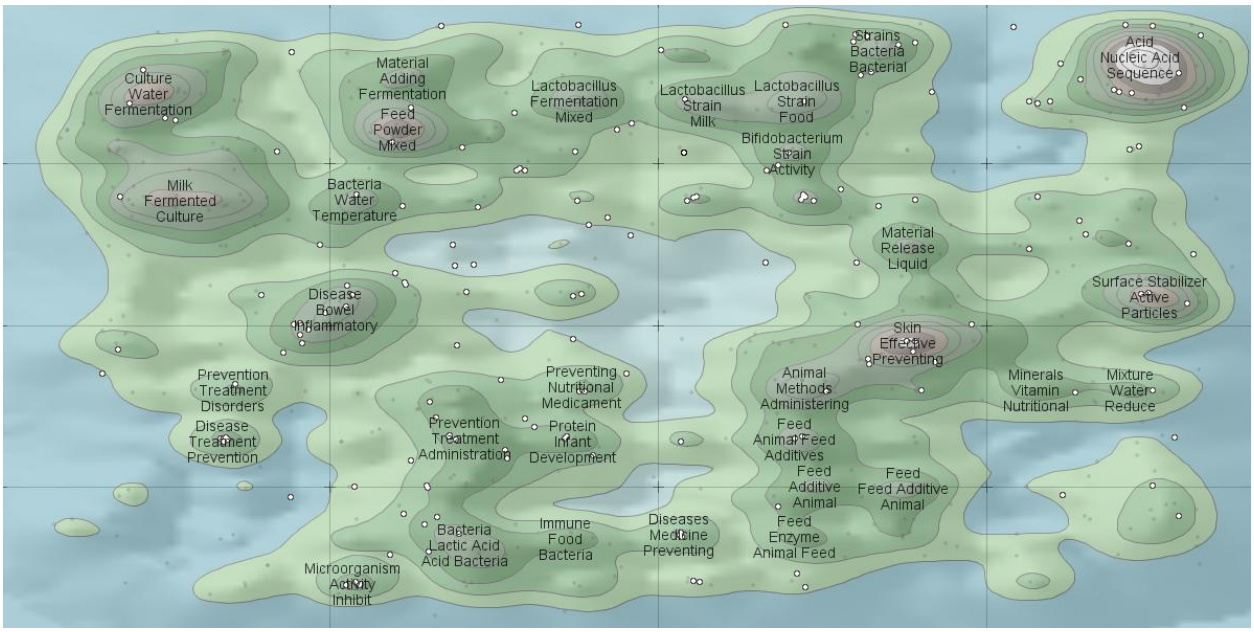

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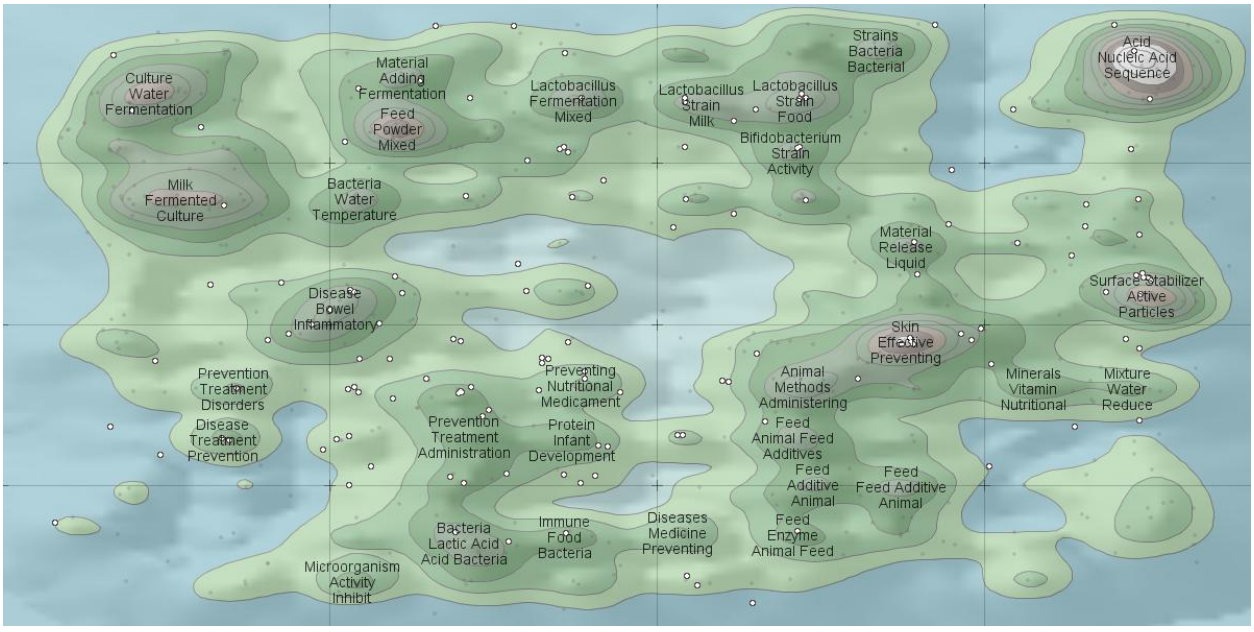

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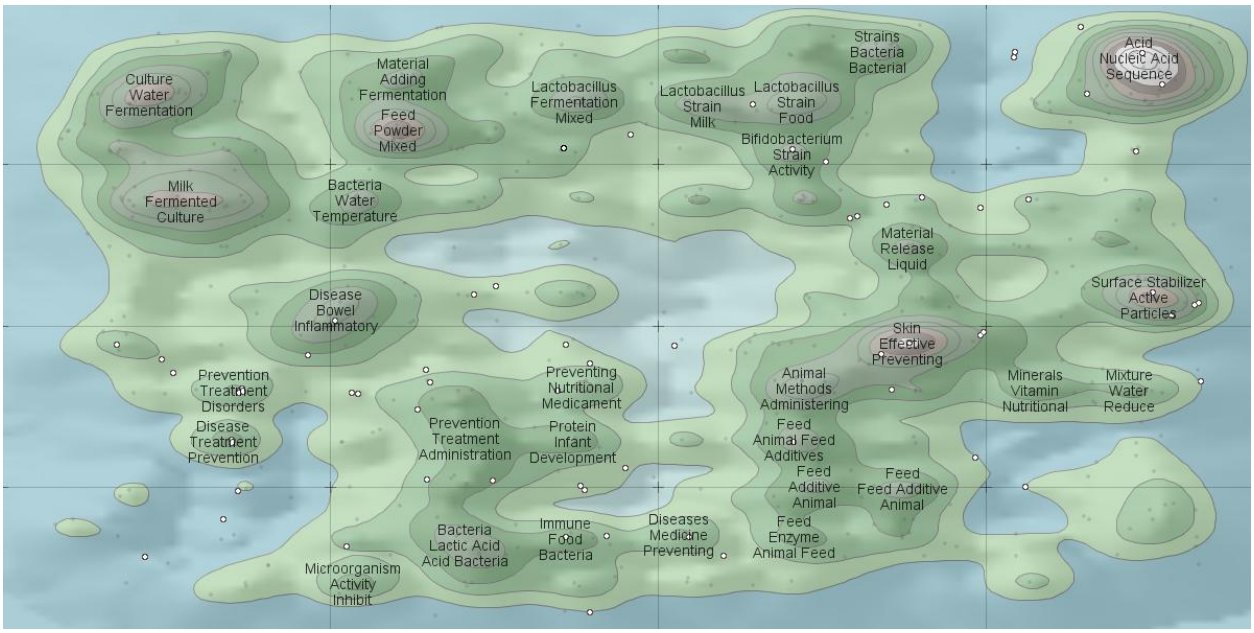
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Material Adding Fermentation
Feed Powder Mixed
Lactobacillus Fermentation Mixed
Lactobacillus Strain Milk
Lactobacillus Strain Food
Strains Bacteria Bacterial
Bifidobacterium Strain Activity
Acid Nucleic Acid Sequence
Milk Fermented Culture
Bacteria Water Temperature
Material Release Liquid
Surface Stabilizer Active Particles
Disease Bowel Inflammatory
Skin Effective Preventing
Prevention Treatment Disorders
Disease Treatment Prevention
Preventing Nutritional Medicament
Prevention Treatment Administration
Protein Infant Development
Animal Methods Administering
Feed Animal Feed Additives
Feed Additive Animal
Feed Feed Additive Animal
Minerals Vitamin Nutritional
Mixture Water Reduce
Bacteria Lactic Acid Acid Bacteria
Immune Food Bacteria
Diseases Medicine Preventing
Feed Enzyme Animal Feed
Microorganism Activity Inhibit

Appendix 5: Correlation Matrix for Patent data in Personal Care, Food & Agriculture industry, Pharmaceuticals industry and Chemicals Industry

The first column and row refer to industry sectors (i.e. PC, FA, PH and CH). For the other columns or rows in the matrix, they refer to subject areas by which the subject area is indicated after 'under scroll' symbol, for example PC_PC refers to Personal Care area in Personal Care sector and FA_PH refers to Pharmaceuticals area in Food & Agriculture sector.

The correlation coefficient will go from 0 to 1 by which 0 indicates no linear relationship and 1 indicates a perfect linear relationship. For the plus and minus sign, they indicate whether it is an uphill or downhill relationship, either a direct or an inverse association. The 1's down the diagonal simply mean that each variable correlated with itself. The following matrixes are symmetrical on the diagonal.

Appx 5.1 Correlation Matrix for Patent Data in Personal Care Industry

		PC	PC_PC	PC_PCPH
PC	Pearson Correlation	1	.996**	.537*
	Sig. (2-tailed)		.000	.015
	N	20	20	20
PC_PC	Pearson Correlation	.996**	1	.456*
	Sig. (2-tailed)	.000		.043
	N	20	20	20
PC_PCPH	Pearson Correlation	.537*	.456*	1
	Sig. (2-tailed)	.015	.043	
	N	20	20	20

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Appx 5.2 Correlation Matrix for Patent Data in Food & Agriculture Industry

		FA	FA_PCFA	FA_PCFAPH	FA_FA	FA_FAPH	FA_PH	FA_NO	FA_FA1	FA_FA2
FA	Pearson Correlation	1	.292	.063	.948**	.934**	.855**	.881**	.461*	.292
	Sig. (2-tailed)		.211	.793	.000	.000	.000	.000	.041	.211
	N	20	20	20	20	20	20	20	20	20
FA_PCFA	Pearson Correlation	.292	1	-.076	.194	.313	.143	.382	.867**	1.000**
	Sig. (2-tailed)	.211		.749	.413	.179	.548	.096	.000	.000
	N	20	20	20	20	20	20	20	20	20
FA_PCFAPH	Pearson Correlation	.063	-.076	1	.145	-.083	-.076	-.106	.093	-.076
	Sig. (2-tailed)	.793	.749		.542	.728	.752	.657	.695	.749
	N	20	20	20	20	20	20	20	20	20
FA_FA	Pearson Correlation	.948**	.194	.145	1	.785**	.672**	.790**	.298	.194
	Sig. (2-tailed)	.000	.413	.542		.000	.001	.000	.202	.413
	N	20	20	20	20	20	20	20	20	20
FA_FAPH	Pearson Correlation	.934**	.313	-.083	.785**	1	.940**	.834**	.511*	.313
	Sig. (2-tailed)	.000	.179	.728	.000		.000	.000	.021	.179
	N	20	20	20	20	20	20	20	20	20
FA_PH	Pearson Correlation	.855**	.143	-.076	.672**	.940**	1	.759**	.401	.143
	Sig. (2-tailed)	.000	.548	.752	.001	.000		.000	.080	.548
	N	20	20	20	20	20	20	20	20	20
FA_NO	Pearson Correlation	.881**	.382	-.106	.790**	.834**	.759**	1	.533*	.382
	Sig. (2-tailed)	.000	.096	.657	.000	.000	.000		.016	.096
	N	20	20	20	20	20	20	20	20	20
FA_FA1	Pearson Correlation	.461*	.867**	.093	.298	.511*	.401	.533*	1	.867**
	Sig. (2-tailed)	.041	.000	.695	.202	.021	.080	.016		.000
	N	20	20	20	20	20	20	20	20	20
FA_FA2	Pearson Correlation	.292	1.000**	-.076	.194	.313	.143	.382	.867**	1
	Sig. (2-tailed)	.211	.000	.749	.413	.179	.548	.096	.000	
	N	20	20	20	20	20	20	20	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appx 5.3 Correlation Matrix for Patent Data in Pharmaceuticals Industry

		PH	PH_PCPH	PH_FA	PH_FAPH	PH_PH	PH_NO	PH_FA1
PH	Pearson Correlation	1	.311	.499*	.549*	.925**	.059	.448*
	Sig. (2-tailed)		.182	.025	.012	.000	.806	.048
	N	20	20	20	20	20	20	20
PH_PCPH	Pearson Correlation	.311	1	-.128	-.107	.407	-.111	-.053
	Sig. (2-tailed)	.182		.590	.654	.075	.643	.826
	N	20	20	20	20	20	20	20
PH_FA	Pearson Correlation	.499*	-.128	1	.319	.265	-.098	.442
	Sig. (2-tailed)	.025	.590		.171	.258	.680	.051
	N	20	20	20	20	20	20	20
PH_FAPH	Pearson Correlation	.549*	-.107	.319	1	.370	.032	.321
	Sig. (2-tailed)	.012	.654	.171		.109	.893	.168
	N	20	20	20	20	20	20	20
PH_PH	Pearson Correlation	.925**	.407	.265	.370	1	-.159	.321
	Sig. (2-tailed)	.000	.075	.258	.109		.504	.168
	N	20	20	20	20	20	20	20
PH_NO	Pearson Correlation	.059	-.111	-.098	.032	-.159	1	-.111
	Sig. (2-tailed)	.806	.643	.680	.893	.504		.643
	N	20	20	20	20	20	20	20
PH_FA1	Pearson Correlation	.448*	-.053	.442	.321	.321	-.111	1
	Sig. (2-tailed)	.048	.826	.051	.168	.168	.643	
	N	20	20	20	20	20	20	20

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed).

Appx 5.4 Correlation Matrix for Patent Data in Chemicals Industry

		CH	CH_FA	CH_FAPH	CH_PH	CH_NO	CH_FA1
CH	Pearson Correlation	1	.930**	.851**	.863**	.491*	.240
	Sig. (2-tailed)		.000	.000	.000	.028	.308
	N	20	20	20	20	20	20
CH_FA	Pearson Correlation	.930**	1	.728**	.776**	.289	.409
	Sig. (2-tailed)	.000		.000	.000	.217	.073
	N	20	20	20	20	20	20
CH_FAPH	Pearson Correlation	.851**	.728**	1	.531*	.684**	.184
	Sig. (2-tailed)	.000	.000		.016	.001	.439
	N	20	20	20	20	20	20
CH_PH	Pearson Correlation	.863**	.776**	.531*	1	.144	.048
	Sig. (2-tailed)	.000	.000	.016		.546	.841
	N	20	20	20	20	20	20
CH_NO	Pearson Correlation	.491*	.289	.684**	.144	1	-.053
	Sig. (2-tailed)	.028	.217	.001	.546		.826
	N	20	20	20	20	20	20
CH_FA1	Pearson Correlation	.240	.409	.184	.048	-.053	1
	Sig. (2-tailed)	.308	.073	.439	.841	.826	
	N	20	20	20	20	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix 6: Correlation Matrix for Patent Data between Collaboration Industry and Technological Complexity

The first column and row refer to industry sectors (i.e. Intra-PCFA, PCFA, FAFA, FAPH, FACH, and Intra-PCFA, PH). For the other columns or rows in the matrix, they refer to subject areas by which the subject area is indicated after 'under scroll' symbol, for example IPCFA_PC refers to Personal Care area in the industry sector from the intra-collaboration between Personal Care and Food & Agriculture sector.

Appx 6.1 Correlation Matrix for Patent Data in Intra-Personal Care and Food & Agriculture (Intra-PCFA) Industry

		IPCFA	IPCFA_PC	IPCFA_PCFA	IPCFA_FA	IPCFA_FAPH	IPCFA_PH	IPCFA_NO
IPCFA	Pearson Correlation	1	.854**	.080	.716**	.953**	.907**	.608**
	Sig. (2-tailed)		.000	.738	.000	.000	.000	.004
	N	20	20	20	20	20	20	20
IPCFA_PC	Pearson Correlation	.854**	1	.246	.306	.788**	.923**	.597**
	Sig. (2-tailed)	.000		.295	.189	.000	.000	.005
	N	20	20	20	20	20	20	20
IPCFA_PCFA	Pearson Correlation	.080	.246	1	-.106	-.072	.082	-.076
	Sig. (2-tailed)	.738	.295		.658	.762	.730	.749
	N	20	20	20	20	20	20	20
IPCFA_FA	Pearson Correlation	.716**	.306	-.106	1	.683**	.380	.175
	Sig. (2-tailed)	.000	.189	.658		.001	.098	.459
	N	20	20	20	20	20	20	20
IPCFA_FAPH	Pearson Correlation	.953**	.788**	-.072	.683**	1	.865**	.594**
	Sig. (2-tailed)	.000	.000	.762	.001		.000	.006
	N	20	20	20	20	20	20	20
IPCFA_PH	Pearson Correlation	.907**	.923**	.082	.380	.865**	1	.664**
	Sig. (2-tailed)	.000	.000	.730	.098	.000		.001
	N	20	20	20	20	20	20	20
IPCFA_NO	Pearson Correlation	.608**	.597**	-.076	.175	.594**	.664**	1
	Sig. (2-tailed)	.004	.005	.749	.459	.006	.001	
	N	20	20	20	20	20	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Appx 6.2 Correlation Matrix for Patent Data in Collaboration between Personal Care and Food & Agriculture (PCFA) Industry

		PCFA	PCFA_PC	PCFA_PCPH	PCFA_FAPH
PCFA	Pearson Correlation	1	.978**	.218	.218
	Sig. (2-tailed)		.000	.357	.357
	N	20	20	20	20
PCFA_PC	Pearson Correlation	.978**	1	.076	.076
	Sig. (2-tailed)	.000		.750	.750
	N	20	20	20	20
PCFA_PCPH	Pearson Correlation	.218	.076	1	-.053
	Sig. (2-tailed)	.357	.750		.826
	N	20	20	20	20
PCFA_FAPH	Pearson Correlation	.218	.076	-.053	1
	Sig. (2-tailed)	.357	.750	.826	
	N	20	20	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Appx 6.3 Correlation Matrix for Patent Data in Collaboration between Food & Agriculture and Food & Agriculture (FAFA) Industry

		FAFA	FAFA_FA
FAFA	Pearson Correlation	1	1.000**
	Sig. (2-tailed)		.000
	N	20	20
FAFA_FA	Pearson Correlation	1.000**	1
	Sig. (2-tailed)	.000	
	N	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Appx 6.4 Correlation Matrix for Patent Data in Collaboration between Food & Agriculture and Pharmaceuticals (FAPH) Industry

		FAPH	FAPH_FAPH	FAPH_PH	FAPH_NO
FAPH	Pearson Correlation	1	.358	.944**	.835**
	Sig. (2-tailed)		.121	.000	.000
	N	20	20	20	20
FAPH_FAPH	Pearson Correlation	.358	1	.061	.444*
	Sig. (2-tailed)	.121		.800	.050
	N	20	20	20	20
FAPH_PH	Pearson Correlation	.944**	.061	1	.667**
	Sig. (2-tailed)	.000	.800		.001
	N	20	20	20	20
FAPH_NO	Pearson Correlation	.835**	.444*	.667**	1
	Sig. (2-tailed)	.000	.050	.001	
	N	20	20	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appx 6.5 Correlation Matrix for Patent Data in Collaboration between Food & Agriculture and Chemicals (FACH) Industry

		FACH	FACH_FA	FACH_FAPH
FACH	Pearson Correlation	1	.688**	.688**
	Sig. (2-tailed)		.001	.001
	N	20	20	20
FACH_FA	Pearson Correlation	.688**	1	-.053
	Sig. (2-tailed)	.001		.826
	N	20	20	20
FACH_FAPH	Pearson Correlation	.688**	-.053	1
	Sig. (2-tailed)	.001	.826	
	N	20	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Appx 6.6 Correlation Matrix for Patent Data in Collaboration between Intra-Personal Care and Food & Agriculture with Pharmaceuticals (Intra-PCFA, PH) Industry

		IPCFAPH	IPCFAPH_PC	IPCFAPH_PH
IPCFAPH	Pearson Correlation	1	.459*	.840**
	Sig. (2-tailed)		.042	.000
	N	20	20	20
IPCFAPH_PC	Pearson Correlation	.459*	1	-.096
	Sig. (2-tailed)	.042		.686
	N	20	20	20
IPCFAPH_PH	Pearson Correlation	.840**	-.096	1
	Sig. (2-tailed)	.000	.686	
	N	20	20	20

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).