NISTEP REPORT No. 110

Science Map 2006

-Study on Hot Research Areas (2001–2006) by Bibliometric Method-

English Ver.

June 2008

Research Unit for Science and Technology Analysis and Indicators
National Institute of Science and Technology Policy (NISTEP)

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This material is the English translation of the main points extracted from the "Science Map 2006 (original version, Japanese)" issued by NISTEP in June 2008.

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Ministry of Education, Culture, Sports, Science and Technology (MEXT)

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Highlights

【Terminology used in this report】

- Most-cited research papers

  The top 1 percent most-cited research papers during each year in each of 22 fields (including clinical medicine, plant and animal science, chemistry, and physics). For this report, the most-cited research papers among those published from 2001 through 2006 were used.

- Co-citation

  Indicates two important research papers that are both cited by another research paper. Frequently co-cited research papers are likely to have a certain amount of commonality of content. Groups of research papers with commonality of research content can therefore be obtained by grouping research papers with strong co-citation relationships.

- Core paper

  One of the most-cited research papers that form a research front

- Citing paper

  A research paper that cites a core paper

- Research front

  A set of most-cited research papers obtained when the most-cited research papers for the survey's target years are grouped (first stage) using co-citation relationships

- Research area

  A set of most-cited research papers obtained when research fronts are re-grouped (second stage).

- Hot research area

  A research area comprising six or more research fronts

- Quasi-hot research area

  A research area comprising five or fewer research fronts

- Research group

  A group of research areas: research on heart and blood vessels, research on infectious diseases/immunology, cancer research, study of obesity, brain research, post-genomics, plant science research, environment, chemical synthesis, nanoscience, condensed matter physics, and particle physics/cosmology.

- Individual Research Area Map

  A map showing what kinds of research themes make up hot research areas. The unit of visualization is research fronts. The greater the degree of co-citation, the closer the research fronts that form a hot research area appear on the map.

- Academic Disciplines Relation Map

  A map showing the relationship between hot research areas and existing academic disciplines. The unit of visualization is hot research areas. Hot research areas made up of similar fields (22 fields, including clinical medicine, plant and animal science, chemistry, physics) appear closer together on the map.

- Research Area Correlation Map

  A map showing relatedness among research areas. The unit of visualization is research areas. The greater the degree of co-citation, the closer the research areas appear on the map.

- Vertical projection and horizontal projection

  Diagrams obtained by applying orthographic projection along the vertical and horizontal axes of the Research Area Correlation Map. Orthographic projection on the vertical axis is the vertical projection, and orthographic projection on the horizontal axis is the horizontal projection.

Science Map 2006 Highlights

1. What is the Science Map?

There is a long history of attempts to describe the structure and development of science and technology from a bibliometric perspective. The dramatic development of information processing technology and enhancement of databases of scientific papers and patents in recent years have brought innovation to research in this field. The mapping of knowledge is a growing area of research, and a variety of studies are being conducted, mainly in the USA and Europe. The targets of mapping are diverse. They include analysis of relationships between fields of science through examination of journal citations and analysis of co-authorships by country, organization, and researcher.

The National Institute of Science and Technology Policy's Science Map project aims to periodically observe dynamic change in natural science.[1] The unit of the mapping is research areas.

Analysis of scientific research using Science Map is carried out through 1) structuring of research areas through the clustering of research papers, 2) visualization of research areas by mapping, and 3) content analysis of hot research areas.

Science Map 2006 used the top 1 percent highly-cited research papers (approximately 50,000) during each year in each of 22 fields (including Clinical medicine, Plant and Animal Science, Chemistry, Physics, etc.) among research papers published during the six years 2001 through 2006. These highly-cited research papers were clustered in two stages (research papers → research fronts → research areas) by using "co-citation." Six hundred eighty-seven research areas were obtained. Of these, detailed content analysis was performed on 124 hot research areas above a certain size.

These highlights summarize the results of the following analyses using the Science Map.

- O The snapshot of the current status of scientific research
- O Changes in scientific research, a comparison of Science Map 2004 and Science Map 2006
- O Observation of inter-/multi-disciplinary research on the Science Map
- O The breadth and intensity of research activities in Japan, the USA, and China

How to read the Science Map

In the main part of this report, three Science Maps (the Individual Research Area Map, the Academic Disciplines Relation Map, and the Research Area Correlation Map) are used to visualize and analyze scientific research. In this summary, only analysis using the Research Area Correlation Map is described, so the Research Area Correlation Map will be referred to as "the Science Map."

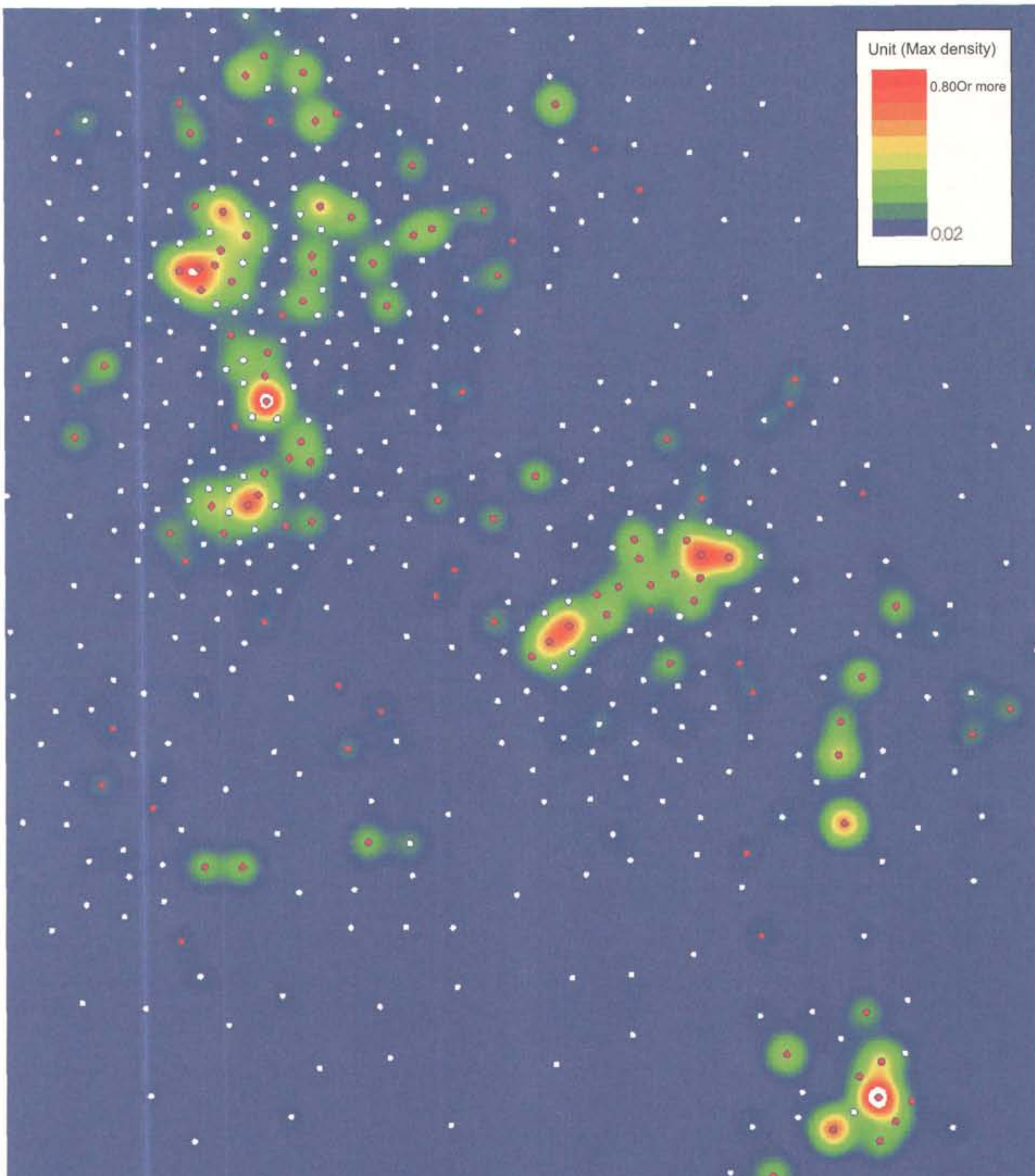
Figure 1 and Figure 2 depict the Science Map. The unit of visualization is research areas. Research areas with a high degree of co-citation are located near one another.

In the Science Map 2006, all 687 research areas obtained by clustering research papers were mapped. By showing the positions of 124 hot research areas for which content analysis was performed, the roles of the hot research areas within scientific research as a whole become evident. In Figure 1, the white dots represent the positions of research areas, and the red dots the positions of hot research areas. The Science Map can be regarded as a two-dimensional aerial map showing the accumulations of core papers and the formation of mountains of science on the land. The hot research areas are mountains that exceed a certain elevation.

Because showing all 687 research areas on the Science Map makes it overly complex, hot research areas alone are shown in these Highlights. (See Figure 2.)

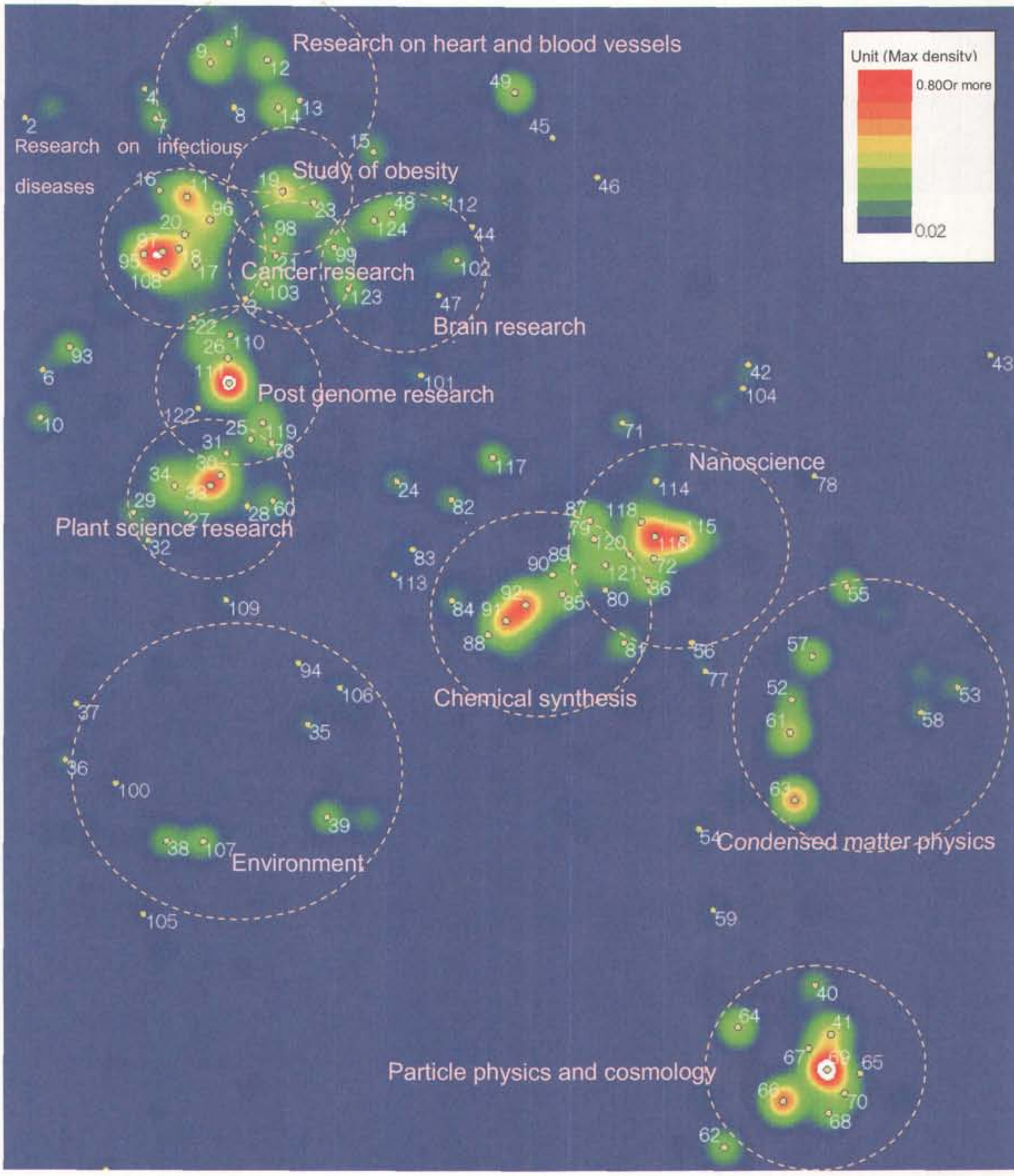
[1] This is the third report. The first report is NISTEP REPORT No. 95, Study on Rapidly-developing Research Area (May 2005); the second report is NISTEP REPORT No. 100, Science Map 2004 (March 2007).

Figure 1: Science Map 2006 (showing the positions of all research areas)



Note 1: Because a gravitational model was used to create this map, up-down and left-right have no meaning; relative position carries meaning. In these Highlights, life science happens to be positioned at the upper left and particle physics/cosmological research at the lower right.
Note 2: White dots indicate the positions of research areas, and red dots the positions of hot research areas. Some research areas with few co-citations with other areas are so far from the center of the map that they are not included above.
Note 3: This map was created through a four-step process. 1) Determine the location of each research area according to the strength of co-citation relationships with the other research areas. 2) Express the position of each research area with a dot, and establish hypothetical spreads for research areas. 3) Divide that map into a grid with squares of a given area, calculating core-paper density (number of core papers divided by mesh area) for each square of the grid. 4) Based on these values, assign colors.
Data: Tabulated from Thomson Reuters' "Essential Science Indicators" by the National Institute of Science and Technology Policy

Figure 2: Science Map 2006 (showing the positions only of hot research areas)



Note 1: The yellow circles indicate the center locations of hot research areas. The numbers next to the yellow circles are the hot research areas' ID numbers. Gradations in the map correspond to the density of core papers. Warm colors represent greater concentrations of core papers, with colors becoming cooler as the density of core papers decreases. The standard for colors in the Science Map is "Observational cosmology and an elementary model for it (ID 69)," which has the highest density of core papers. Places with a maximum density of about 0.8 are red; higher densities are represented as white.

Note 2: Some research areas with few co-citations with other areas are so far from the center of the map that they are not included above.

Data: Tabulated from Thomson Reuters' "Essential Science Indicators" by the National Institute of Science and Technology Policy

2. The snapshot of the current status of scientific research

(1) Relationships among research areas

Scientific research develops through mutual relationships. The Science Map shows that research areas can be divided into several groups, and that these groups of research areas are interrelated.

The research areas at the lower right of the Science Map are related to particle physics/cosmology. The group of research areas related to condensed matter physics spreads out above them. There are two groups of research areas at the center of the Science Map. The group of research areas related to nanoscience is at the center-right, and the group of research areas related to chemical synthesis at the center left. To the left and below chemical synthesis is the group of research areas related to environmental research. Unlike the group of research areas related to chemical synthesis that concentrate close together, this group is spread out on the map.

Groups of research areas related to life science are at the upper left of the Science Map. The lowest of these groups and the closest to the group of chemical synthesis is plant science research. Above it spreads post-genomics, with linkage to research on infectious diseases/immunology, cancer research, study of obesity, and brain research. Above them is the group of research areas related to research on heart and blood vessels.

(2) What does core-paper density indicate?

Looking at the Science Map, both particle physics/cosmology and life science have high core-paper density. The characteristics of each group, however, are different. Particle physics/cosmology has a limited relationship to other groups of research areas, so its position is unlikely to change significantly, and its core papers are likely to remain concentrated. In life science, on the other hand, the evolution of science has brought about links among research areas that developed separately, creating new research areas. This makes it likely that the locations of core papers will shift on the map.

The Science Map shown in Figure 2 can be regarded as depicting a two-dimensional aerial map with accumulations of core papers forming mountains of science on the land. On the Science Map, grids with red gradation are those with high core-paper density. Core-paper density is high in research areas and groups of research areas in which many highly-cited research papers are published and frequently co-cited. This is characteristic of all parts of the map with high densities.

The processes, by which regions with high core-paper density form, however, are not uniform. Figure 3 shows the orthographic projection of the Science Map 2006 on vertical and horizontal axes. Orthographic projection on the vertical axis is the vertical projection, and orthographic projection on the horizontal axis is the horizontal projection.

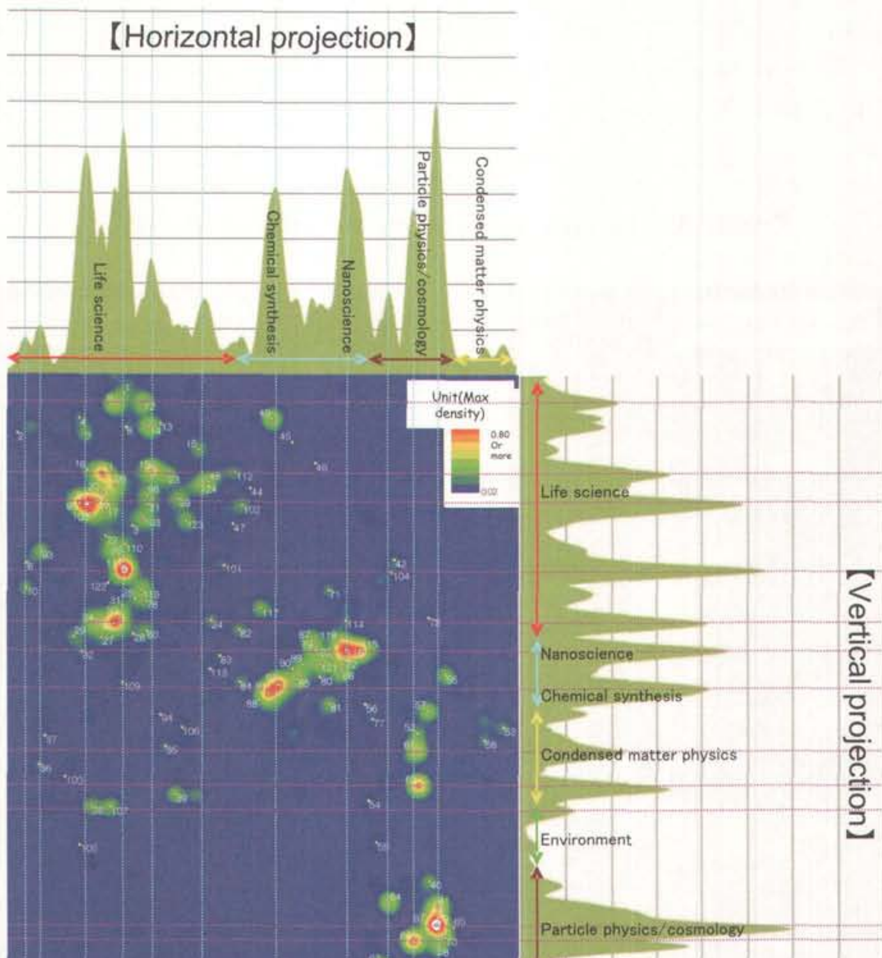
Looking at the breadth of research areas in these vertical and horizontal projections, the group of research areas related to life science has the broadest breadth. The breadths of other groups vary somewhat in their vertical and horizontal projections. The particle physics/cosmology group of research areas is separate from other research areas and has a narrow skirt.

The isolated location of the particle physics/cosmology group on the map is attributable to a limited knowledge transfer between this group and other groups. Particle physics/cosmology has ultimate goals such as the unification of force fields and understanding of the origin of the universe, and experimental and theoretical research are co-evolved over time in deep entanglement. There is thus a tendency towards co-citation among specific research papers and research areas, resulting in a relatively narrow distribution for the group of research areas on the map. Because co-citation with research areas other than particle physics/cosmology is limited, even in time series, the peaks of particle physics/cosmology will probably change little, and core papers will remain concentrated.

The situation is different for the group of research areas related to life science. The subjects of life science research are diverse (plants, animals, fungi, etc.), as are its approaches (i.e., the molecular, cell, organ, and individual level). Thus, widely diverse themes can be set and joined in complex combinations to advance understanding of nature. This makes it possible for research areas fuse, separate, move, nucleate, and disappear on the map. There is therefore no need for the core papers to concentrate in a single region the way those of particle physics/cosmology do.

Furthermore, citation of life science related research papers begins sooner after publication than with other fields. In other words, the process of research area formation is more volatile. A snapshot of a given time such as the Science Map should therefore enable one to view research areas in various phases of development. In fact, on the Science map that plots 687 research areas (Figure 1), the majority of research areas are observed in the life science related region.

Figure 3: Science Map 2006 in horizontal and vertical projection



Note 1: Orthographic projection on the vertical axis is the vertical projection, and orthographic projection on the horizontal axis is the horizontal projection.
Note 2: The height of the mountains indicates core-paper density. The higher the mountain, the greater the concentration of core papers.
Data: Tabulated from Thomson Reuters' "Essential Science Indicators" by the National Institute of Science and Technology Policy

3. Changes in scientific research, a comparison of Science Map 2004 and Science Map 2006

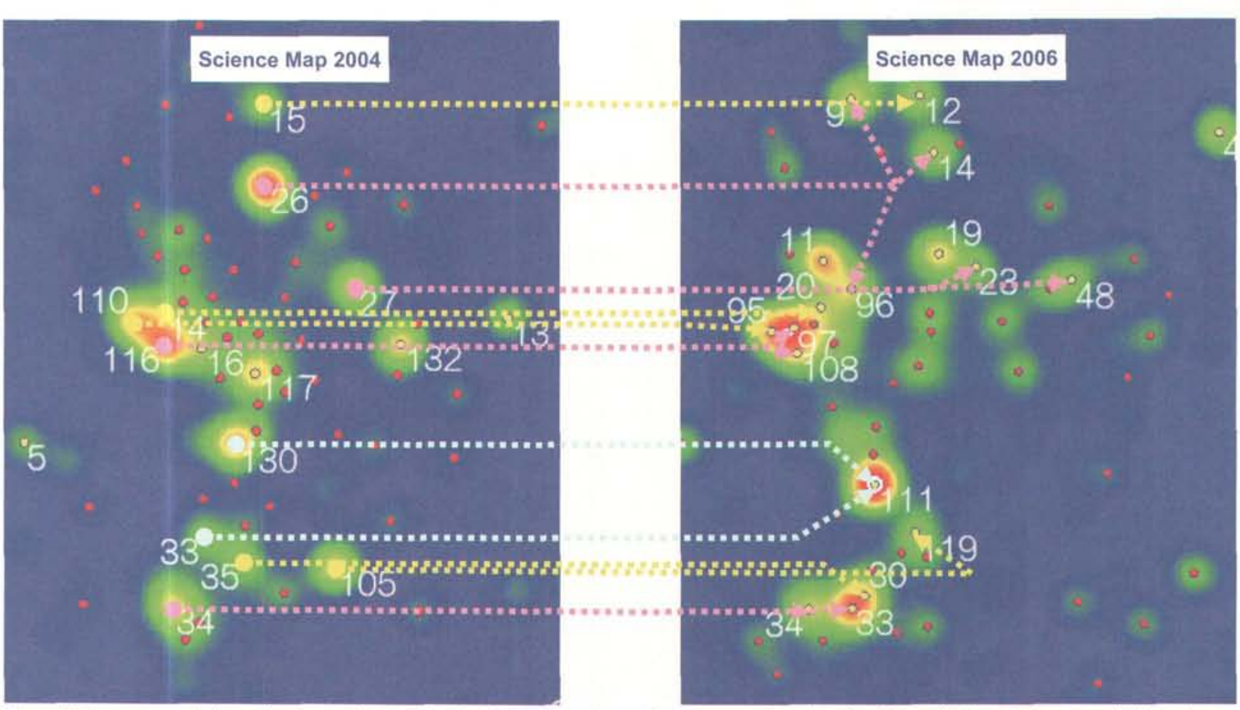
Comparison of Science Map 2004 (covering the years 1999–2004) and Science Map 2006 (2001–2006) and interviews with experts confirmed steady, ongoing change over two years. The important points were as follows.

(1) Life science

In life science related research areas, post-genomics is about to bridge 1) plant science research that focuses mainly on studying plants and fungi and 2) heart and blood vessels research, brain research, study of obesity, cancer research, and research on infectious diseases/immunology that focus mainly on studying animals and fungi.

Two factors contribute to this phenomenon. First, there is the trend in life science research to attempt to understand broader and more complex regulatory mechanisms of life phenomena. Research on life phenomena in animals and plants, long focused on elucidating the regulatory mechanisms for transcription from DNA to RNA. Beginning in 2000, however, much research on RNAi and other regulatory mechanisms at the RNA level, regulatory mechanisms after protein translation, and *in vivo* protein localization regulation has also been published. On the Science Map, this trend can be observed in the fusion of "Research on epigenetic transcriptional regulation (2004, ID 130)" and "Analysis of mechanism of regulation of plant growth (2004, ID 33)" to form "Multi-hierarchical regulatory mechanism of life phenomena (2006, ID 111)" (movement indicated by the blue arrow in Figure 4).

Figure 4: Changes in life science related research



Note: Yellow arrows indicate hot research areas in which concentrations of core papers continued without division. Red arrows indicate hot research areas in which concentrations of core papers divided into multiple groups. Blue arrows indicate hot research areas that fused on the Science Map 2006. This indicates a correspondence relationship in which there were at least 80 core papers, with at least 20 overlapping between different hot research areas. Hot research areas with at least 80 core papers are depicted as yellow dots, while the locations of those with less than 80 core papers are indicated with red dots.
Data: Tabulated from Thomson Reuters' "Essential Science Indicators" by the National Institute of Science and Technology Policy

Second, the position of protein research changed. In the Science Map 2004, "Research on proteome (2004, ID 105)" had a somewhat isolated position between chemical synthesis and life science. In the Science Map 2006, however, its successor research area, "Isotope labeling/quantitative mass spectrometry/protein analysis (2006, ID 119)," moved to the center of the post-genomics group of research areas. This kind of research has a very strong "chemistry" element to it, which can be taken as a scientific trend. In mass spectrographic analysis of proteins, Koichi Tanaka of Shimadzu Corp. developed a "desorption ionization" method for mass spectrographic analysis of macromolecules, which earned him a Nobel Prize in chemistry. As genome sequencing using model organisms advances, comprehensive research on proteins is drawing attention. Mass spectrography is being aggressively incorporated into life science related research and has taken root as a post-genomics method.

<Plant science research>

Links between post-genomics and plant science research have grown stronger, changing the characters of some research areas and dividing others. "Stress response in plants (2004, ID 34)" in the Science Map 2004 divided into "Environmental stress response/metabolic profiling/cellular structure and phospholipid metabolism in plant (2006, ID 33)" and "Plant defense against infection/plant immunity" in the Science Map 2006. In the 2000s, research on gene identification, intergenetic networks, transcriptome analysis, and metabolome in model plants has grown active. More detailed research has progressed, and various research communities have formed. Experts indicated that henceforth the relationship between such research and environmental and food-related issues will likely become important. As in the Science Map 2004, Japan is making a strong effort in plant science. China's presence in the field, however, is growing, so that trend bears watching.

<Clinical medicine>

Clinical medicine is one of the more rapidly changing fields in science. Since the Science Map 2004, research areas directly related to or linked to clinical medicine have continued at a larger size or grown so large that they have split. In the Science Map 2006, it was found that many research areas expected to grow further in the future were scattered around the group of research areas relate to life science. The seeds for the next hot research areas have already been planted.

(2) Chemical synthesis and nanoscience

In life science and nanoscience, as research at the molecular level progresses, the territory of "chemistry" is broadening. Nanoscience is steadily developing. As can be seen in the Science Map, the volume of research linking chemical synthesis and nanoscience is increasing.

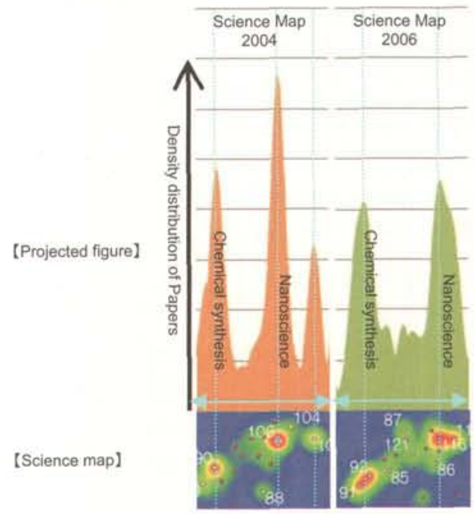
<Chemical synthesis>

Research on asymmetric synthesis using organic catalysts showed a rapid increase. Understanding nature at the level of chemical structural formulas is fundamental to chemistry. With life science and nanoscience research at the molecular level progressing, the territory covered by chemistry is expanding. On the Science Map, chemistry is located between life science and physics, reflecting this situation.

<Nanoscience>

Nanoscience is steadily progressing. In the Science Map 2004, "Development of nanostructure and its application to molecular devices (2004, ID 106)" is observed as a single research area. It has since expanded to three independent research areas, "Study on supramolecular nanodevice by molecular machine and single-molecule conductor (2006, ID 86)," "DNA-nanomaterial and nanodevice (2006, ID 87)," and "Study on synthesis and optical application of metal and metal oxide nanoparticle/nanostructure (2006, ID116)." As can be seen in the Science Map (See Figure 5), the volume of research linking chemical synthesis and nanoscience is increasing.

Figure 5: Increase in research areas between chemical synthesis and nanoscience



Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Reuters' "Essential Science Indicators"

(3) Condensed matter physics and particle physics/cosmology

In condensed matter physics, quantum computing and superconductivity were extracted as hot research areas. Launch of the European Organization for Nuclear Research's (CERN) Large Hadron Collider (LHC) will be a large step for particle physics/cosmology. Discoveries of new phenomena and verification and testing of theories will take place.

<Condensed matter physics>

Condensed matter physics includes hot research areas related to quantum computing and superconductivity. Comparing the Science Map 2004 with the Science Map 2006, the number of research papers in "Ferromagnetic semiconductor spintronics (2006, ID 55)" and "Electrical control of spin in semiconductors/quantum computer using solid state components (2006, ID 57)" increased. Experts suggested that while the location of condensed matter physics in between chemical synthesis and particle physics/cosmology on the map will probably not change, the hot research areas are likely to change with the times.

<Particle physics/cosmology>

Comparing the Science Map 2004 with the Science Map 2006, the hot research areas from 2004 generally continued, although some merged. This is because particle physics/cosmology has ultimate goals such as the unification of force fields and understanding of the origin of the universe, and research continues to evolve in those directions. Relationships between particle physics/cosmology and other groups of research areas were not expected to change significantly, and indeed observation of changes in the Science Map over time found no change in the group's position on the map, even though research content changed.

Particle physics/cosmology is a field that progresses as experimentation and theory mutually stimulate one another. Theory has led the way, but with the launch of the European Organization for Nuclear Research's (CERN) Large Hadron Collider (LHC), discoveries of new phenomena and verification and testing of theories will take place.

4. Observation of inter-/multi-disciplinary research on the Science Map

It was found that the mapping is helpful to distinguish multidisciplinary research, e.g., environmental research, from interdisciplinary research, e.g., nanoscience.

Figure 6 shows the field distribution of core papers in the Science Map, and plots inter-/multi-disciplinary hot research areas by analysis of field category.

The differences in the distribution of hot research areas in nanoscience and environment were distinctive. In the map, the group of research areas related to nanoscience stakes out a clear domain between chemical synthesis and physics, but the group of research areas related to environment spreads out spatially. This indicates that mapping is helpful to distinguish multidisciplinary research from interdisciplinary research.

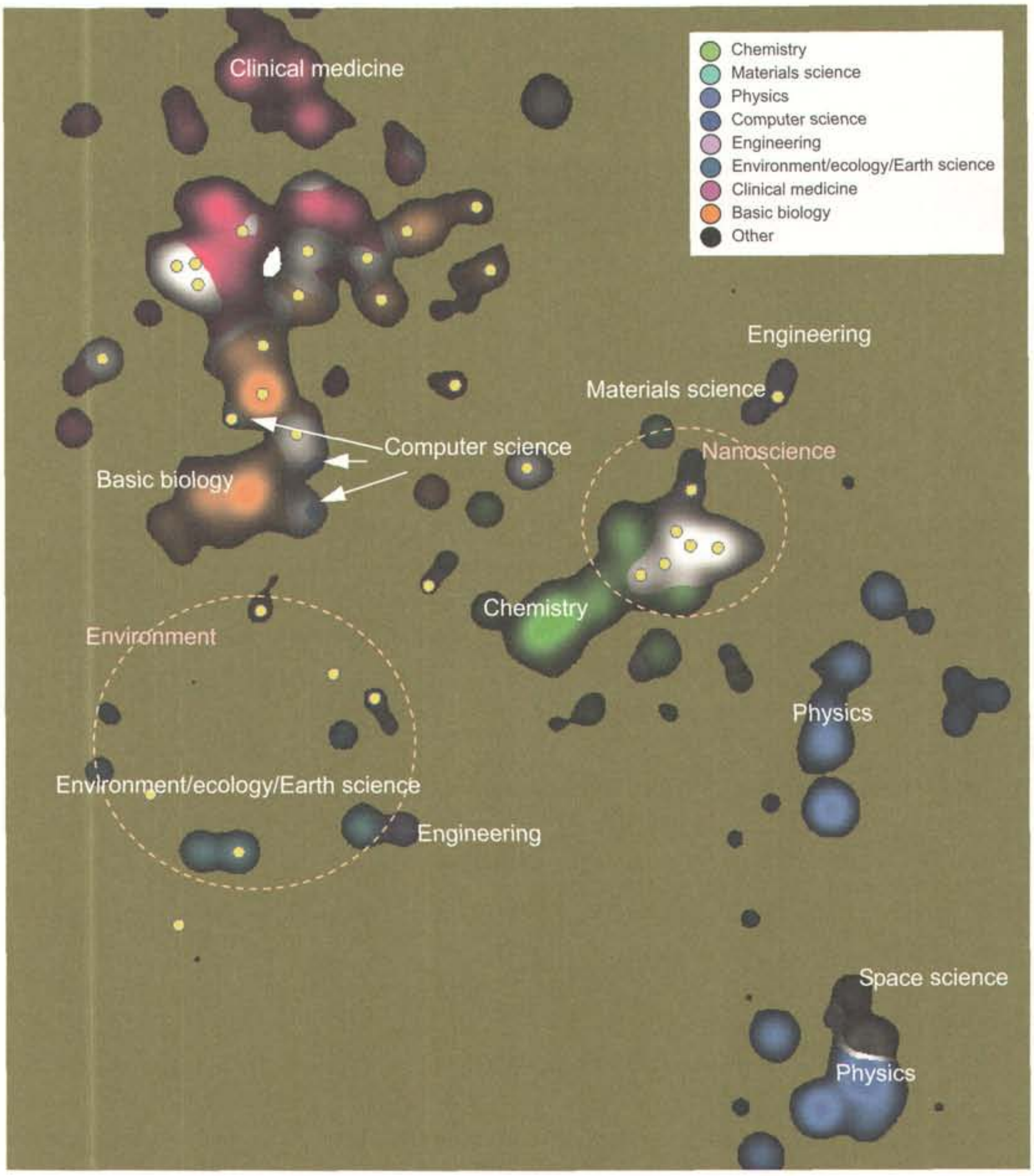
Interdisciplinary research that relies on shared knowledge is generated when separate fields such as physics and chemistry interact. Nanoscience typifies this phenomenon. In interdisciplinary research that relies on shared knowledge, the important thing is that research development stages (research methods and research targets) should be the same in multiple fields. If development stages differ, generation of interdisciplinary research is extremely unlikely. For example, interdisciplinary research in nanoscience was realized during the early 1990s because both chemistry and physics were targeting nanoscale phenomena and matter, the former at the molecular level and the latter at the bulk level. The accumulation of knowledge is a precondition that sets the stage for interdisciplinary research that relies on shared knowledge. Observation of such research can therefore be expected in the Science Map where existing research interacts. In fact, nanoscience appears on the Science Map where differing fields such as physics and chemistry intersect.

In multidisciplinary research, various disciplines address scientific and social challenges independently rather than in collaboration. Thus it shares goals of research. Environmental research typifies this phenomenon. For example, in environmental research, study of biodiversity requires approaches from plant and animal science, while research on the environmental impacts of chemicals requires approaches from chemistry. These research areas stand on the foundation of knowledge in existing fields, and goal-oriented approaches are common. This means that in the Science Map, environmental research is likely to come from the vicinity of existing fields. In fact, the environment group of research areas appears on the Science Map with ongoing links to existing fields, and a broad spread with sometimes weak ties to environmental research.

It thus becomes clear that interdisciplinary research that relies on shared knowledge (nanoscience) and multidisciplinary research that relies on shared goals (environment) are observed in differing forms in the Science Map.

The points to bear in mind differ when promoting interdisciplinary type research or multidisciplinary type research. To promote interdisciplinary research that relies on shared knowledge, an arena for interdisciplinary research must be constructed when the research development stages (research methods and targets) of multiple fields match. On the other hand, to promote multidisciplinary research that relies on shared goals, clear goals must be set, and an arena for researchers who have the knowledge to meet those goals to gather must be constructed.

Figure 6: Locations of inter-/multi-disciplinary research areas in the Science Map



Note: Locations where at least 60 percent of core papers in a given field are distributed have that field's color. Locations where less than 60 percent of a given field's core papers are distributed are considered inter-/multi-disciplinary and not given a field color.
Data: Tabulated from Thomson Reuters' "Essential Science Indicators" by the National Institute of Science and Technology Policy

5. The breadth and intensity of research activities in Japan, the USA, and China

Adding information such as the ratios of each country's research papers to the Science Map enables visualization of activity in the countries. In the Science Map 2006, it became clear that the breadth and intensity of China's scientific research are expanding.

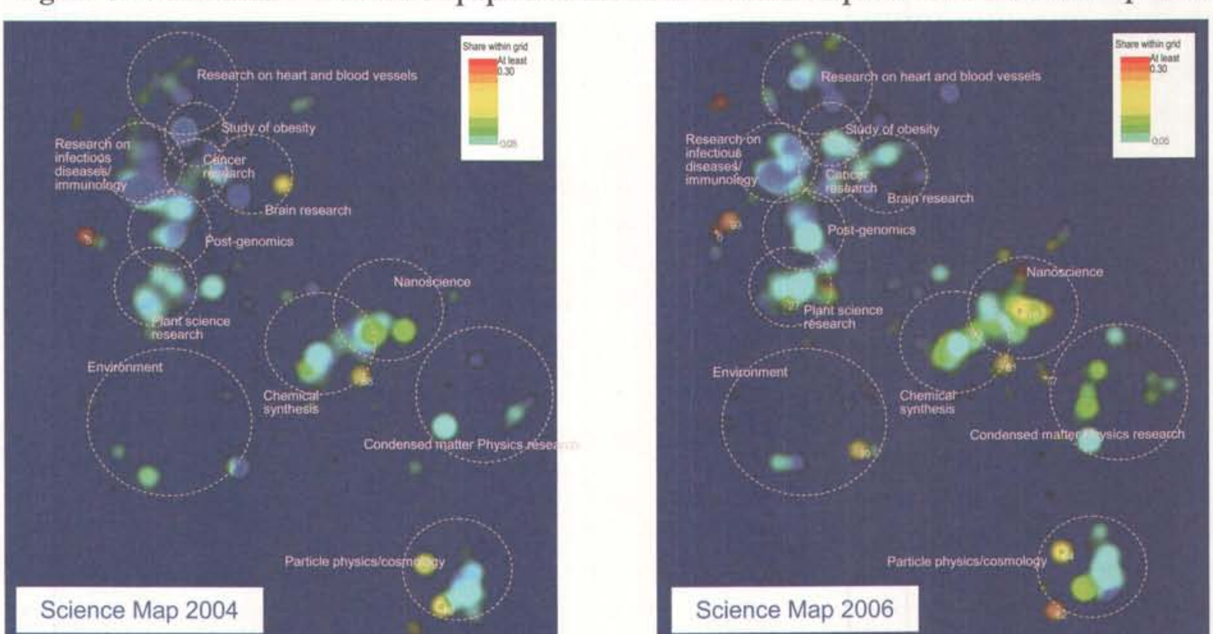
Japan's average share of research papers in the 124 hot research areas derived for the Science Map 2006 is 9.6%, an increase from the Science Map 2004 (9.1%). Furthermore, the percentage of the 124 hot research areas for which Japan has a 0-percent share decreased. Within the 124 hot research areas, Japan's presence is relatively large in hot research areas in physics, chemistry, and plant and animal science.

The hot research area where Japan's share of core papers is highest is "Construction of artificial photosynthesis model mimicking antenna system and charge separation system (ID 80)," with an 80-percent share. Japan's next highest shares are in "High-temperature superconductivity spectroscopy/new electron phase (ID 58)," "Innate immunity (ID 108)," "Brane cosmology from the perspective of duality of anti de sitter space and conformal field theory (ID 65)," and "Ghrelin/function and pathophysiological significance (ID 15)."

Looking at other countries, even though many nations around the world are increasing their production of research papers, the USA remains an important source of knowledge for science as a whole. The USA's activities as illustrated in the Science Map show lower shares of research papers in the chemical synthesis and nanoscience groups of research areas than in life science.

In the Science Map 2004, China's scientific research was limited to nanoscience. Over the following two years, China increased both the breadth and intensity of its activities. (See Figure 7.) China increased its share of research papers in nanoscience, with an increase in the neighboring area of physics as well. Furthermore, in the Science Map 2006, China's share of research papers in plant science research also increased. The breadth of scientific research in China has thus extended to life science.

Figure 7: China's share of research papers as shown in Science Map 2004 and Science Map 2006



Note: Research paper shares of at least 5 percent are shown in light blue, and shares of at least 30 percent in red. Research paper shares were calculated by whole number count.

Data: Tabulated from Thomson Reuters' "Essential Science Indicators" by the National Institute of Science and Technology Policy

6. Future developments

Use of the Science Map has established methodology for observation of dynamic change in natural science, analysis of the forms of inter-/multi-disciplinary research areas, and analysis of the status of scientific activity in various countries. The following are four possible developments for the future developments.

<Periodic observation of science>

Comparison of the Science Map 2004 and the Science Map 2006 and interviews with experts confirmed that scientific research gradually changes over a two-year period. Even as the Science Map 2006 was being created, science continued its development with accomplishments such as the production of iPS cells. By carrying out periodic observation of science and taking panoramic snapshots of science over time with the Science Map, we can describe dynamic change in natural science, such as the way one scientific innovation influences other research areas.

Furthermore, considering the application of the Science Map to science and technology policy, finding emerging research areas that will develop in the future is an important theme. This research experimented with attempting to find research areas likely to develop in the future. Beginning with the next Science Map, trends in these research areas will be tracked. This should deepen knowledge of methods for using science mapping to find emerging research areas.

<Linkage of the Science Map with other data>

Adding statistical data to the Science Map, such as the ratios of research papers from various countries, is effective. The Science Map 2006 clearly showed that China is expanding the breadth and intensity of its scientific research activity. In addition to the ratios of research papers for various countries, linkage to the distribution of research funding or the distribution of universities and government research institutions, for example, is possible. Analysis of the relationship between the development of scientific research and such information over time could obtain data on the influence of research funding on the development of scientific research or the role of universities and government research institutions in the generation of knowledge. Moreover, detailed investigation of co-authorship within research areas could clarify dependence on interaction among researchers and organizations in the process of forming scientific knowledge.

<Linkage of science and technology>

Considered from the perspective of science and technology, the breadth of observation using the Science Map is limited to science, in terms of results published in research papers. In order to take a broader view of science and technology, it is necessary to create technology maps as well, using data such as patents. Using the research papers cited in patent documents, Science Maps and technology maps could be linked. The knowledge transfer from science to technology and from technology to science and field dependence could be observed.

<The Science Map as an arena for discussion>

During interviews, we were struck by the usefulness of the Science map as a basis for discussion. In most interviews with experts, they express their opinions based on their own backgrounds. With shared data such as the Science Map, researchers from different fields can engage in more meaningful discussion of the development of scientific research. By sharing the same "arena," researchers can mutually adjust their sense of distance, facilitating discussion among researchers or among researchers and policy makers. In the future, we would like to pursue this idea of the Science Map as an arena for discussion.

Part I

1. Introduction

The Third Science and Technology Basic Plan advocates the securing of a certain amount of resources for basic research that brings about diverse knowledge and innovation and the steady advancement of such research. As basic research, the Plan lists research based on the free ideas of researchers and research based on policies that aims for future applications. In the promotion of basic research, although the former is eliminated by principles of theme selection and resource concentration, it is necessary to monitor the status of field balance and inter/multi-disciplinary areas and to confirm that the national government is steadily promoting them. In other words, it is necessary to regularly monitor the status of basic science and to perform effective benchmarking of long-term basic science policy.

Based on awareness of these issues, the National Institute of Science and Technology Policy began monitoring the status of scientific research by using databases of scientific papers in FY 2003[2]. This research has the following two purposes.

(i) Creation of "Science Maps" that provide a panoramic view of recent trends in science, especially basic research

(ii) Extraction of hot research areas that are garnering the attention of researchers and producing many scientific papers and observation of those research areas over time

There is a long history of attempts to describe the structure and development of science and technology knowledge from a bibliometric perspective. The dramatic development of information processing technology and enhancement of databases of scientific papers and patents in recent years have brought innovation to research in this field. The mapping of knowledge is drawing attention as a new type of research, and a variety of studies are being conducted, mainly in the USA and Europe[3]. The targets of mapping are diverse. They include analysis of relationships between fields of science through examination of journal citations and analysis of co-authorships by country, organization, and researcher. The National Institute of Science and Technology Policy's Science Maps are distinctive in that the target of their mapping is research areas.

This report uses scientific papers published from 2001 through 2006 to create Science Maps. It reports the results of analysis of "The snapshot of the current status of scientific research" (Chapter 3), "Changes in scientific research, a comparison of Science Map 2004 and Science Map 2006" (Chapter 4), "Observation of inter-/multi-disciplinary research on the Science Map" (Chapter 5), and "The breadth and intensity of research activities in Japan, the USA, and China" (Chapter 6). In addition, along with performing this research on an ongoing basis, survey methods were adjusted and analysis methods were improved. These changes are discussed in Chapter 2.

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[2] This is the third report. The first report is "NISTEP REPORT No. 95: Study on Rapidly-developing Research Areas (May 2005)"; the second report is "NISTEP REPORT No. 100: Science Map 2004 (March 2007)."

[3] For a comprehensive review, see Börner, K., Chen, C., and Boyack, K. W. (2003), "Visualizing Knowledge Domains," *Annual Review of Information Science and Technology*, 37, 179–255.

2. Methodology

Analysis of scientific research using the Science Maps can be performed in three steps: 1) construction of research areas by clustering scientific papers, 2) visualization of research areas through mapping, and 3) content analysis of hot research areas. Below, an overview of the survey method is given, and methodological improvements in Science Map 2006 are discussed.

2-1 Construction of research areas by clustering scientific papers

The method for clustering scientific papers is the same as that in the previous study ("NISTEP REPORT No. 100: Science Map 2004"). Clustering of scientific papers obtained 687 research areas. Of these, 124 hot research areas of at least a certain size were analyzed in detail.

For clustering of scientific papers, the top 1 percent of highly-cited papers (approximately 50,000) during each year in each of 22 fields (including clinical medicine, plant and animal science, chemistry, physics, etc.) among scientific papers published during the six years 2001 through 2006 were used. These highly-cited papers were grouped in two stages (scientific papers → research fronts → research areas) by using "co-citation."

【Co-citation】

Co-citation occurs when two notable scientific papers are both cited by another scientific paper. Frequently co-citied scientific papers are likely to have a certain amount of commonality of content. Groups of scientific papers with commonality of research content can therefore be obtained by clustering scientific papers with strong co-citation relationships.

In this study, the groups of scientific papers that comprise the core of a research area are called "core papers," and scientific papers that cite core papers are called "citing papers." The 5,538 research fronts compiled in Thomson Scientific's Essential Science Indicators (ESI) were used as clusters of scientific papers in the first-stage clustering. These research fronts were grouped again to obtain 687 research areas.

Details of the clustering are summarized in the table below. Targets of clustering for Science Map 2004 were highly-cited papers (the top 1 percent most-cited papers) from the years 1999 through 2004; for Science Map 2006, they were highly-cited papers from the years 2001 through 2006.

About 200 more research fronts were obtained during first-stage clustering for Science Map 2006 than for Science Map 2004. The number of core papers included in the research fronts was roughly the same in both studies. The number of research areas obtained during second-stage clustering for Science Map 2006 was 687, a 10-percent increase over Science Map 2004.

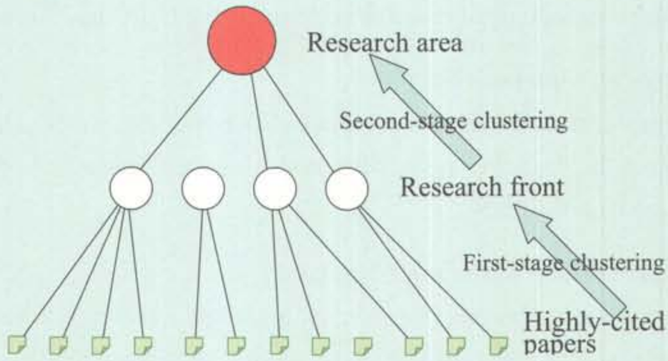
Compared with Science Map 2004, the number of research fronts per research area obtained decreased in Science Map 2006. The figures were 5.6 for Science Map 2004, and 5.2 for Science Map 2006. The number of hot research areas (areas including at least 6 research fronts) subjected to content analysis for Science Map 2006 was therefore 124, 9 fewer than in Science Map 2004.

References on co-citation analysis:

Small, H. and Sweeney, E. (1985a), "Clustering the Science Citation Index using Co-citations. I. A Comparison of Methods," *Scientometrics*, 7, 3-6, 391-409.

Small, H., Sweeney, E., and Greenlee, E. (1985b), "Clustering the Science Citation Index using Co-citations. II. Mapping Science," *Scientometrics*, 8, 5-6, 321-340.

Image of the clustering of scientific papers using co-citation relationships



Details of clustering (comparison of Science Map 2004 and Science Map 2006)

		Science Map 2004	Science Map 2006
Research subject	Period	1999-2004	2001-2006
	Highly-cited research papers	About 47,000	About 51,000
First-stage clustering	No. of research fronts	5350	5538
	No. of core papers included	21,411	21,428
Second-stage clustering	No. of research areas	626	687
	No. of research fronts included	3502	3551
	No. of core papers included	15,531	15,165
	No. of hot research areas	133	124
	No. of quasi–hot research areas	493	563

Note 1: Hot research area: research area made up of at least six research fronts
Note 2: Quasi–hot research area: research area made up of five or fewer research fronts

2-2 Visualization through mapping

In order to analyze the interrelationships among research fronts and the interfaces between research areas, the following three types of maps were created. For Science Map 2006, improvements were added to the Research Area Correlation Map. Part I of this report describes the results of a panoramic analysis of science as a whole using the Academic Disciplines Relation Map and the Research Area Correlation Map. Part II describes the results of analysis of individual research areas using the Individual Research Area Map.

(1) Individual Research Area Map (see Part II)

This map shows what kinds of research themes comprise each hot research area. The unit of visualization is research fronts. The greater the degree of co-citation in the research fronts that comprise a hot research area, the closer they are located on the map.

(2) Academic Disciplines Relation Map (see Chapter 5)

This map shows the relationships between hot research areas and existing academic fields. The unit of visualization is the 124 hot research areas. Hot research areas with similar field compositions (22 fields, including clinical medicine, plant and animal science, chemistry, and physics, etc.) are located near one another on the map.

(3) Research Area Correlation Map (see Chapters 3, 4, 5, and 6)

This map shows correlations between research areas. The unit of visualization is the 687 research areas. Research areas with a high degree of co-citation are located near one another.

<Improvements of the Research Area Correlation Map>

In Science Map 2006, all 687 research areas obtained by clustering scientific papers are mapped in the Research Area Correlation Map. By mapping all 687 research areas and showing the 124 hot research areas for which content analysis was performed, the aim was to make clearer the position and function of the hot research areas in scientific research as a whole.

This change took a hint from topographical maps. The hot research areas in the Science Map are those that reach a certain volume in terms of their number of scientific papers. If we liken the Science Map to a topographical map, these areas would be like mountains that surpass a certain elevation. For a mountain climber who wishes to travel from mountain to mountain, the information only about peaks of mountain would be incomplete. This is because information on how the mountains are connected (whether there are peaks or valleys between the high mountains, how deep the valleys are, and so on) would not be included.

Returning to the Science Map, this is similar to the question of how the hot research areas are connected (whether there is interconnected research). In order to cover this information, it is necessary to add the between-mountain data to the map. This was the intention behind creating the Research Area Correlation Map using all 687 research areas.

In addition to the subjects of mapping, the visualization method for the Research Area Correlation Map was also changed. Instead of the past method of showing research areas as circles, they are now mapped to show gradations depending on the density of core papers in research areas. This is an attempt to make the visualization easier to understand in analogy with the contour lines of topographical maps.

Furthermore, a method to connect Science Maps from different periods (in this case, Science Map 2004 and Science Map 2006) was developed. A model that considers virtual attraction forces between research areas with shared core papers in Science Map 2004 and Science Map 2006 was considered, and a computer program to calculate optimal research area position on a two time period map was developed[4].

2-3 Content analysis of research areas

Names and overviews of the hot research areas obtained by clustering scientific papers were determined through content analysis by experts. Changes were added to the method of content analysis of hot research areas in Science Map 2006. In addition, a questionnaire and an interview survey from the perspective of a panoramic view of the research areas were carried out regarding the developmental status of hot research areas in an attempt to capture the dynamism of scientific research.

(1) Changes to the method used for content analysis of hot research areas

For Science Map 2006, a list of Japanese experts was created from the authors of core papers that make up hot research areas. Core paper authors and experts recommended by core paper authors were asked to carry out content analysis. When there were no Japanese among the authors of core papers that make up a hot research area, researchers whose work is seen as close according to information gathered over the internet and so on were asked to perform that task.

Through Science Map 2004, the National Institute of Science and Technology Policy's Science and Technology Foresight Center first carried out the content analysis of hot research areas. After that, experts in the hot research areas were asked to verify the validity of the content analysis.

(2) Implementation of the questionnaire on the development status of hot research areas

A questionnaire regarding the development status of hot research areas since the latter half of the 1990s and during the coming five years was given to those who carried out the content analysis of the hot research areas. They were asked about the following two points. (See Part II.)

Content of questionnaire

(i) In the hot research area, what changes do you think took place from the latter half of the 1990s to 2001–2006 (the survey's subject period)? Please fill in the appropriate number(s). (Multiple answers are acceptable.)

1. During the latter half of the 1990s, it was part of a somewhat larger research area, and as research subsequently advanced, it became an independent research area.
2. During the latter half of the 1990s, research was carried out separately, but as research subsequently advanced, it tended to fuse and form a research area.
3. During the latter half of the 1990s, this kind of research area was not recognized, but as subsequently advanced, a research area formed.
4. During the latter half of the 1990s, a precursor research area existed, and as research subsequently advanced, the amount of related research increased rapidly.
5. During the latter half of the 1990s, a precursor research area existed, but as research subsequently advanced, the quality of the research changed.
6. During the latter half of the 1990s, a precursor research area existed, was considered important, and many papers were

[4] Details of the methodology are to be published in a future paper (now being prepared for submission by Igami and Saka).

published in the area, so research has not changed quantitatively or qualitatively.

(ii) What changes do you think will occur in this hot research area during the years 2006–2010? Please fill in the appropriate number(s). (Multiple answers are acceptable.)

1. It will probably divide into multiple research areas.
2. It will probably fuse with another research area.
3. A quantitative expansion of research will probably occur.
4. A qualitative change in research will probably occur.
5. There will probably be no noteworthy quantitative expansion of or qualitative change in research.

(3) Implementation of interview survey from the perspective of a panoramic view of the research areas

For Science Map 2006, analysis of the Science Map as a whole was added to analysis of individual hot research areas. Ten experts were asked the following four questions in an interview survey.

Interview content

(i) Does the Science Map express the status of scientific research today?

(ii) If there were a past Science Map (from 10–15 years before), what changes would have occurred?

(iii) If there is a future Science Map (5–10 years from now), what changes will occur?

(iv) Other

2-4 Points to bear in mind regarding research areas obtained with the Science Map

The research areas in the Science Map were obtained through a process that includes the extraction and clustering of highly-cited papers. The results therefore depend on what kind of scientific papers were compiled in the database and on the threshold value used for clustering. Thus, when using the results reported here, the following two points should be borne in mind.

(1) Some fields are very active in terms of publishing research results in the form of scientific papers, but other research areas focus on applied development and publish few papers. The maps obtained through this study therefore cannot provide a comprehensive overview of science as a whole.

(2) This study examined trends over the past few years for research areas that have reached a certain number of published scientific papers. Research areas in which change is very rapid or that are small in scale therefore may not have been captured by this study.

3. The snapshot of the current status of scientific research

For Science Map 2006, the 124 hot research areas shown in Figure 1 were derived. The content of individual hot research areas is shown in Part II.

Figure 1: List of hot research areas

ID	Research Area	ID	Research Area
1	Drug-eluting stent	32	Inducible defense mechanism in plant
2	Stage classification, treatment algorithm and outcome prediction of hepatocarcinoma	33	Environmental stress response / metabolic profiling / cellular structure and phospholipid metabolism in plant
3	Basic and clinical study on antitumor effect of histone deacetylase (HDAC) inhibitors	34	Plant defense against infection / plant immunity
4	Biodefense by blood coagulation regulatory system	35	Environmental pollution study of bromine flame retardant made mainly of polybrominated diphenylethers (PBDEs)
5	Deep mycosis	36	Assistive technology for detection, prediction and countermeasure of animal and plant activity change caused by climate change
6	Study on highly pathogenic avian influenza subtype H5N1	37	Biodiversity
7	Bone metabolism control by drug and its clinical application	38	Climatic effect of air pollutant and mineral dust
8	History of effect and adverse effect of hormone replacement therapy (HRT)	39	Earth history
9	Thromboembolism study	40	Gamma-ray burst and relative celestial explosion phenomenon
10	Conventional infectious diseases / resistant bacterial infectious diseases	41	Formation and evolution of the galaxy
11	Control of lymphocyte-activating organ dysfunction by antibody therapy and others	42	Solid macromolecule type fuel cell / mass and heat transfer
12	Study on risk assessment, therapeutic effect, and diagnostic method for cardiac diseases	43	Nitride semiconductor transistor / high-voltage and high-frequency application
13	Drug therapy of diabetes / thiazolidine derivatives	44	Integrated comprehension of brain function by neuron-glia interaction
14	Arteriosclerosis, abnormal lipid metabolism and abnormal carbohydrate metabolism affecting the onset of acute coronary syndrome, and inhibitory effect of hypolipidemic agents and proglycemic agents on the onset of acute coronary syndrome	45	Visceral sensation and neural mechanism of emotion and empathy
15	Ghrelin / function and pathophysiological significance	46	Decision-making neuroscience
16	Hormone therapy / breast cancer prevention	47	Kinetics of AMPA receptor and spine morphology in synaptic plasticity
17	Molecular targeting therapy / type III tyrosine kinase-related tumor	48	Cause analysis and therapy development for psychiatric and nerve disease
18	Basic and clinical study on antibody therapy for HER2 (human epidermal growth factor receptor 2) positive breast cancer	49	Functional analysis of human brain and drug therapy of psychiatric disease
19	Obesity and diabetes	50	Structural analysis of the production process from the perspective of a network
20	New development in molecular therapy targeting EGFR mutations and others	51	Economic environment surrounding businesses
21	Study on regulation of tissue stem cell by extracellular environment and characteristics of cancer stem cell	52	Metamaterials
22	Cancer / gene expression profiling analysis	53	Superconductive properties of magnesium diboride and its application
23	Biological elucidation and clinical application of damaged tissue repair mechanism	54	Attosecond quantum dynamics
24	Elucidation of behavior principle of ion/water channel molecule	55	Ferromagnetic semiconductor spintronics
25	Genome-wide gene expression analysis and expression regulatory function analysis	56	Quantum information control with multidimensional photon
26	Histone diversity and life phenomena	57	Electrical control of spin in semiconductors / quantum computer using solid state components
27	Plant functional genomics study	58	High-temperature superconductivity spectroscopy / new electron phase
28	Plant cell proteome analysis	59	High energy density science
29	Plant-microorganism interaction	60	Complex networks
30	Light environment response control / flower bud formation mechanism in plant	61	Quantum information/communication, optical nanoscience
31	Redox regulation	62	Hadron spectroscopy

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

List of hot research areas (continued)

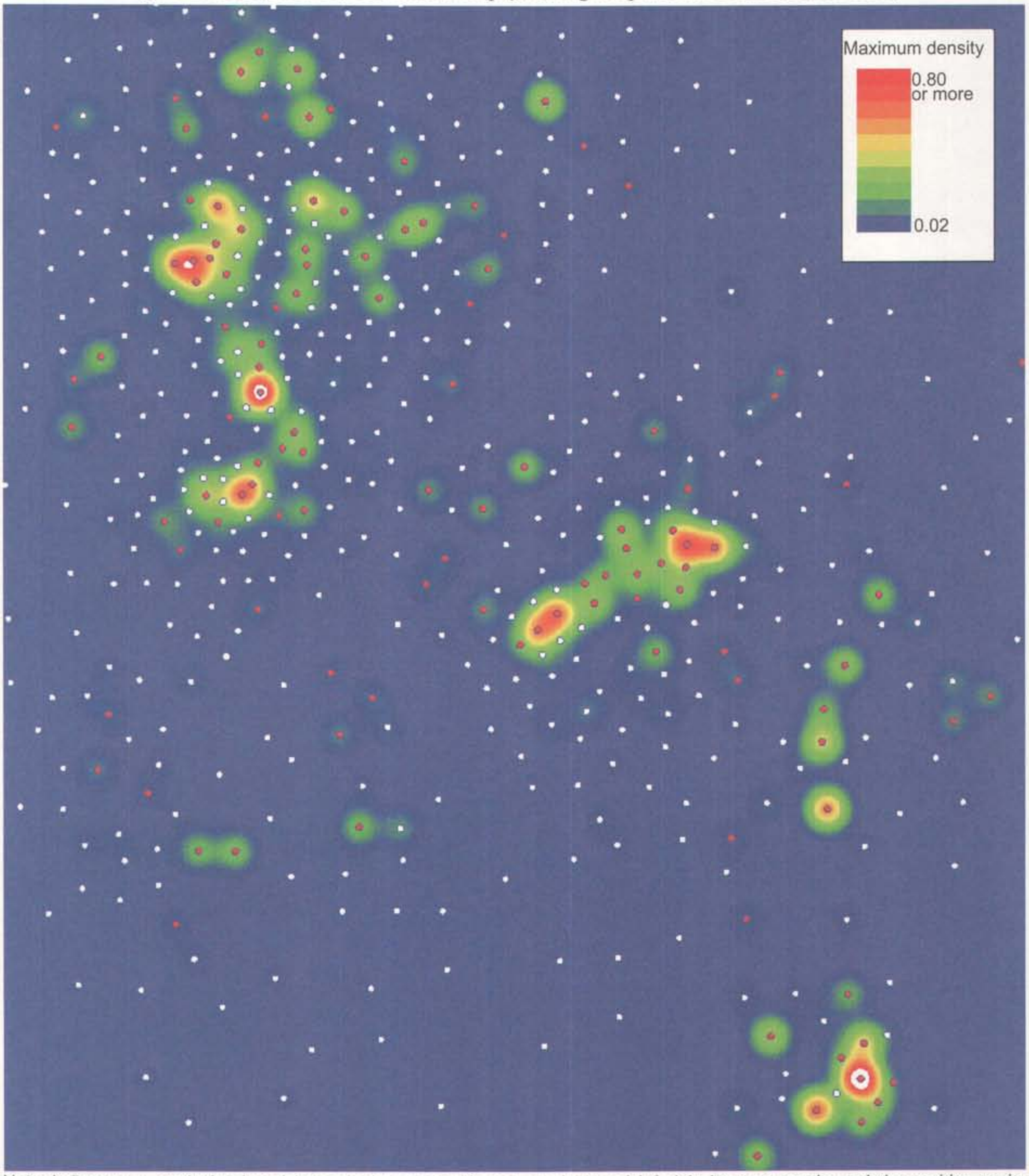
ID	Research Area	ID	Research Area
63	New quantum condensed phase where substances strongly interact with each other	94	Epidemiological study about the effect of air pollution (especially particle-like substances) on cardiovascular disease
64	Search for quark matter through high-energy nuclear collision	95	Study on HCV and HIV
65	Brane cosmology from the perspective of duality of anti de sitter space and conformal field theory	96	Elucidation of in-vivo function of drug transporter in human
66	Explore physics beyond the standard model from flavor physics of B meson and neutrino, dark matter and muon anomalous magnetic efficiency	97	Suppression of immune reaction centered on foxp3-positive, CD25-positive and CD4-positive regulatory t cells
67	Field theory on noncommutative space	98	Apoptosis (cell death) and inflammation
68	Verification and integrability of AdS/CFT correspondence	99	Embryonic stem cell / neural induction
69	Observational cosmology and an elementary model for it	100	Study on exchange between atmosphere and continental ecosystem of CO_2 and others
70	High-dimensional black holes	101	Proteinous infectious agent / new paradigm for genetic material
71	Nanofiber technology with the electro-spinning process and tissue engineering research	102	Physiological function of TRP channel
72	Study of solar cells using inorganic oxides, organic-inorganic hybrids or organic polymers	103	Activation of hypoxia-inducible factor 1 and formation of tumor microenvironment
73	Ultra fine crystal grain / macrostrain process	104	Solid macromolecule type fuel cell / macromolecular electrolyte film
74	Space-time code	105	Quantification of water vapor, clouds, aerosol and albedo based on satellite and ground-based observation
75	Multifunctional signature / multifunctional coding	106	Water environment
76	Interactome analysis	107	Aerosol
77	Molecule-based nano-quantum magnet	108	Innate immunity
78	Macromolecule nanocomposite	109	Microbiodiversity
79	Living radical polymerization	110	Study on ubiquitination and sumoylation of protein
80	Construction of artificial photosynthesis model mimicking antenna system and charge separation system	111	Multi-hierarchical regulatory mechanism of life phenomena
81	Porous coordination polymer	112	Molecular mechanism and physiological role of endogenous cannabinoid signal
82	Retrieval of binding specificity of sugar chain recognition protein by neoglycolipid sugar chain microarray	113	Photosynthetic light reaction apparatus / structure, function and regulation
83	Activation of oxygen molecule by metalloenzyme	114	Study of laminated film and capsule
84	Protein folding	115	Carbon nanotube synthesis and device evaluation
85	Ionic liquid	116	Study on synthesis and optical application of metal and metal oxide nanoparticle/nanostructure
86	Study on supramolecular nanodevice by molecular machine and single-molecule conductor	117	Micro-bio system and micro chemical system
87	DNA-nanomaterial and nanodevice	118	Mesoporous material / silica organic-inorganic hybrid material / organic supramolecular complex
88	Catalytic asymmetric addition reaction of carbon nucleophile	119	Isotope labeling / quantitative mass spectrometry / protein analysis
89	Bioimaging probe	120	Organic transistor / improvement in performance and function
90	Synthetic polymer-immobilized catalyst technology	121	Polymer organic led and phosphorescent organic LED
91	Catalytic asymmetric synthesis	122	Bioinformatics / transcriptome
92	Molecular conversion reaction using transition metal catalyst	123	Pathogenesis and pathology of parkinson's disease and intracellular quality control mechanism by autophagy
93	Pathogenic mechanism and preventive/therapeutic method of severe acute respiratory syndrome (SARS)	124	Molecular pathology and therapy of alzheimer's disease

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

(1) Research Area Correlation Map

Figure 2 and Figure3 are Research Area Correlation Maps. The unit of visualization is research areas. The stronger the degree of co-citation, the closer together the research areas are on the map.

Figure 2: Research Area Correlation Map (showing the positions of all research areas)



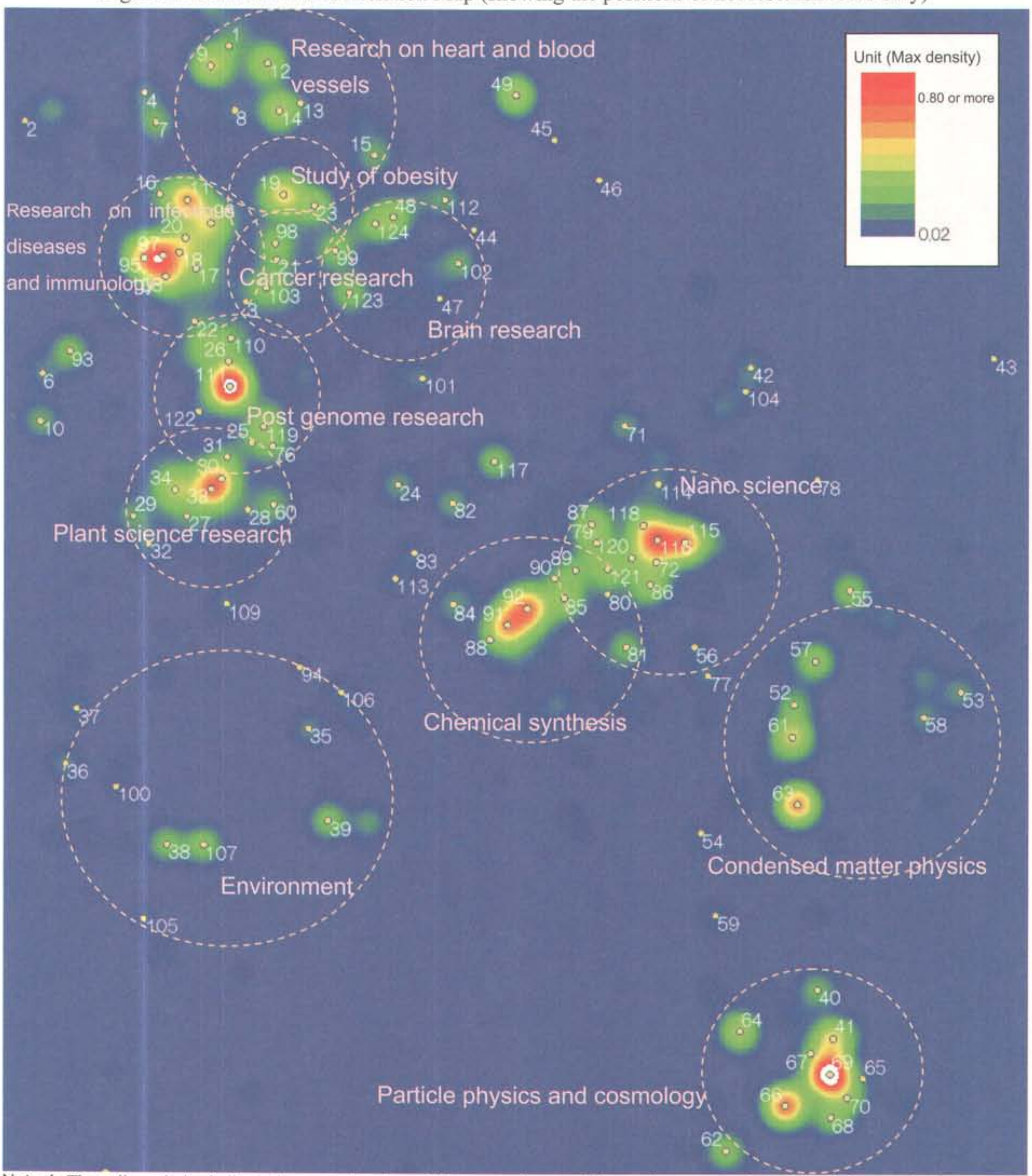
Note 1: Because a gravitational model was used to create this map, up-down and left-right have no meaning; relative position carries meaning. In the map, life science happens to be positioned at the upper left and particle physics/cosmological research at the lower right.

Note 2: White dots indicate the positions of research areas, and red dots the center positions of hot research areas. Some research areas with few co-citations with other areas are so far from the center of the map that they are not included above.

Note 3: This map was created through a four-step process. 1) Determine the location of each research area according to the strength of co-citation relationships with the other research areas. 2) Express the position of each research area with a dot, and establish hypothetical spreads for research areas. 3) Divide that map into a grid with squares of a given area, calculating core-paper density (number of core papers divided by mesh area) for each square of the grid. 4) Based on these values, assign colors. See p.13 for detail.

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

Figure 3: Research Area Correlation Map (showing the positions of hot research areas only)



Note 1: The yellow circles indicate the center locations of hot research areas. The numbers next to the yellow circles are the hot research areas' ID numbers.

Note 2: Some research areas with few co-citations with other research areas are so far from the center of the map that they are not included above.

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

In Science Map 2006, Research Area Correlation Map, all 687 research areas derived from clustering scientific papers are mapped. The aim of showing the 124 hot research areas for which content analysis was performed is to clarify the position of the hot research areas within scientific research as a whole. The white circles in Figure 2 indicate the positions of research areas, while the red circles indicate the center position of hot research areas.

Because showing all 687 research areas on the Science Map would make it overly complex, in this report, only the positions of hot research areas are shown on maps, as in Figure 3. Gradations in the map correspond to the density of core papers. Warm colors represent greater concentrations of core papers, with colors becoming cooler as the density of core papers decreases. The standard for colors in the Science Map is "Observational cosmology and an elementary model for it (ID 69)," which has the highest density of core papers. Places with a maximum density of about 0.8 are red; higher densities are represented as white.

From the Correlation Map, one can see that the 124 research areas divide into groups of research areas, and that groups are interrelated.

The research areas at the lower right of the Correlation Map are related to particle physics/cosmology. The group of research areas related to condensed matter physics spreads out above them. There are two groups of research areas at the center of the Correlation Map. The group of research areas related to nanoscience is at the center-right, and the group of research areas related to chemical synthesis at the center left. To the left and below chemical synthesis is the group of research areas related to environmental research. Unlike the group of research areas related to chemical synthesis that concentrate close together, this group is spread out on the map.

Groups of research areas related to life science are at the upper left of the Correlation Map. The lowest of these groups and the closest to the group of chemical synthesis is plant science research. Above it spreads post-genomics, with linkage to research on infectious diseases/immunology, cancer research, study of obesity, and brain research. At the top is the group of research areas related to research on heart and blood vessels. Post-genomics forms a bridge between plant science research, where the research subject is plants, and cancer research, study of obesity, and so on, where it is animals.

(2) The characteristic of areas on the Research Area Correlation Map with high core-paper density

The Research Area Correlation Map shown in Figure 2 can be regarded as depicting an aerial map with accumulations of core papers forming mountains of science on the land. On the Research Area Correlation Map, areas with red gradation are those with high core-paper density. Core-paper density is high in research areas and groups of research areas in which many hot (highly-cited) scientific papers are published and frequently co-cited. This is characteristic of all parts of the map with high densities.

The processes by which regions with high core-paper density form, however, are not uniform. Here we will consider the characteristic of high core-paper density on the Research Area Correlation Map by contrasting the life science research area group with the particle physics/cosmology research area group.

Figure 4 shows an orthographic projection of the Science Map 2006 Research Area Correlation Map on vertical and horizontal axes. Orthographic projection on the vertical axis is the vertical projection, and orthographic projection on the horizontal axis is the horizontal projection.

Looking at the breadth of research areas in these vertical and horizontal projections, the group of research areas related to life science is the broadest. The breadths of other groups vary somewhat in their vertical and horizontal projections. Calculated from the range covered by the vertical and horizontal axes, however, life science has the widest distribution of any research area group. The particle physics/cosmology group of research areas is separate from other research areas and has a narrow skirt.

The isolated location of the particle physics/cosmology group on the map is attributable to its core papers being cited only by citing papers in a limited number of fields. Particle physics/cosmology has ultimate goals such as structuring a unified field theory and understanding the origin of the universe, and experimental and theoretical research have co-evolved over time in deep entanglement. There is thus a tendency towards co-citation among specific scientific papers and research areas, resulting in a relatively narrow distribution for the group of research areas on the map. Because co-citation with research areas other than particle physics/cosmology is limited, even in time series, the peaks of particle physics/cosmology will probably change little, and core papers will remain concentrated

The situation is different for the group of research areas related to life science. The subjects of life science research are diverse (plants, animals, fungi, etc.), as are its approaches (i.e., the molecular, cellular, organ, and individual level). Thus, widely diverse themes can be set and joined in complex combinations to advance understanding of nature.

This makes it possible for research areas that have developed separately to link, for research areas to shift, and for new research areas to appear as science advances. There is therefore no need for the core papers to concentrate in a specific region the way those of particle physics/cosmology do.

Furthermore, citation of life science related scientific papers begins sooner after publication than with other fields. In other words, the process of research area formation is more volatile. A snapshot of a given time such as the Science Map should therefore enable one to view research areas in various phases of development. In fact, on the Research Area Correlation Map that plots 687 research areas (Figure 2), the majority of research areas are observed in the life science related region, indicating the variety of its research themes.

Thus, although high core-paper density shown in red is seen for both life science and particle physics/cosmology on the Research Area Correlation Map, the characteristic of their peaks differs.

Figure 5 depicts horizontal and vertical projections for Science Map 2004. Looking at changes over time from Science Map 2004 to Science Map 2006, the positions of the mountains of particle physics/cosmology did not change, while those of life science shifted. This confirms the characteristics discussed above. The following chapter discusses time-series analysis in detail, including this data.

The visualization method for the Research Area Correlation Map

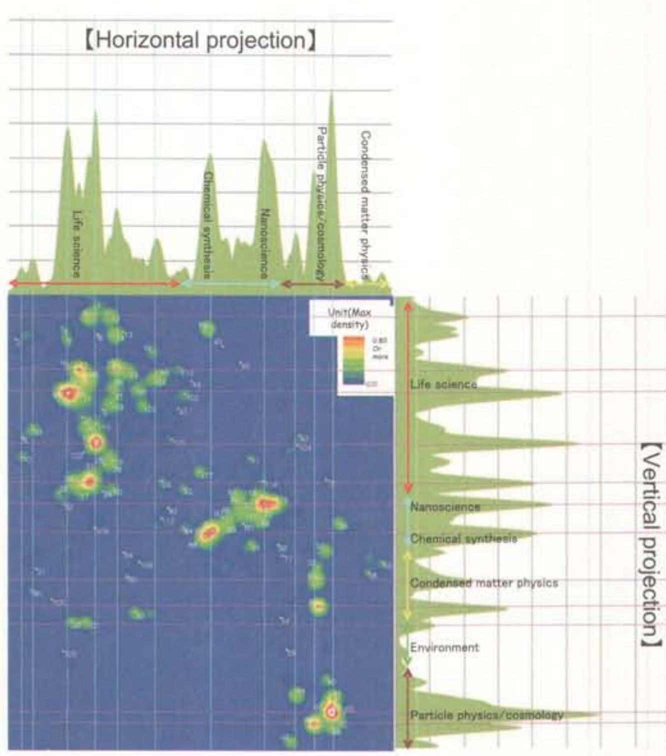
Ordinarily, mapping obtains only the center positions of research areas. There is therefore some freedom in how to depict the breadth of individual research areas on the map. On the Individual Research Area Maps, the breadth of research areas is expressed using the radiuses of circles.

This time, research area breadth on the Research Area Correlation Map is expressed using a Gaussian function. This has two factors. The first factor is the design-based decision to analogize the map with topographical maps as described in the text. The second factor is a technical issue involving the use of circles. Because the maximum number of core papers in a research area divided by the minimum number is on the order of 10^4, it is difficult to use circles to express size on a map.

In concrete terms, research areas' core papers were distributed in terms of a Gaussian function, centered on positions found with a mapping program. Core paper distribution in the Science Map is expressed by superposing the Gaussian function obtained for each research area $\rho(x, y)$(the 687 research areas in Science Map 2006). The value of $\rho(x, y)$ integrated for all surfaces is the total the number of core papers.

For actual visualization, in order to express the distribution of core papers on a two-dimensional plane by using computers, the Science Map was divided into a mesh of area dx×dy. Next, the number of core papers included in the mesh were counted, and core paper density (number of core papers/(dx×dy)) was calculated to approximate $\rho(x, y)$. For the Research Area Correlation Map, colors were determined in accordance with the core-paper density in each mesh.

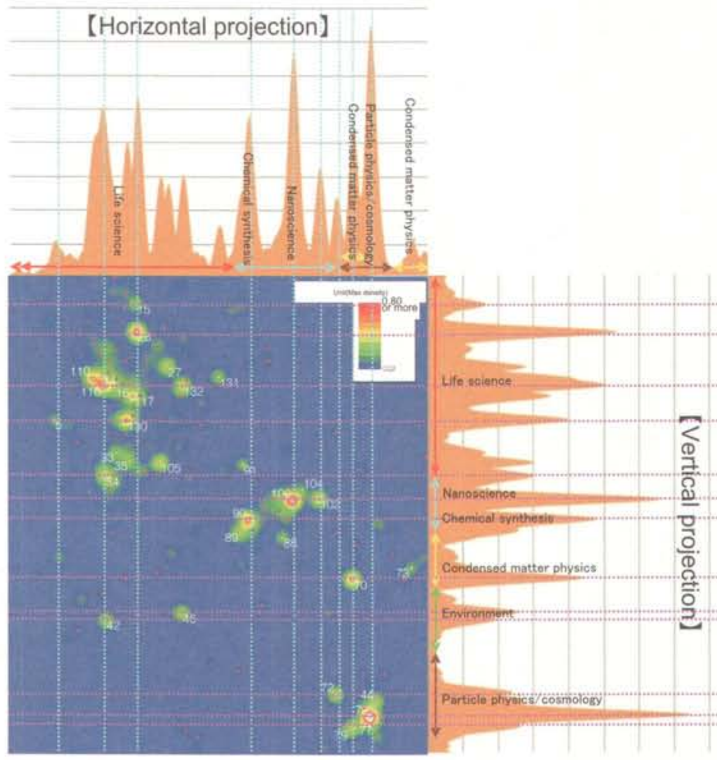
Figure 4: Science Map 2006 in horizontal and vertical projection



Note 1: Orthographic projection on the vertical axis is the vertical projection, and orthographic projection on the horizontal axis is the horizontal projection.

Note 2: The height of the mountains indicates core-paper density. The higher the mountain, the greater the concentration of core papers.

Figure 5: Science Map 2004 in horizontal and vertical projection



Note 1: Orthographic projection on the vertical axis is the vertical projection, and orthographic projection on the horizontal axis is the horizontal projection.

Note 2: The height of the mountains indicates core-paper density. The higher the mountain, the greater the concentration of core papers.

4. Changes in scientific research, a comparison of Science Map 2004 and Science Map 2006

4-1 The dynamics of scientific research

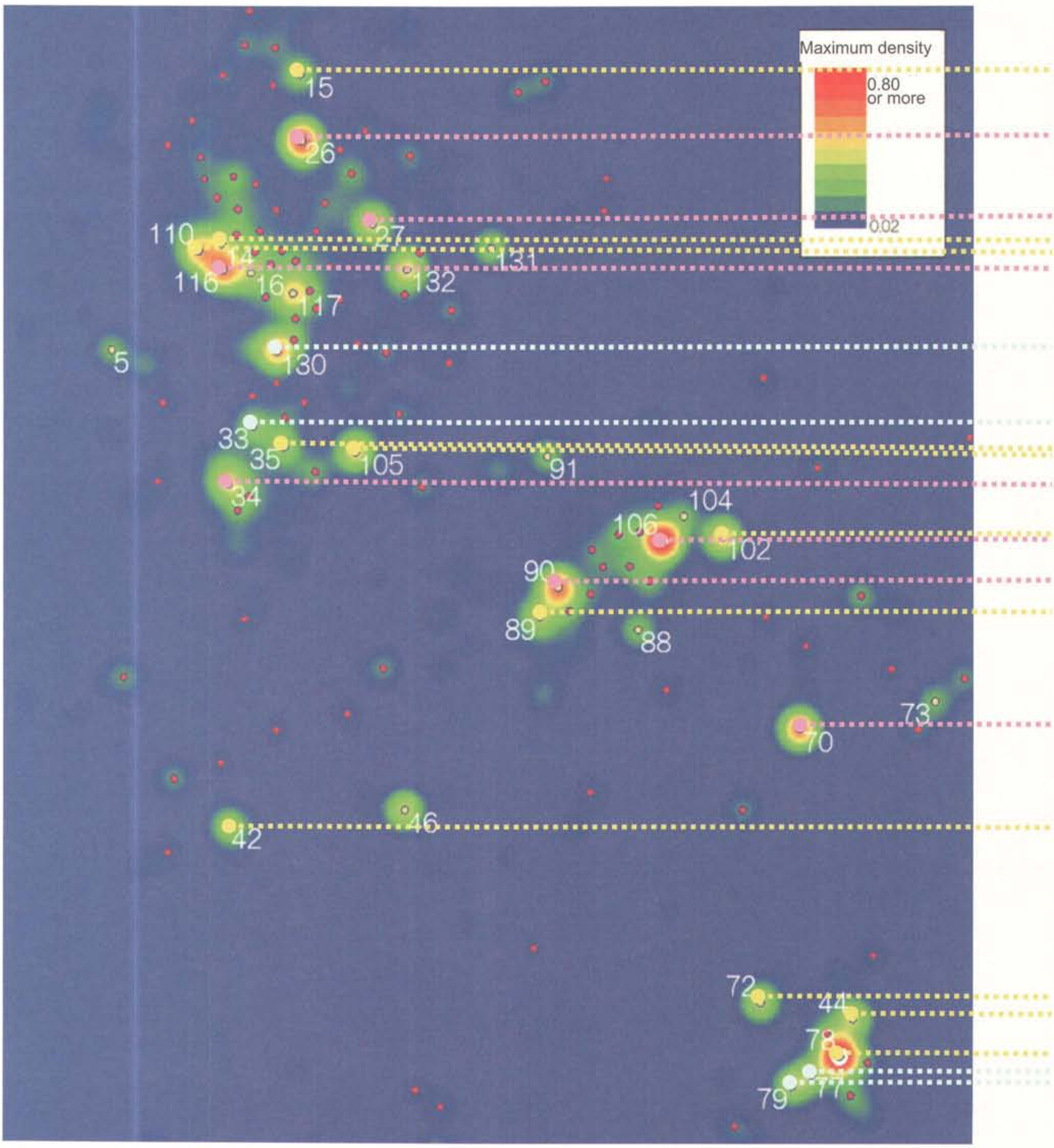
This chapter addresses the dynamics of scientific research as glimpsed through the Science Map. Changes between 2004 and 2006 will be discussed through the results of the interview survey and comparison of the two Research Area Correlation Maps.

Figure 6 shows the Research Area Correlation Map in Science Map 2004, while Figure 7 shows the same map for Science Map 2006. The ways in which hot research areas are developing can be grasped by using core papers included in both Science Map 2004 and Science Map 2006 as markers. The number of core papers found in both Science Map 2004 and Science Map 2006 shows their correspondence relationship. Yellow arrows indicate hot research areas in which concentrations of core papers continued without division. Red arrows indicate hot research areas in which concentrations of core papers divided into multiple groups. Blue arrows indicate hot research areas that fused on the Science Map 2006. This indicates a correspondence relationship in which there were at least 80 core papers, with at least 20 overlapping between different hot research areas.

Areas with high core-paper density accordingly include many core papers held over from Science Map 2004. This may seem obvious, but conversely it may indicate that in order for a research area to grow large, a core of ongoing scientific knowledge is necessary.

Below, this report discusses the dynamics of scientific research in various research areas.

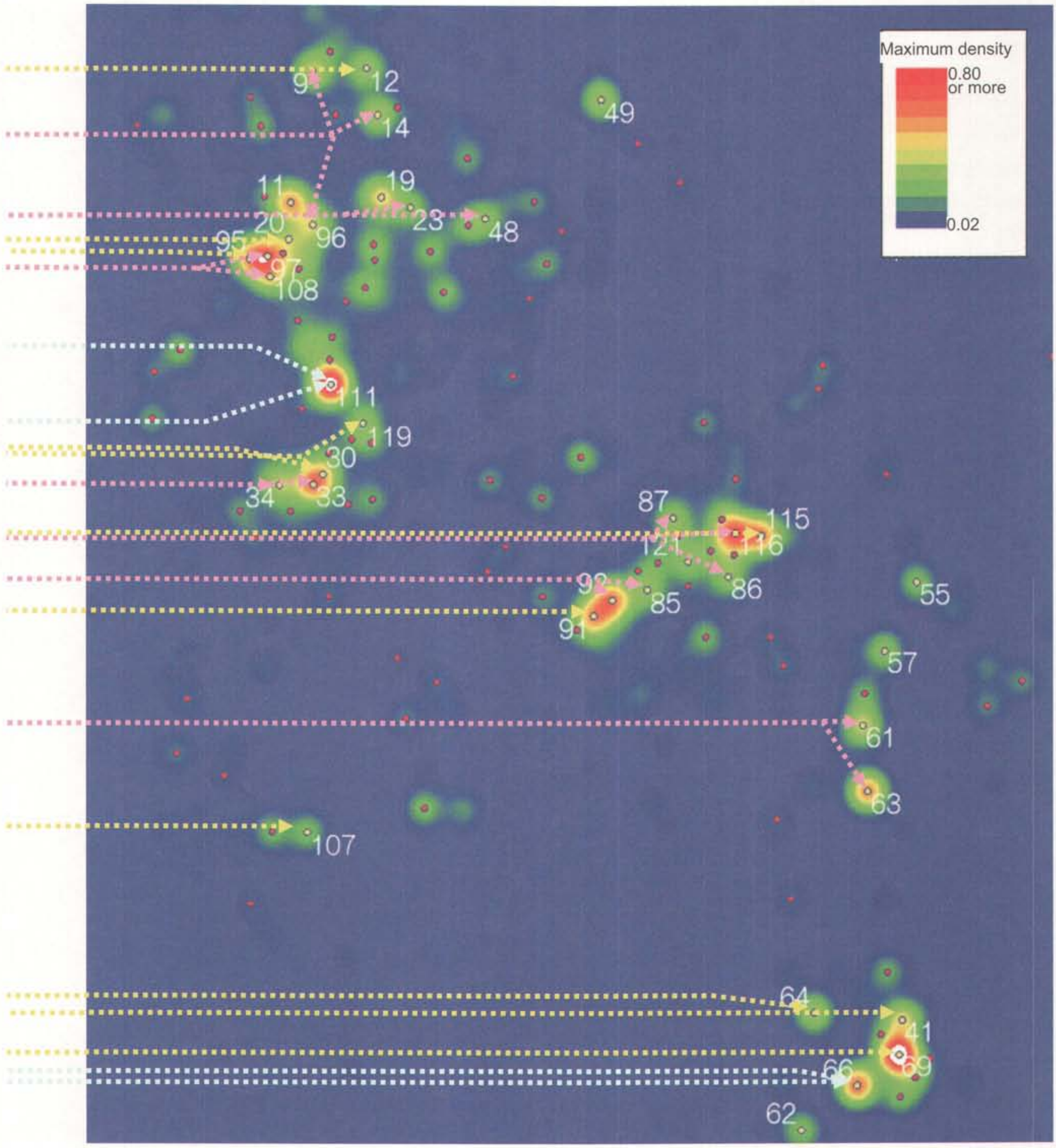
Figure 6: Science Map 2004



Note: Hot research areas with at least 80 core papers are depicted as yellow dots, some with area names, while the positions of those with less than 80 core papers are indicated with red dots.

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

Figure 7: Science Map 2006



Note: Hot research areas with at least 80 core papers are depicted as yellow dots, some with area names, while the positions of those with less than 80 core papers are indicated with red dots.

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

(1) Life science

Here we will discuss heart and blood vessels research, brain research, study of obesity, cancer research, research on infectious diseases/immunology, post-genomics, and plant science research, which can be grouped together as life science related.

Looking at life science as a whole in Science Map 2004 and Science Map 2006, in Science Map 2006, its research areas are laid out vertically like a backbone. This is because post-genomics is in a position bridging plant science research that focuses mainly on plants and fungi and heart and blood vessels research, brain research, study of obesity, cancer research, and research on infectious diseases/immunology that focus mainly on studying animals and fungi. The changing role of post-genomics as a bridge between research areas matched the opinion of experts in the interview survey as well.

We examined hot research areas considered likely to have made a major contribution to this positional change. For Science Map 2004, "Research on epigenetic transcriptional regulation (2004, ID 130)" and "Analysis of mechanism of regulation of plant growth (2004, ID 33)" were derived as separate hot research areas, but for Science Map 2006, they fused to form "Multi-hierarchical regulatory mechanism of life phenomena (2006, ID 111)." Research on life phenomena in animals and plants long focused on elucidating the regulatory mechanisms for transcription from DNA to RNA. Beginning in 2000, however, much research on RNAi and other regulatory mechanisms at the RNA level, regulatory mechanisms after protein translation, and in vivo protein localization regulation has also been published. A trend towards research that attempts to understand more complex and broad based regulatory mechanisms of life phenomena is apparent.

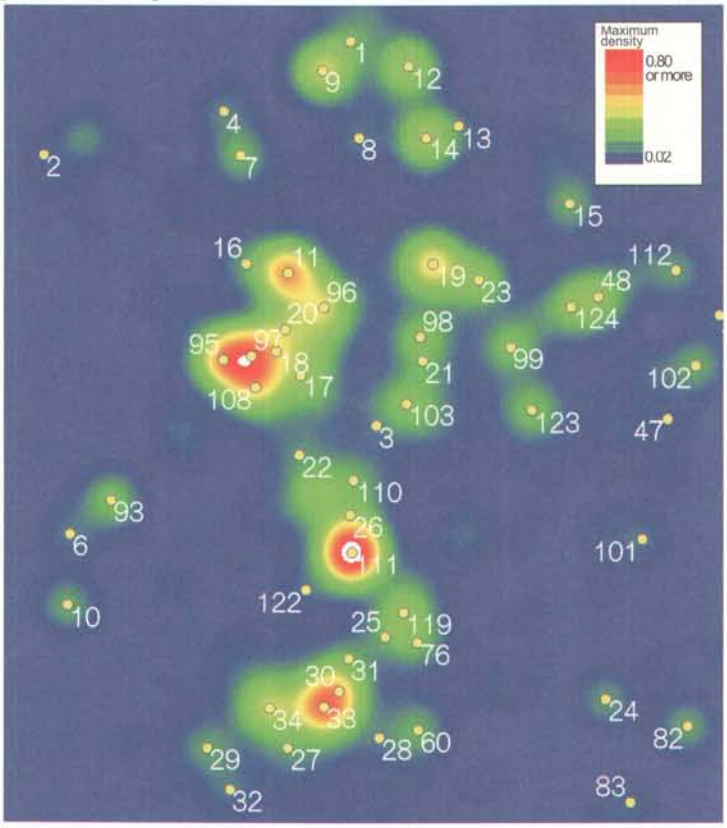
Furthermore, "Research on proteome (2004, ID 105)" remained in Science Map 2006 as "Isotope labeling/quantitative mass spectrometry/protein analysis (2006, ID 119)," but its position on the map changed. In Science Map 2004, it had a somewhat isolated position between chemical synthesis and life science. In Science Map 2006, however, it moved to the center of the post-genomics group of research areas. In mass spectrographic analysis of proteins, Koichi Tanaka of Shimadzu Corp. developed a desorption ionization method for mass spectrographic analysis of polymers, which earned him a Nobel Prize in chemistry. This kind of research has a very strong "chemistry" element to it. As genome sequencing using model organisms advances, comprehensive research on proteins is drawing attention. Mass spectrography is being aggressively incorporated into life science related research and has taken root as a post-genomics method. One can take this as a scientific trend.

Today, the advancement of genomics is accelerating. DNA has been sequenced, but there are more types of proteins, and their spatial positions, amounts, and timing of expression vary. As these become clearer in the future, the distance between understanding of life phenomena and molecular biology and clinical medicine will become shorter. As clinical medicine related research areas grow more intimately connected with post-genomics, disease will be understood at the molecular level. Research will deepen, with more advanced treatments becoming available.

The progress of post-genomics, however, has been accompanied by another noteworthy change. In the interview survey, it was pointed out that "In the past, life science research did not require large amounts of research funding. The rise of genomics has brought about a sort of research style in the USA that requires the investment of large amounts of funds, and other countries are following suit." Unless research funding is maintained at a certain level, countries can fall behind in global competition.

In addition, as post-genomics has advanced, research at the molecular level has flourished. Research themes have thus fragmented, and some fear that few people have a grasp of the overall picture. There are some Science Map 2004 research areas such as "Stem cell therapy on nervous, hematopoietic, and cardiovascular system (2004, ID 27)" that have divided for Science Map 2006, and research communities addressing more detailed research are forming within such research areas. The fragmenting of research communities to obtain more detailed research results is a positive outcome, but research and systems that share the results among communities are necessary. Researchers who look at the entire picture, such as physiologists, are needed.

Figure 8: Science Map 2006 (enlarged view of life science research areas and list of research areas)



ID	Research Area
1	Drug-eluting stent
2	Stage classification, treatment algorithm and outcome prediction of hepatocarcinoma
3	Basic and clinical study on antitumor effect of histone deacetylase (HDAC) inhibitors
4	Biodefense by blood coagulation regulatory system
6	Study on highly pathogenic avian influenza subtype H5N1
7	Bone metabolism control by drug and its clinical application
8	History of effect and adverse effect of hormone replacement therapy (HRT)
9	Thromboembolism study
10	Conventional infectious diseases / resistant bacterial infectious diseases
11	Control of lymphocyte-activating organ dysfunction by antibody therapy and others
12	Study on risk assessment, therapeutic effect, and diagnostic method for cardiac diseases
13	Drug therapy of diabetes / thiazolidine derivatives
14	Arteriosclerosis, abnormal lipid metabolism and abnormal carbohydrate metabolism affecting the onset of acute coronary syndrome, and inhibitory effect of hypolipidemic agents and proglycemic agents on the onset of acute coronary syndrome
15	Ghrelin / function and pathophysiological significance
16	Hormone therapy / breast cancer prevention
17	Molecular targeting therapy / type III tyrosine kinase-related tumor
18	Basic and clinical study on antibody therapy for HER2 (human epidermal growth factor receptor 2) positive breast cancer
19	Obesity and diabetes
20	New development in molecular therapy targeting EGFR mutations and others

ID	Research Area
21	Study on regulation of tissue stem cell by extracellular environment and characteristics of cancer stem cell
22	Cancer / gene expression profiling analysis
23	Biological elucidation and clinical application of damaged tissue repair mechanism
24	Elucidation of behavior principle of ion/water channel molecule
25	Genome-wide gene expression analysis and expression regulatory function analysis
26	Histone diversity and life phenomena
27	Plant functional genomics study
28	Plant cell proteome analysis
29	Plant-microorganism interaction
30	Light environment response control / flower bud formation mechanism in plant
31	Redox regulation
32	Inducible defense mechanism in plant
33	Environmental stress response / metabolic profiling / cellular structure and phospholipid metabolism in plant
34	Plant defense against infection / plant immunity
44	Integrated comprehension of brain function by neuron-glia interaction
47	Kinetics of AMPA receptor and spine morphology in synaptic plasticity
48	Cause analysis and therapy development for psychiatric and nerve disease
60	Complex networks
76	Interactome analysis

ID	Research Area
82	Retrieval of binding specificity of sugar chain recognition protein by neoglycolipid sugar chain microarray
83	Activation of oxygen molecule by metalloenzyme
93	Pathogenic mechanism and preventive/therapeutic method of severe acute respiratory syndrome (SARS)
95	Study on HCV and HIV
96	Elucidation of in-vivo function of drug transporter in human
97	Suppression of immune reaction centered on foxp3-positive, CD25-positive and CD4-positive regulatory t cells
98	Apoptosis (cell death) and inflammation
99	Embryonic stem cell / neural induction
101	Proteinous infectious agent / new paradigm for genetic material
102	Physiological function of TRP channel
103	Activation of hypoxia-inducible factor 1 and formation of tumor microenvironment
108	Innate immunity
110	Study on ubiquitination and sumoylation of protein
111	Multi-hierarchical regulatory mechanism of life phenomena
112	Molecular mechanism and physiological role of endogenous cannabinoid signal
119	Isotope labeling / quantitative mass spectrometry / protein analysis
122	Bioinformatics / transcriptome
123	Pathogenesis and pathology of parkinson's disease and intracellular quality control mechanism by autophagy
124	Molecular pathology and therapy of alzheimer's disease

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

(2) Plant science research

Next, let us turn our attention to plant science research, which addresses mainly plants and fungi. "Stress response in plants (2004, ID 34)" in Science Map 2004 divided into "Environmental stress response/metabolic profiling/cellular structure and phospholipid metabolism in plant (2006, ID 33)" and "Plant defense against infection/plant immunity" in Science Map 2006. The strengthening ties between post-genomics and plant science research likely influenced this division. In the 2000s, research on gene identification, intergenetic networks, transcriptome analysis, and metabolome analysis in model plants has grown active. More detailed research has progressed, and various research communities have formed.

Regarding "Plant defense against infection/plant immunity (2006, ID 34)," Kiyotaka Okada (Director-General, National Institute for Basic Biology) pointed out, "Through research on model plants of the thale cress (*Arabidopsis thaliana*), isolation of strains vulnerable to infection has progressed, leading to further advances in research. Isolation of receptors related to infection with mold or bacteria (toll-like receptors) in particular is flourishing. This type of research was handled by agricultural science departments as "plant physiology," and few researchers adopted methods from molecular biology. Research was stymied. At that point, base sequencing of thale cress model plants and an influx of young researchers activated the plant science research and transformed the research area into one of Japan's stronger ones." The young researchers who appeared on the scene in 1985 and 1986 include Okada, Yoshiro Shimura (now President of the National Institutes of Natural Science), Kazuo Shinozaki (now Director of the Riken Plant Science Center), and Yoshibumi Komeda (now a Professor at the University of Tokyo). The four men entered the field of plant physiology from other research areas. They are examples of the importance of interaction among researchers from different fields. On the other hand, it was pointed out that the accumulation of research from a plant physiology perspective is a major reason that the importance of Japan's presence in molecular biology research on plants grew so rapidly. In addition to molecular-level approaches such as genes and proteins, it is important to have physiological perspectives on plant bodies.

Henceforth the relationship between such research and the environment will likely grow stronger. Japan is making a strong effort in plant science research, but in the interview survey it was pointed out that there is no road map showing how to leverage the knowledge obtains in the plant science research to social issues such as environment and food issues. As for China's activities in plant science research, an increase in the percentage of papers from China in hot research areas has been observed. (See 6-2 below.)

(3) Clinical medicine

Heart and blood vessels research, brain research, study of obesity, cancer research, and research on infectious diseases/immunology are directly or indirectly related to Clinical medicine.

First, comparing Science Map 2004 and Science Map 2006, the number of hot research areas decreased slightly. In Science Map 2004, clinical medicine had many hot research areas with a small number of core papers. Core papers in these hot research areas remained in Science Map 2006 as well, so the hot research areas either grew and continued or grew and divided.

Looking at examples of hot research areas that continued, "Clinical trial of therapeutic agent for cardiovascular disease (2004, ID 15)" was succeeded by "Study on risk assessment, therapeutic effect, and diagnostic method for cardiac diseases (2006, ID 12)." "Research on cancer therapy (2004, ID 14)" continued as "New development in molecular therapy targeting EGFR mutations and others (2006, ID 20)." "Research on infection mechanism and therapy of HCV and HIV (2004, ID 110)" continued as "Study on HCV and HIV (2006, ID 95)."

On the other hand, some hot research areas divided between Science Map 2004 and Science Map 2006. "Signal transducing molecules associated with lifestyle-related diseases (2004, ID 26)," which was a single area in Science Map 2004, divided into three areas, "Thromboembolism study (2006, ID 9)," "Arteriosclerosis, abnormal lipid metabolism and abnormal carbohydrate metabolism affecting the onset of acute coronary syndrome, and inhibitory effect of hypolipidemic agents and proglycemic agents on the onset of acute coronary syndrome (2006, ID 14)," and "Elucidation of in-vivo function of drug transporter in human (2006, ID 96)." Looking at the Individual Area Map for "Signal transducing molecules associated with lifestyle-related diseases (2004, ID 26)" in Science Map 2004, research fronts related to signal transduction paths associated with specific diseases such as myocardial infarction and malignancies had a structure of loose connections within a framework of research on signal transduction. Subsequently, research on different kinds of signal transduction advanced, and their ties with specific disease research such as heart and blood vessels research and cancer research strengthened, resulting in division into multiple areas. In addition, "Stem cell therapy on nervous, hematopoietic, and cardiovascular system (2004, ID 27)" divided into "Biological elucidation and clinical application of damaged tissue repair mechanism (2006, ID 23)" and "Cause analysis and therapy development for psychiatric and nerve disease (2006, ID 48)."

Furthermore, "Research on immune system (2004, ID 116)" split into "Suppression of immune reaction centered on foxp3-positive, CD25-positive and CD4-positive regulatory T cells (2006, ID 97)" and "Innate immunity (2006, ID 108)." Immune system research targets two types of immunity, acquired ("Suppression of immune reaction centered on foxp3-positive, CD25-positive and CD4-positive regulatory T cells (ID 97)") and natural ("Study on HCV and HIV [ID 95]" and "Innate immunity [ID 108].") Formerly, only acquired immunity was understood. Subsequent research showed in molecular biology terms that acquired immunity works after natural immunity happens. Today, research on natural immunity is drawing attention, and a research community has formed, leading to the split.

As is the case with "Innate immunity (ID 108)," 10 years ago research on "Ghrelin/function and pathophysiological significance (ID 15)" did not exist. Ghrelin research is advancing along with research on aging (growth promotion and senescence inhibition) and obesity. In the interview survey, an opinion was given stating that circulatory system disease, the subject of heart and blood vessels research, is chronic and requires long treatment periods, and the prognosis changes depending on how acute episodes are handled. In order to maintain quality of life in an aging society, systems for treating this kind of disease need to improve. In the past, embryonic stem cell research could only be performed at a limited number of research institutions, but Yamanaka *et al.* at Kyoto University changed this situation by establishing iPS cells. A respondent in the interview survey pointed out that now any research institution can participate, so competition will increase. The relationship between "Embryonic stem cell/neural induction (ID 99)" and cancer research is noteworthy. In addition, because infectious disease research is influenced by global warming and other environmental changes, research on diseases such as malaria may become important in Japan in the future.

(4) Chemical synthesis

Two hot research areas, "Catalytic asymmetric synthesis (2006, ID 91)" and "Molecular conversion reaction using transition metal catalyst (2006, ID 92)," are at the core of chemical synthesis in Science Map 2006. Ryoji Noyori, a 2001 Nobel Laureate for chemistry, is a pioneer in the latter research area. This asymmetric synthesis using transition metals as catalysts is characterized by high catalytic activity, with minute amounts of platinum or iridium producing large quantities of salvaged materials.

Comparing Science Map 2004 and Science Map 2006, the number of core papers in "Catalytic asymmetric synthesis (ID 91, 2006)" increased. This hot research area comprises research fronts that use organic catalysts for asymmetric synthesis. Asymmetric synthesis using organic catalysts is relatively environmentally friendly because it does not require metal catalysts.

In the interview survey, a respondent pointed out the following about chemistry in general. "Subjects such as structural analysis of protein and DNA polymerase can now be research in university chemistry departments, so the territory of chemistry has expanded. The fundamental point of chemistry is understanding matter at the level of chemical structural formulas. Genome data such as proteins and DNA can now be studied at the molecular structural level, as a consequence, the gap between life science and chemistry has become smaller. In condensed matter physics as well, research at the molecular level (chemical structural formula level) is advancing." On the Research Area Correlation Map as well, chemistry is located between life science and nanoscience, matching the opinion of that expert.

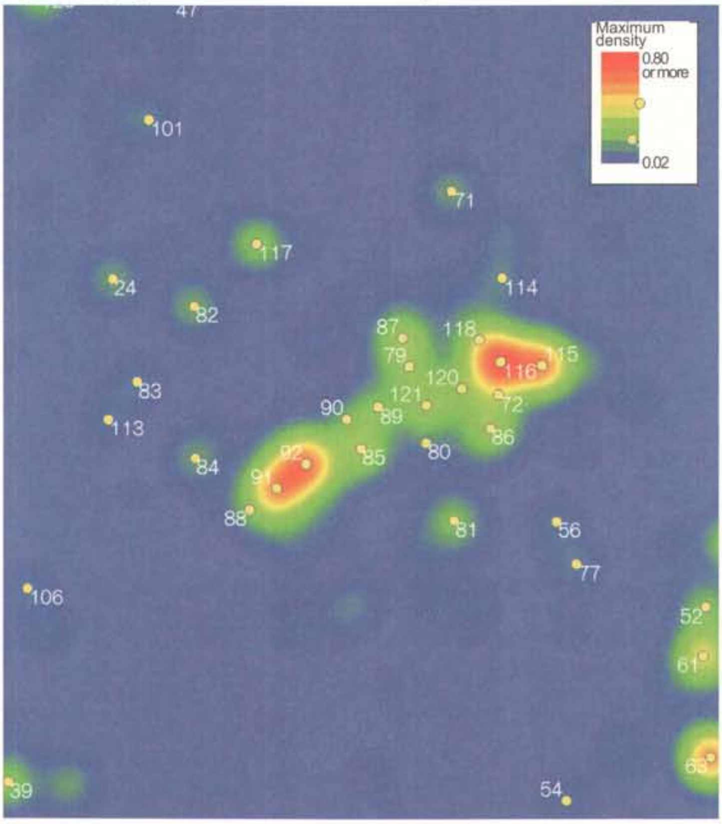
(5) Nanoscience

The core hot research areas for nanoscience are "Carbon nanotube synthesis and device evaluation (2006, ID 115)" and "Study on synthesis and optical application of metal and metal oxide nanoparticle/nanostructure (2006, ID 116)." These research areas have developed rapidly over the past 10 years. Experts pointed out that 10 years ago they were much smaller on the map.

As can be seen in Science Map 2006, nanoscience is steadily progressing. For example, topics comprising the single hot research area "Development of nanostructure and its application to molecular devices (2004, ID 106)" in Science Map 2004 have grown and divided into three independent areas. They are "Study on supramolecular nanodevice by molecular machine and single-molecule conductor (2006, ID 86)," "DNA-nanomaterial and nanodevice (2006, ID 87)," and "Study on synthesis and optical application of metal and metal oxide nanoparticle/nanostructure (2006, ID 116)."

In the interview survey, a respondent pointed out that "Physics has approached from bulk and chemistry from molecules to nanoscience. The boundaries between physics and chemistry seem to be gradually getting vaguer." For example, research on carbon nanotubes during the 1990s was carried out mainly by physicists, but in about 2000, chemical modification of nanotubes became possible. This has led recently to participation by chemists in this research. Looking at changes between Science Map 2004 and Science Map 2006 (Figure 10), research linking chemical synthesis and nanoscience has increased.

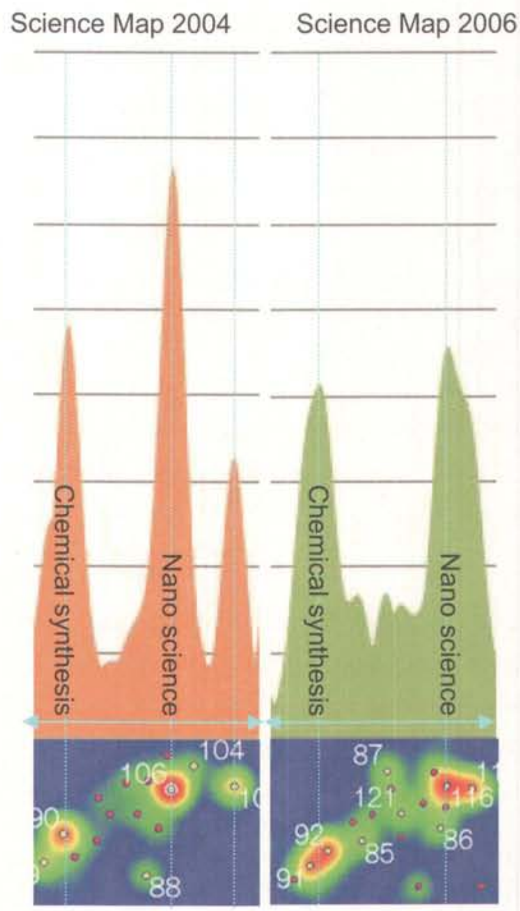
Figure 9: Science Map 2006 (expanded view of chemical synthesis/nanoscience and list of research areas)



ID	Research Area	ID	Research Area
24	Elucidation of behavior principle of ion/water channel molecule	86	Study on supramolecular nanodevice by molecular machine and single-molecule conductor
39	Earth history	87	DNA-nanomaterial and nanodevice
42	Solid macromolecule type fuel cell / mass and heat transfer	88	Catalytic asymmetric addition reaction of carbon nucleophile
52	Metamaterials	89	Bioimaging probe
54	Attosecond quantum dynamics	90	Synthetic polymer-immobilized catalyst technology
56	Quantum information control with multidimensional photon	91	Catalytic asymmetric synthesis
61	Quantum information/communication, optical nanoscience	92	Molecular conversion reaction using transition metal catalyst
63	New quantum condensed phase where substances strongly interact with each other	101	Proteinous infectious agent / new paradigm for genetic material
71	Nanofiber technology with the electro-spinning process and tissue engineering research	104	Solid macromolecule type fuel cell / macromolecular electrolyte film
72	Study of solar cells using inorganic oxides, organic-inorganic hybrids or organic polymers	106	Water environment
77	Molecule-based nano-quantum magnet	113	Photosynthetic light reaction apparatus / structure, function and regulation
79	Living radical polymerization	114	Study of laminated film and capsule
80	Construction of artificial photosynthesis model mimicking antenna system and charge separation system	115	Carbon nanotube synthesis and device evaluation
81	Porous coordination polymer	116	Study on synthesis and optical application of metal and metal oxide nanoparticle/nanostructure
82	Retrieval of binding specificity of sugar chain recognition protein by neoglycolipid sugar chain microarray	117	Micro-bio system and micro chemical system
83	Activation of oxygen molecule by metalloenzyme	118	Mesoporous material / silica organic-inorganic hybrid material / organic supramolecular complex
84	Protein folding	120	Organic transistor / improvement in performance and function
85	Ionic liquid	121	Polymer organic led and phosphorescent organic LED

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

Figure 10: Increase in research areas between chemical synthesis and nanoscience



Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

An increase in research areas linking chemical synthesis and nanoscience

Research Area Correlation Maps for chemical synthesis and nanoscience, with their horizontal projections. The two peaks for nanoscience in Science Map 2004 have resolved into one. In addition, the valley between chemical synthesis and nanoscience became higher, indicating an increase in research areas linking the two researches.

(6) Condensed matter physics

Condensed matter physics mainly includes hot research areas related to quantum computing and superconductivity. (See Figure 11.) Comparing Science Map 2004 and Science Map 2006, the number of scientific papers in "Ferromagnetic semiconductor spintronics (2006, ID 55)" and "Electrical control of spin in semiconductors/quantum computer using solid state components (2006, ID 57)" increased. The interview survey found that these research areas did not exist 10 years ago. In condensed matter physics, researchers seems to cluster in areas where breakthroughs have been achieved, such as high-temperature superconductivity 20 years ago and laser cooling 10 years ago, and then carry out steady research once the boom has quieted somewhat.

"Quantum electronics and its application to quantum information processing (2004, ID 70)" in Science Map 2004 divided into two hot research areas, "Quantum information/communication, optical nanoscience (2006, ID 61)" and "New quantum condensed phase where substances strongly interact with each other (2006, ID 63)," in Science Map 2006.

The latter area includes three research themes loosely linked by the perspective of the physics of strongly correlated systems (research on Bose-Einstein condensation through laser cooling, research on high-temperature superconductivity, research on high-energy fields). This indicates a loose relationship between particle physics/cosmology and condensed matter physics. Particle physics/cosmology researchers indicated that although links with condensed matter physics are weak, they are ongoing. The positional relationship of the fields on the Research Area Correlation Map matches the sense of the experts.

The opinion of the experts in the interview survey was that the position of condensed matter physics between chemical synthesis and particle physics/cosmology will not change, but the hot research areas derived will vary over time. They further indicated that "Ferromagnetic semiconductor spintronics (2006, ID 55)," "Electrical control of spin in semiconductors/quantum computer using solid state components (2006, ID 57)," and "Quantum information/communication, optical nanoscience (2006, ID 61)" would probably enter the application phase, while research on "New quantum condensed phase where substances strongly interact with each other (2006, ID 63)" in the condensed matter physics field would likely continue.

(7) Particle physics/cosmology

Experts pointed out that the relationship between research on elementary particles and space research has grown stronger along with greater precision and improved observation parameters in space observation. This agrees with the positions of hot research areas on the map. (See Figure 11.)

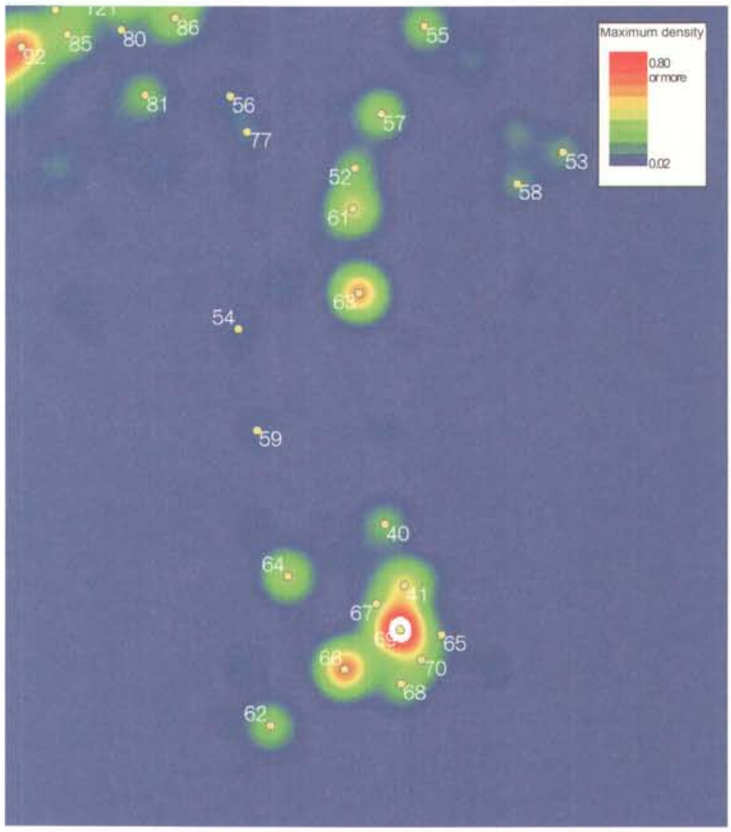
Comparing the Science Map 2004 with the Science Map 2006, the hot research areas from 2004 generally continued, although some merged. In the projections shown in

Figure 4 and Figure 5, although the core-paper density of particle physics/cosmology becomes lower slightly, in the aerial view of science, its mountains are conspicuously high and narrow. These characteristics did not change between the two Science Maps, indicating that the pattern of research activity itself did not change. This is because particle physics/cosmology has ultimate goals such as construction of a unified field theory and understanding of the origin of the universe, and research continues to evolve in those directions.

Relationships between particle physics/cosmology and other groups of research areas are not expected to change significantly, and indeed observation of changes in the Science Map over time found no change in the group's position on the map, even though research content changed.

Particle physics/cosmology is a field that advances as experiments and theories stimulate each other. Theory has led the way, but the launch of the European Organization for Nuclear Research's (CERN) Large Hadron Collider (LHC) is expected to lead to the development of research. Discoveries of new phenomena through the verification and testing of theories will take place.

Figure 11: Science Map 2006 (Expanded view of condensed matter physics/particle physics/cosmology and list of research areas)



ID	Research Area	ID	Research Area
40	Gamma-ray burst and relative celestial explosion phenomenon	65	Brane cosmology from the perspective of duality of anti de sitter space and conformal field theory
41	Formation and evolution of the galaxy	66	Explore physics beyond the standard model from flavor physics of B meson and neutrino, dark matter and muon anomalous magnetic efficiency
52	Metamaterials	67	Field theory on noncommutative space
53	Superconductive properties of magnesium diboride and its application	68	Verification and integrability of AdS/CFT correspondence
54	Attosecond quantum dynamics	69	Observational cosmology and an elementary model for it
55	Ferromagnetic semiconductor spintronics	70	High-dimensional black holes
56	Quantum information control with multidimensional photon	77	Molecule-based nano-quantum magnet
57	Electrical control of spin in semiconductors / quantum computer using solid state components	80	Construction of artificial photosynthesis model mimicking antenna system and charge separation system
58	High-temperature superconductivity spectroscopy / new electron phase	81	Porous coordination polymer
59	High energy density science	85	Ionic liquid
61	Quantum information/communication, optical nanoscience	86	Study on supramolecular nanodevice by molecular machine and single-molecule conductor
62	Hadron spectroscopy	90	Synthetic polymer-immobilized catalyst technology
63	New quantum condensed phase where substances strongly interact with each other	92	Molecular conversion reaction using transition metal catalyst
64	Search for quark matter through high-energy nuclear collision		

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

4-2 Newly-derived research areas

Figure 12 shows 19 hot research areas whose core papers have no overlap with the core papers of the 133 hot research areas derived for Science Map 2004. In other words, these are "newly-derived hot research areas" in Science Map 2006. The average number of core papers comprising these research areas is low at 32.4, about half the 77.0 average of the 124 hot research areas. Average year of publication should roughly indicate the period within which a research area formed. The average year of publication in these research areas was 2003.7, while for all 124 hot research areas it was 2003.4.

These newly-derived hot research areas can be divided into three patterns (A, B, and C).

<Pattern A (Figure 12, red IDs)>

There is no overlap between the relevant research area's core papers and core papers comprising research fronts in Science Map 2004. In other words, connections with precursor research had not yet formed, but they surfaced as research areas after Science Map 2004. Example: Visceral sensation and neural mechanism of emotion and empathy (ID 45)

<Pattern B (Figure 12, blue IDs)>

There is overlap between the research area's core papers and core papers in Science Map 2004, and the average year of publication is old (before 2003.4). In most cases, there was somewhat mature precursor research, and part of that area split off and was derived as a new area. Example: Protein folding (ID 84)

<Pattern C (Figure 12, white IDs)>

There is overlap between the research area's core papers and core papers in Science Map 2004, and the average year of publication is recent (after 2003.4). There was a link with precursor research, but newly published scientific papers formed strong co-citation relationships, and a new field was derived for Science Map 2006. Example: Metamaterials (ID 52)

Figure 12: Newly-derived hot research areas

ID	Research Area	Number of core Paper	Average year of publication	No. of papers included among SM 2004 RF papers
2	Stage classification, treatment algorithm and outcome prediction of hepatocarcinoma	14	2002.6	6
5	Deep mycosis	45	2004.0	16
10	Conventional infectious diseases / resistant bacterial infectious diseases	59	2003.2	26
28	Plant cell proteome analysis	25	2003.2	13
36	Assistive technology for detection, prediction and countermeasure of animal and plant activity change caused by climate change	38	2004.1	10
40	Gamma-ray burst and relative celestial explosion phenomenon	66	2004.9	12
43	Nitride semiconductor transistor / high-voltage and high-frequency application	19	2003.1	10
44	Integrated comprehension of brain function by neuron-glia interaction	19	2004.7	3
45	Visceral sensation and neural mechanism of emotion and empathy	17	2003.7	0
46	Decision-making neuroscience	13	2003.3	4
52	Metamaterials	66	2003.8	15
59	High energy density science	28	2004.2	6
71	Nanofiber technology with the electro-spinning process and tissue engineering research	49	2003.5	16
77	Molecule-based nano-quantum magnet	32	2003.6	8
83	Activation of oxygen molecule by metalloenzyme	29	2003.6	8
84	Protein folding	45	2003.1	16
94	Epidemiological study about the effect of air pollution (especially particle-like substances) on cardiovascular disease	13	2004.1	2
105	Quantification of water vapor, clouds, aerosol and albedo based on satellite and ground-based observation	18	2004.3	8
113	Photosynthetic light reaction apparatus / structure, function and regulation	26	2003.7	7

Note: Pattern A IDs are highlighted in red and Pattern B IDs in blue.

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

4-3 Exploring candidates for hot research areas

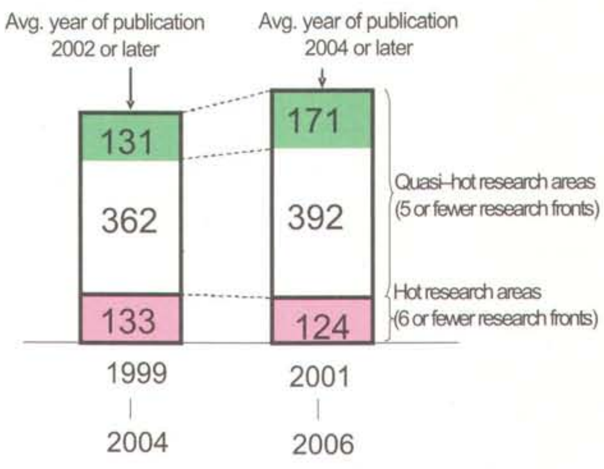
Figure 13 shows the composition of research areas for Science Map 2004 and Science Map 2006. As noted in the "Survey method" chapter above, the number of research fronts per research area is smaller in Science Map 2006 than in Science Map 2004. Hot research areas in Science Map 2006 therefore total 124, 9 fewer than in Science Map 2004.

Looking at quasi–hot research areas (research areas with five or fewer research fronts), on the other hand, there were 493 in Science Map 2004, and 563 in Science Map 2006, so Science Map 2006 had more. Of these, areas in which the average year of publication of core papers was new (2002 or later for Science Map 2004 and 2004 or later for Science Map 2006) numbered 131 in Science Map 2004 and 171 in Science Map 2006. Thus, more than half the larger amount of quasi–hot research areas in Science Map 2006 can be accounted for by areas whose average year of core-paper publication was 2004 or later.

In addition, as seen in the previous section, almost all newly-derived hot research areas in Science Map 2006 (Figure 12) include some core papers that were part of research fronts in Science Map 2004.

The fact that the research areas of Science Map 2006 include more quasi–hot research areas and that more of quasi–hot areas include core papers published more recently suggests that Science Map 2006 contains many areas with the seeds to become hot research areas in accordance with Pattern C as described in the previous section.

Figure 13: Comparison of Science Map 2004 and Science Map 2006



We also looked at the positions on Science Map 2006 of the quasi–hot research areas whose core papers had an average year of publication of 2004 or later. In previous time series analyses, it was found that research areas comprising a small number of research fronts are unstable, and some of them will disappear over the course of a time series analysis. The following analysis therefore addresses only quasi–hot research areas with at least 10 core papers. Of the 186 quasi–hot research areas with an average year of core-paper publication of 2004 or later, 49 had at least 10 core papers. Below, these quasi–hot research areas are called "hot research area candidates."

Figure 14 shows hot research area candidates plotted on the Research Area Correlation Map. The yellow dots are hot research area candidates. They are shown with the average year of publication of their core papers.

About half the hot research area candidates are found in the upper left portion of the Research Area Correlation Map (the life science region). Several areas are in the environment region, which has few hot research areas in Science Map 2006. Because the environment field has fewer scientific papers than other fields, not many areas have been derived as hot research areas in the Science Maps. In light of growing worldwide interest in global warming and other environmental issues, a distinct group of environment research areas may form on future Science Maps.

Below, we focus attention on hot research area candidates with distinctive positions on the Research Area Correlation Map, such as a location between life science and nanoscience..

First, there is one hot research area candidate ("A" on the map) located between life science and nanoscience. This is an area related to "Development of microfluid devices for analysis of single cells." To date, experiments on cells have targeted multiple cells in test tubes and Petri dishes for collection of data. This means that the data integrated the conditions of individual cells. The aim of this research is to be able to take just a few cells, apply appropriate stimuli, and observe changes in real time. If this method becomes established, various chemistry operations such as mixing of reaction solutions, reactions, isolation, purification, detection, and so on can be micro-miniaturized. This would reduce the space required for research, lessen environmental impact, save time, and lower costs.

The hot research area candidate between life science and environment, shown as "B" on the map, is "Research on the threat of frog extinction from chytridiomycosis." Today, amphibian species and population worldwide are declining. Pollution of the growth environment, environment destruction, climate change, and the impact of exotic species have been listed as major causes, but in recent years chytridiomycosis, an infectious fungal disease has attracted attention and research. It is an infectious disease caused by a chytrid fungus that is parasitic on the epidermises of frogs. Research has found that when global warming increases rainfall, the body temperatures of coldblooded frogs make it easy for the chytrid to proliferate and for the infection to spread. This area is characterized by its integration of perspectives from ecology (protecting the ecosystems of amphibians, including frogs), environmental science (global warming), immunology and infectious disease research, plant and animal science, and clinical medicine in its research.

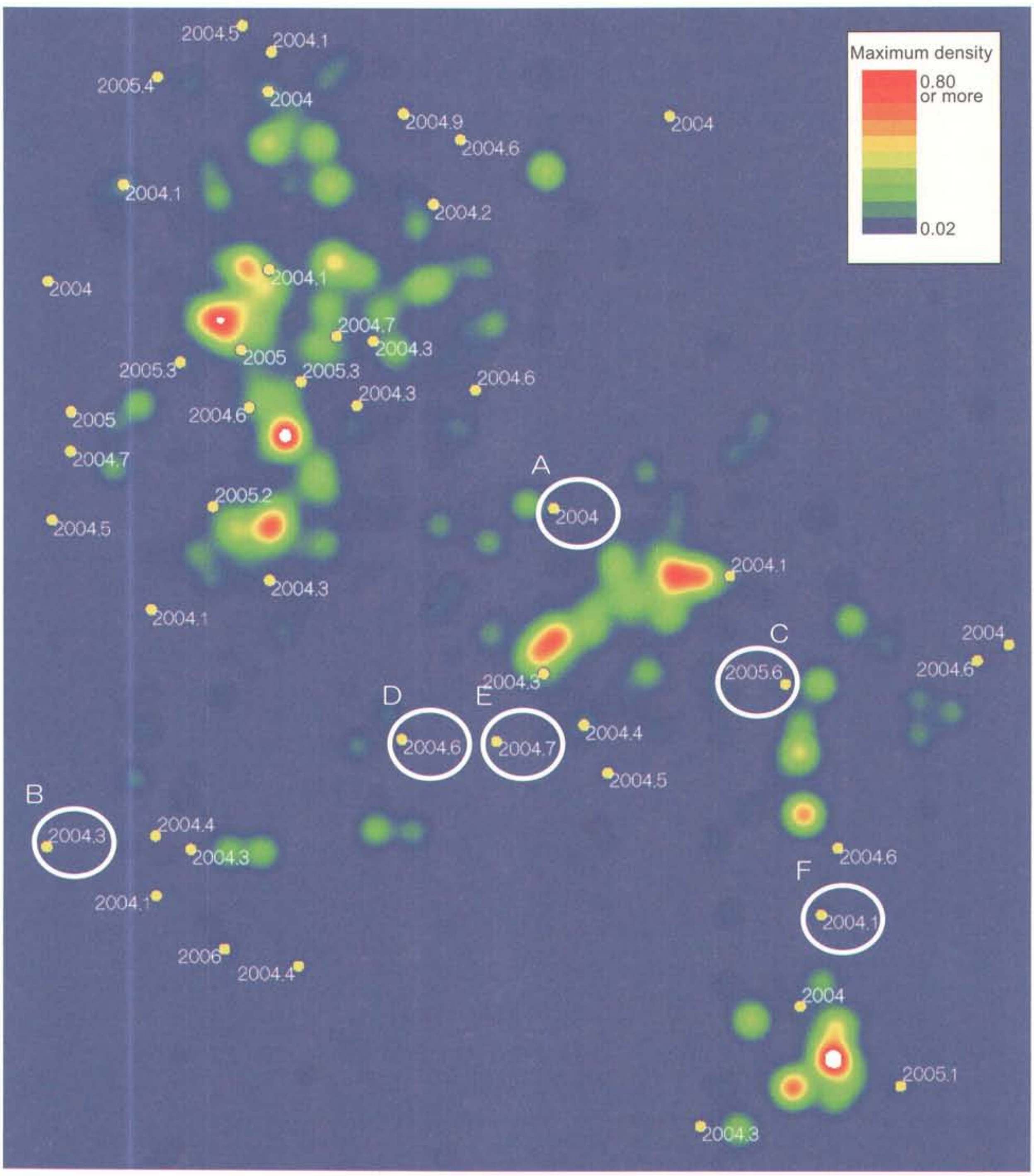
In between nanoscience and condensed matter physics is "The physics of graphene," shown as "C" on the map. In 2004, measurement of the physical properties of graphene, a substance made of a single layer of graphite, became possible. Both theoretical and experimental research on its electrical conductivity characteristics, quantum Hall effect, and so on are progressing. The average year of publication for this area's core papers is very new at 2005.6.

"D" on the map is the hot research area candidate "Bio fuel cells." The area includes the sequencing and analysis of the genome of the iron-reducing bacterium Geobacter sulfurreducens, which is attracting attention for its potential as a bio fuel cell material for its ability to bioremediate radioactive metal and generate electricity. The area is expected to develop among the life science (post-genomics), chemical synthesis, and environment groups.

The hot research area candidate "E," "Various NMR measurement methods such as pulsed field gradient spin echo," is located between chemical synthesis and environment.

The hot research area candidate "F" between condensed matter physics and particle physics/cosmology on the map is "Research on the Casimir effect". The Casimir effect is a peculiar attraction force that takes place when two uncharged metallic plates are placed parallel to each other. The reason the phenomenon was mapped between condensed matter physics and particle physics/cosmology is that it is sometimes brought up in discussions of wormholes in cosmology.

Figure 14: The positions of research areas expected to develop in the future



Note: Yellow dots are hot research area candidates. They are shown with the average year of publication of their core papers.
Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

5. Observation of inter-/multi-disciplinary research on the Science Map

This chapter discusses the results of analysis of inter-/multi-disciplinary areas using the Academic Disciplines Relation Map and the Research Area Correlation Map.

5-1 Analysis using the Academic Disciplines Relation Map

(1) How to read the Academic Disciplines Relation Map

First, the relatedness of existing academic fields and the 124 hot research areas was examined. Figure 15 shows the Academic Disciplines Relation Map. It compares the distribution across 22 fields[5] of the core papers comprising hot research areas and uses a model in which hot research areas with similar field distribution ratios are attracted to each other (a gravity model) to move each hot research area to the most stable position for the map as a whole. Hot research areas with similar field distributions of their core papers therefore tend to cluster together.

The relative position relationships of hot research areas on the map are important; location in terms of up, down, left, or right is not significant. Data on the distribution across the 22 fields of the core papers comprising hot research areas is found in Part II "4. Field distribution of core papers making up hot research areas." The numbers in the Academic Disciplines Relation Map are the research area IDs assigned to each hot research area in the database. The names of the hot research areas corresponding to the ID numbers are listed on the Academic Disciplines Relation Map.

Hot research areas outside the roughly circular dotted line in the center of the Academic Disciplines Relation Map are those with at least 60 percent of core papers fall into one of the 22 fields. Hot research areas inside the dotted line are those with less than 60 percent of core papers fall into a single field, and are thus inter-/multi-disciplinary areas.

On the Academic Disciplines Relation Map, research area IDs shaded in red are hot research areas where Japanese scientific papers account for at least 15 percent of the papers. Those shaded in orange are greater than 9 percent but less than 15 percent. Those shaded in yellow are greater than 4 percent but less than 9 percent. Those shaded in blue are greater than 0 percent but less than 4 percent. Those that are unshaded are 0 percent Japanese papers.

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[5] The 22 fields are the following: agricultural sciences, biology and biochemistry; chemistry; clinical medicine; computer science; economics and business; engineering; environment/ecology; geosciences; immunology; materials science; mathematics; microbiology; molecular biology and genetics; multidisciplinary; neuroscience and behavior; pharmacology/toxicology; physics; plant and animal science; psychiatry/psychology; social sciences/general; and space sciences.

(4) Characteristics of the 124 research areas as seen from the Academic Disciplines Relation Map

Of the 124 hot research areas, 40 are in the life science related fields of clinical medicine or plant and animal science. Of those 40, more than half (23) are in clinical medicine. Chemistry, physics, engineering, and materials science account for another 40 hot research areas, with 5 derived in environment/ecology and geosciences. In addition, space sciences and social sciences, general have a few hot research areas. The inter-/multi-disciplinary field accounts for 32 of the 124 hot research areas, about 25 percent of the total.

Comparing Science Map 2004 and Science Map 2006, the number of inter-/multi-disciplinary areas fell from about 30 percent to 25 percent. Six hot research areas that were inter-/multi-disciplinary areas in Science Map 2004, including "Ghrelin; its mechanism of action (2004, ID 113)" and "High-efficiency dye-sensitised solar cell (2004, ID 103)," shifted into specific fields in Science Map 2006. The process by which inter-/multi-disciplinary areas shift into specific fields is probably related to the process by which researcher communities form. The following is a hypothesis.

When research is emerging and its researcher community is not yet clearly defined, each researcher publishes in his or her own specialty field. Scientific papers thus appear in various fields. Theses research areas are classified as inter-/multi-disciplinary areas, because research areas are judged to be "inter-/multi-disciplinary areas" based on field distribution of core papers in this analysis. Subsequently, however, as time passes and the researcher community determines the most important venues for presenting results, opportunities to publish scientific papers in journals in a specific field increase. This results in inter-/multi-disciplinary areas shifting into specific fields.

From this hypothesis, we can surmise that because the content of inter-/multi-disciplinary areas is constantly changing, there is no reason that the number of inter-/multi-disciplinary areas derived for the Science Map should remain fixed. It will be necessary to look at the next Science Map in order to judge the meaning of the decrease in the number of inter-/multi-disciplinary areas observed in Science Map 2006.

None of the 124 hot research areas is located in the fields of agricultural sciences, immunology, pharmacology/toxicology, microbiology, or mathematics. Because this study derives research areas with at least a certain number of core papers, research areas in fields with few core papers, such as mathematics, are not observed. In this case, the roles of mathematics and so on can be measured through the distribution of core mathematics papers in the hot research areas. This analysis found that scientific papers belonging to such existing academic fields were included in the core papers of the 124 hot research areas. The existing academic fields of agricultural sciences, immunology, pharmacology/toxicology, microbiology, and mathematics therefore have fundamental characteristics and are elements that help make up the hot research areas.

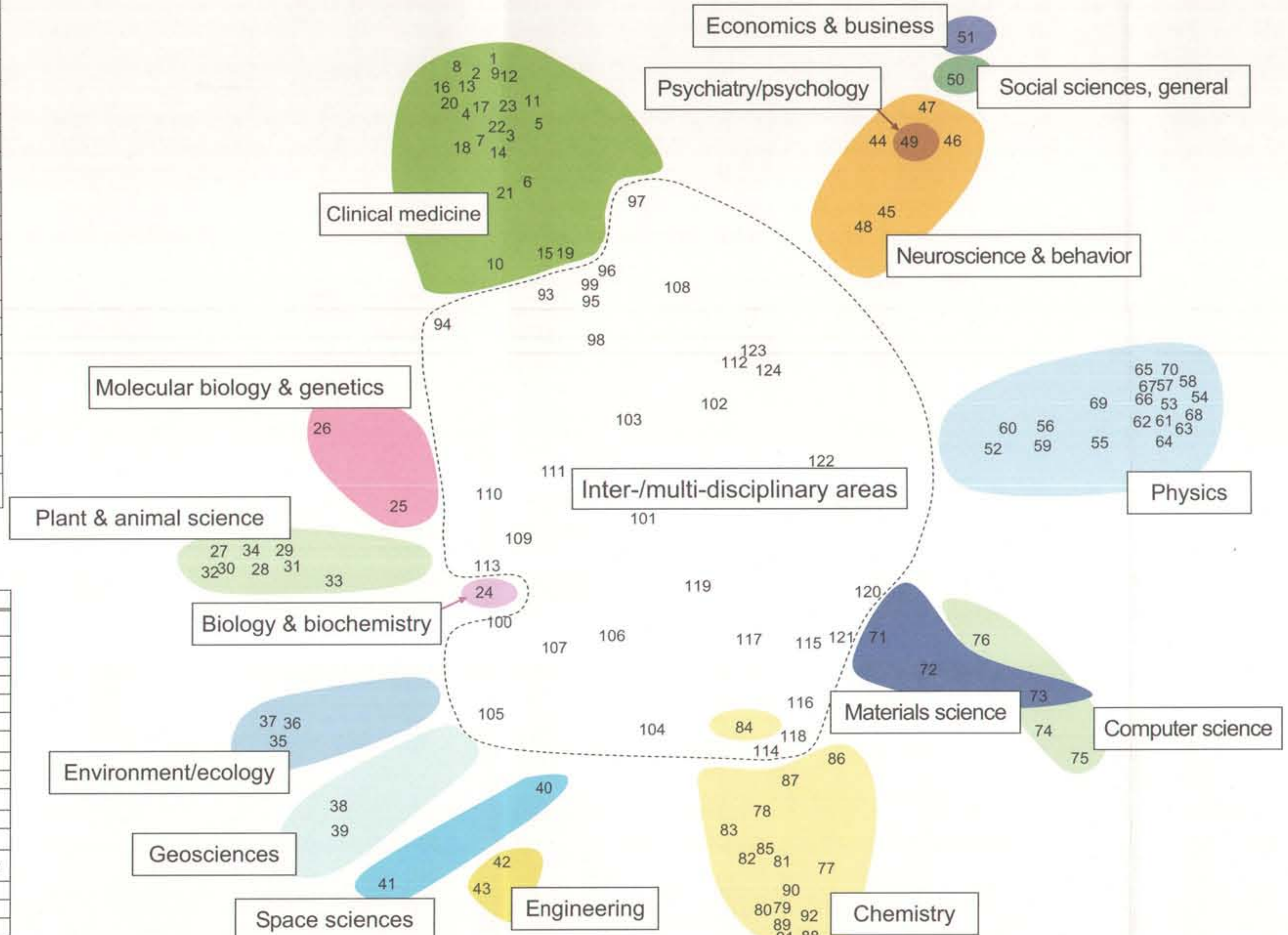
Figure 15: Academic Disciplines Relation Map

- This map compares the distribution across 22 fields of the core papers that make up hot research areas. It was created using a model in which hot research areas with similar field distributions are attracted to each other (a gravity model).
- About one-fourth (32) of the hot research areas are inter-/multi-disciplinary areas whose core papers do not tend to belong to a specific field.
- The Japanese presence is relatively strong in hot research areas with core papers that tend towards physics, chemistry, and plant and animal science.

Field	ID	Research Area
Clinical medicine	1	Drug-eluting stent
	2	Stage classification, treatment algorithm and outcome prediction of hepatocarcinoma
	3	Basic and clinical study on antitumor effect of histone deacetylase (HDAC) inhibitors
	4	Biodefense by blood coagulation regulatory system
	5	Deep mycosis
	6	Study on highly pathogenic avian influenza subtype H5N1
	7	Bone metabolism control by drug and its clinical application
	8	History of effect and adverse effect of hormone replacement therapy (HRT)
	9	Thromboembolism study
	10	Conventional infectious diseases / resistant bacterial infectious diseases
	11	Control of lymphocyte-activating organ dysfunction by antibody therapy and others
	12	Study on risk assessment, therapeutic effect, and diagnostic method for cardiac diseases
	13	Drug therapy of diabetes / thiazolidine derivatives
	14	Arteriosclerosis, abnormal lipid metabolism and abnormal carbohydrate metabolism affecting the onset of acute coronary syndrome, and inhibitory effect of hypolipidemic agents and proglycemic agents on the onset of acute coronary syndrome
	15	Ghrelin / function and pathophysiological significance
	16	Hormone therapy / breast cancer prevention
	17	Molecular targeting therapy / type III tyrosine kinase-related tumor
	18	Basic and clinical study on antibody therapy for HER2 (human epidermal growth factor receptor 2) positive breast cancer
	19	Obesity and diabetes
	20	New development in molecular therapy targeting EGFR mutations and others
	21	Study on regulation of tissue stem cell by extracellular environment and characteristics of cancer stem cell
	22	Cancer / gene expression profiling analysis
	23	Biological elucidation and clinical application of damaged tissue repair mechanism

Field	ID	Research Area
Biology & biochemistry	24	Elucidation of behavior principle of ion/water channel molecule
Molecular biology & genetics	25	Genome-wide gene expression analysis and expression regulatory function analysis
	26	Histone diversity and life phenomena
Plant & animal science	27	Plant functional genomics study
	28	Plant cell proteome analysis
	29	Plant-microorganism interaction
	30	Light environment response control / flower bud formation mechanism in plant
	31	Redox regulation
	32	Inducible defense mechanism in plant
	33	Environmental stress response / metabolic profiling / cellular structure and phospholipid metabolism in plant
	34	Plant defense against infection / plant immunity
Environment/ ecology	35	Environmental pollution study of bromine flame retardant made mainly of polybrominated diphenylethers (PBDEs)
	36	Assistive technology for detection, prediction and countermeasure of animal and plant activity change caused by climate change
	37	Biodiversity
Geo-sciences	38	Climatic effect of air pollutant and mineral dust
	39	Earth history
Space sciences	40	Gamma-ray burst and relative celestial explosion phenomenon
	41	Formation and evolution of the galaxy
Engineer-ing	42	Solid macromolecule type fuel cell / mass and heat transfer
	43	Nitride semiconductor transistor / high-voltage and high-frequency application

Japanese share of core papers
- 15%～
- 9%～15%
- 4%～9%
- 0%～4%
- 0%



Field	ID	Research Area
Inter-/multi-disciplinary areas	93	Pathogenic mechanism and preventive/therapeutic method of severe acute respiratory syndrome (SARS)
	94	Epidemiological study about the effect of air pollution (especially particle-like substances) on cardiovascular disease
	95	Study on HCV and HIV
	96	Elucidation of in-vivo function of drug transporter in human
	97	Suppression of immune reaction centered on foxp3-positive, CD25-positive and CD4-positive regulatory t cells
	98	Apoptosis (cell death) and inflammation
	99	Embryonic stem cell / neural induction
	100	Study on exchange between atmosphere and continental ecosystem of CO2 and others
	101	Proteinous infectious agent / new paradigm for genetic material
	102	Physiological function of TRP channel
	103	Activation of hypoxia-inducible factor 1 and formation of tumor microenvironment

Field	ID	Research Area
Inter-/multi-disciplinary areas	104	Solid macromolecule type fuel cell / macromolecular electrolyte film
	105	Quantification of water vapor, clouds, aerosol and albedo based on satellite and ground-based observation
	106	Water environment
	107	Aerosol
	108	Innate immunity
	109	Microbiodiversity
	110	Study on ubiquitination and sumoylation of protein
	111	Multi-hierarchical regulatory mechanism of life phenomena
	112	Molecular mechanism and physiological role of endogenous cannabinoid signal
	113	Photosynthetic light reaction apparatus / structure, function and regulation
	114	Study of laminated film and capsule

Field	ID	Research Area
Inter-/multi-disciplinary areas	115	Carbon nanotube synthesis and device evaluation
	116	Study on synthesis and optical application of metal and metal oxide nanoparticle/nanostructure
	117	Micro-bio system and micro chemical system
	118	Mesoporous material / silica organic-inorganic hybrid material / organic supramolecular complex
	119	Isotope labeling / quantitative mass spectrometry / protein analysis
	120	Organic transistor / improvement in performance and function
	121	Polymer organic led and phosphorescent organic LED
	122	Bioinformatics / transcriptome
	123	Pathogenesis and pathology of parkinson's disease and intracellular quality control mechanism by autophagy
	124	Molecular pathology and therapy of alzheimer's disease

Field	ID	Research Area
Neuroscience & behavior	44	Integrated comprehension of brain function by neuron-glia interaction
	45	Visceral sensation and neural mechanism of emotion and empathy
	46	Decision-making neuroscience
	47	Kinetics of AMPA receptor and spine morphology in synaptic plasticity
	48	Cause analysis and therapy development for psychiatric and nerve disease
Psychiatry/ psychology	49	Functional analysis of human brain and drug therapy of psychiatric disease
Social sciences, general	50	Structural analysis of the production process from the perspective of a network
Economics & business	51	Economic environment surrounding businesses

Field	ID	Research Area
Physics	52	Metamaterials
	53	Superconductive properties of magnesium diboride and its application
	54	Attosecond quantum dynamics
	55	Ferromagnetic semiconductor spintronics
	56	Quantum information control with multidimensional photon
	57	Electrical control of spin in semiconductors / quantum computer using solid state components
	58	High-temperature superconductivity spectroscopy / new electron phase
	59	High energy density science
	60	Complex networks
	61	Quantum information/communication, optical nanoscience
	62	Hadron spectroscopy
	63	New quantum condensed phase where substances strongly interact with each other
	64	Search for quark matter through high-energy nuclear collision
	65	Brane cosmology from the perspective of duality of anti de sitter space and conformal field theory
	66	Explore physics beyond the standard model from flavor physics of B meson and neutrino, dark matter and muon anomalous magnetic efficiency
	67	Field theory on noncommutative space
	68	Verification and integrability of AdS/CFT correspondence
	69	Observational cosmology and an elementary model for it
	70	High-dimensional black holes
Materials science	71	Nanofiber technology with the electro-spinning process and tissue engineering research
	72	Study of solar cells using inorganic oxides, organic-inorganic hybrids or organic polymers
	73	Ultra fine crystal grain / macrostrain process
Computer science	74	Space-time code
	75	Multifunctional signature / multifunctional coding
	76	Interactome analysis
Chemistry	77	Molecule-based nano-quantum magnet
	78	Macromolecule nanocomposite
	79	Living radical polymerization
	80	Construction of artificial photosynthesis model mimicking antenna system and charge separation system
	81	Porous coordination polymer
	82	Retrieval of binding specificity of sugar chain recognition protein by neoglycolipid sugar chain microarray
	83	Activation of oxygen molecule by metalloenzyme
	84	Protein folding
	85	Ionic liquid
	86	Study on supramolecular nanodevice by molecular machine and single-molecule conductor
	87	DNA-nanomaterial and nanodevice
	88	Catalytic asymmetric addition reaction of carbon nucleophile
	89	Bioimaging probe
	90	Synthetic polymer-immobilized catalyst technology
	91	Catalytic asymmetric synthesis
	92	Molecular conversion reaction using transition metal catalyst

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

5-2 Observation of inter-/multi-disciplinary research on the Research Area Correlation Map

This section discusses observations of inter-/multi-disciplinary areas on the Research Area Correlation Map.

Figure 17 shows the field distribution of core papers on the Research Area Correlation Map, with inter-/multi-disciplinary hot research areas plotted according to analysis of the field classification of journals. The 22 field classifications were compressed into 8 field classifications on the map. Figure 16 shows the relationships between the 22 fields and the 8 fields. On the map, regions with core-paper distribution of at least 60 percent in a specific field are shown with the field's corresponding color. Regions where core-paper distribution in a specific field is less than 60 percent are considered to have a high degree of interdisciplinary/multidisciplinary nature and are assigned no colors.

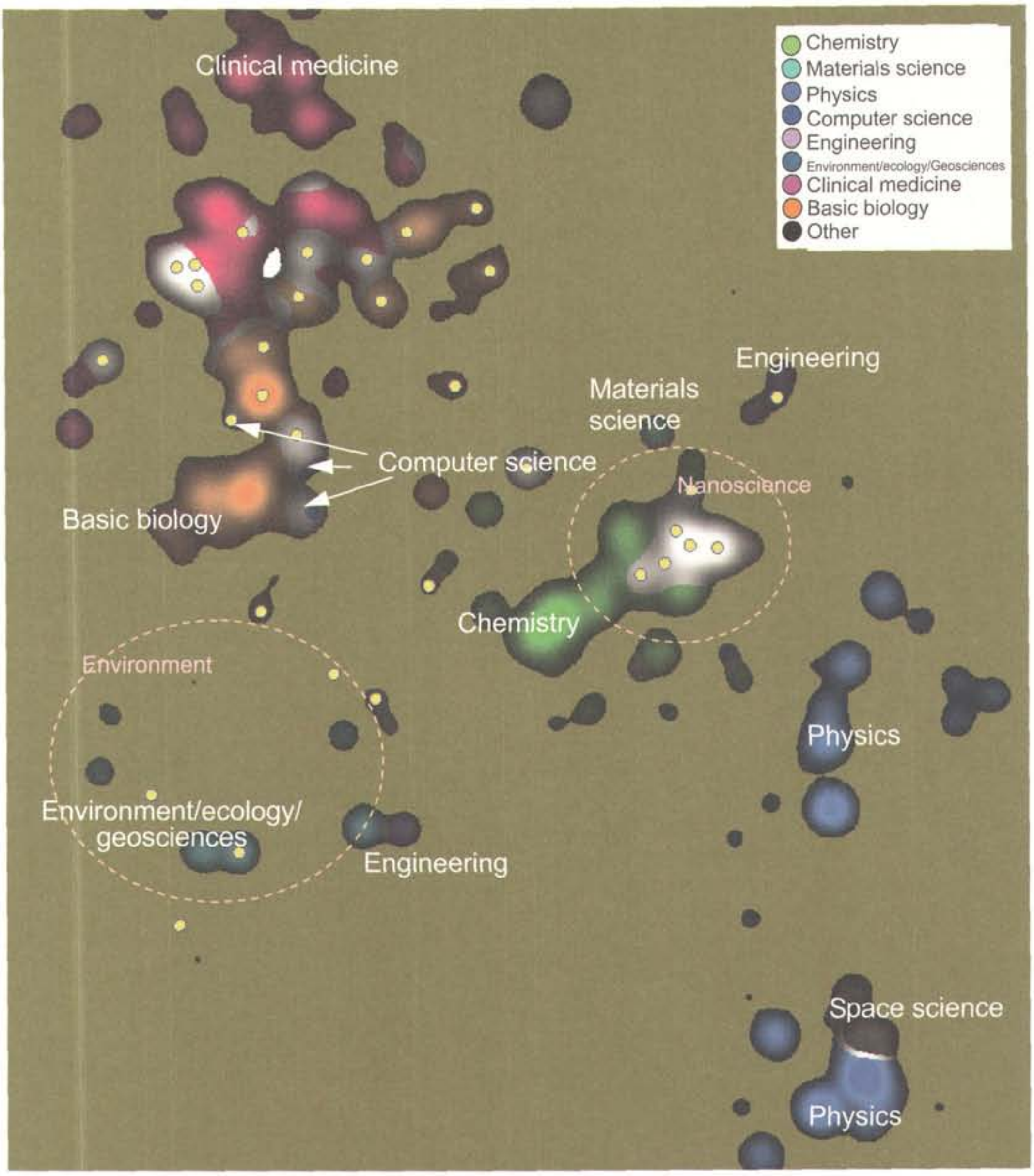
Looking at the positions of inter-/multi-disciplinary hot research areas as plotted on the Research Area Correlation Map, most are found in the nanoscience, environment, and life science (especially in post-genomics and between post-genomics and clinical medicine) fields.

The differences in the distribution of hot research areas in nanoscience and environment were distinctive. In the map, the group of research areas related to nanoscience stakes out a clear domain between chemical synthesis and physics, but the group of research areas related to environment spreads out spatially. This indicates that mapping is helpful to distinguish multidisciplinary research from interdisciplinary research. The following is a hypothesis.

Figure 16: The relationship between the 22 fields and the 8 fields

22 fields	8 fields
Chemistry	Chemistry
Materials science	Materials science
Physics	Physics
Computer science	Computer science and mathematics
Mathematics	
Engineering	Engineering
Environment/ecology	Environment/ecology/geoscien
Geosciences	
Clinical medicine	Clinical medicine
Agricultural sciences	Basic biology
Biology & biochemistry	
Immunology	
Microbiology	
Molecular biology & genetics	
Neuroscience & behavior	
Pharmacology/toxicology	
Plant & animal science	
Economics & business	Other
Multidisciplinary	
Psychiatry/psychology	
Social sciences, general	
Space sciences	

Figure 17: The positioning of inter-/multi-disciplinary areas on the Research Area Correlation Map



Note: Regions with core-paper distribution of at least 60 percent in a specific field are shown with the field's corresponding color. Regions where core-paper distribution in a specific field is less than 60 percent are considered to have a high degree of interdisciplinary/multidisciplinary nature and are assigned no colors.

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

Interdisciplinary research that relies on shared knowledge is generated when separate fields such as physics and chemistry interact. Nanoscience typifies this phenomenon. In interdisciplinary research that relies on shared knowledge, the important thing is that research development stages (research methods and research targets) should be the same in multiple fields. For example, interdisciplinary research in nanoscience was realized during the early 1990s because both chemistry and physics were targeting nanoscale phenomena and matter, the former at the molecular level and the latter at the bulk level. In research that relies on shared knowledge, if development stages differ, generation of interdisciplinary research is extremely unlikely. In other words, the accumulation of knowledge is a precondition that sets the stage for interdisciplinary research that relies on shared knowledge. Observation of such research can therefore be expected in the Research Area Correlation Map where existing research interacts. In fact, nanoscience appears on the map where differing fields such as physics and chemistry intersect.

In multidisciplinary research, various disciplines address scientific and social challenges independently rather than in collaboration. Thus it shares goals of research. Environmental research typifies this phenomenon. For example, study of biodiversity requires approaches from plant and animal science, while research on the environmental impacts of chemicals requires approaches from chemistry. These research areas stand on the foundation of knowledge in existing fields, and goal-oriented approaches are common. This means that in the Research Area correlation map, environmental research is likely to come from the vicinity of existing fields. In fact, the environment group of research areas appears on the Research Area correlation map with ongoing links to existing fields, and a broad spread with sometimes weak ties to environmental research. If information exchange within the environment group of research areas deepens, in the future it may come to comprise a distinct research area like chemical synthesis.

Research in life science includes both interdisciplinary and multidisciplinary aspects. In proteome research, for example, development of the desorption ionization method for mass spectrometry of biopolymers in chemistry and increased interest in comprehensive investigation of proteins in life science occurred at the same time, so life science research aggressively adopted mass spectrometry, and it took root as a post-genomics method. That is an example of interdisciplinary research relying on shared knowledge. On the other hand, defeating cancer is a shared goal of researchers using various approaches in a variety of fields, namely clinical medicine, immunology, and molecular biology. Therefore research in life science is expected to have a mixture of the inter- and multi-disciplinary characteristics.

In order to promote the success of interdisciplinary research that relies on shared knowledge, the development status of scientific research must be carefully tracked. In addition to ascertaining that the development stages of multiple fields match as scientific research develops over the medium and long terms, breakthroughs that can accelerate integration of fields need to be observed at an early point. Based on such observation, arenas for inter-disciplinary research must be created at the appropriate time. If a shared arena were created for physicists from 30 years ago and chemists today, the difference in their accumulations of knowledge would prevent nanoscience from being created.

In order to promote multidisciplinary research that relies on shared goals, clear goals must be set, and an arena for researchers who have the knowledge to meet those goals to gather must be constructed. In the USA, for example, an initiative called Cyber-enabled Discovery and Innovation (CDI) began during FY 2008. The goal of this initiative is to explore new knowledge management and visualization tools to extract useful information from the various kinds of data that have grown exponentially in recent years. This issue is recognized in numerous fields, including analysis of scientific papers, patent analysis, genetic data analysis, and web analysis. In order to grapple with this shared issue, CDI is to gather experts in information science, science policy research, bioinformatics, and so on to advance research. This is a good example of how to promote multidisciplinary research that relies on shared goals.

6. The breadth and intensity of research activities in Japan, the USA, and China

6-1 The status of activities in Japan

(1) The strength of Japan's presence in the 124 hot research areas

In order to compare the relative strength of Japan's presence in the hot research areas, average shares of major countries in the 124 hot research areas in Science Map 2006 and 133 hot research areas in science Map 2004 were calculated. (See Figure 18.)

Figure 18: Changes in national shares in the hot research areas

Avg. share (%)	USA	Germany	UK	Japan	France	South Korea	China
Science Map 2004	62.8	12.9	12.0	9.1	7.3	1.8	2.0
Science Map 2006	60.2	13.9	12.6	9.6	8.1	2.3	3.7

Note: Research paper shares were calculated using integer counting.
Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

Compared with Science Map 2004, the USA's share fell, while the shares of Germany, the UK, Japan France, South Korea, and China increased.

(2) Hot research areas in which Japan's presence is relatively strong

Among the 124 hot research areas, Japan's presence in physics, chemistry, and plant and animal science was relatively large. Hot research areas in which Japanese scientific papers accounted for more than 9 percent are shown in Figure 19.

Japanese scientific papers had a share of more than 9 percent in 14 out of the 19 hot research areas in physics. In 10 of these, Japanese papers accounted for more than 15 percent. The physics-related hot research areas with the highest ratio of Japanese scientific papers was "High-temperature superconductivity spectroscopy/new electron phase," at 44 percent.

Japanese scientific papers had a share of more than 9 percent in 8 out of the 16 hot research areas in chemistry. Japanese papers accounted for more than 15 percent in "Construction of artificial photosynthesis model mimicking antenna system and charge separation system" (80 percent), "Macromolecule nanocomposite" (33 percent), and "Catalytic asymmetric synthesis" (18 percent).

In life science, Japanese scientific papers had a share of more than 9 percent in 6 out of 8 hot research areas in plant and animal science. The highest ratio of Japanese papers was in "Plant-microorganism interaction," at 22 percent. In "Ghrelin/function and pathophysiological significance" (clinical medicine), the ratio of Japanese papers was high, at 34 percent.

Figure 19: Hot research areas where Japan's share of core papers is at least 9 percent

ID	Name of Research Area	# of core paper	# of Japanese papers	Rate of Japanese paper
80	Construction of artificial photosynthesis model mimicking antenna system and charge separation system	20	16	80
58	High-temperature superconductivity spectroscopy / new electron phase	45	20	44
108	Innate immunity	133	51	38
65	Brane cosmology from the perspective of duality of anti de sitter space and conformal field theory	17	6	35
15	Ghrelin / function and pathophysiological significance	58	20	34
78	Macromolecule nanocomposite	21	7	33
59	High energy density science	28	8	29
104	Solid macromolecule type fuel cell / macromolecular electrolyte film	22	6	27
123	Pathogenesis and pathology of parkinson's disease and intracellular quality control mechanism by autophagy	71	19	27
53	Superconductive properties of magnesium diboride and its application	49	13	27
55	Ferromagnetic semiconductor spintronics	85	21	25
56	Quantum information control with multidimensional photon	26	6	23
47	Kinetics of AMPA receptor and spine morphology in synaptic plasticity	22	5	23
62	Hadron spectroscopy	90	20	22
29	Plant-microorganism interaction	50	11	22
19	Obesity and diabetes	173	37	21
40	Gamma-ray burst and relative celestial explosion phenomenon	66	13	20
73	Ultra fine crystal grain / macrostrain process	83	16	19
113	Photosynthetic light reaction apparatus / structure, function and regulation	26	5	19
118	Mesoporous material / silica organic-inorganic hybrid material / organic supramolecular complex	76	14	18
91	Catalytic asymmetric synthesis	205	37	18
57	Electrical control of spin in semiconductors / quantum computer using solid state components	106	19	18
30	Light environment response control / flower bud formation mechanism in plant	102	18	18
66	Explore physics beyond the standard model from flavor physics of B meson and neutrino, dark matter and muon anomalous magnetic efficiency	265	46	17
38	Climatic effect of air pollutant and mineral dust	75	12	16
43	Nitride semiconductor transistor / high-voltage and high-frequency application	19	3	16
54	Attosecond quantum dynamics	26	4	15
10	Conventional infectious diseases / resistant bacterial infectious diseases	59	9	15
41	Formation and evolution of the galaxy	167	25	15

ID	Name of Research Area	# of core paper	# of Japanese papers	Rate of Japanese paper
27	Plant functional genomics study	35	5	14
20	New development in molecular therapy targeting EGFR mutations and others	93	13	14
96	Elucidation of in-vivo function of drug transporter in human	136	18	13
31	Redox regulation	38	5	13
98	Apoptosis (cell death) and inflammation	71	9	13
77	Molecule-based nano-quantum magnet	32	4	13
89	Bioimaging probe	56	7	13
28	Plant cell proteome analysis	25	3	12
25	Genome-wide gene expression analysis and expression regulatory function analysis	26	3	12
90	Synthetic polymer-immobilized catalyst technology	26	3	12
42	Solid macromolecule type fuel cell / mass and heat transfer	35	4	11
21	Study on regulation of tissue stem cell by extracellular environment and characteristics of cancer stem cell	27	3	11
79	Living radical polymerization	63	7	11
48	Cause analysis and therapy development for psychiatric and nerve disease	86	9	10
64	Search for quark matter through high-energy nuclear collision	134	14	10
102	Physiological function of TRP channel	58	6	10
24	Elucidation of behavior principle of ion/water channel molecule	49	5	10
70	High-dimensional black holes	79	8	10
33	Environmental stress response / metabolic profiling / cellular structure and phospholipid metabolism in plant	221	22	10
61	Quantum information/communication, optical nanoscience	162	16	10
85	Ionic liquid	103	10	10
69	Observational cosmology and an elementary model for it	415	40	10
117	Micro-bio system and micro chemical system	78	7	9
103	Activation of hypoxia-inducible factor 1 and formation of tumor microenvironment	68	6	9
120	Organic transistor / improvement in performance and function	69	6	9
115	Carbon nanotube synthesis and device evaluation	235	20	9

Note: Research paper shares were calculated using integer counting.

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

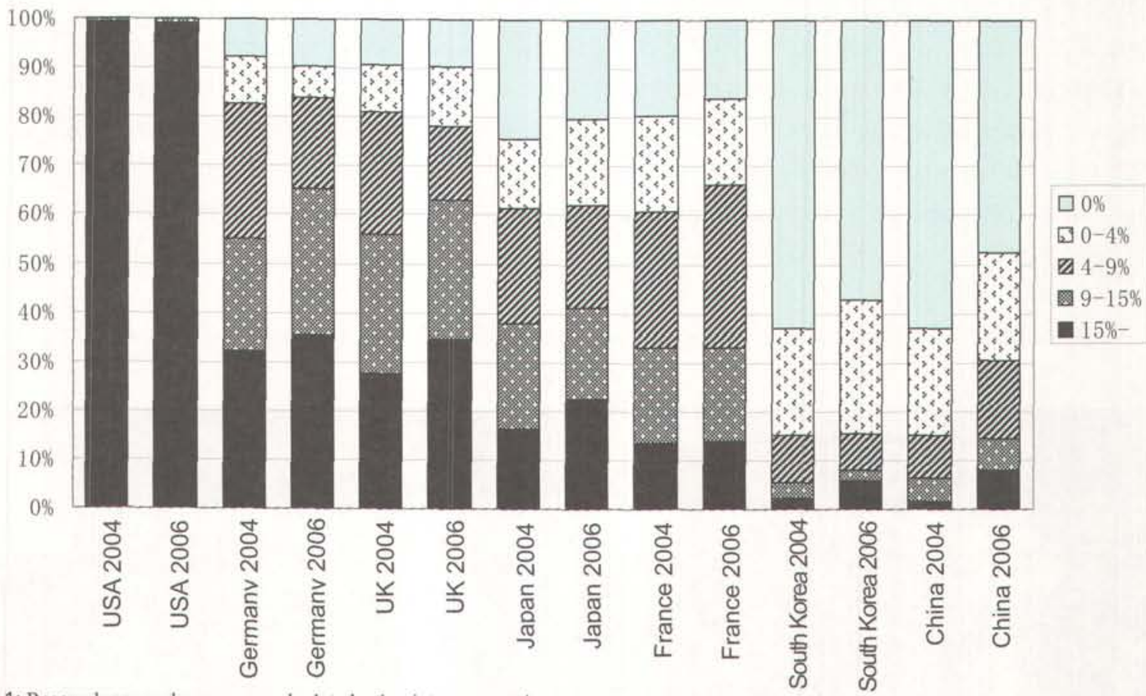
(3) Hot research areas where Japan's presence is relatively weak

Japan's presence was small in psychiatry/psychology, environment/ecology, and computer science, with few hot research areas in which Japanese scientific papers accounted for 9 percent or more. In social sciences, general, and economics, Japan had no presence at all.

Of the 32 inter-/multi-disciplinary areas, the ratio of Japanese scientific papers was more than 9 percent in 8 areas. In the previous study, Japanese papers accounted for more than 9 percent of papers in 19 out of 39 inter-/multi-disciplinary areas, suggesting something of a Japanese presence in these areas, but that declined somewhat in the current study.

Figure 20 shows distribution by country of scientific papers across the 124 hot research areas. Compared with the previous study (Science Map 2004), hot research areas where Japan had no scientific papers declined from above 20 percent to 20 percent. France, South Korea, and China exhibited the same trend.

Figure 20: Distribution of various countries shares of scientific papers across the hot research areas



Note 1: Research paper shares were calculated using integer counting.

Note 2: In the Figure, "2004" refers to Science Map 2004 (the previous study) and "2006" to Science Map 2006 (the current study).

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

(4) Japan's presence on the Research Area Correlation Map

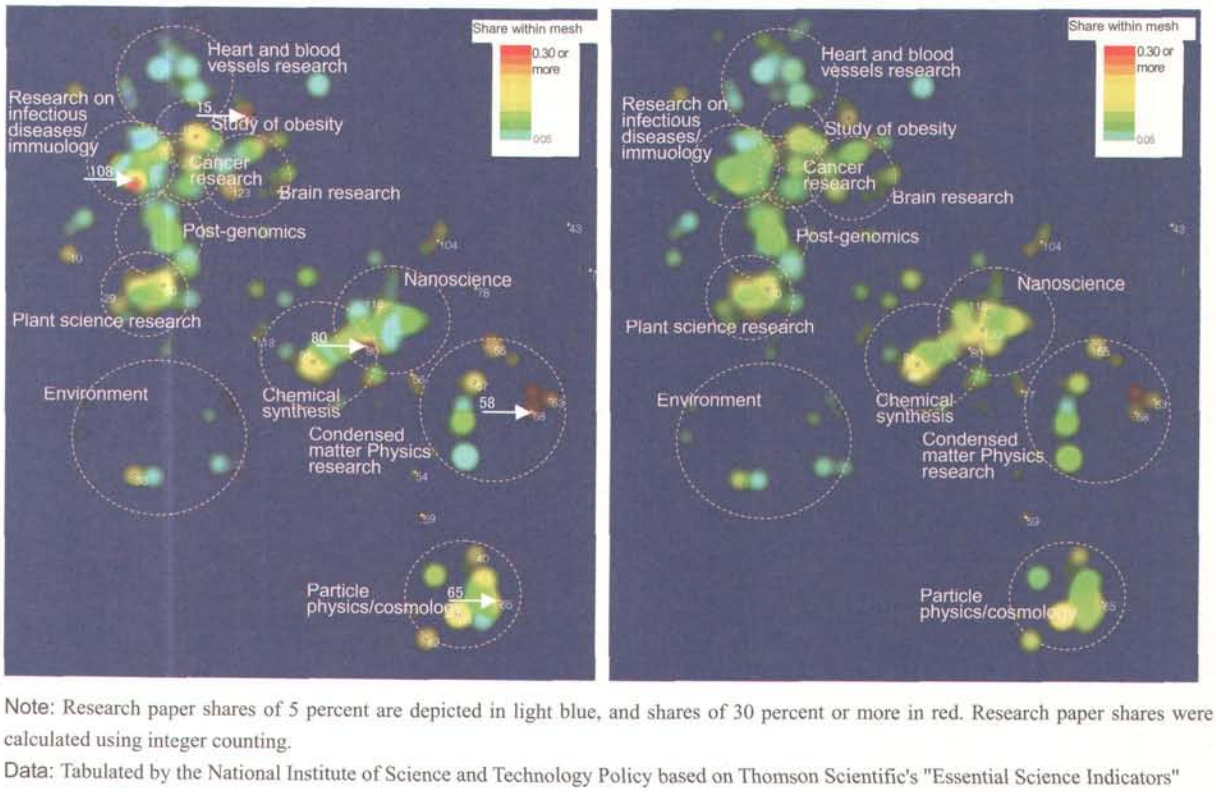
Figure 21 shows the ratio of Japanese scientific papers on Science Map 2006. On the maps, regions where the ratio of Japanese scientific papers is 5 percent are light blue, and regions where the ratio is at least 30 percent are red. There are two maps, one showing shares of core papers that are Japanese, and the other depicting shares of citing papers that are Japanese. The former is the Japanese percentage of core papers that comprises a research area, while the latter is the Japanese percentage of scientific papers that cite those core papers.

The hot research area with the highest ratio of Japanese core papers is "Construction of artificial photosynthesis model mimicking antenna system and charge separation system (ID 80)," at 80 percent. This is followed by "High-temperature superconductivity spectroscopy/new electron phase (ID 58)," "Innate immunity (ID 108)," "Brane cosmology from the perspective of duality of anti de sitter space and conformal field theory (ID 65)," and "Ghrelin/function and pathophysiological significance (ID 15)," all of which have high ratios of Japanese papers.

With the exception of ID 65, the vicinities of these hot research areas are red, indicating that Japanese research forms the core of the areas. As for ID 65, while Japanese scientific papers have a high share, on the map it is yellow. This is because the core papers that comprise ID 65 are few in number relative to all papers in particle physics/cosmology research areas, and therefore the Japanese share of core papers in the vicinity of ID 65 is relatively low. As this case illustrates, one must consider the size of the hot research area and its relationships with nearby research areas in order to interpret the percentages for Japanese scientific papers shown in Figure 19.

Figure 21: Japanese shares of scientific papers in Science Map 2006 [a] core papers and [b] citing papers

[a] [b]



Note: Research paper shares of 5 percent are depicted in light blue, and shares of 30 percent or more in red. Research paper shares were calculated using integer counting.

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

When illustrating Japanese shares of scientific papers on the Research Area Correlation Map, even if one says that Japanese shares are high, this does not necessarily mean that the research areas will have the same meaning on the map. Looking at

Figure 3, for example, core-paper density around "Research on infectious diseases/immuology" is high, and that field accounts for a very large number of the world's scientific papers. One may therefore say that in "Innate immunity (ID 108)," Japan has a strong presence in a hot research area that is fiercely competitive internationally. In order to retain this vigor into the future, Japan may need to invest resources equivalent to its international competitors.

On the other hand, core-paper density around "Construction of artificial photosynthesis model mimicking antenna system and charge separation system (ID 80)" is not so high. This hot research area is located where nanoscience and chemical synthesis overlap. It is therefore possible that ID 80 is a hot research area on the border between nanoscience and chemical synthesis, where Japan uniquely leads the way in research.

"High-temperature superconductivity spectroscopy/new electron phase (ID 58)" and "Superconductive properties of magnesium diboride and its application (ID 53)" form an isolated island on the map, and the Japanese share of scientific papers is high. Superconductivity has a long history in research and development. The high share of Japanese core papers reflects the country's accumulations of knowledge and human resources in superconductivity research.

Looking at nearby regions on the map, the number of core papers comprising superconductivity research is lower than in quantum computing and so on. Furthermore, interaction with other research areas is not particularly common. Looking at the world situation therefore, the extent of superconductivity research's overlap with scientific research as a whole is likely to remain small. Considering dynamic change in scientific research as a whole, in addition to advancing superconductivity research itself, how to connect its accumulated knowledge and human resources with the development of other research areas is a long-term issue.

6-2 The status of activities in the USA and China in the Science Map

Here we will demonstrate how to read the status of other countries on the Science Map by using the USA and China as examples. On the map, differences between the leading country in scientific research (the USA) and one that is rapidly growing in vigor (China) are clearly visible. Below, we discuss this in more detail.

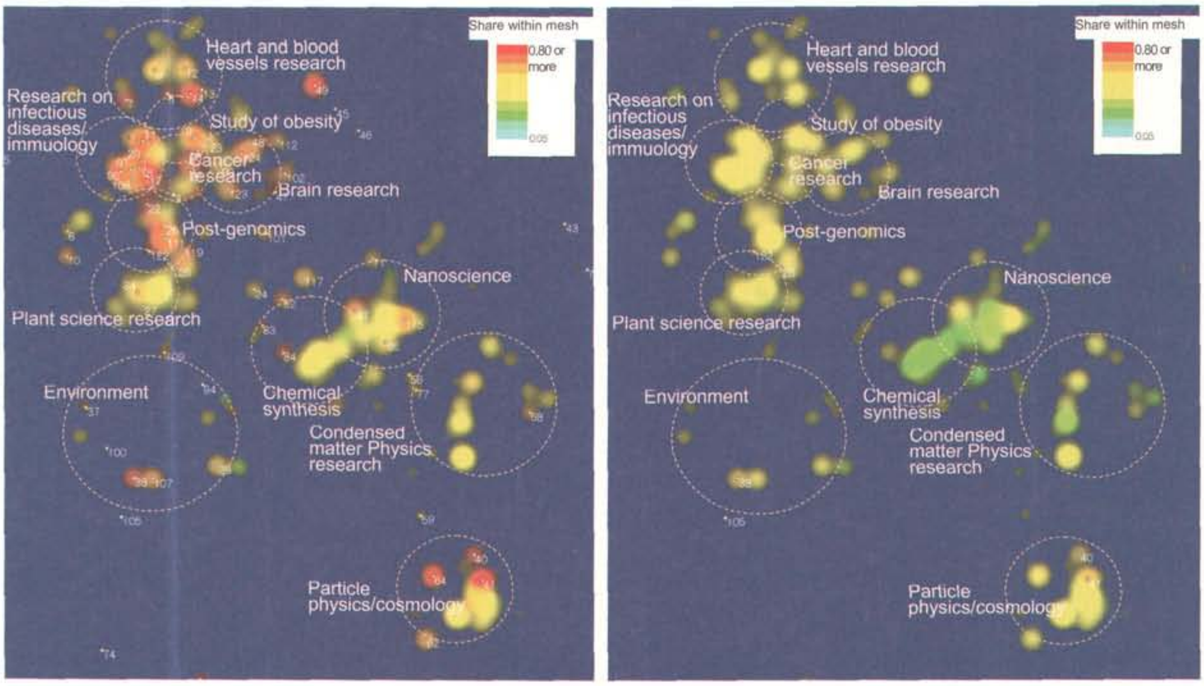
(1) The USA

In terms of core papers, the USA has a high share in every hot research area (at least 50 percent in 90 of them). Looking at the overall balance of the Research Area Correlation Map, however, there are gradations in that country's shares of core papers, as illustrated in Figure 22. Compared with the life science group of research areas, the US share of scientific papers in the chemical synthesis and nanoscience groups of research areas is smaller.

Comparing US shares of core papers and citing papers, the USA has a smaller share of citing papers. This corresponds with the increased production of scientific papers in China, and the concomitant decrease in the percentage of scientific papers that are American[6]. Although the USA's share of total research paper production declined, its share of core papers remained high. This indicates that even though research paper production in many countries is increasing, the USA will remain a major source of knowledge for science as a whole.

Figure 22: US shares of scientific papers in Science Map 2006 [a] core papers and [b] citing papers

[a] [b]



Note: Research paper shares of 5 percent are depicted in light blue, and shares of 80 percent or more in red. Research paper shares were calculated using integer counting.

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

[6] Microanalysis of research papers found the same situation.

(5) China

China's shares of scientific papers contrast those of the USA. Compared to core papers, the Chinese share of citing papers is higher. This indicates that China is in a catching-up phase in terms of scientific research.

Looking at core papers (Figure 23 [a]), the Chinese share is particularly high in "Study on highly pathogenic avian influenza subtype H5N1 (ID 6)," "Hadron spectroscopy (ID 62)," and "Pathogenic mechanism and preventive/therapeutic method of severe acute respiratory syndrome (SARS) (ID 93)." The Chinese share of scientific papers in each case is more than 25 percent.

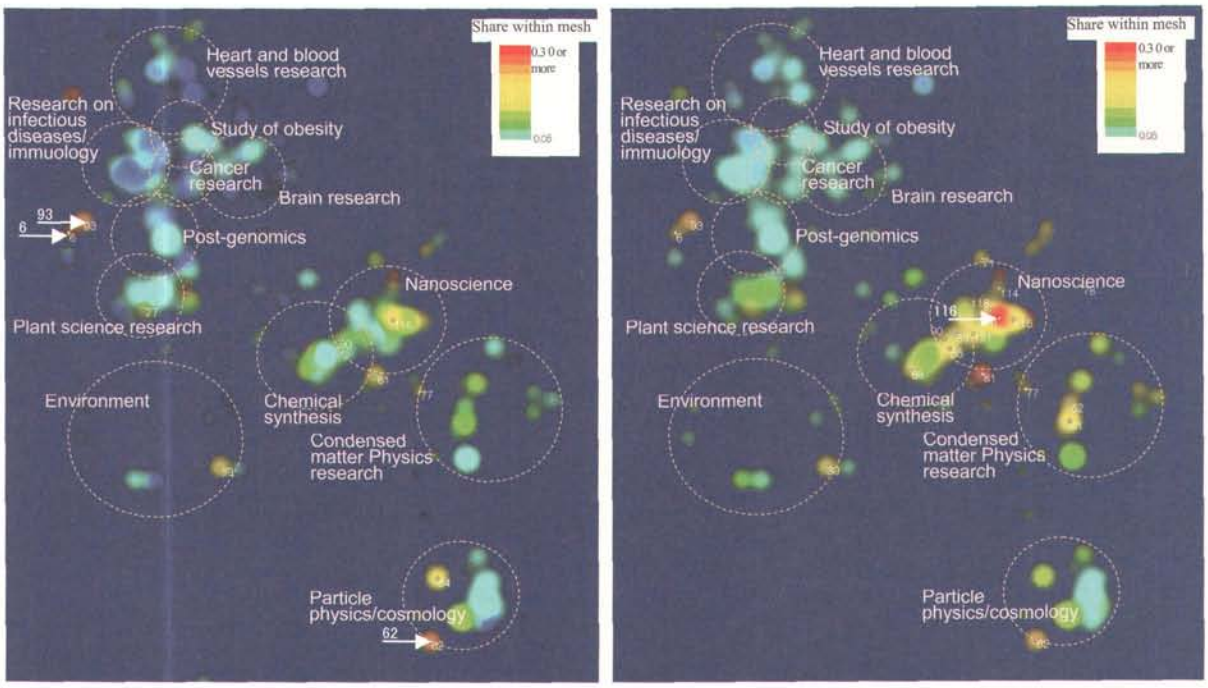
Comparing Science Map 2004 and Science Map 2006, both the breadth and intensity of China's scientific research increased.

Focusing on citing papers (Figure 23 [b]), in Science Map 2004, China's share of scientific papers in nanoscience was 10–15 percent (yellow region). In Science Map 2006, China's share in nanoscience was even larger, reaching 33 percent in "Study on synthesis and optical application of metal and metal oxide nanoparticle/nanostructure (ID 116)," the red region on the map. Furthermore, the breadth of China's activities broadened, with areas in which the Chinese share of scientific papers was 10–15 percent (yellow regions) spreading to condensed matter physics.

Of particular note are research areas related to plant science research. In Science Map 2004, the Chinese share of scientific papers was very small in terms of both citing papers and core papers. In Science Map 2006, however, the Chinese share in citing papers in particular increased. The span of Chinese scientific research activities is thus widening to include life science. Currently the increase in the Chinese share of core papers is not especially pronounced. In the future, however, increased quality is expected along with the growing quantity.

Figure 23: Chinese shares of scientific papers in Science Map 2006 [a] core papers and [b] citing papers

[a] [b]

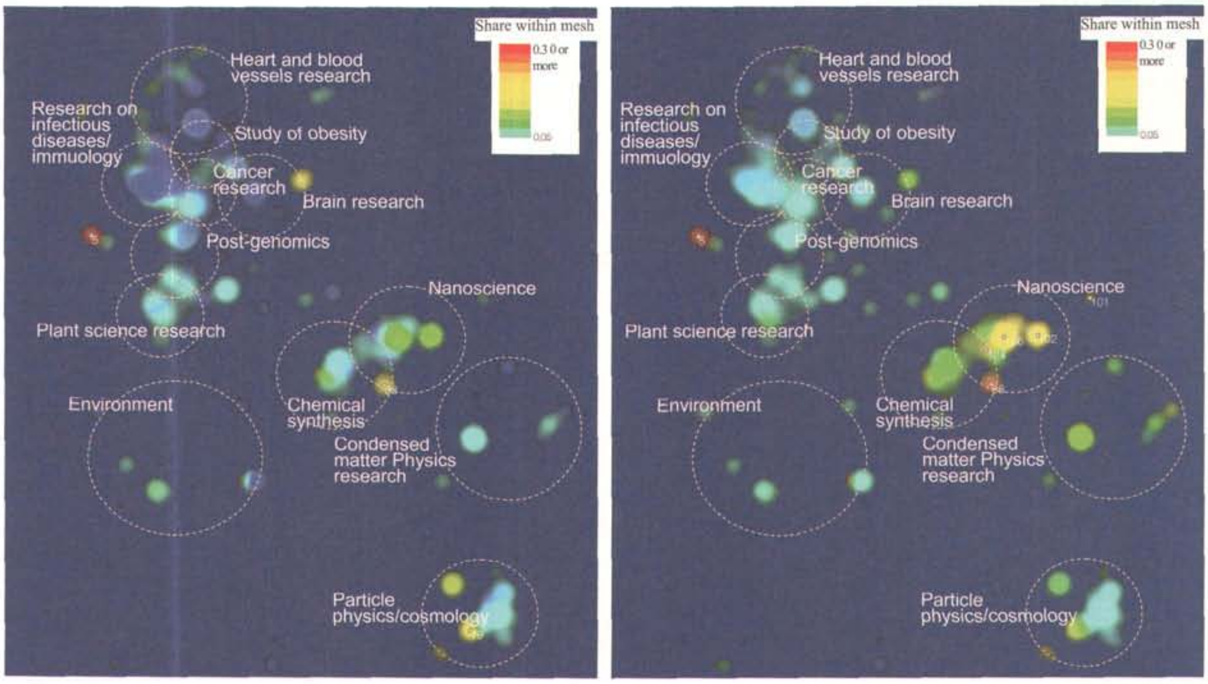


Note: Research paper shares of 5 percent are depicted in light blue, and shares of 30 percent or more in red. Research paper shares were calculated using integer counting.

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

Figure 24: Chinese shares of scientific papers in Science Map 2004 [a] core papers and [b] citing papers

[a] [b]



Note: Research paper shares of 5 percent are depicted in light blue, and shares of 30 percent or more in red. Research paper shares were calculated using integer counting.

Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Scientific's "Essential Science Indicators"

7. Conclusions and future developments

There is a long history of attempts to describe the structure and development of science and technology from a bibliometric perspective. The dramatic development of information processing technology and enhancement of databases of scientific papers and patents in recent years have brought innovation to research in this field. The mapping of knowledge is attracting attention as a new area of research, and a variety of studies are being conducted, mainly in the USA and Europe[7]. The targets of mapping are diverse. They include analysis of relationships between fields of science through examination of journal citations and analysis of co-authorships by country, organization, and researcher.

The National Institute of Science and Technology Policy's Science Map project aims to periodically observe dynamic change in scientific research. The unit of mapping is research areas.

The methodology to create the science map based on clustering of highly-cited papers was established through the former two studies. Science Map 2006 followed the same methodology. Science Map 2006 also added changes to the survey methods that will continue in future studies, as well as improvements to the analytical methods.

First, NISTEP commissioned outside experts to carry out content analysis of research areas, mapping which had previously been performed at NISTEP. Obtaining the cooperation of a broad community of experts is intended to enable more accurate analysis. Furthermore, the Research Area Correlation Map was used to take a broad view of science as a whole, and an interview survey was carried out regarding whether the positions of research areas on the map were appropriate and whether new research areas have appeared over the past 10 years.

In addition, the mapping methods were improved. An improved visualization method made the Research Area Correlation Map easier to understand, and a method was developed to connect Science Maps created at different times (in this case, Science Map 2004 and Science Map 2006).

Below we discuss Science Map 2006's conclusions and future developments.

7-1 Conclusion

(1) Changes in scientific research, a comparison of Science Map 2004 and Science Map 2006

Comparison of Science Map 2004 (covering the years 1999–2004) and Science Map 2006 (2001–2006) and interviews with experts confirmed steady, ongoing change even over two years. The important points were as follows.

Life science

In life science related research areas, post-genomics is in a position bridging plant science research that focuses mainly on plants and fungi and heart and blood vessels research, brain research, study of obesity, cancer research, and research on infectious diseases/immunology that focus mainly on studying animals and fungi.

Two factors contribute to this phenomenon. First is a trend towards research that attempts to understand more complex and broad based regulatory mechanisms of life phenomena. Research on life phenomena in

[7] For a comprehensive review, see Börner, K., Chen, C., and Boyack, K. W. (2003), "Visualizing Knowledge Domains," *Annual Review of Information Science and Technology*, 37, 179–255.

animals and plants long focused on elucidating the regulatory mechanisms for transcription from DNA to RNA. Beginning in 2000, however, much research on RNAi and other regulatory mechanisms at the RNA level, regulatory mechanisms after protein translation, and in vivo protein localization regulation has also been published. In the Science Map, an example of this trend is the fusion of "Research on epigenetic transcriptional regulation (2004, ID 130)" and "Analysis of mechanism of regulation of plant growth (2004, ID 33)" to form "Multi-hierarchical regulatory mechanism of life phenomena (2006, ID 111)."

Second is a change in the position of protein research. In Science Map 2004, "Research on proteome (2004, ID 105)" had a somewhat isolated position between chemical synthesis and life science. In Science Map 2006, however, its successor, "Isotope labeling/quantitative mass spectrometry/protein analysis (2006, ID 119)," is located in the center of the post-genomics research area. In mass spectrographic analysis of proteins, Koichi Tanaka of Shimadzu Corp. developed a desorption ionization method for mass spectrographic analysis of polymers, which earned him a Nobel Prize in chemistry. This kind of research has a very strong "chemistry" element to it. As genome sequencing using model organisms advances, comprehensive research on proteins is drawing attention. Mass spectrography is being aggressively incorporated into life science related research and has taken root as a post-genomics method. Science Map 2006 shows this trend clearly.

Plant science research

As the ties between post-genomics and plant science research grow stronger, the nature of research areas changed, and some research areas divided. In the 2000s, research on gene identification, intergenetic networks, transcriptome analysis, and metabolome analysis using model plants has grown active. More detailed research has progressed, and various research communities have formed. Experts pointed out that in the future there will be an emphasis on the relationship between environmental issues and food issues. As in Science Map 2004, Japan is making a strong effort in plant science, but China's presence is strengthening, so this trend bears watching.

Clinical medicine

Clinical medicine is one of the faster-changing fields in science. Research areas directly or indirectly related to clinical medicine have maintained or increased their size, or increased in size and divided, since Science Map 2004. Research areas that are expected to develop in the future are scattered in the vicinity of life science in Science Map 2006, so the seeds of coming hot research areas in the field are already emerging.

Chemical synthesis

Research on asymmetric synthesis using organic catalysts showed rapid growth. The fundamental point of chemistry is understanding matter at the level of chemical structural formulas. As research at the molecular level has advanced in life science and nanoscience, chemistry has expanded its bounds compared with the past. On the Research Area Correlation Map as well, chemistry is located between life science and physics, reflecting that situation.

Nanoscience

Nanoscience is steadily progressing. In the Science Map 2004, "Development of nanostructure and its application to molecular devices (2004, ID 106)" is observed as a single research area. It has since expanded to three independent research areas, "Study on supramolecular nanodevice by molecular machine and single-molecule conductor (2006, ID 86)," "DNA-nanomaterial and nanodevice (2006, ID 87)," and "Study on synthesis and optical application of metal and metal oxide nanoparticle/nanostructure (2006, ID116)." As can be seen in the Science Map, the volume of research linking chemical synthesis and nanoscience is increasing.

Condensed matter physics

Condensed matter physics includes the hot research areas of quantum computing and superconductivity. Comparing Science Map 2004 and Science Map 2006, the number of scientific papers in "Ferromagnetic semiconductor spintronics (2006, ID 55)" and "Electrical control of spin in semiconductors/quantum computer using solid state components (2006, ID 57)" increased. According to experts, the position of condensed matter physics between chemical synthesis and particle physics/cosmology will probably not change, but the hot research areas derived will likely vary over time.

Particle physics/cosmology

Comparing the Science Map 2004 with the Science Map 2006, the hot research areas observed in 2004 generally continued, although some merged.

This is because particle physics/cosmology has ultimate goals such as construction of a unified field theory and understanding of the origin of the universe, and research will continue to evolve in those directions. Relationships between the particle physics/cosmology group of research areas and other groups of research areas are not expected to change significantly. Observation of changes in the Science Map over time will likely find no change in the group's position on the map, even though research content changes.

Particle physics/cosmology is a field that advances as experiments and theories stimulate each other. Theory has led the way, but the launch of the European Organization for Nuclear Research's (CERN) Large Hadron Collider (LHC) is expected to lead to the development of research in which discoveries of new phenomena through the verification and testing of theories will take place.

(2) The observation of inter-/multi-disciplinary research on the Science Map

Interdisciplinary research that relies on shared knowledge (nanoscience) and multidisciplinary research that relies on shared goals (environment) are observed in differing forms in the Science Map.

Interdisciplinary research that relies on shared knowledge is generated when separate fields such as physics and chemistry interact. Nanoscience typifies this phenomenon. In interdisciplinary research that relies on shared knowledge, the important thing is that research development stages (research methods and research targets) should be the same in multiple fields. If development stages differ, generation of interdisciplinary research is extremely unlikely. For example, interdisciplinary research in nanoscience was realized during the early 1990s because both chemistry and physics were targeting nanoscale phenomena and matter, the former at the molecular level and the latter at the bulk level. The accumulation of knowledge is a precondition that sets the stage for interdisciplinary research that relies on shared knowledge. Observation of such research can therefore be expected in the Science Map where existing research interacts. In fact, nanoscience appears on the Science Map where differing fields such as physics and chemistry intersect.

In multidisciplinary research, various disciplines address scientific and social challenges independently rather than in collaboration. Thus it shares goals of research. Environmental research typifies this phenomenon. For example, in environmental research, study of biodiversity requires approaches from plant and animal science, while research on the environmental impacts of chemicals requires approaches from chemistry. These research areas stand on the foundation of knowledge in existing fields, and goal-oriented approaches are common. This means that in the Science Map, environmental research is likely to come from the vicinity of existing fields. In fact, the environment group of research areas appears on the Science Map with ongoing links to existing fields, and a broad spread with sometimes weak ties to environmental research.

The points to bear in mind differ when promoting interdisciplinary type research or multidisciplinary type research. To promote interdisciplinary research that relies on shared knowledge, an arena for interdisciplinary research must be constructed when the research development stages (research methods and targets) of multiple fields match. On the other hand, to promote multidisciplinary research that relies on shared goals, clear goals must be set, and an arena for researchers who have the knowledge to meet those goals to gather must be constructed.

(3) Japan's strength of presence in scientific research

Japan's average share of scientific papers in the 124 hot research areas derived for Science Map 2006 is 9.6%, an increase from Science Map 2004 (9.1%). Furthermore, the percentage of the 124 hot research areas for which Japan has a 0-percent share decreased. Within the 124 hot research areas, Japan's presence is relatively large in hot research areas in physics, chemistry, and plant and animal science.

The hot research area where Japan's share of core papers is highest is "Construction of artificial photosynthesis model mimicking antenna system and charge separation system (ID 80)," with an 80-percent share. Japan's next highest shares are in "High-temperature superconductivity spectroscopy/new electron phase (ID 58)," "Innate immunity (ID 108)," "Brane cosmology from the perspective of duality of anti de sitter space and conformal field theory (ID 65)," and "Ghrelin/function and pathophysiological significance (ID 15)."

Looking at other countries, even though many nations around the world are increasing their production of scientific papers, the USA remains an important source of knowledge for science as a whole. The USA's activities as illustrated in the Science Map show lower shares of scientific papers in the chemical synthesis and nanoscience groups of research areas than in life science.

In Science Map 2004, China's scientific research was limited to nanoscience. Over the following two years, China increased both the breadth and intensity of its activities. China increased its share of scientific papers in nanoscience, with an increase in the neighboring area of physics as well. Furthermore, in Science Map 2006, China's share of scientific papers in plant science research also increased. The breadth of scientific research in China has thus extended to life science.

7-2 Future developments

Based on our experience with this study, the following are four developments we will add to future research.

Periodic observation of science

Comparison of Science Map 2004 and Science Map 2006 and interviews with experts confirmed that scientific research gradually changes even over a two-year period. Even as Science Map 2006 was being created, science continued its development with accomplishments such as the production of iPS cells. By carrying out periodic observation of science and taking panoramic snapshots of science over time with the Science Map, we can describe dynamic change in science, such as the way one scientific innovation influences other research areas. Furthermore, considering the application of the Science Map to science and technology policy, finding emerging research areas that will develop in the future is an important theme. This research experimented with attempting to find research areas likely to develop in the future. Beginning with the next Science Map, trends in these research areas will be tracked. This should deepen knowledge of methods for using science mapping to find emerging research areas.

Linkage of the Science Map with other data

Adding statistical data to the Science Map, such as the ratios of scientific papers from various countries, is effective. Science Map 2006 clearly showed that China is expanding the breadth and intensity of its scientific research activity. In addition to the ratios of scientific papers for various countries, linkage to the distribution of research funding or the distribution of universities and government research institutions, for example, is possible. Analysis of the relationship between the development of scientific research and related information over time could obtain data on the influence of research funding on the development of scientific research or the role of universities and government research institutions in the generation of knowledge. Moreover, detailed investigation of co-authorship within research areas could clarify dependence on interaction among researchers and organizations in the process of forming scientific knowledge.

Linkage of science and technology

Considered from the perspective of science and technology, the breadth of observation using the Science Map is limited to science. In order to take a broader view of science and technology, it is necessary to create technology maps as well, using data such as patents. Using the scientific papers cited in patent documents, Science Maps and technology maps could be linked. Knowledge transfer from science to technology and from technology to science and field dependence could be observed.

The Science Map as an arena for discussion

During the interview survey, we were struck by the usefulness of the Science map as a basis for discussion. In most interviews with experts, they express their opinions based on their own backgrounds. With shared data such as the Science Map, researchers from different fields can engage in more meaningful discussion of the development of scientific research. By sharing the same "arena," researchers can mutually adjust their sense of distance, facilitating discussion among researchers or among researchers and policymakers. In the future, we would like to pursue this idea of the Science Map as an arena for discussion.

Part II

1. Details of survey methodology: Content analysis of hot research areas

Results of content analysis of the 124 hot research areas established through database analysis are shown beginning on page 61. Content analysis of the hot research areas consisted of the following matters.

(i) Hot research areas and hot research area IDs

Hot research areas were assigned names expressing their content by experts in Japan. The hot research area ID numbers are consecutive numbers.

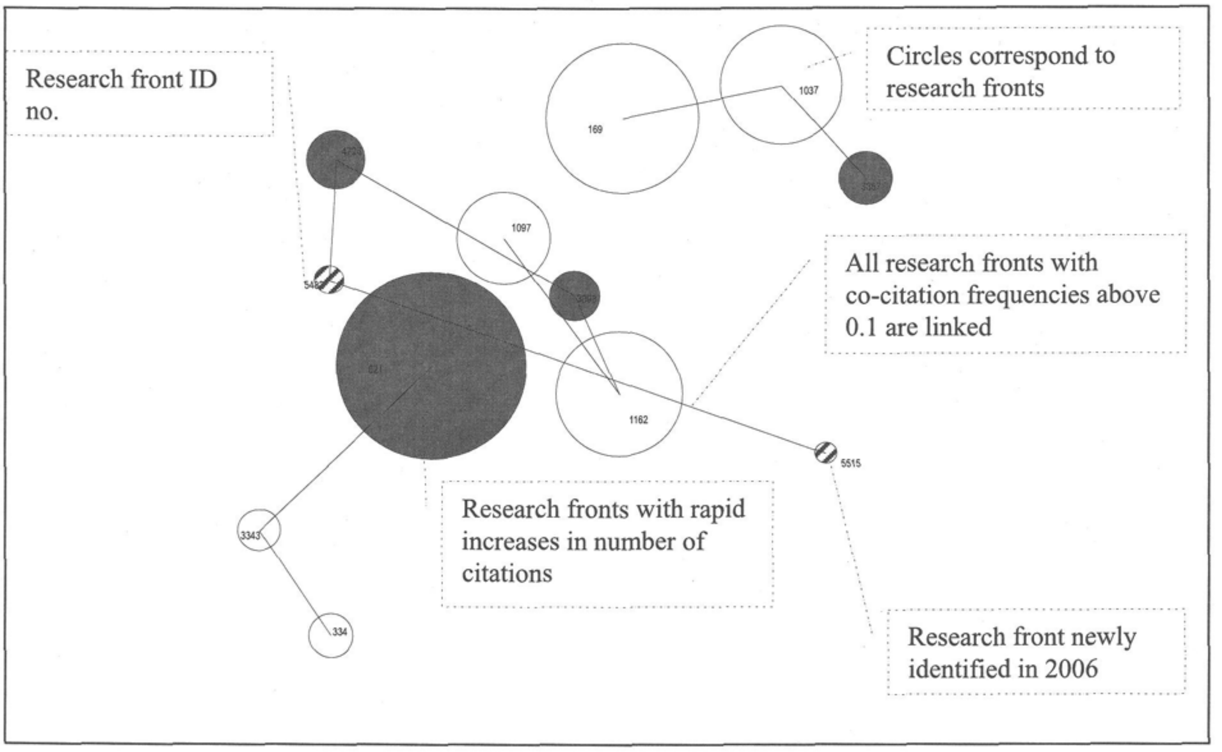
(ii) Statistical information on hot research areas

The number of research fronts that comprise hot research areas, those in which the number citations rapidly increased, the number of core papers comprising a research front and the number of Japanese core papers, the number of cited papers, the number of times cited, and the average year of core paper publication were addressed.

(iii) Individual Research Area Map

Individual Research Area Maps were shown in order to express visually the relatedness of research fronts within hot research areas. The following is an explanation of the map of individual research areas.

- Circles in the Individual Research Area Maps correspond to research fronts.
- The number next to a circle is the ID number of that research front.
- The area of a given circle is proportional to the number of citations of core papers in that research front.
- Deep colors indicate research fronts whose citations of core papers increased markedly (rapidly developing research fronts).
- Diagonal lines within a circle indicate a research front that is new in 2006.
- The stronger the co-citation relationship between research fronts, the closer the location of their circles. The weaker the relationship, the more distant their circles.
- Research fronts with a certain degree of co-citation relationship are connected by lines.



In addition, the content of research fronts is indicated in Individual Research Area Maps in accordance with (1) and (2) below.

(1) When a group of research fronts with similar content can be depicted in an Individual Research Area Map, that group of research fronts is surrounded by a line and its content is written on the map.

(2) When it is difficult to depict a group of research fronts on an Individual Research Area Map, important research fronts in the research area (i.e., those with links to many other research fronts or whose number of citations is increasing rapidly, etc.) are depicted on the map and their content is written.

(iv) Description of Hot Research Area

An "Area overview and research front content" is provided to describe each hot research area. To the extent possible, this section is linked to the interpretations of Individual Research Area Map. A general description of the hot research area and the content of its constituent research fronts are provided. The content of research fronts is described in accordance with (1) and (2) below.

(1) When a group of research fronts with similar content can be depicted, the content is itemized.

(2) When it is difficult to depict a group of research fronts, the content of important research fronts in the research area (i.e., those with links to many other research fronts or whose number of citations is increasing rapidly, etc.) is itemized.

The content analysis results for hot research areas were rechecked and confirmed by those responsible for the analyses.

2. Results of content analysis of hot research area

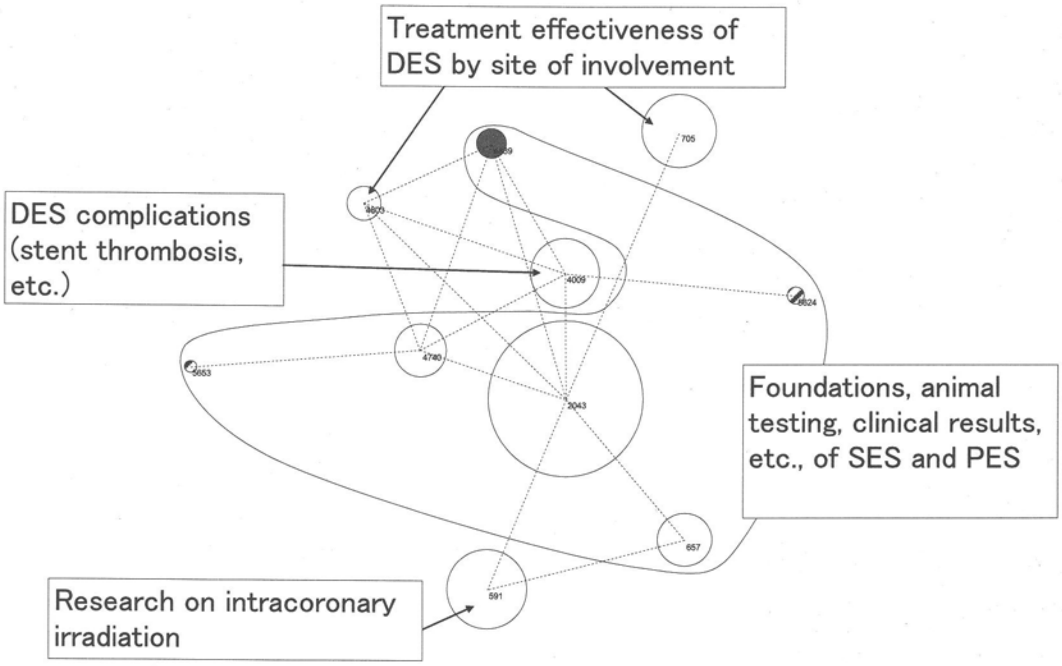
Following are the table of contents and results for the 124 hot research areas.

ID No.	Name of Research area	Page
32	Inducible defense mechanism in plant	76
33	Environmental stress response / metabolic profiling / cellular structure and phospholipid metabolism in plant	77
34	Plant defense against infection / plant immunity	77
35	Environmental pollution study of bromine flame retardant made mainly of polybrominated diphenylethers (PBDEs)	78
36	Assistive technology for detection, prediction and countermeasure of animal and plant activity change caused by climate change	78
37	Biodiversity	79
38	Climatic effect of air pollutant and mineral dust	79
39	Earth history	80
40	Gamma-ray burst and relative celestial explosion phenomenon	80
41	Formation and evolution of the galaxy	81
42	Solid macromolecule type fuel cell / mass and heat transfer	81
43	Nitride semiconductor transistor / high-voltage and high-frequency application	82
44	Integrated comprehension of brain function by neuron-glia interaction	82
45	Visceral sensation and neural mechanism of emotion and empathy	83
46	Decision-making neuroscience	83
47	Kinetics of AMPA receptor and spine morphology in synaptic plasticity	84
48	Cause analysis and therapy development for psychiatric and nerve disease	84
49	Functional analysis of human brain and drug therapy of psychiatric disease	85
50	Structural analysis of the production process from the perspective of a network	85
51	Economic environment surrounding businesses	86
52	Metamaterials	86
53	Superconductive properties of magnesium diboride and its application	87
54	Attosecond quantum dynamics	87
55	Ferromagnetic semiconductor spintronics	88
56	Quantum information control with multidimensional photon	88
57	Electrical control of spin in semiconductors / quantum computer using solid state components	89
58	High-temperature superconductivity spectroscopy / new electron phase	89
59	High energy density science	90
60	Complex networks	90
61	Quantum information/communication, optical nanoscience	91
62	Hadron spectroscopy	91

ID No.	Name of Research area	Page
63	New quantum condensed phase where substances strongly interact with each other	92
64	Search for quark matter through high-energy nuclear collision	92
65	Brane cosmology from the perspective of duality of anti de sitter space and conformal field theory	93
66	Explore physics beyond the standard model from flavor physics of B meson and neutrino, dark matter and muon anomalous magnetic efficiency	93
67	Field theory on noncommutative space	94
68	Verification and integrability of AdS/CFT correspondence	94
69	Observational cosmology and an elementary model for it	95
70	High-dimensional black holes	95
71	Nanofiber technology with the electro-spinning process and tissue engineering research	96
72	Study of solar cells using inorganic oxides, organic-inorganic hybrids or organic polymers	96
73	Ultra fine crystal grain / macrostrain process	97
74	Space-time code	97
75	Multifunctional signature / multifunctional coding	98
76	Interactome analysis	98
77	Molecule-based nano-quantum magnet	99
78	Macromolecule nanocomposite	99
79	Living radical polymerization	100
80	Construction of artificial photosynthesis model mimicking antenna system and charge separation system	100
81	Porous coordination polymer	101
82	Retrieval of binding specificity of sugar chain recognition protein by neoglycolipid sugar chain microarray	101
83	Activation of oxygen molecule by metalloenzyme	102
84	Protein folding	102
85	Ionic liquid	103
86	Study on supramolecular nanodevice by molecular machine and single-molecule conductor	103
87	DNA-nanomaterial and nanodevice	104
88	Catalytic asymmetric addition reaction of carbon nucleophile	104
89	Bioimaging probe	105
90	Synthetic polymer-immobilized catalyst technology	105
91	Catalytic asymmetric synthesis	106
92	Molecular conversion reaction using transition metal catalyst	106
93	Pathogenic mechanism and preventive/therapeutic method of severe acute respiratory syndrome (SARS)	107

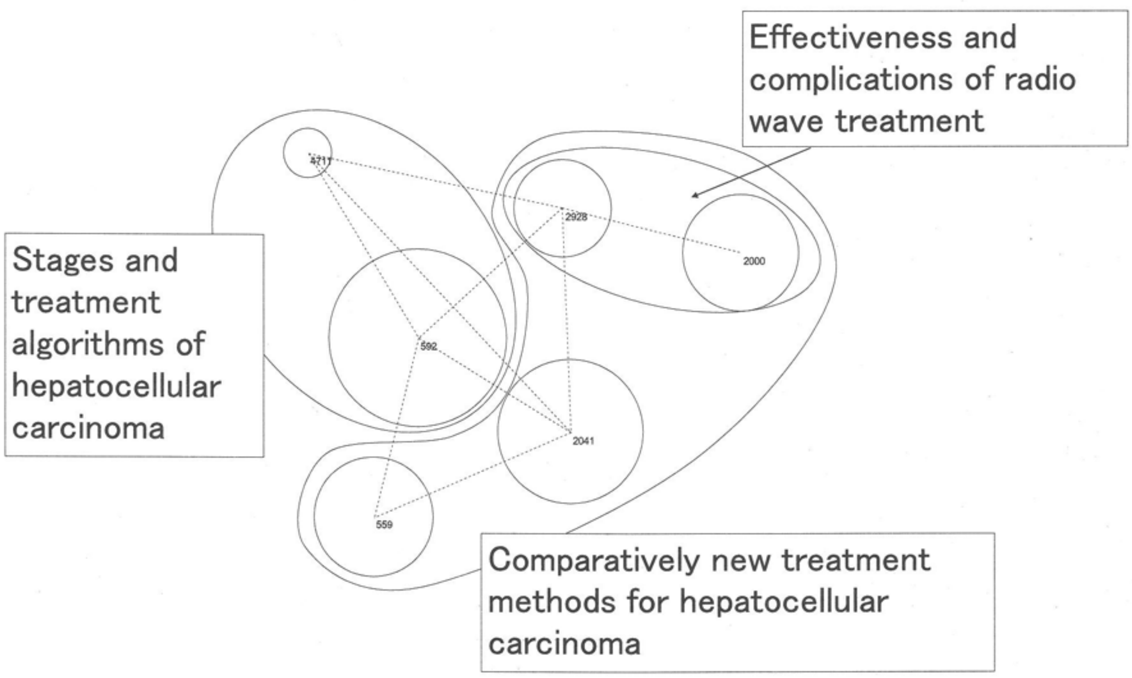
Name of RA	Drug-eluting stent	RA ID	1

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
10 (1)	48(0)	2198	5933	2004.0



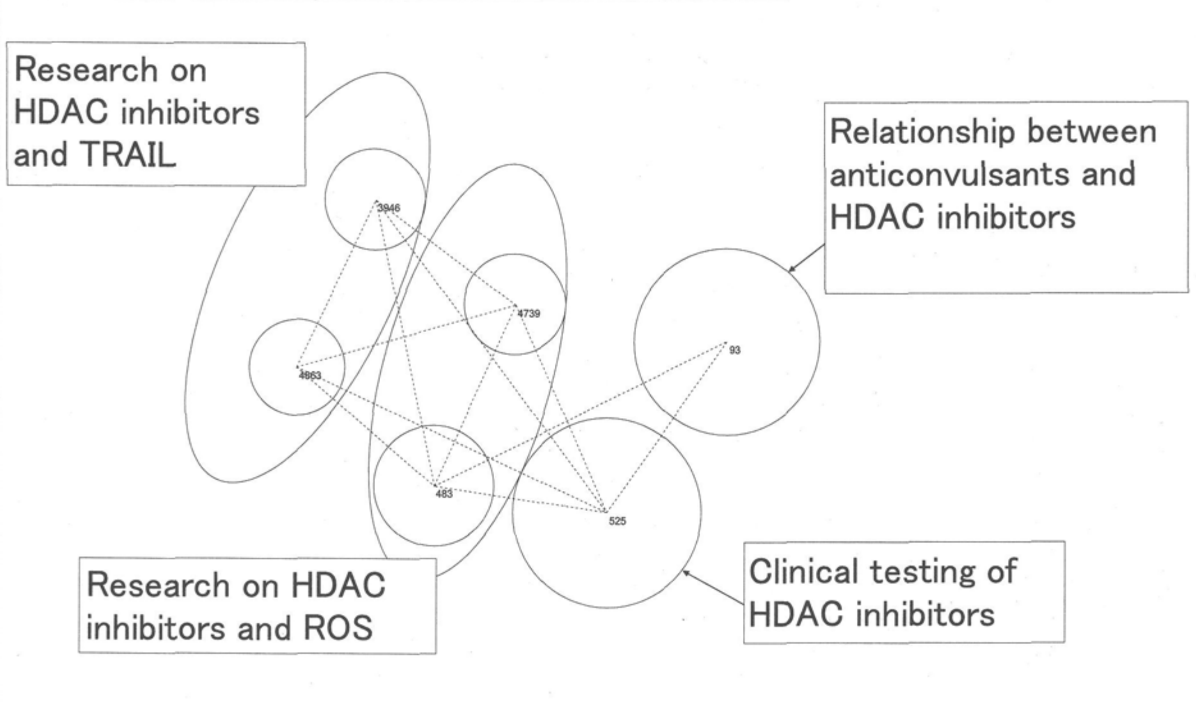
Name of RA	Stage classification, treatment algorithm and outcome prediction of hepatocarcinoma	RA ID	2

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(0)	14(1)	1155	2030	2002.6



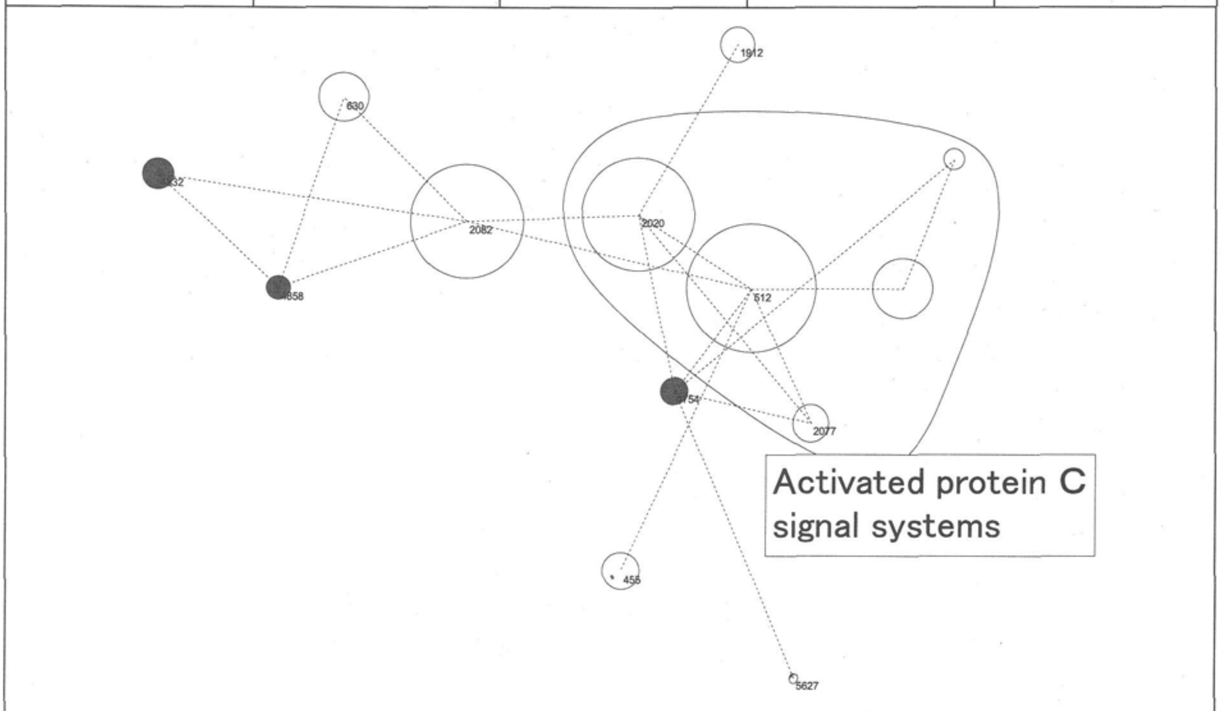
Name of RA	Basic and clinical study on antitumor effect of histone deacetylase (HDAC) inhibitors	RA ID	3

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(0)	16(1)	917	1702	2003.3



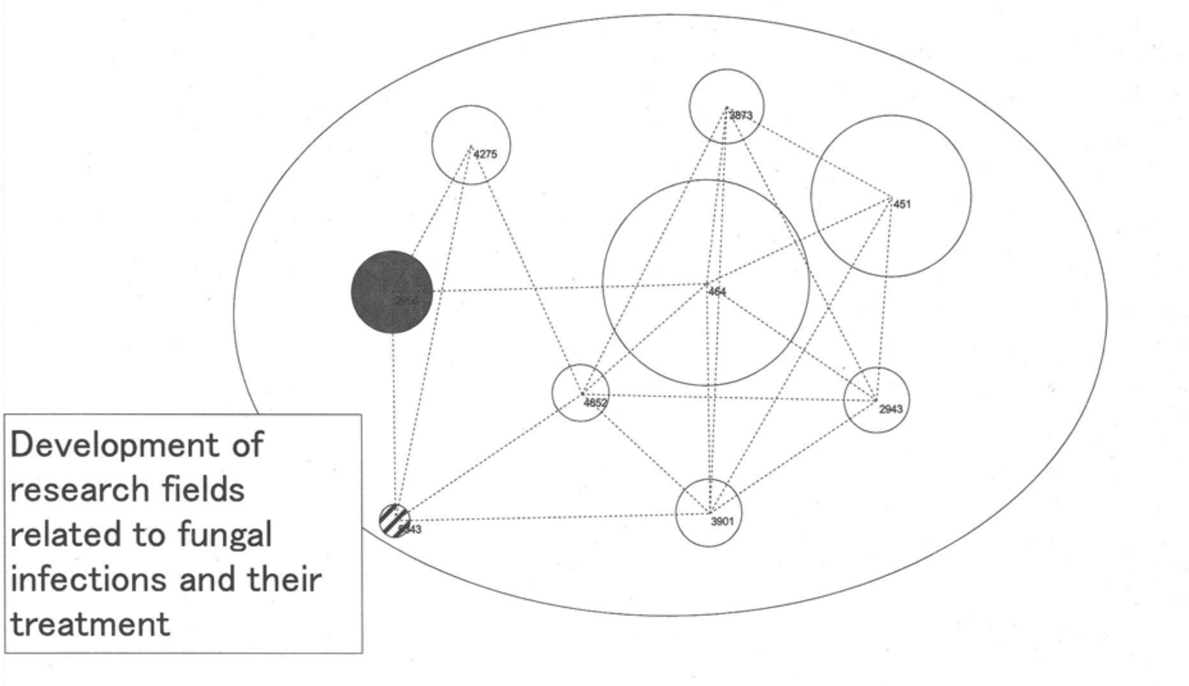
Name of RA	Biodefense by blood coagulation regulatory system	RA ID	4

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13(3)	36(2)	3925	7139	2003.2



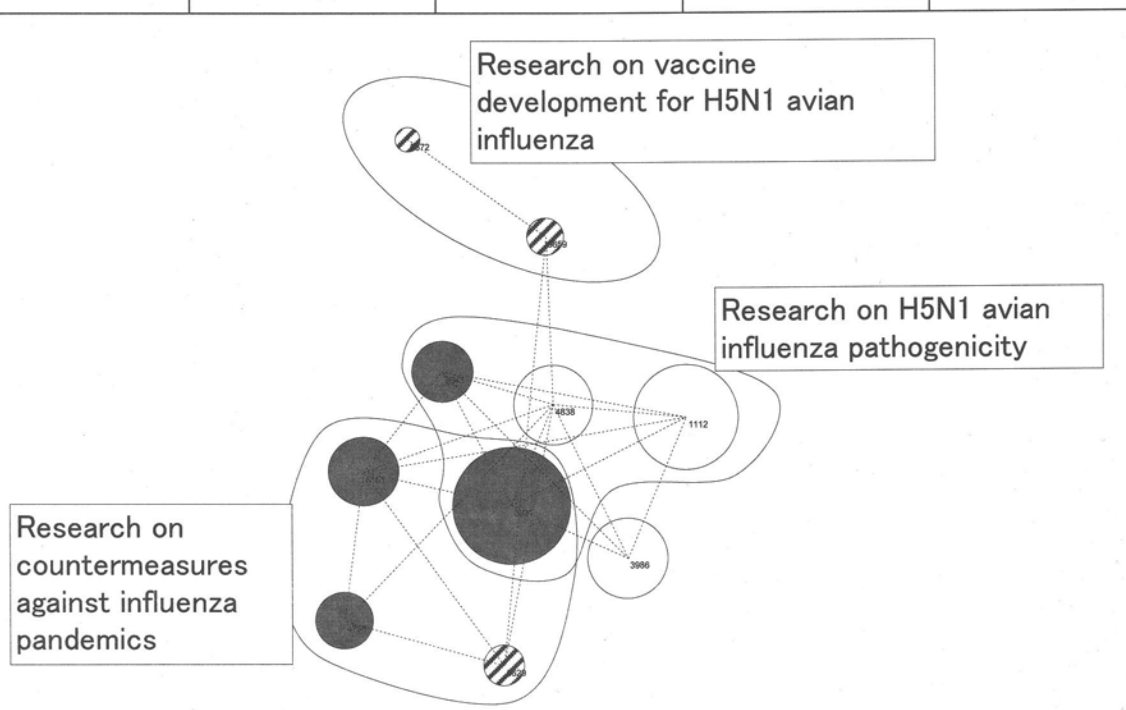
Name of RA	Deep mycosis	RA ID	5

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9(1)	45(2)	1630	3848	2004.0

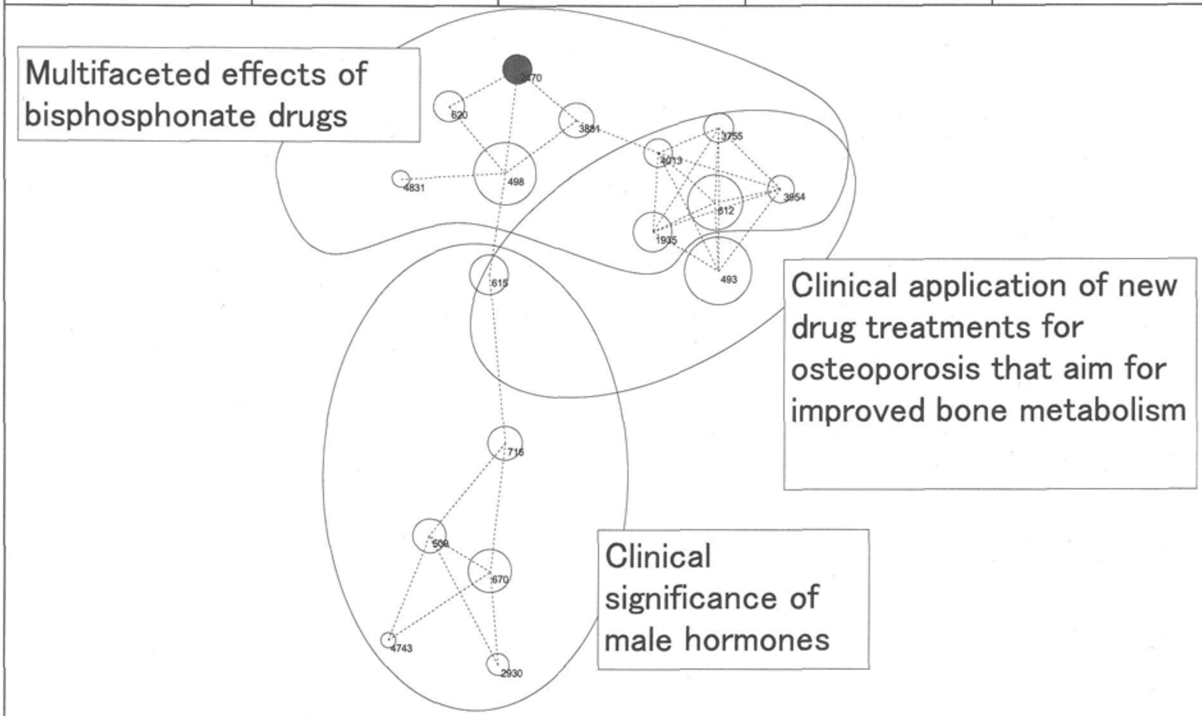


Name of RA	Study on highly pathogenic avian influenza subtype H5N1	RA ID	6

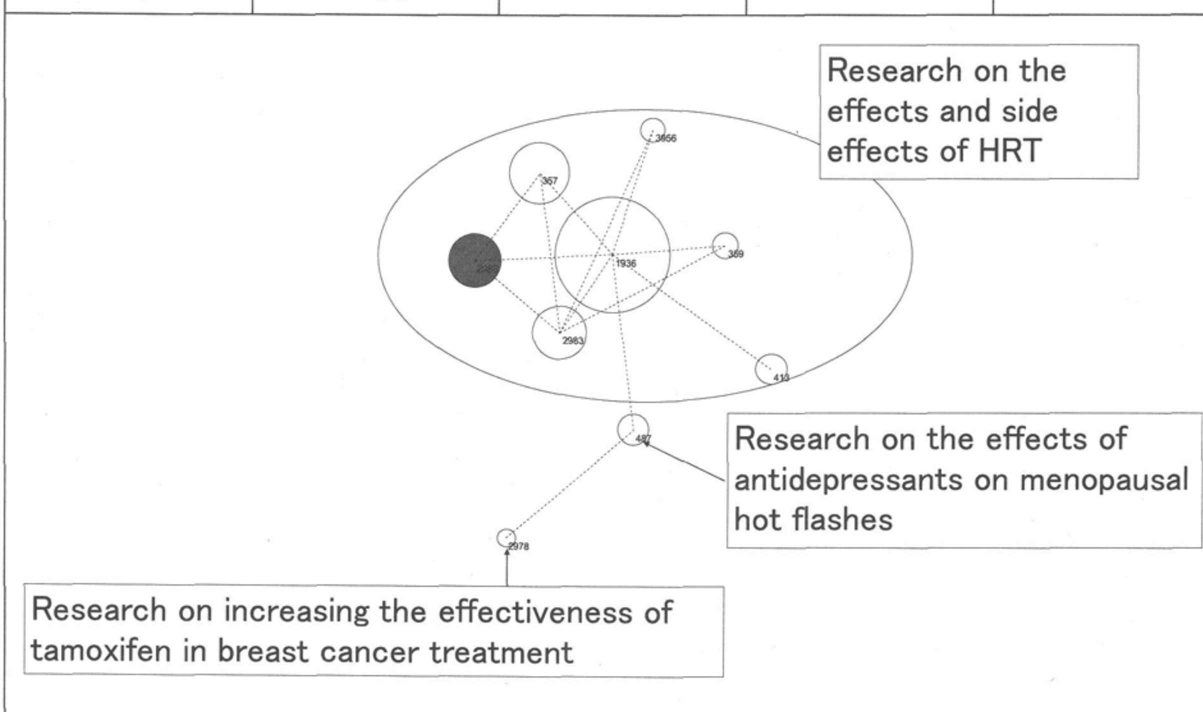
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
10(4)	35(1)	851	1863	2004.8



Name of RA	Bone metabolism control by drug and its clinical application		RA ID	7
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
17(1)	64(0)	3185	6470	2003.4

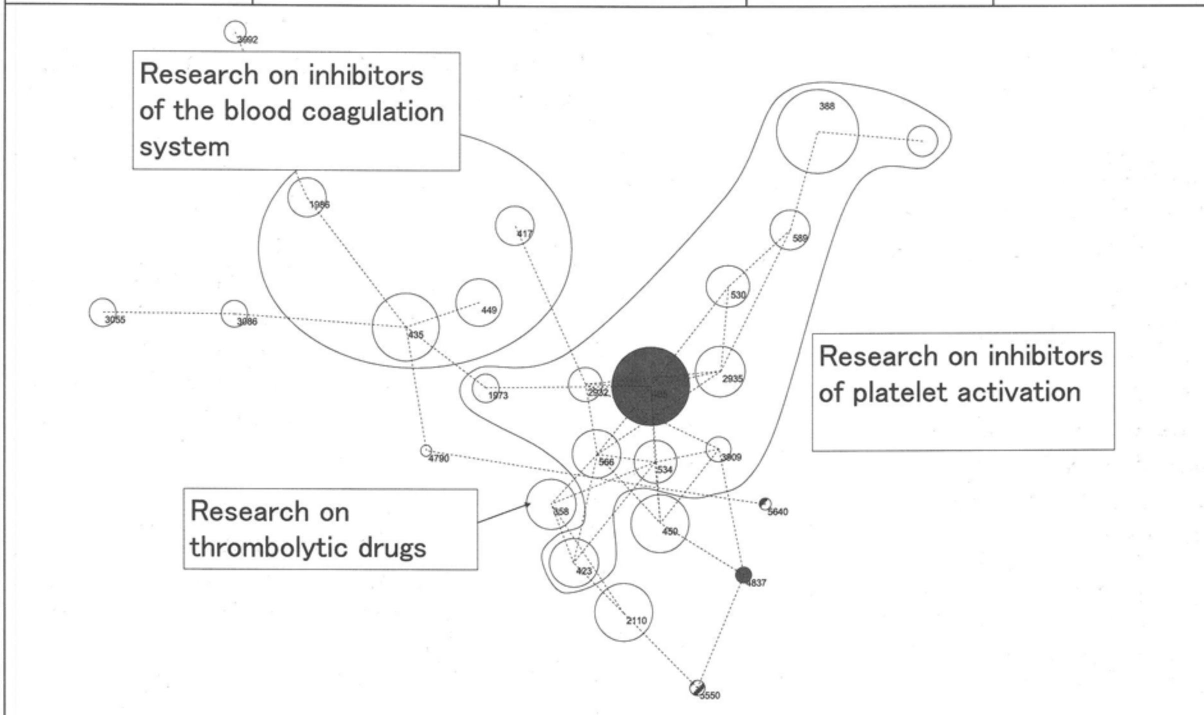


Name of RA	History of effect and adverse effect of hormone replacement therapy (HRT)		RA ID	8
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9(1)	34(0)	4991	10040	2002.5



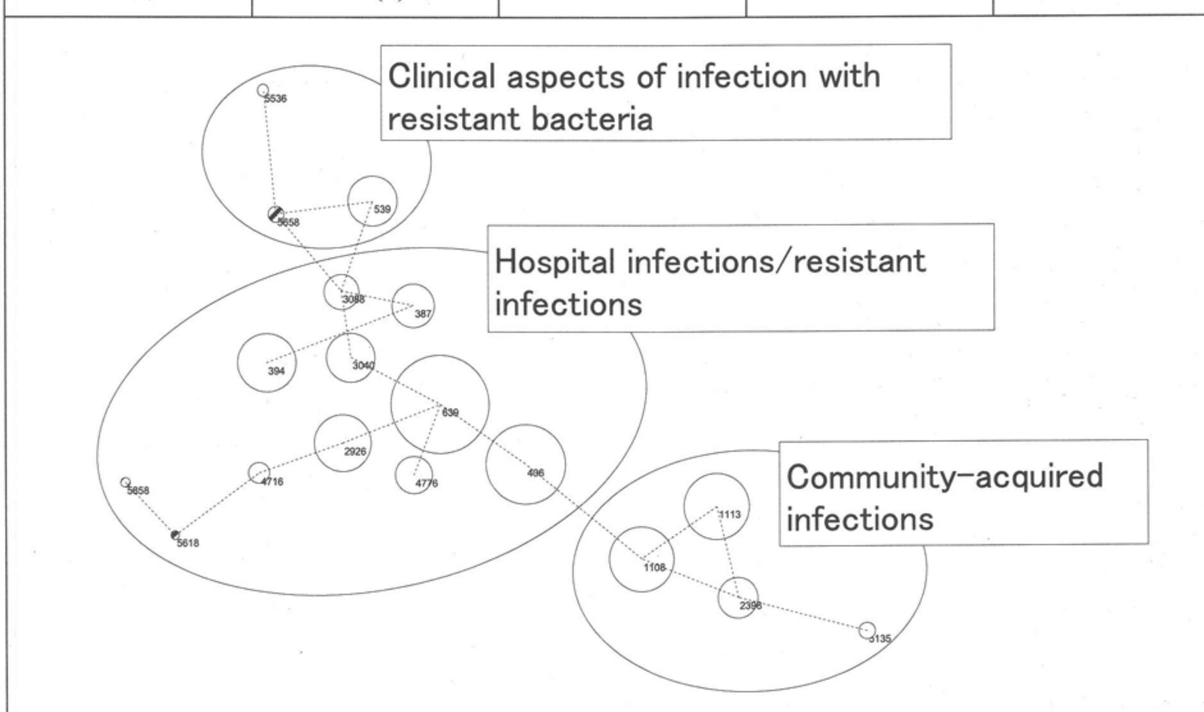
Name of RA	Thromboembolism study	RA ID	9

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
26(2)	146(2)	7534	19491	2003.3

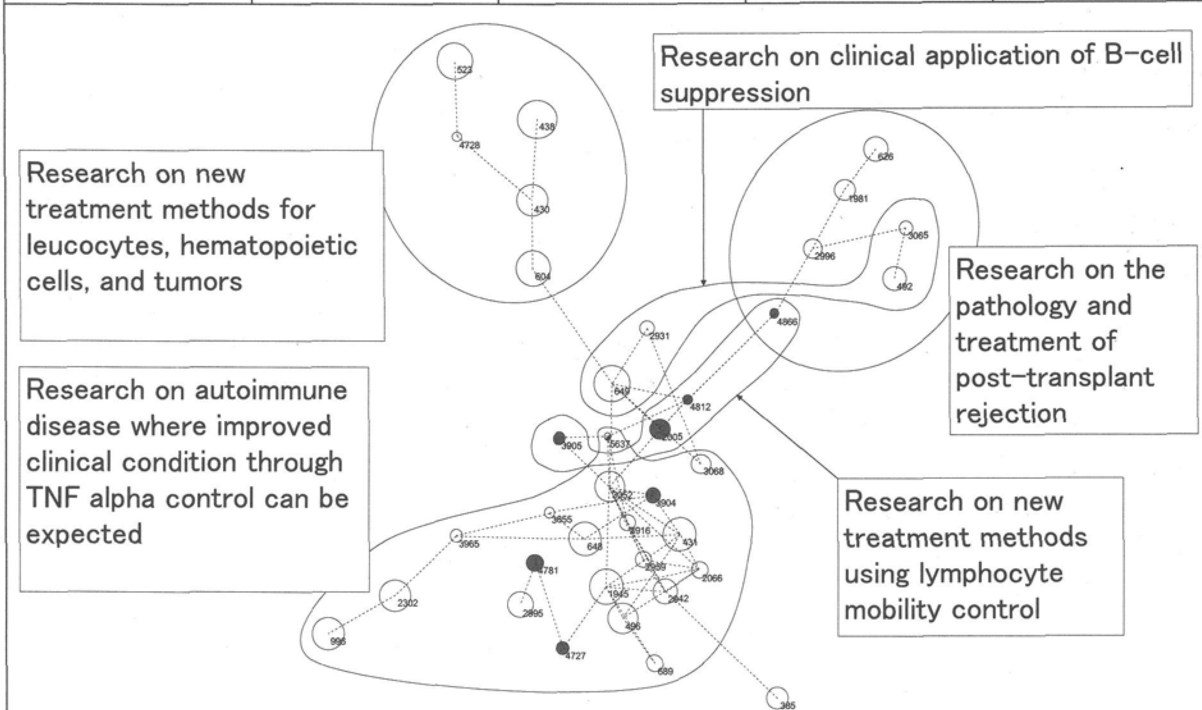


Name of RA	Conventional infectious diseases / resistant bacterial infectious diseases	RA ID	10

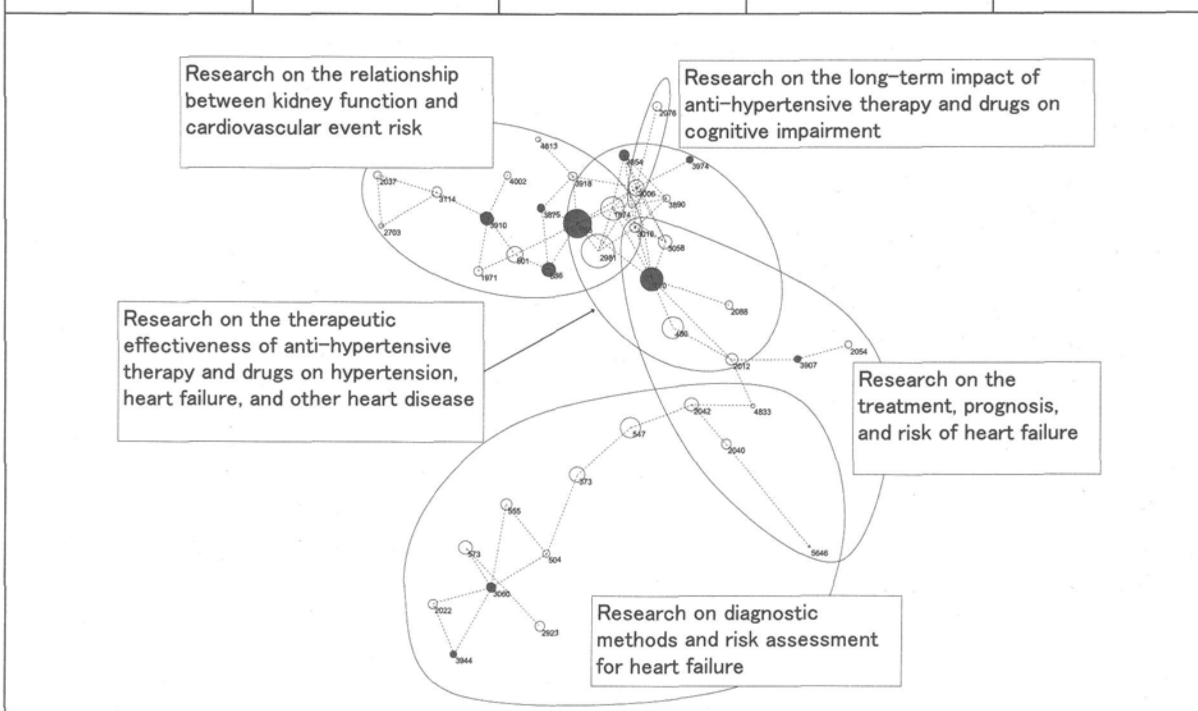
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
18(0)	59(9)	3438	7247	2003.2



Name of RA	Control of lymphocyte-activating organ dysfunction by antibody therapy and others		RA ID	11
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
37(7)	222(1)	9497	22745	2003.6

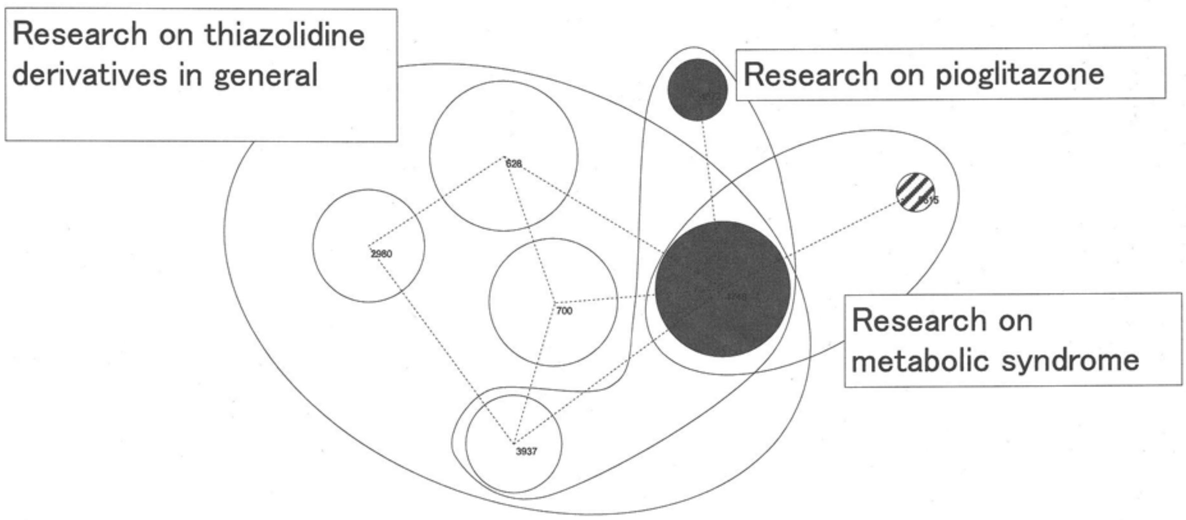


Name of RA	Study on risk assessment, therapeutic effect, and diagnostic method for cardiac diseases		RA ID	12
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
40(10)	114(2)	11166	23693	2002.9



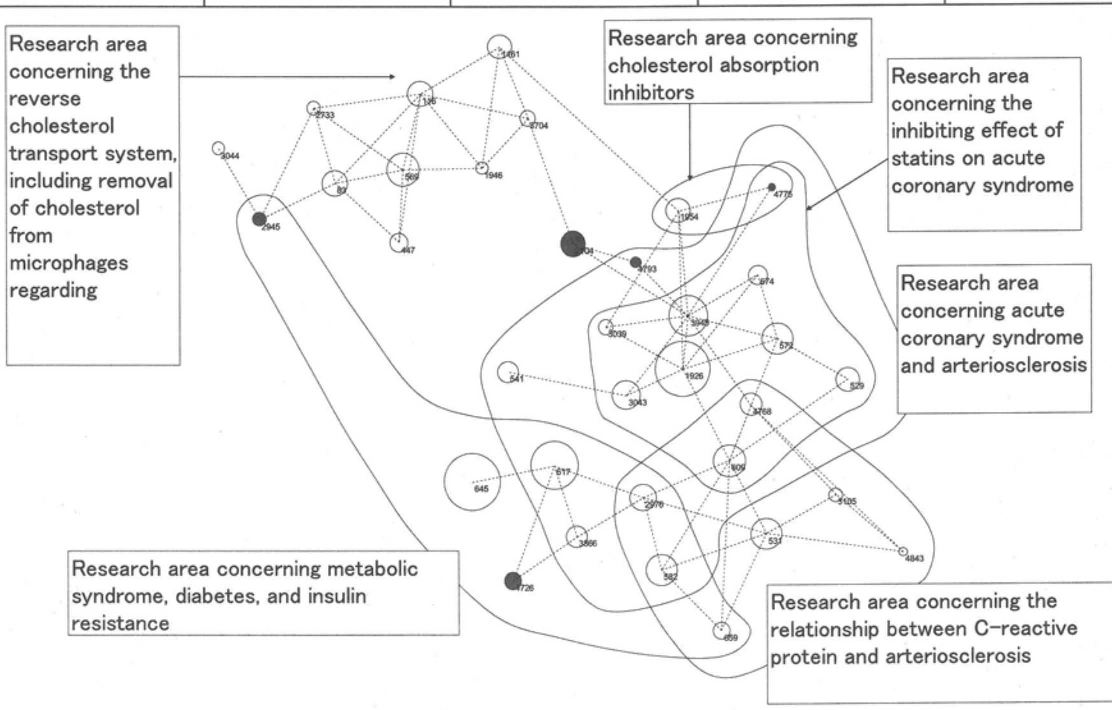
Name of RA	Drug therapy of diabetes / thiazolidine derivatives	RA ID	13

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7(2)	16(0)	639	1142	2003.6

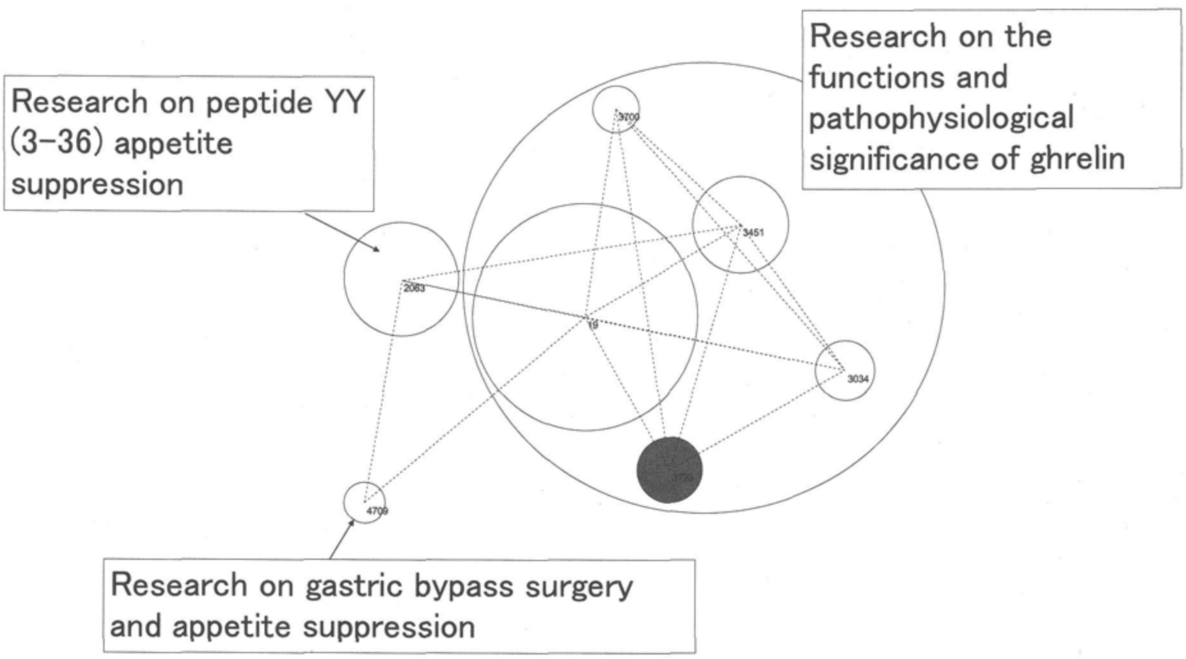


Name of RA	Arteriosclerosis, abnormal lipid metabolism and abnormal carbohydrate metabolism affecting the onset of acute coronary syndrome, and inhibitory effect of hypolipidemic agents and proglycemic agents on the onset of acute coronary syndrome	RA ID	14

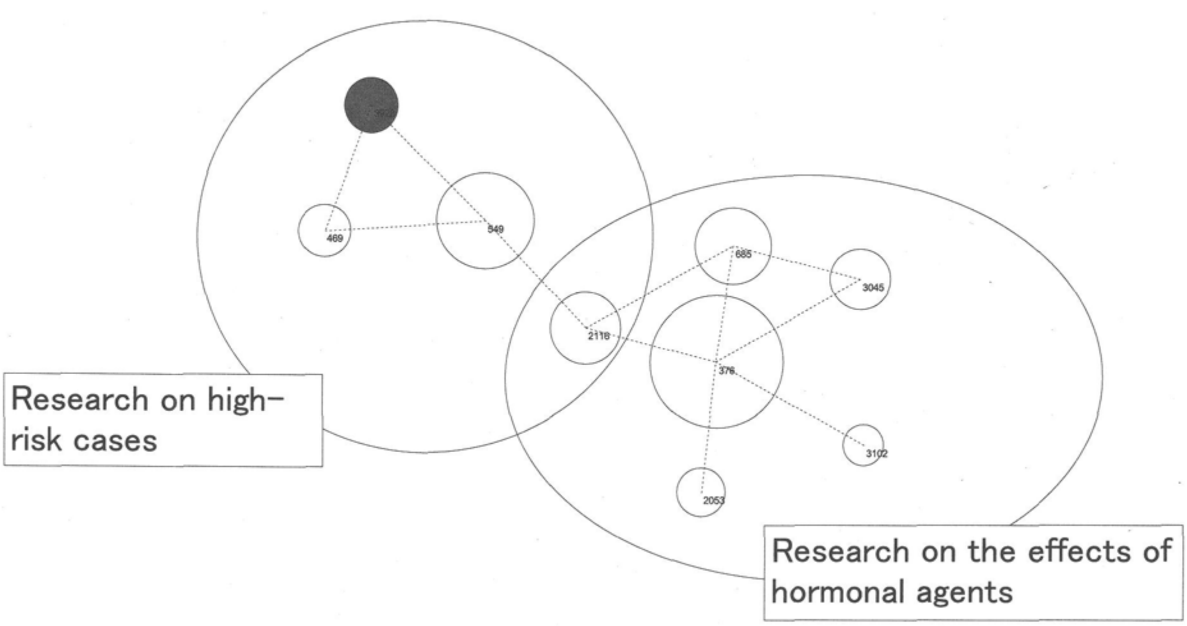
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
34(5)	130(6)	13583	30097	2002.9



Name of RA	Ghrelin / function and pathophysiological significance		RA ID	15
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7(1)	58(20)	2320	10427	2002.5

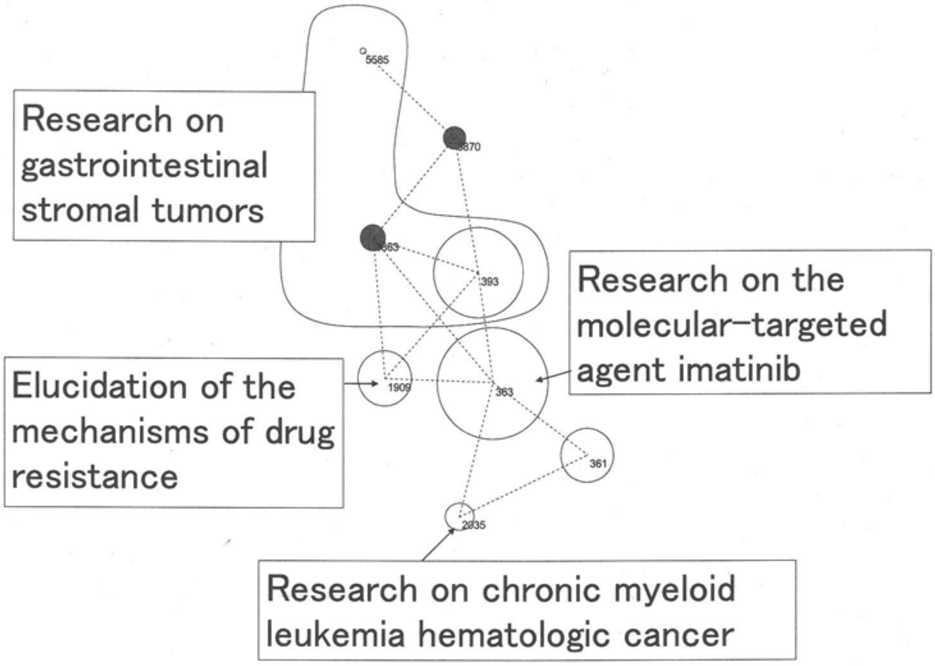


Name of RA	Hormone therapy / breast cancer prevention		RA ID	16
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9(1)	40(0)	2492	6171	2002.9



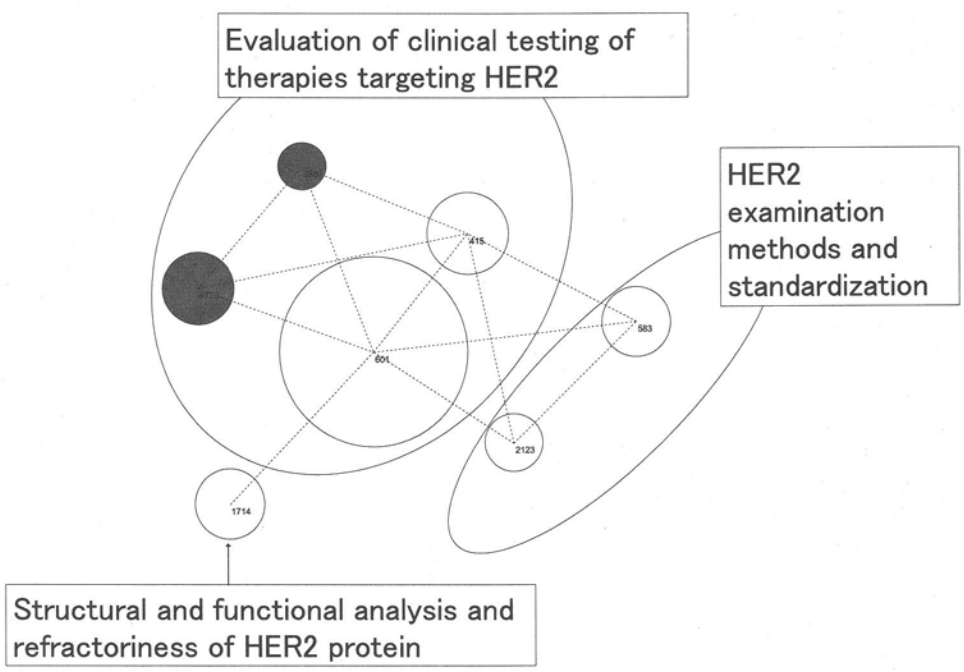
Name of RA	Molecular targeting therapy / type III tyrosine kinase-related tumor	RA ID	17

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(2)	79(1)	4811	15029	2003.0

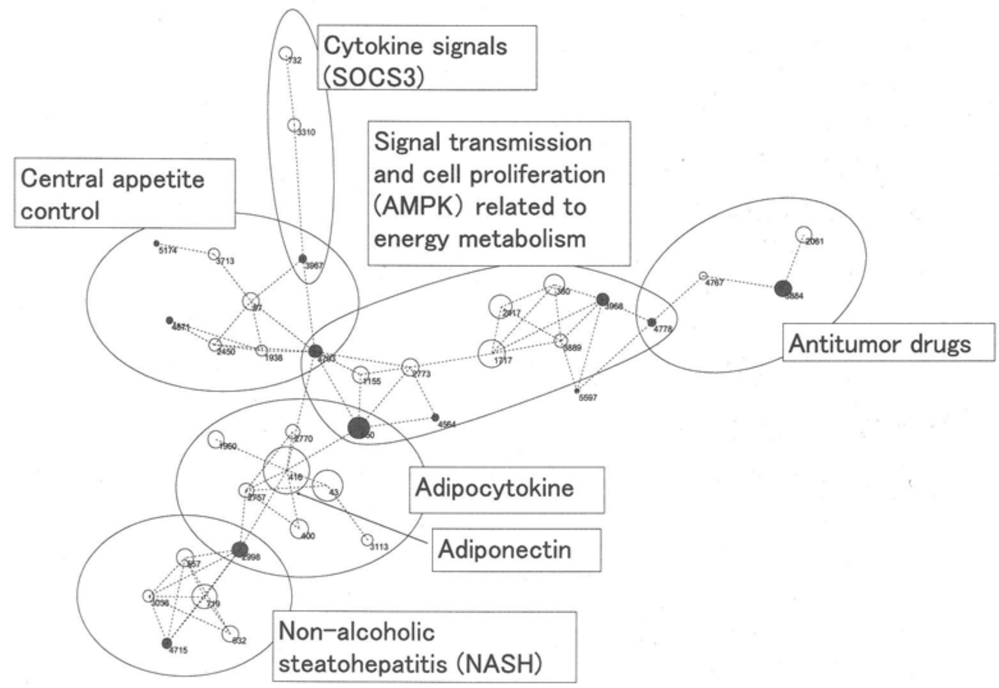


Name of RA	Basic and clinical study on antibody therapy for HER2 (human epidermal growth factor receptor 2) positive breast cancer	RA ID	18

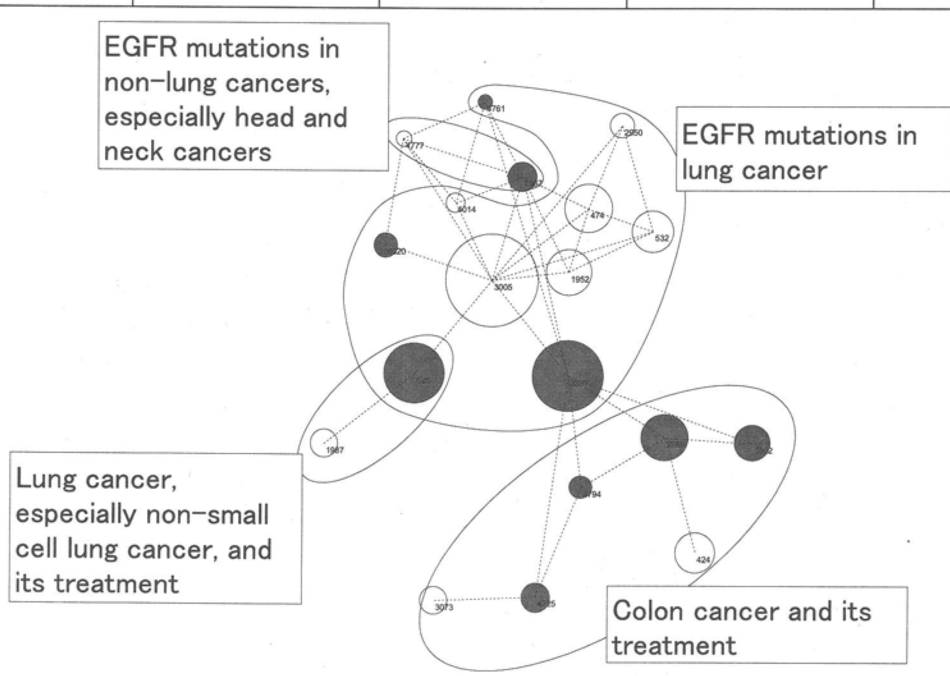
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7(2)	19(1)	2202	3814	2002.9



Name of RA	Obesity and diabetes		RA ID	19
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
37(11)	173(37)	8234	25791	2003.0

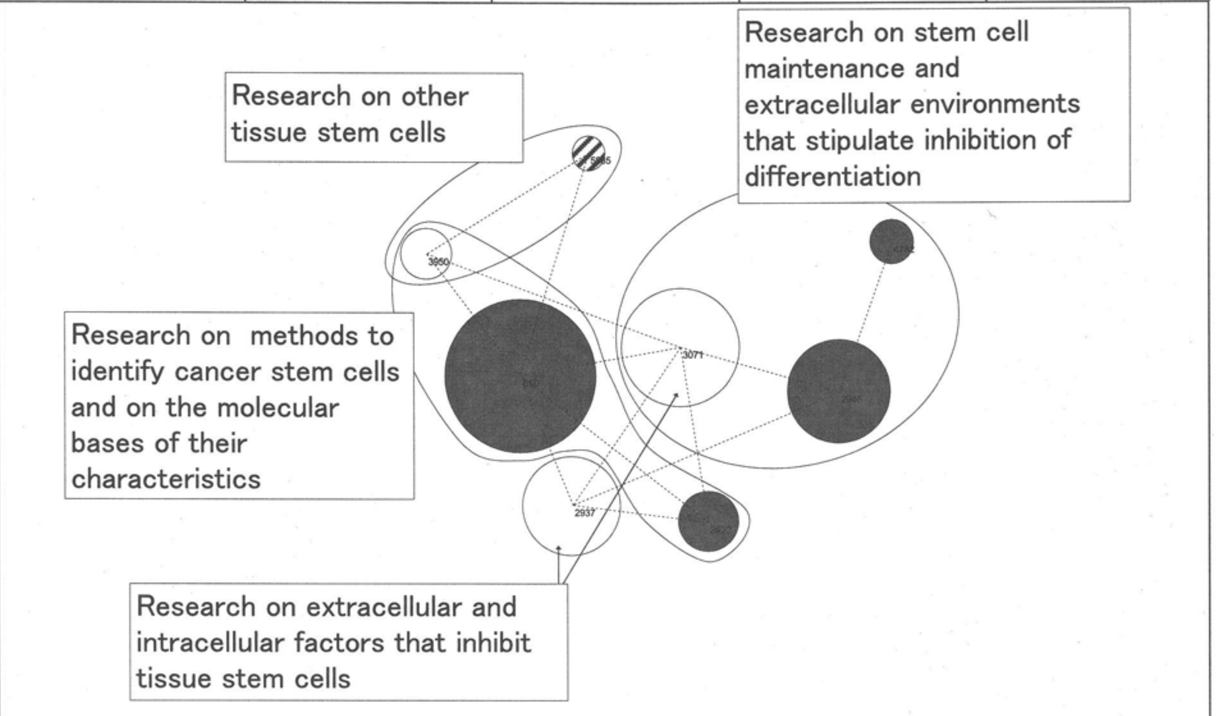


Name of RA	New development in molecular therapy targeting EGFR mutations and others		RA ID	20
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
19(9)	93(13)	5474	16420	2004.0



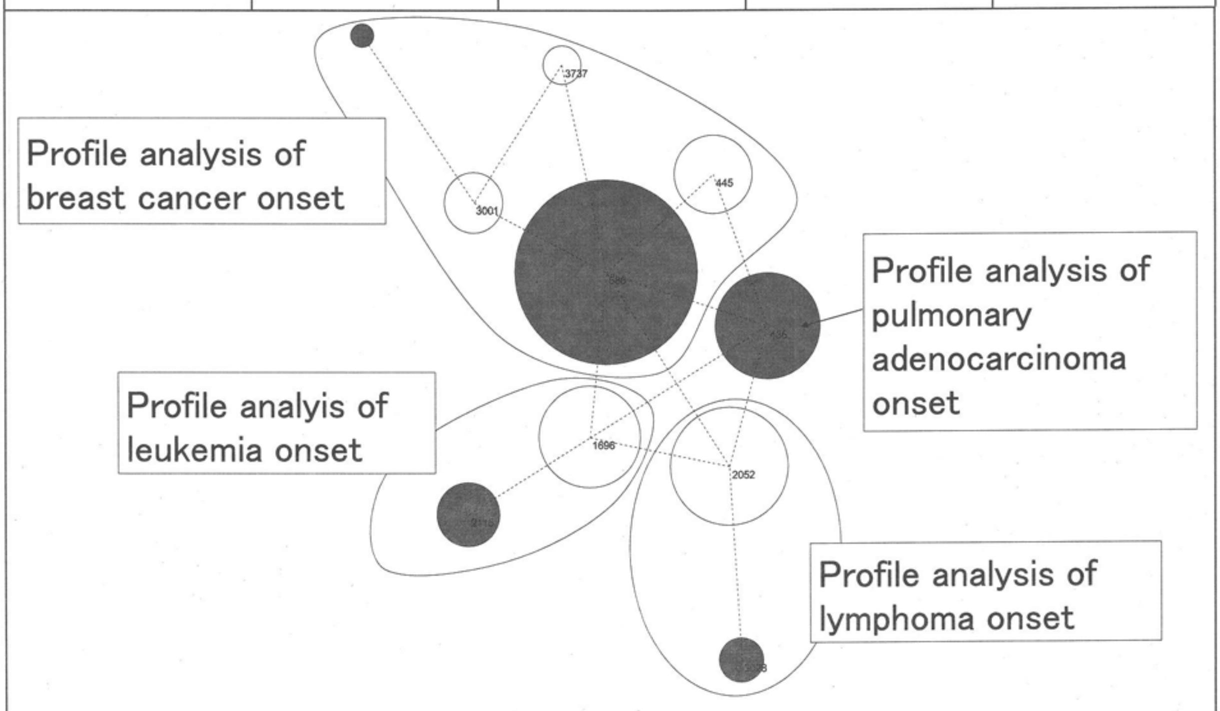
Name of RA	Study on regulation of tissue stem cell by extracellular environment and characteristics of cancer stem cell	RA ID	21

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(4)	27(3)	2090	4356	2003.9

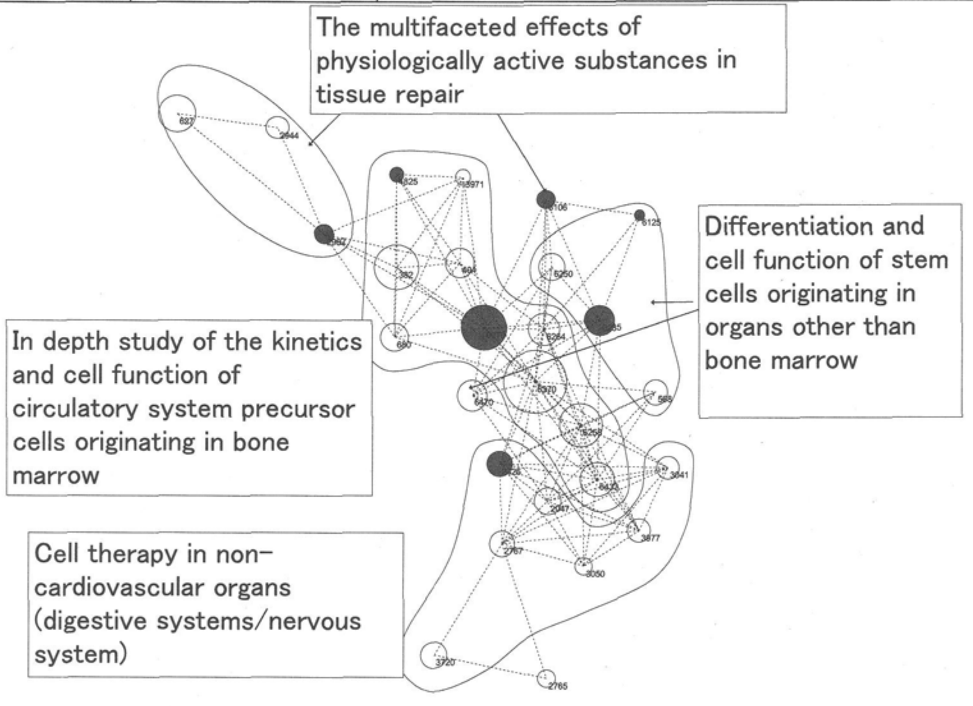


Name of RA	Cancer / gene expression profiling analysis	RA ID	22

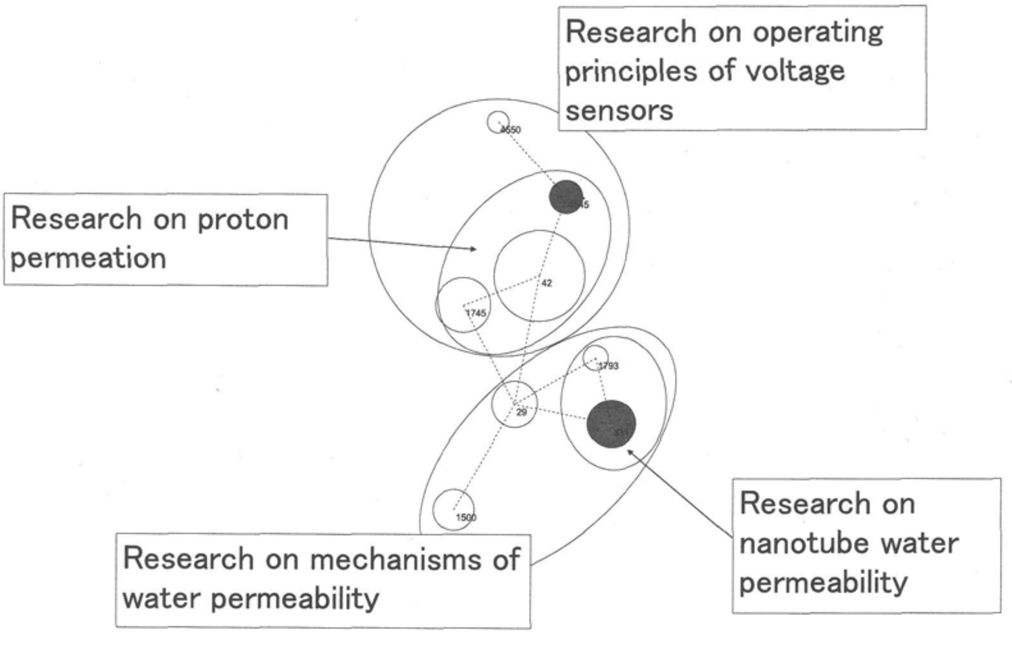
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
10(5)	31(0)	4415	8817	2002.8



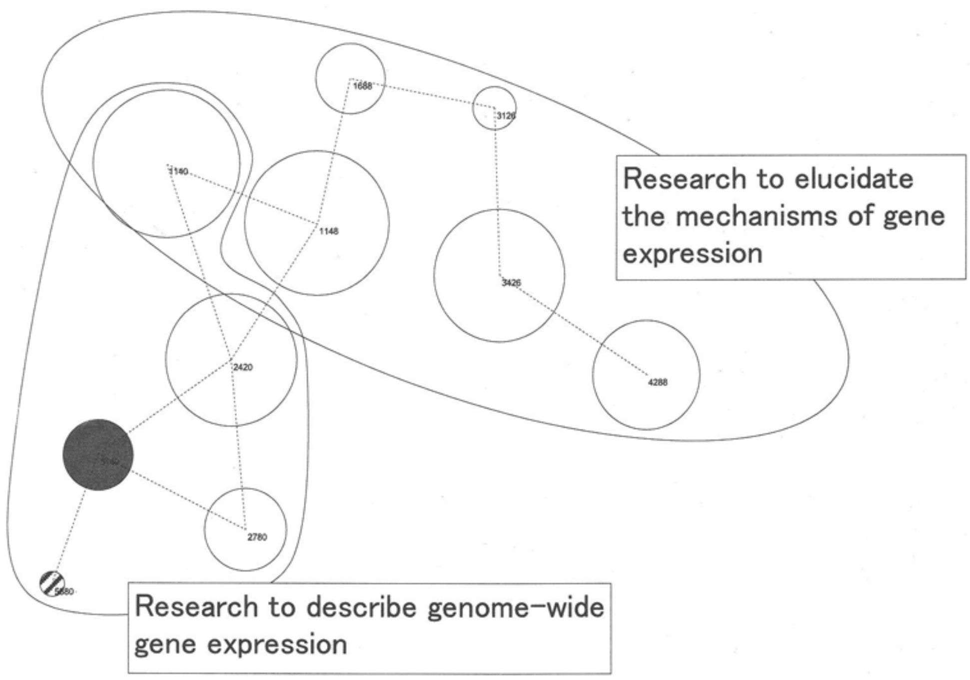
Name of RA	Biological elucidation and clinical application of damaged tissue repair mechanism		RA ID	23
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
27(7)	96(7)	5776	18389	2003.1



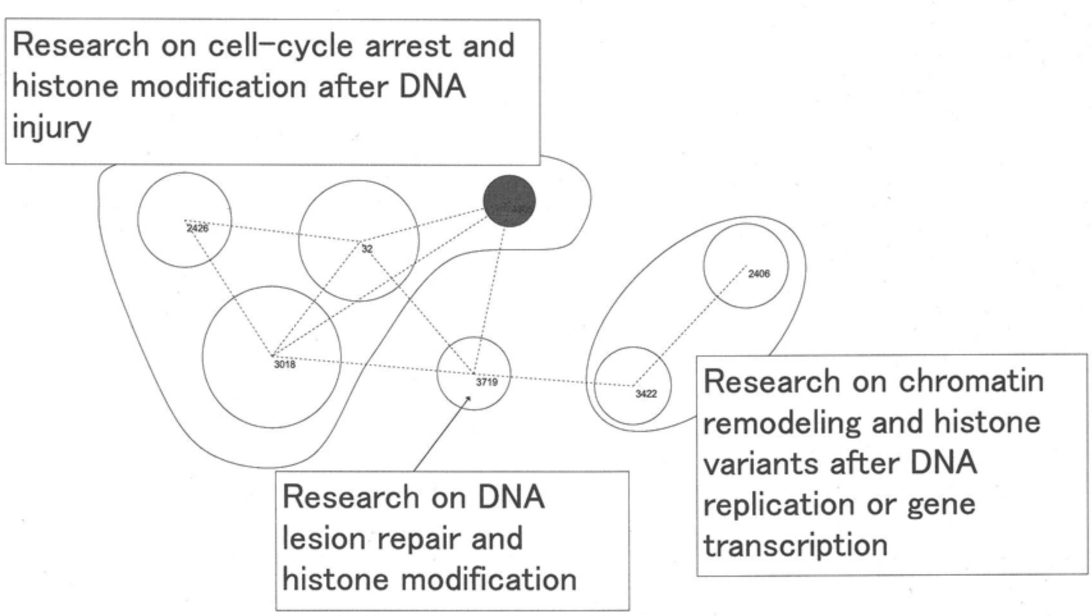
Name of RA	Elucidation of behavior principle of ion/water channel molecule		RA ID	24
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(2)	49(5)	2900	6218	2003.3



Name of RA	Genome-wide gene expression analysis and expression regulatory function analysis	RA ID	25	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
10(1)	26(3)	2783	4710	2003.3

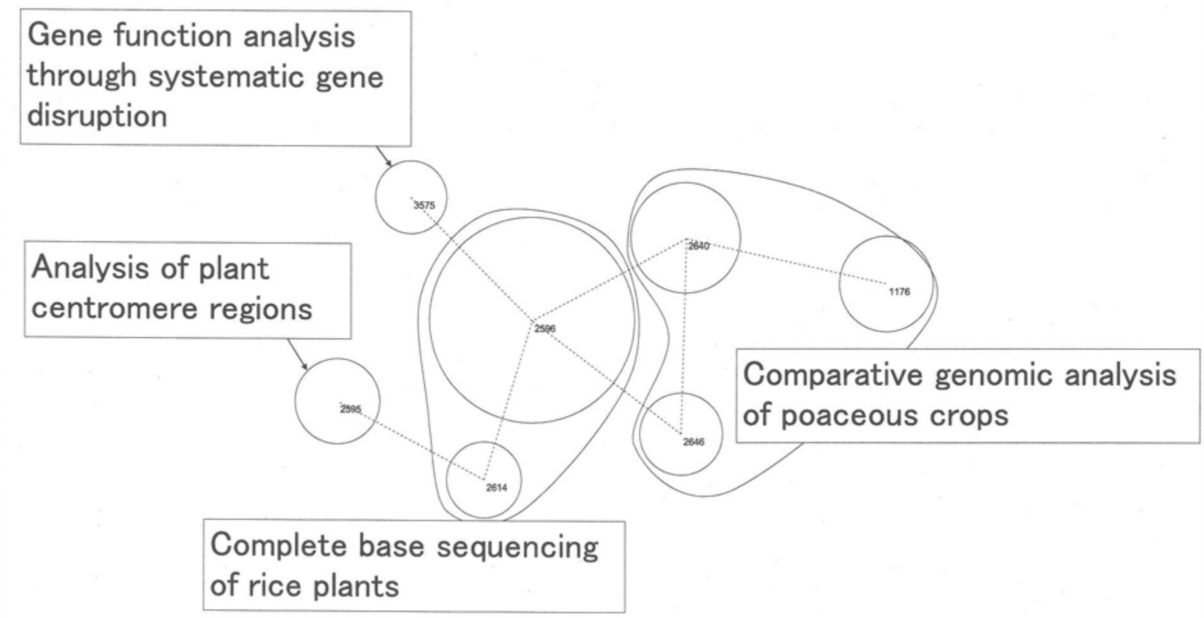


Name of RA	Histone diversity and life phenomena	RA ID	26	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7(1)	35(2)	2347	5138	2003.6



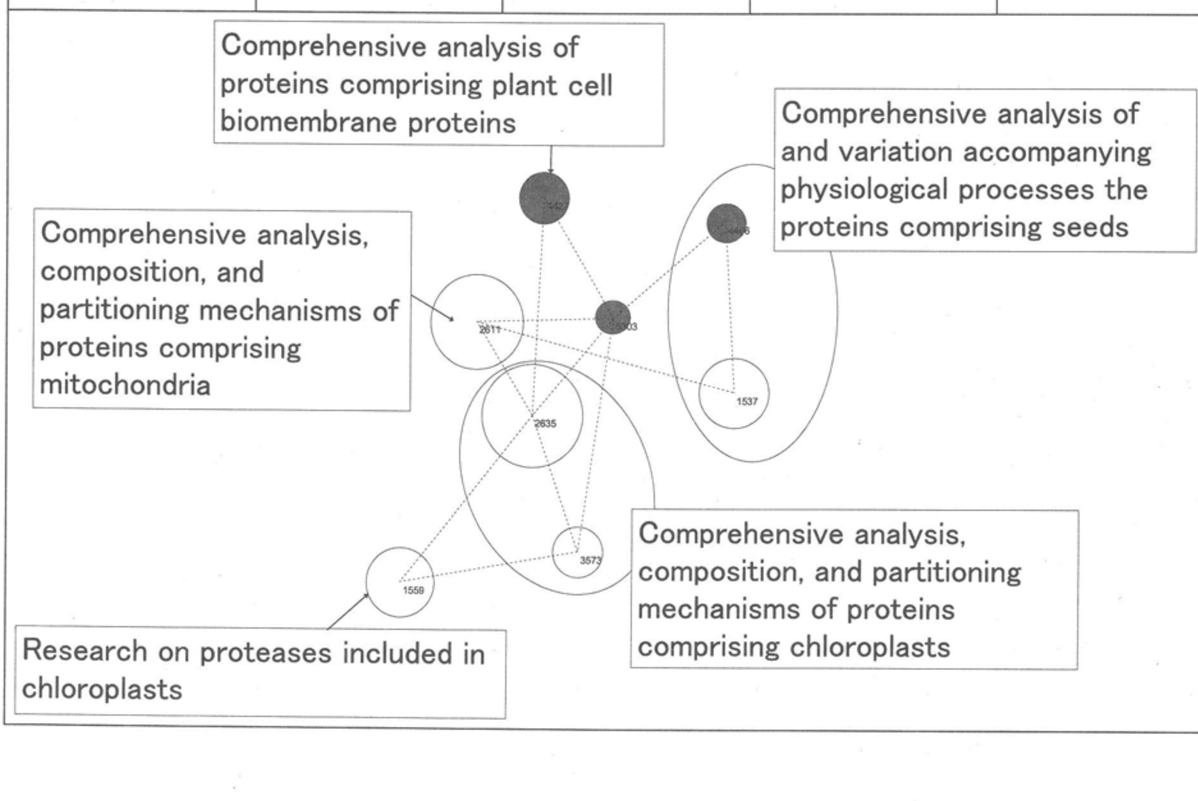
Name of RA	Plant functional genomics study	RA ID	27

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7(0)	35(5)	2034	4382	2002.9

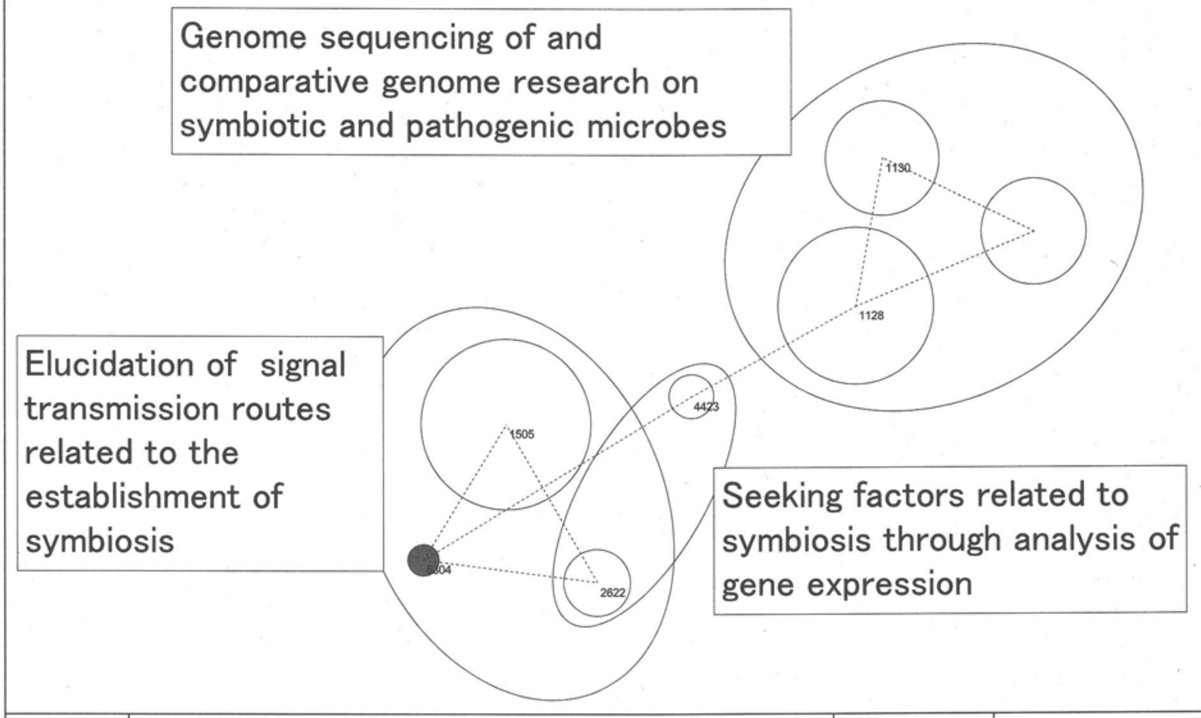


Name of RA	Plant cell proteome analysis	RA ID	28

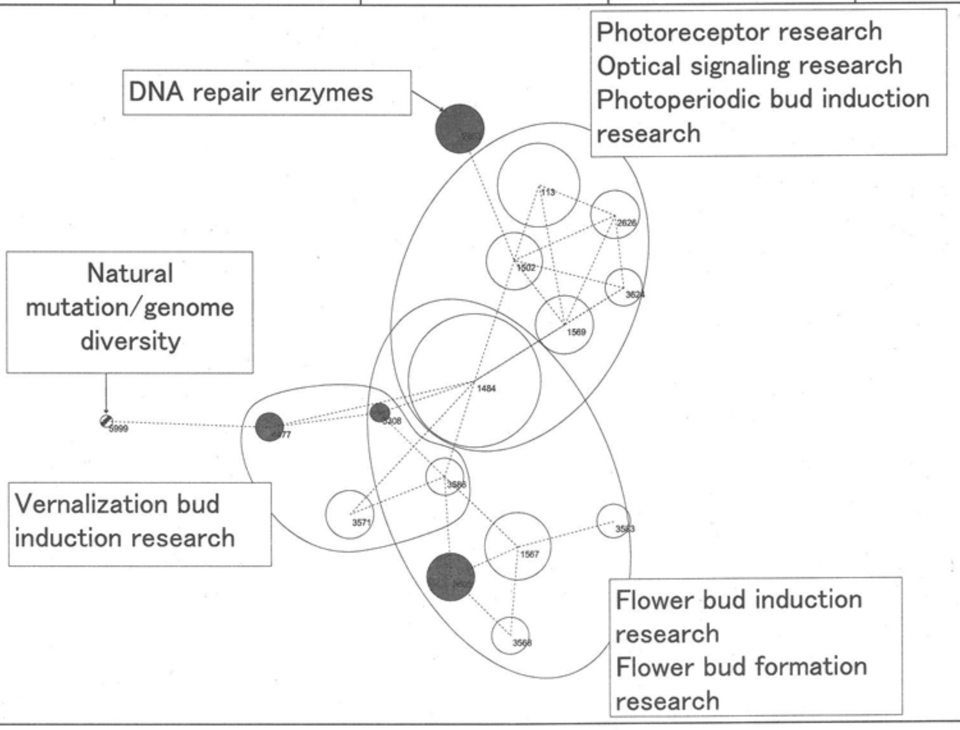
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(3)	25(3)	724	1390	2003.2



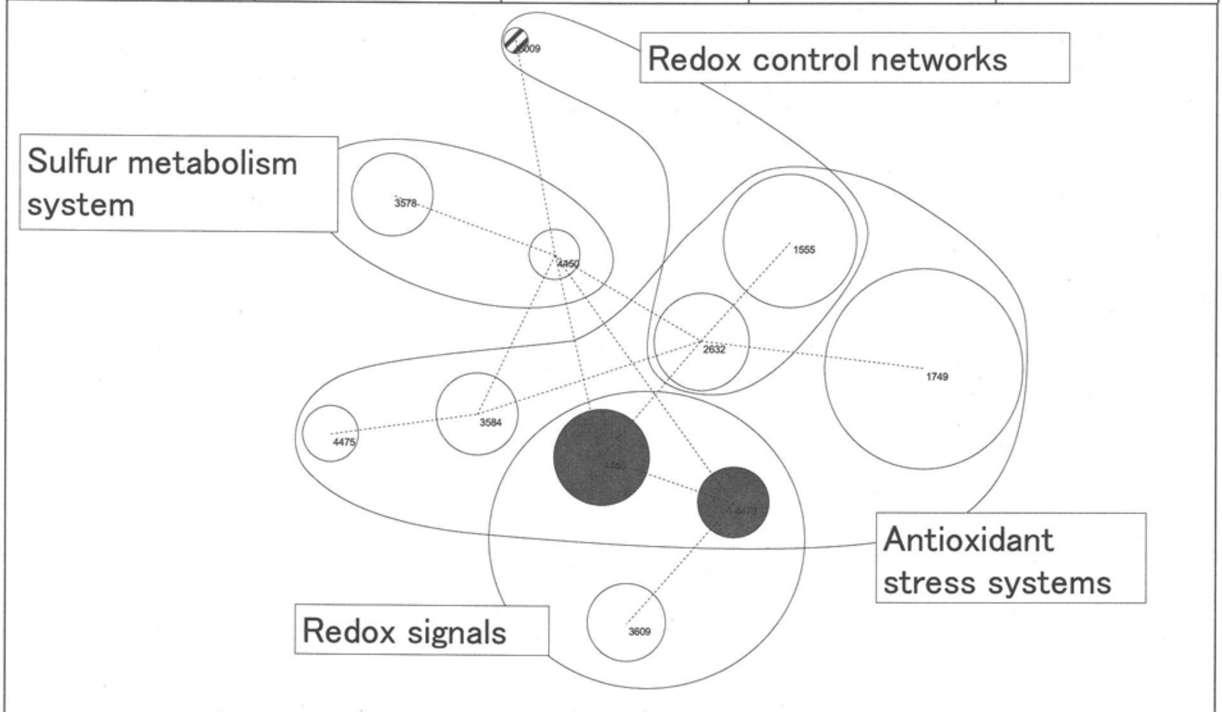
Name of RA	Plant-microorganism interaction		RA ID	29
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7(1)	50(11)	1524	3586	2003.4



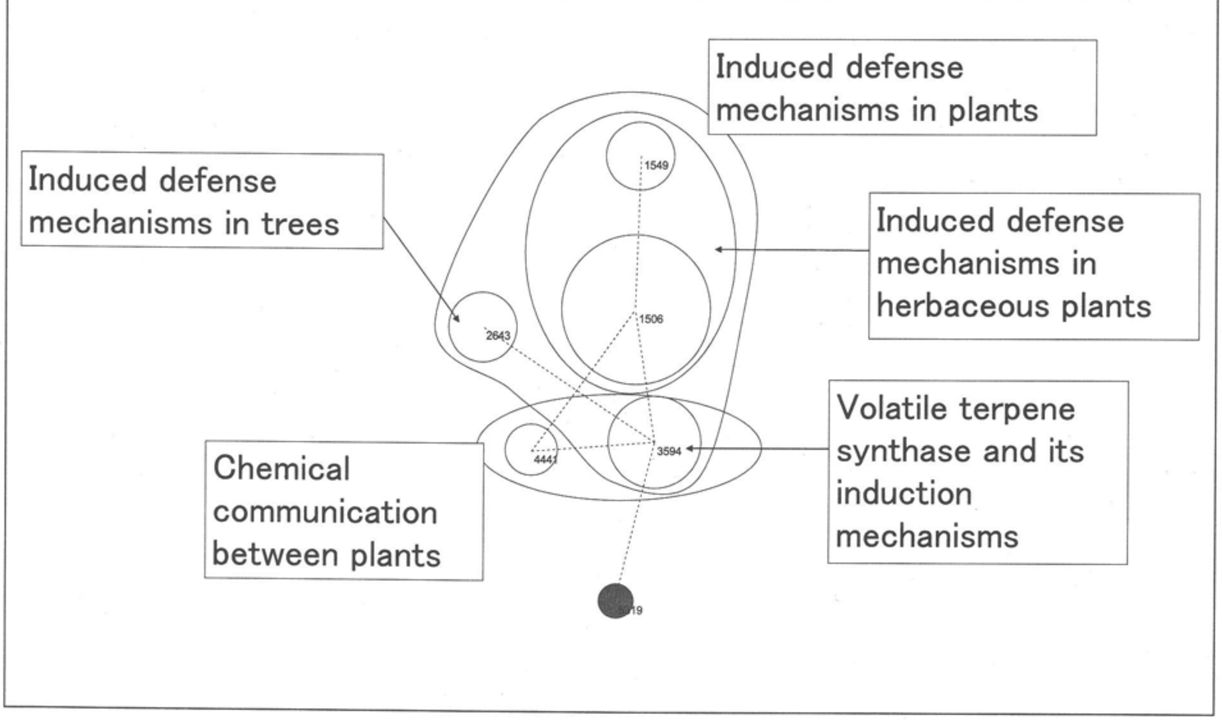
Name of RA	Light environment response control / flower bud formation mechanism in plant		RA ID	30
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
16(4)	102(18)	2392	6984	2002.9



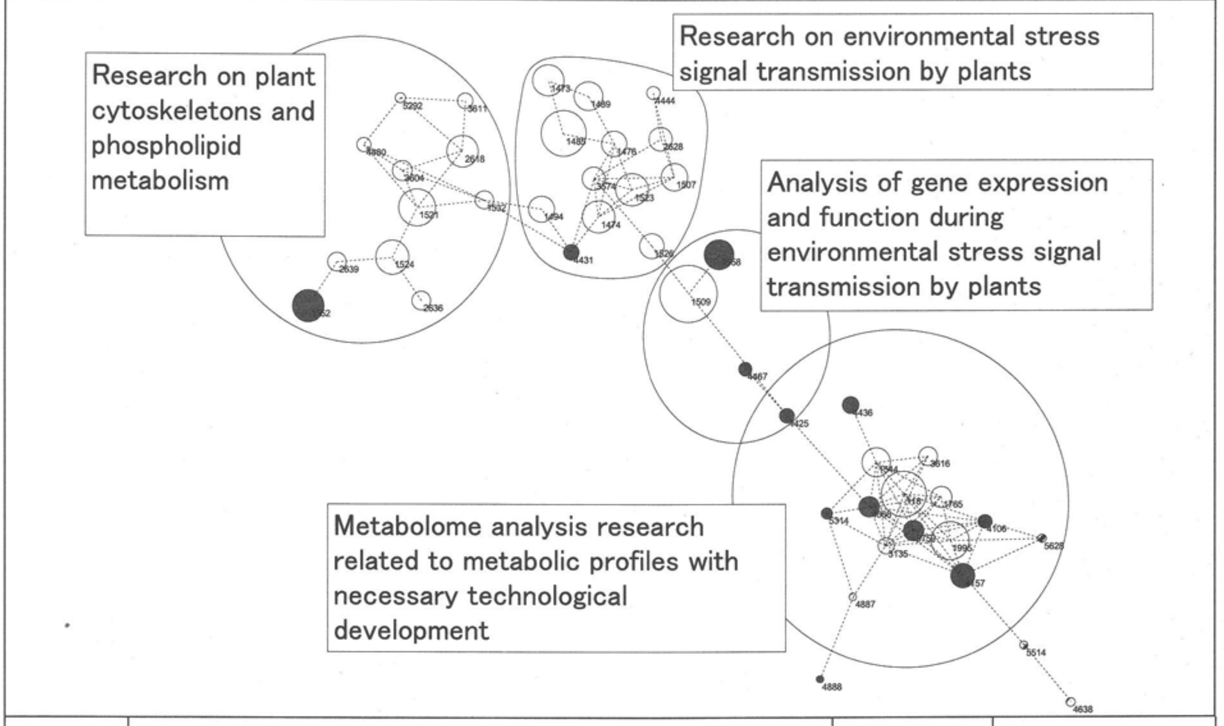
Name of RA	Redox regulation		RA ID	31
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
11(2)	38(5)	1202	2275	2003.5



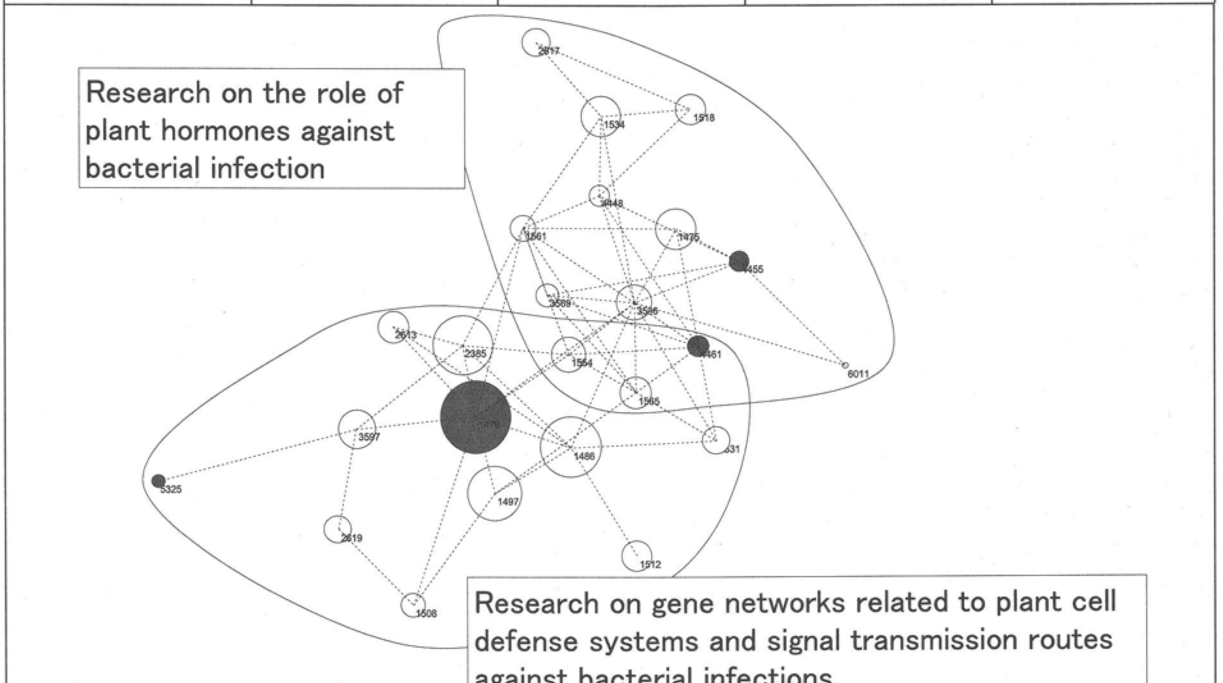
Name of RA	Inducible defense mechanism in plant		RA ID	32
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(1)	34(0)	720	1388	2003.8



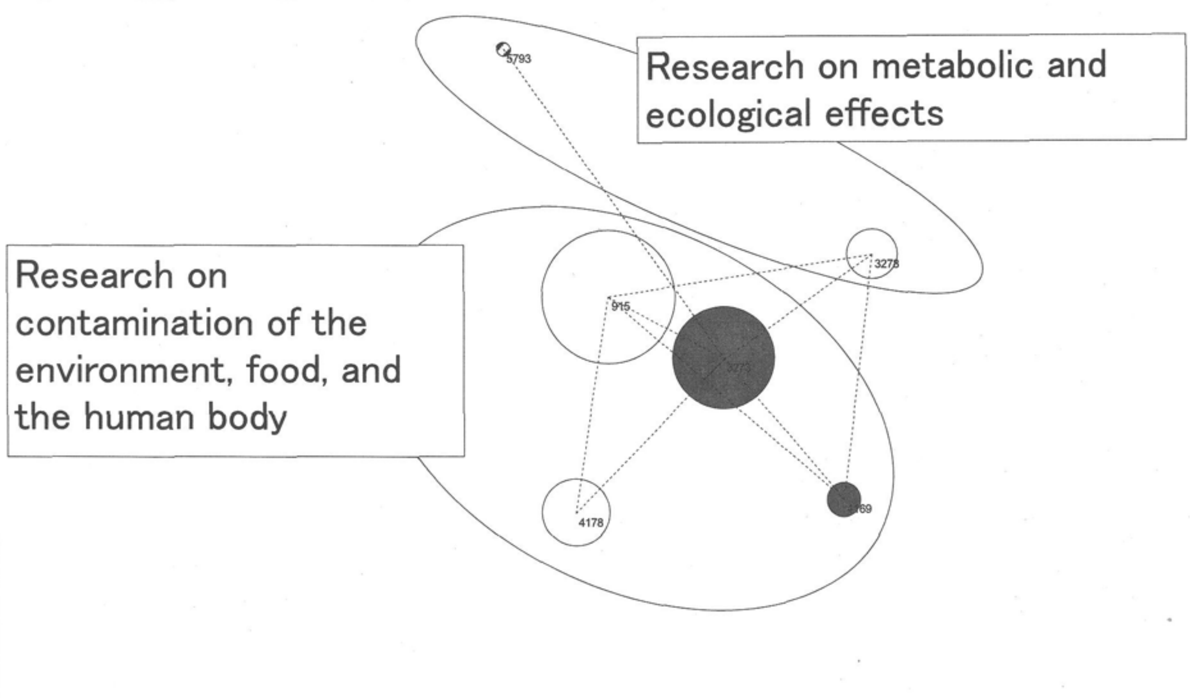
Name of RA	Environmental stress response / metabolic profiling / cellular structure and phospholipid metabolism in plant		RA ID	33
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
45(12)	221(22)	5058	11750	2003.5



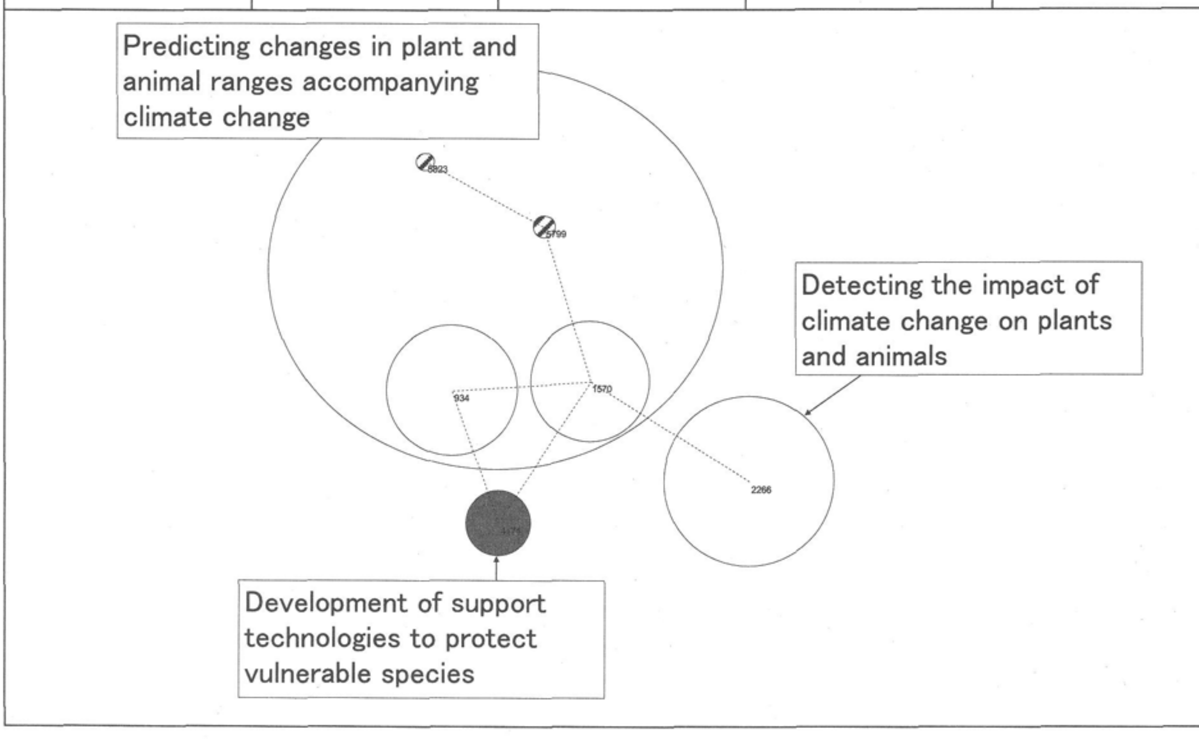
Name of RA	Environmental stress response / metabolic profiling / cellular structure and phospholipid metabolism in plant		RA ID	34
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
24(4)	124(5)	2973	8117	2003.3



Name of RA	Environmental pollution study of bromine flame retardant made mainly of polybrominated diphenylethers (PBDEs)		RA ID	35
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(2)	40(1)	796	2389	2003.5

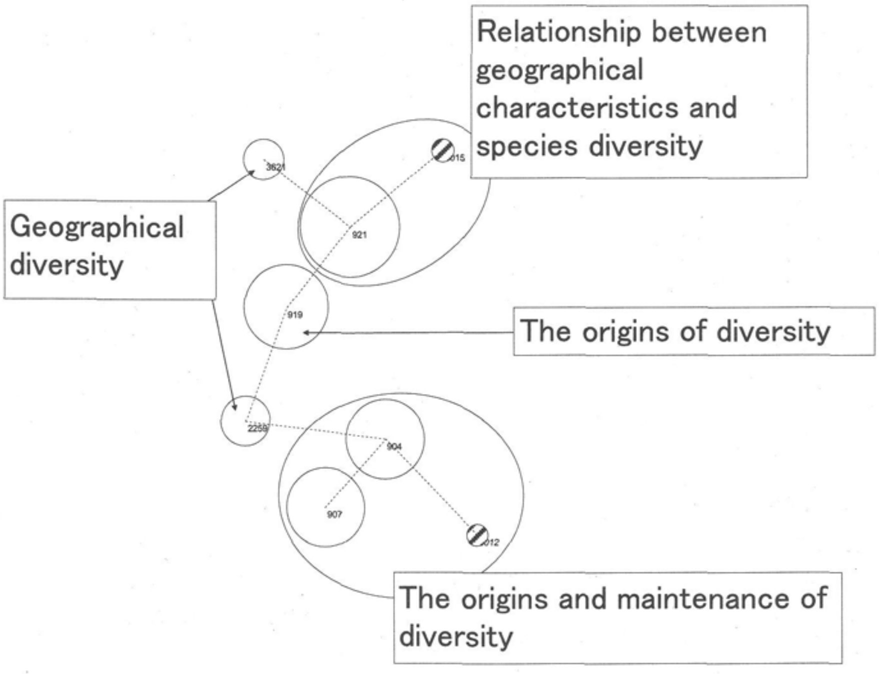


Name of RA	Assistive technology for detection, prediction and countermeasure of animal and plant activity change caused by climate change		RA ID	36
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(1)	38(0)	1572	3059	2004.1



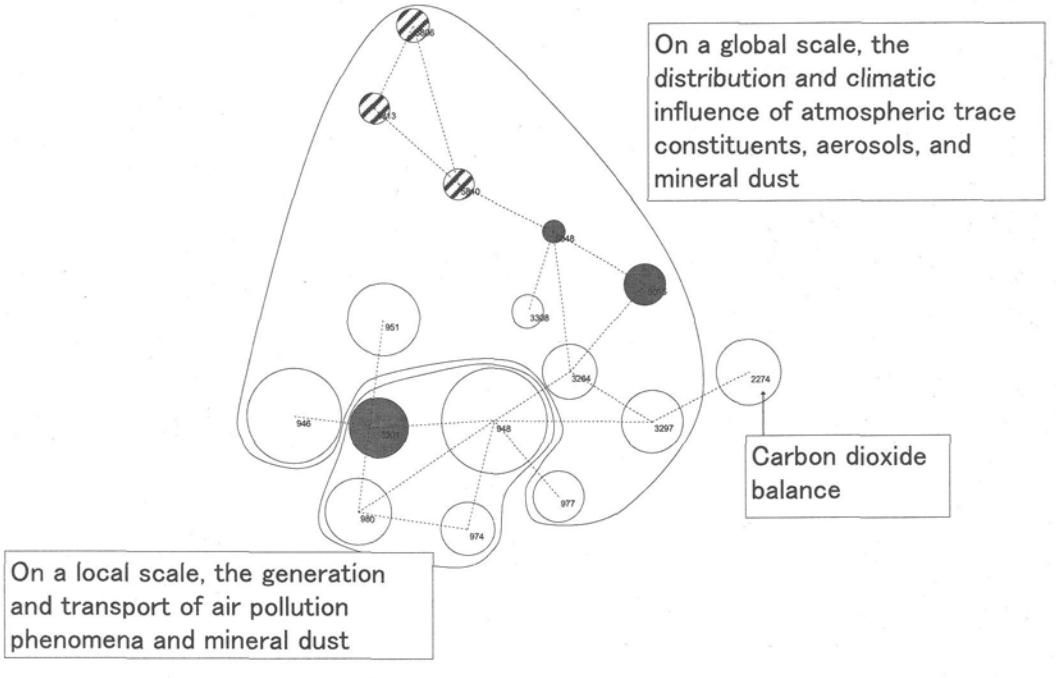
Name of RA	Biodiversity	RA ID	37

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(0)	27(0)	1030	1887	2003.3



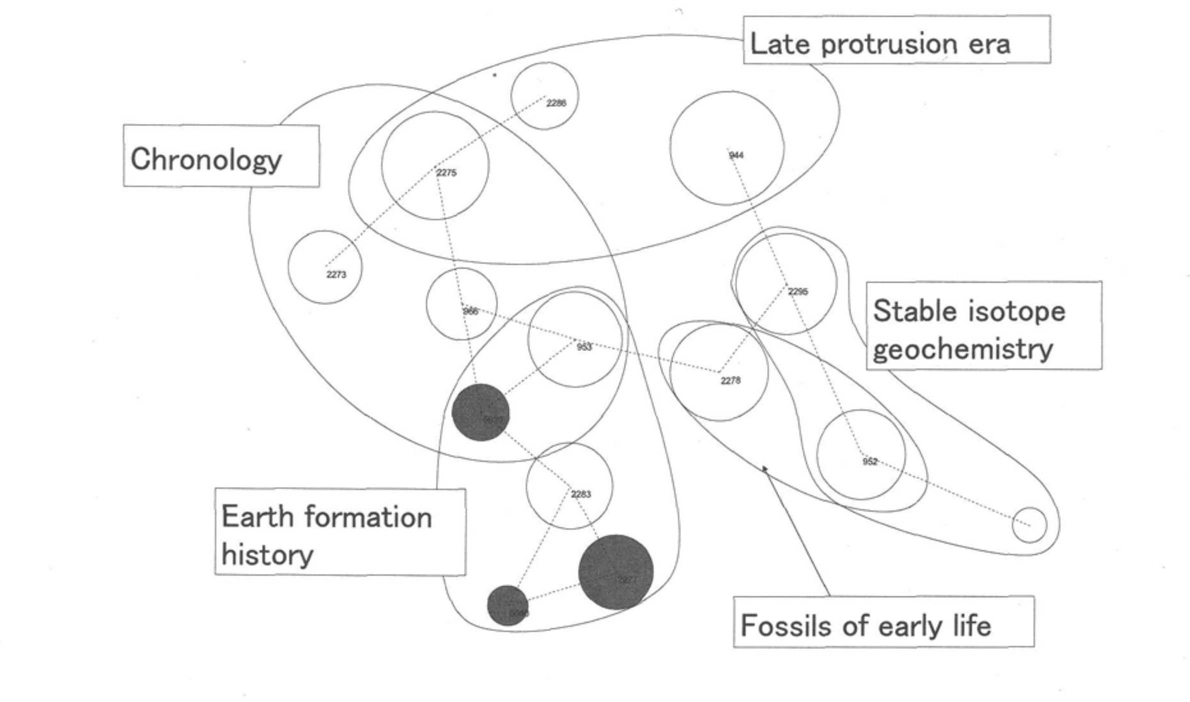
Name of RA	Climatic effect of air pollutant and mineral dust	RA ID	38

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
16(3)	75(12)	1863	3637	2003.9



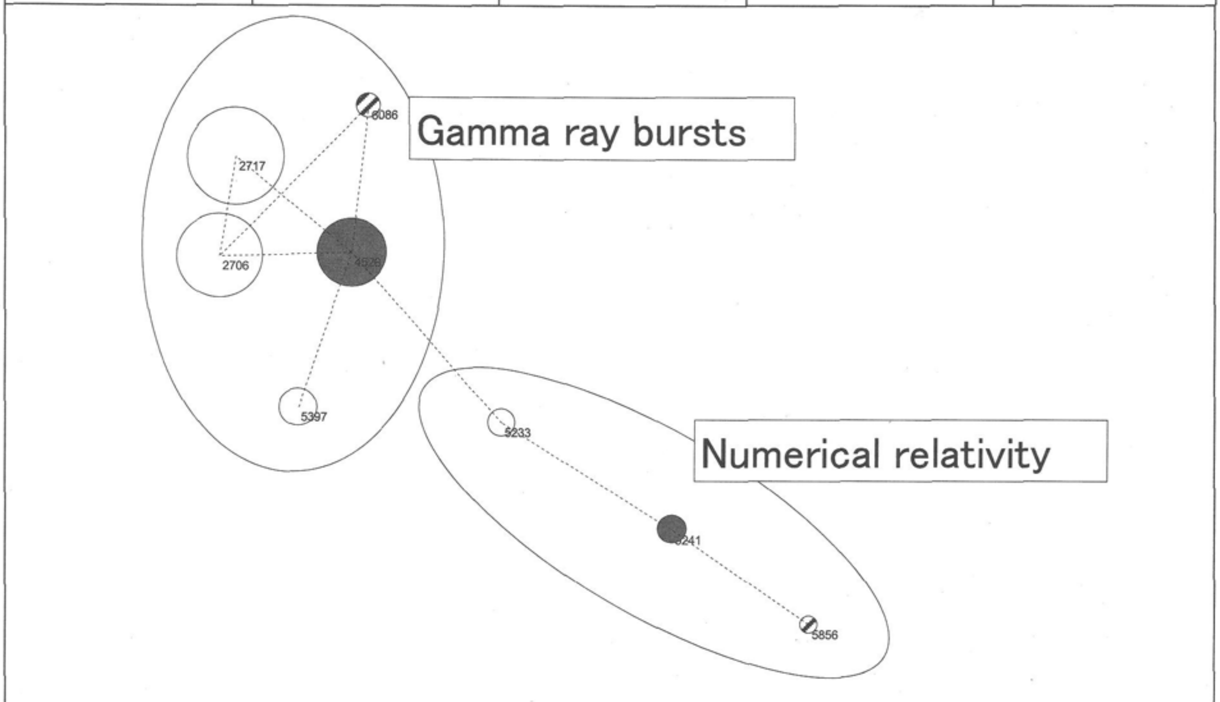
Name of RA	Earth history	RA ID	39

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
14(3)	79(1)	1892	4059	2003.3



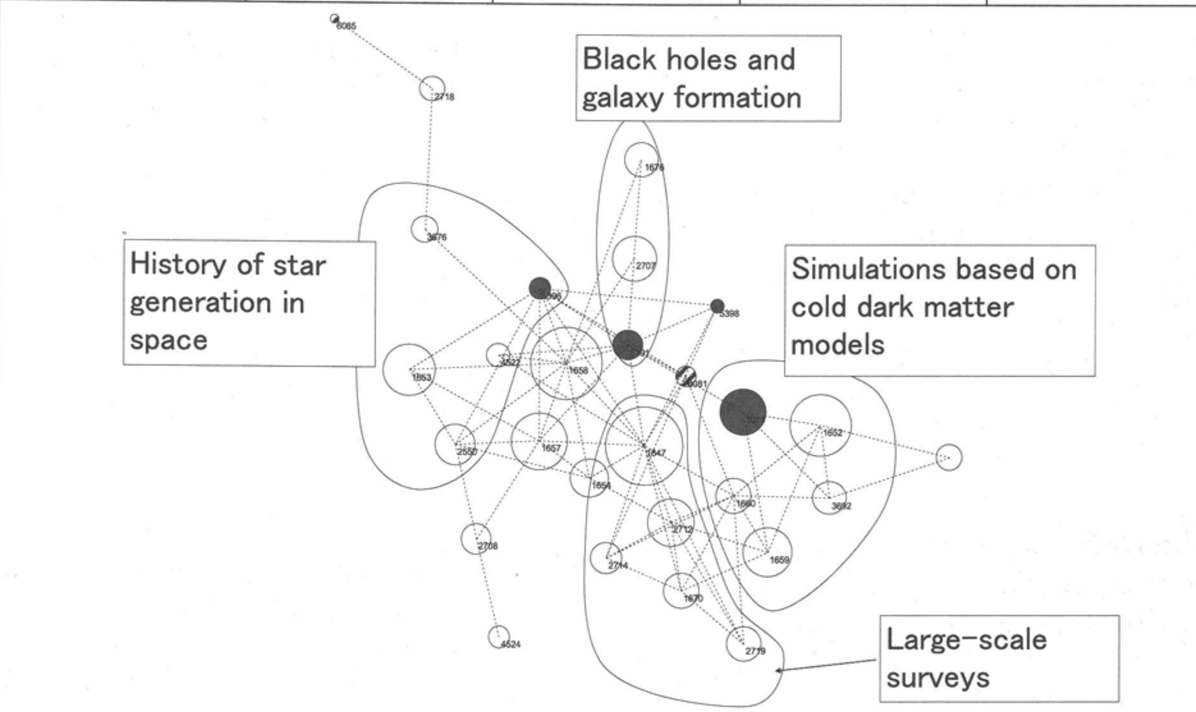
Name of RA	Gamma-ray burst and relative celestial explosion phenomenon	RA ID	40

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(2)	66(13)	1052	3290	2004.9



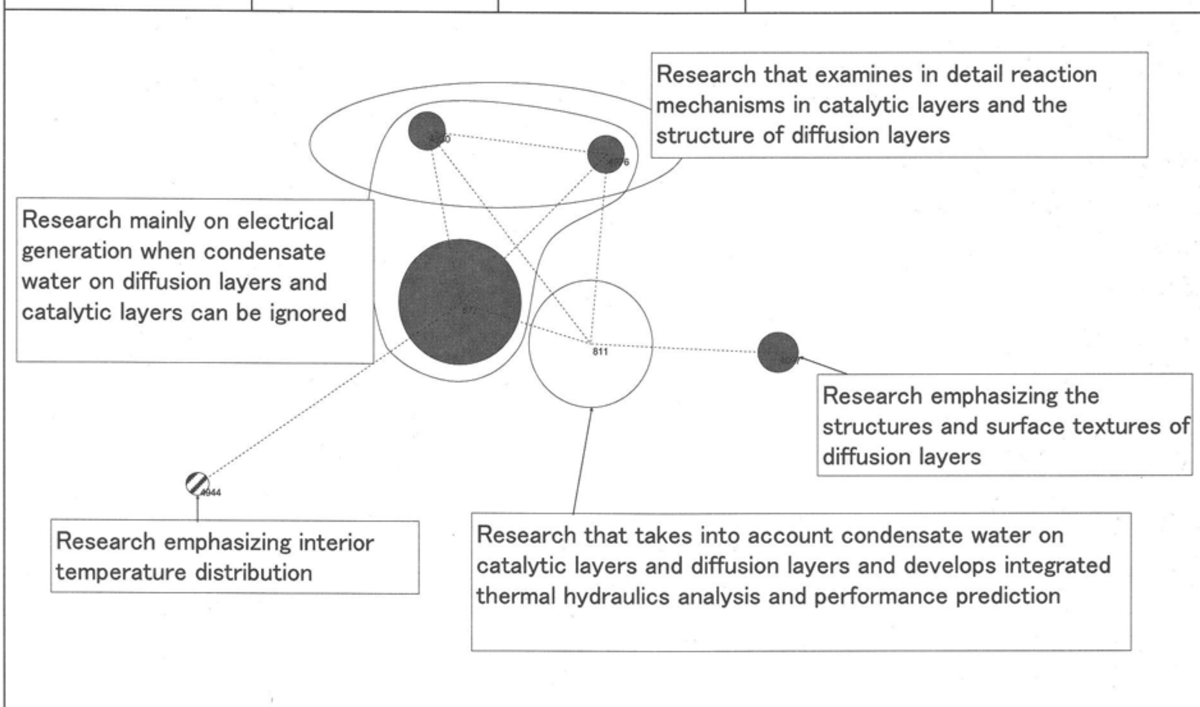
Name of RA	Formation and evolution of the galaxy	RA ID	41

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
28(4)	167(25)	6062	19423	2003.4



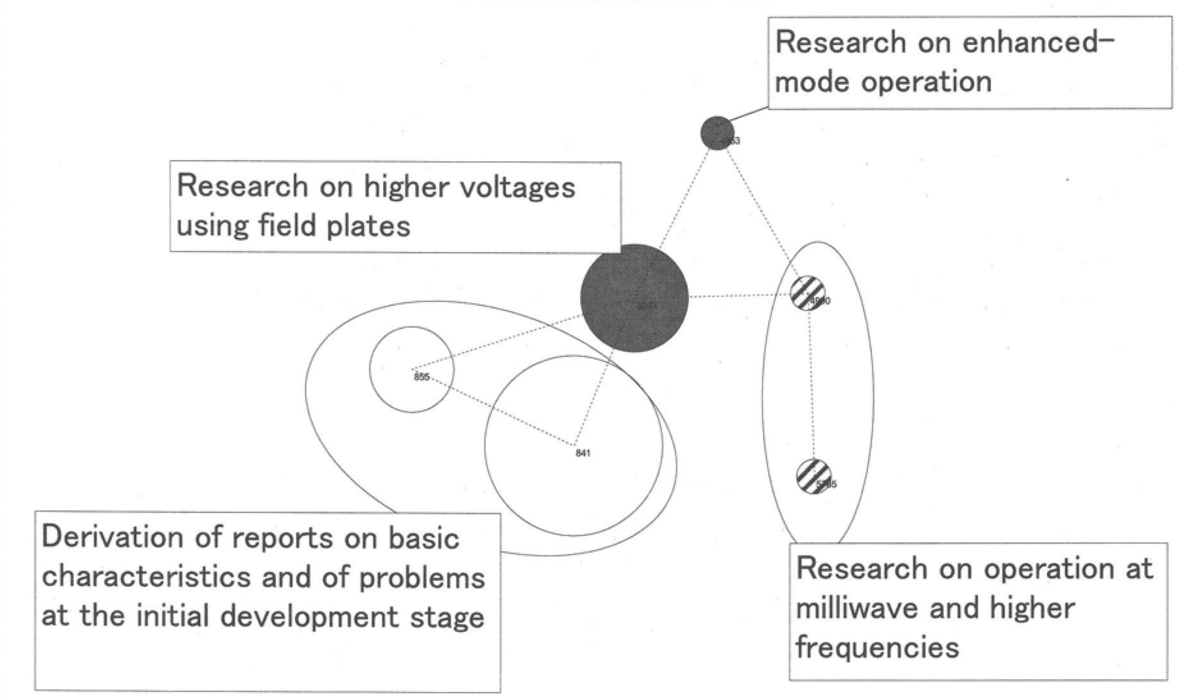
Name of RA	Solid macromolecule type fuel cell / mass and heat transfer	RA ID	42

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(4)	35(4)	434	1068	2004.1



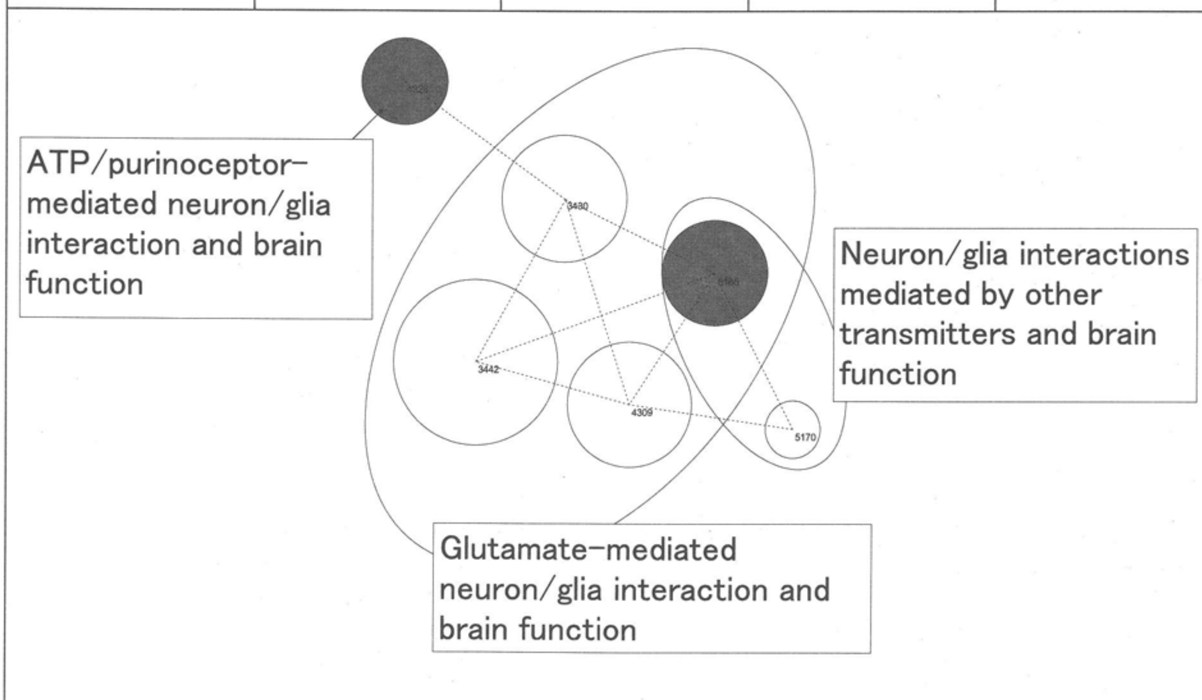
Name of RA	Nitride semiconductor transistor / high-voltage and high-frequency application	RA ID	43

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(2)	19(3)	531	924	2003.1

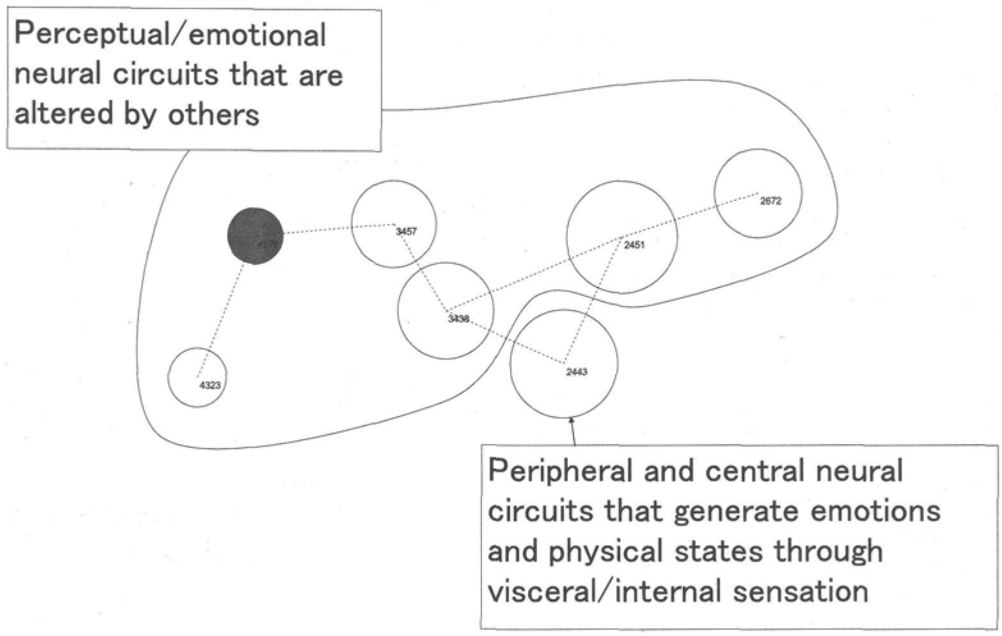


Name of RA	Integrated comprehension of brain function by neuron-glia interaction	RA ID	44

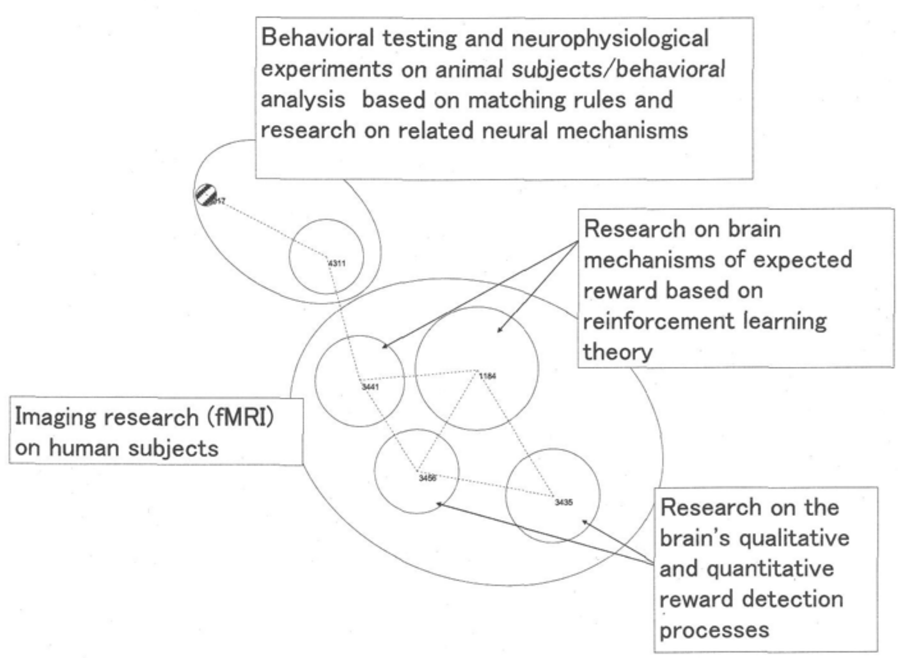
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(2)	19(0)	566	975	2004.7



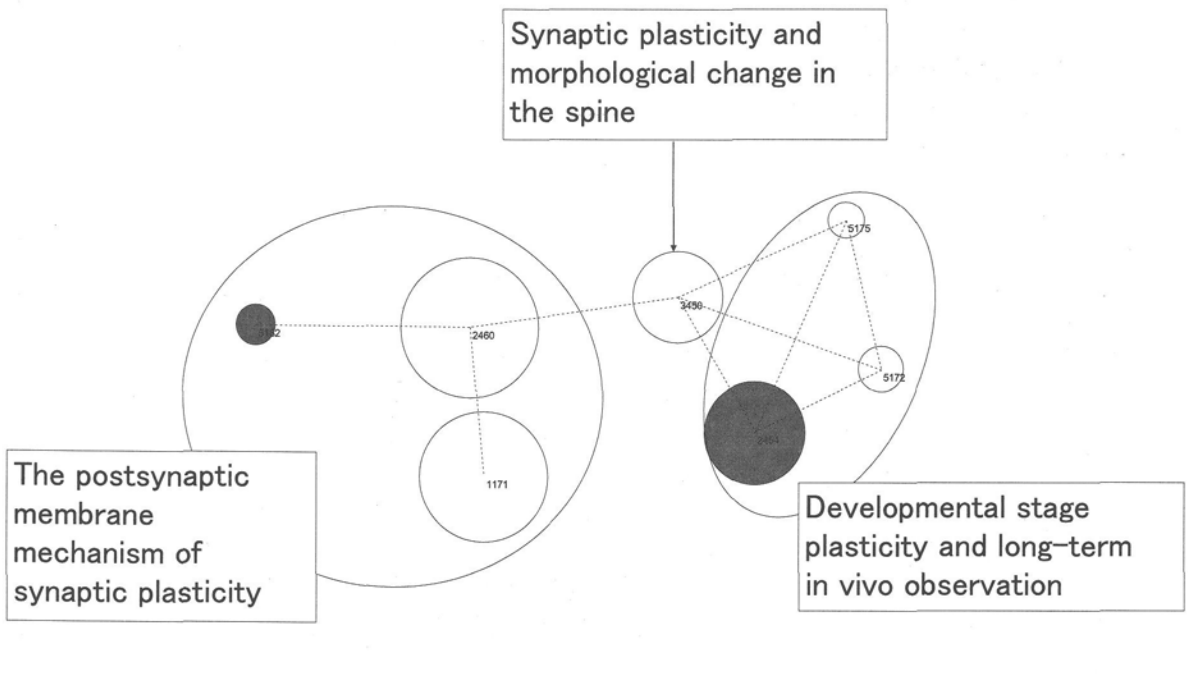
Name of RA	Visceral sensation and neural mechanism of emotion and empathy		RA ID	45
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7(1)	17(0)	934	1409	2003.7



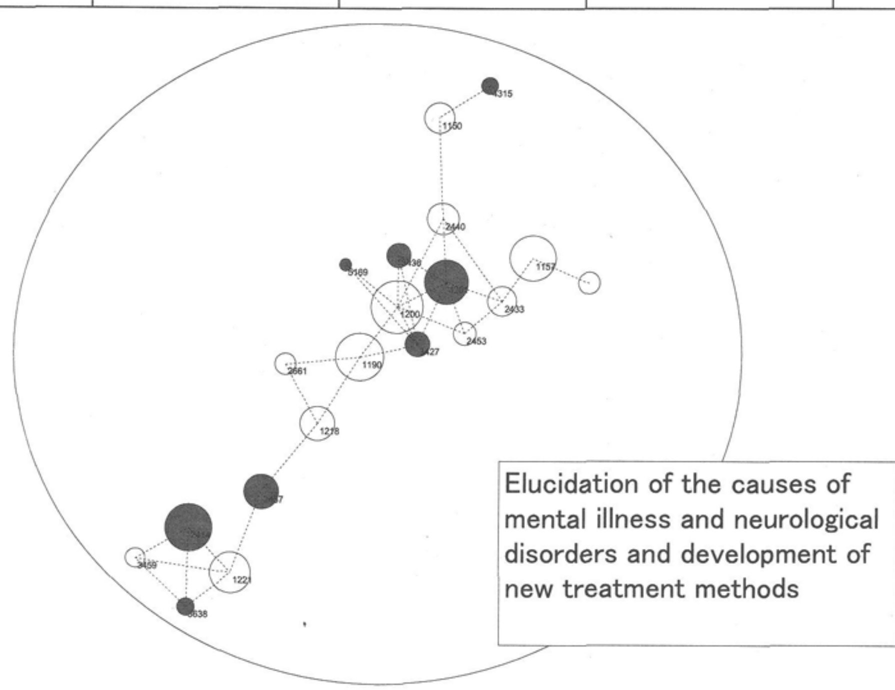
Name of RA	Decision-making neuroscience		RA ID	46
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(0)	13(0)	637	1076	2003.3



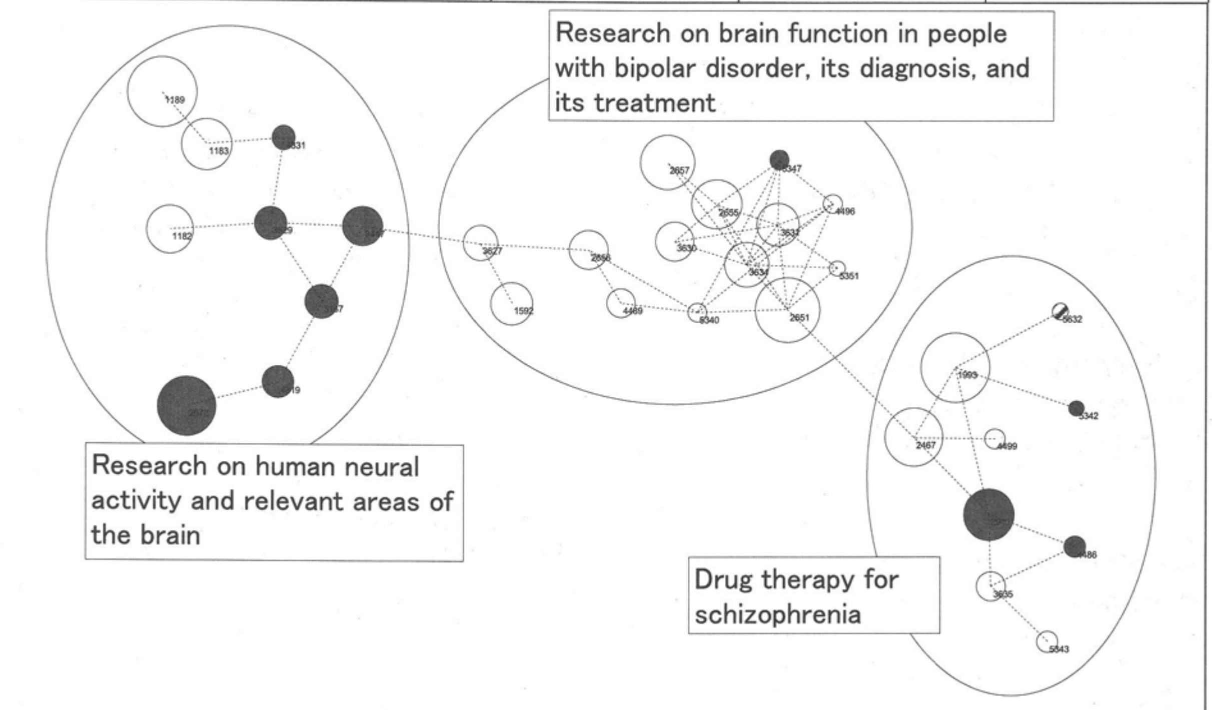
Name of RA	Kinetics of AMPA receptor and spine morphology in synaptic plasticity			RA ID	47
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year	
7(2)	22(5)	1424	2628	2003.5	



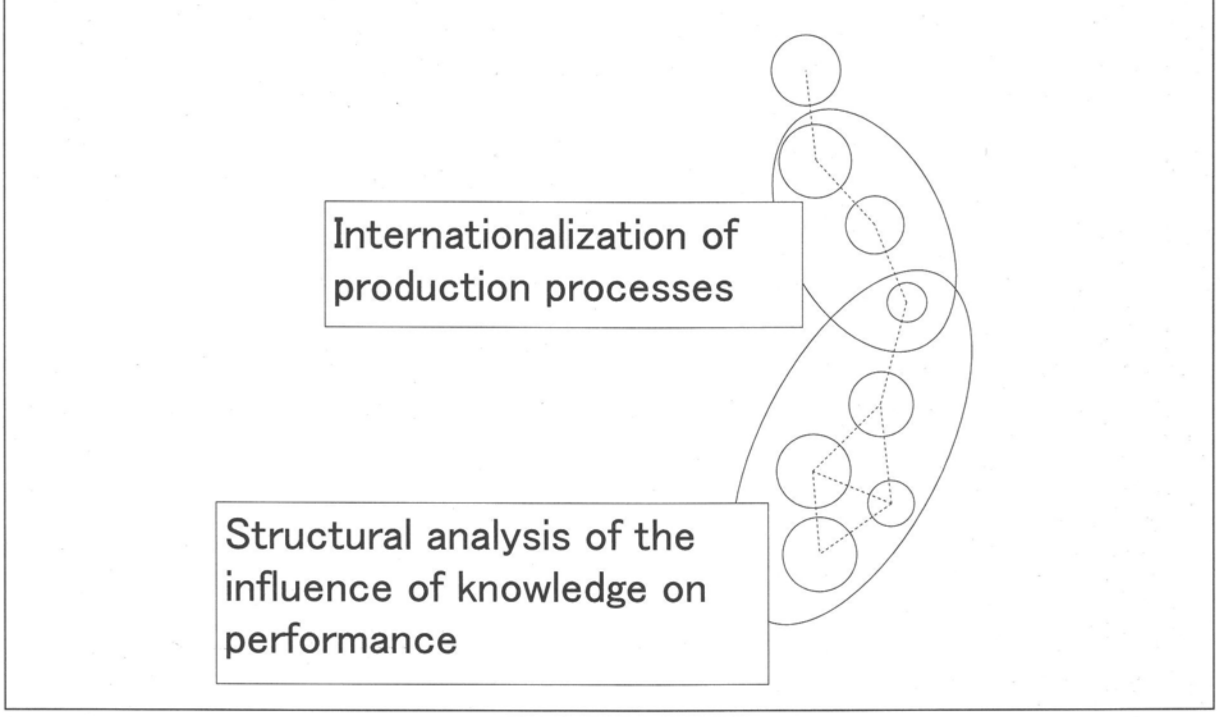
Name of RA	Cause analysis and therapy development for psychiatric and nerve disease			RA ID	48
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year	
20(8)	86(9)	5409	12102	2003.1	



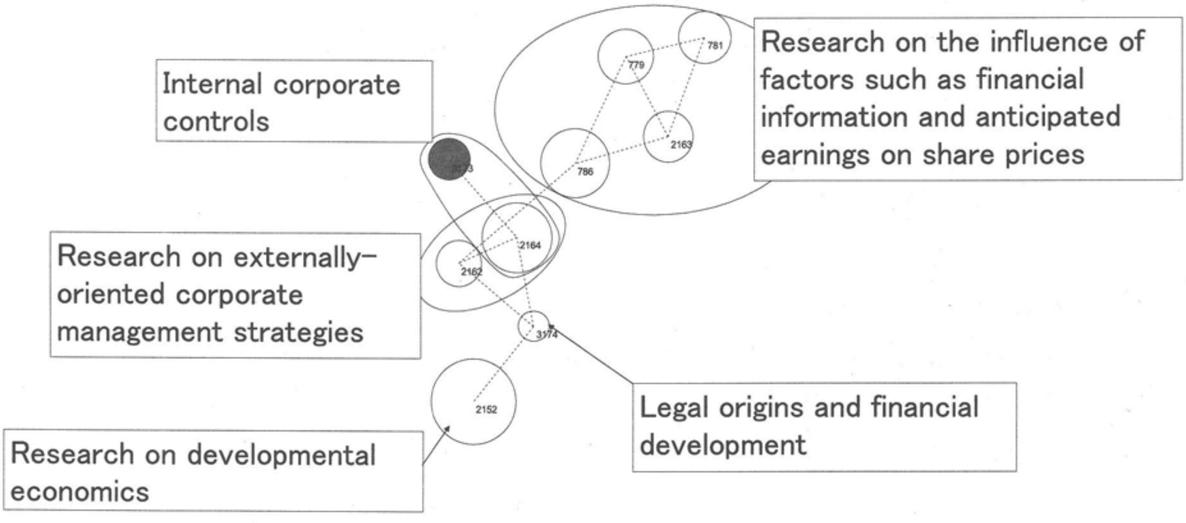
Name of RA	Functional analysis of human brain and drug therapy of psychiatric disease		RA ID	49
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
32(10)	130(3)	4599	9952	2003.5



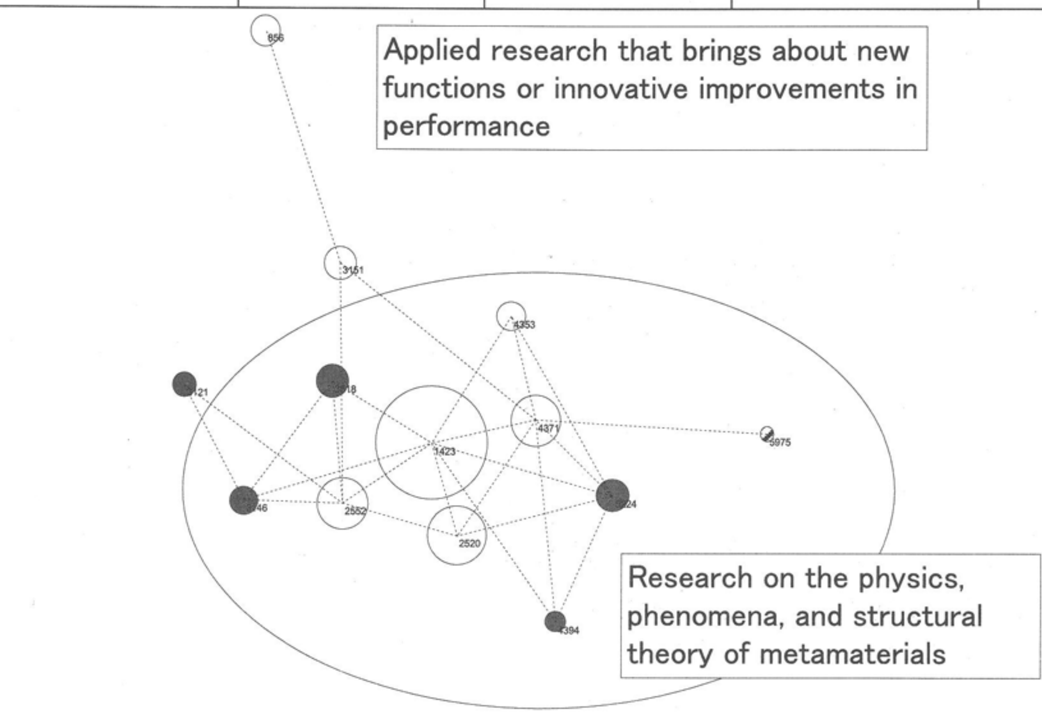
Name of RA	Structural analysis of the production process from the perspective of a network		RA ID	50
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(0)	28(0)	416	800	2003.2



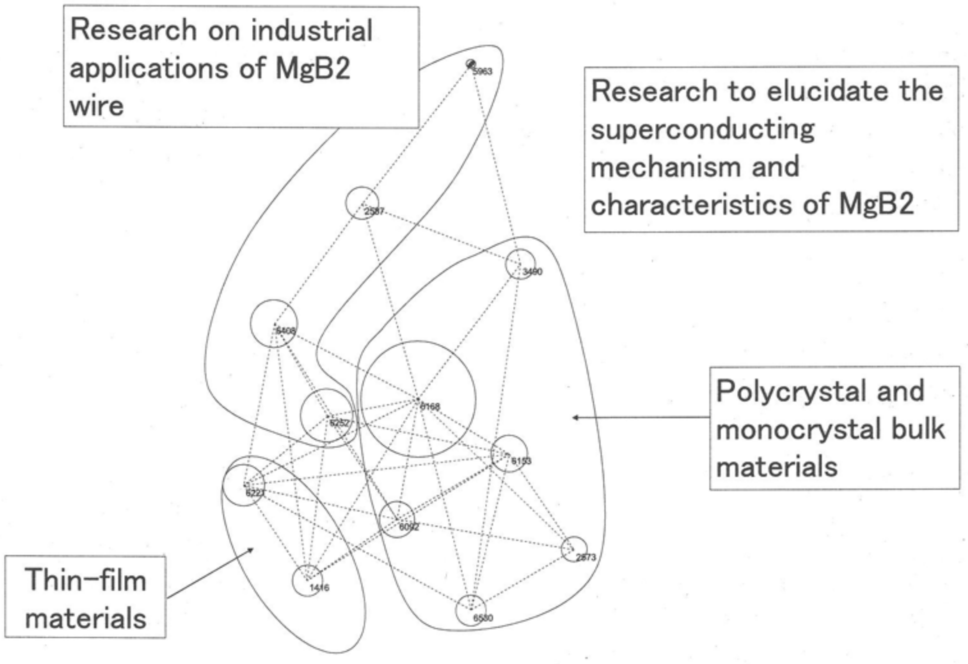
Name of RA	Economic environment surrounding businesses		RA ID	51
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9(1)	38(0)	787	1423	2003.0



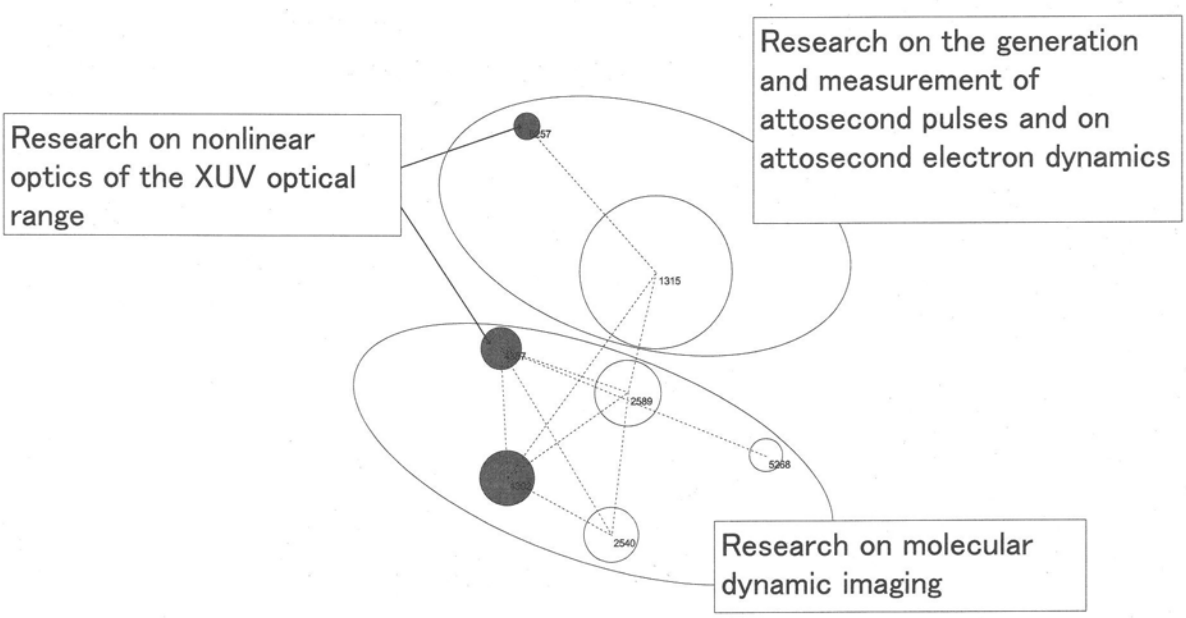
Name of RA	Metamaterials		RA ID	52
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13(5)	66(2)	3004	4508	2003.8



Name of RA	Superconductive properties of magnesium diboride and its application		RA ID	53
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
12(0)	49(13)	2585	9613	2001.7

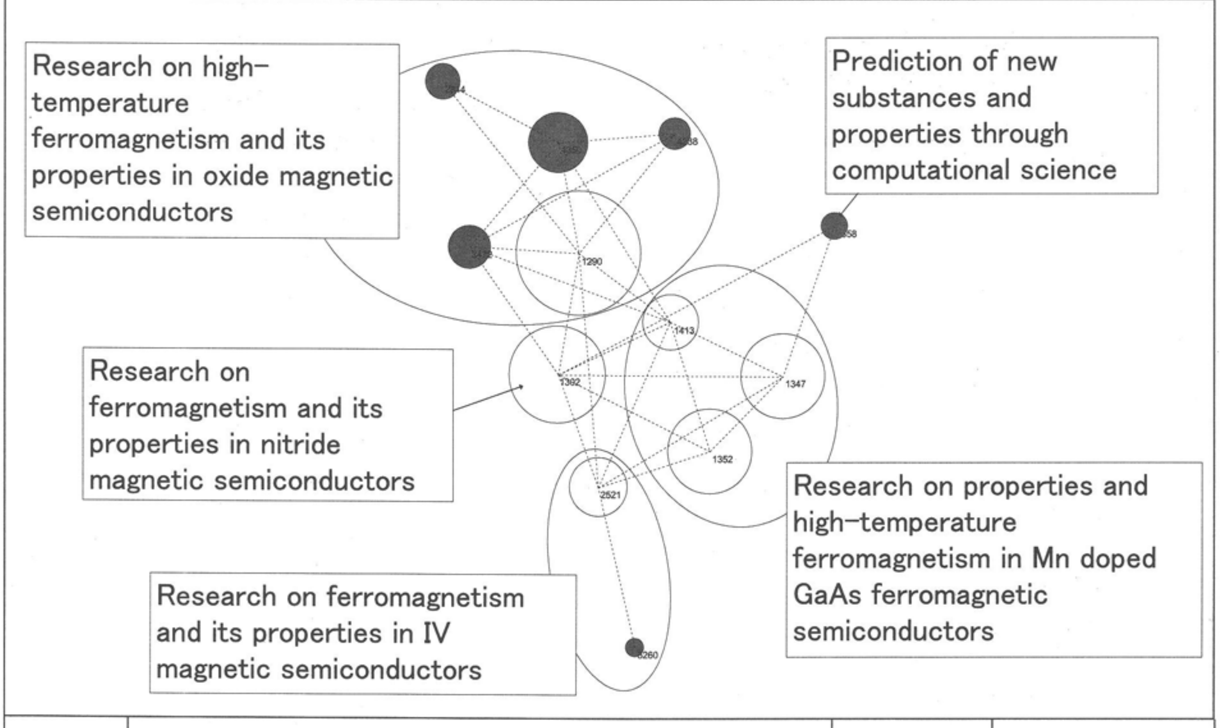


Name of RA	Attosecond quantum dynamics		RA ID	54
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7(3)	26(4)	1236	3075	2003.3



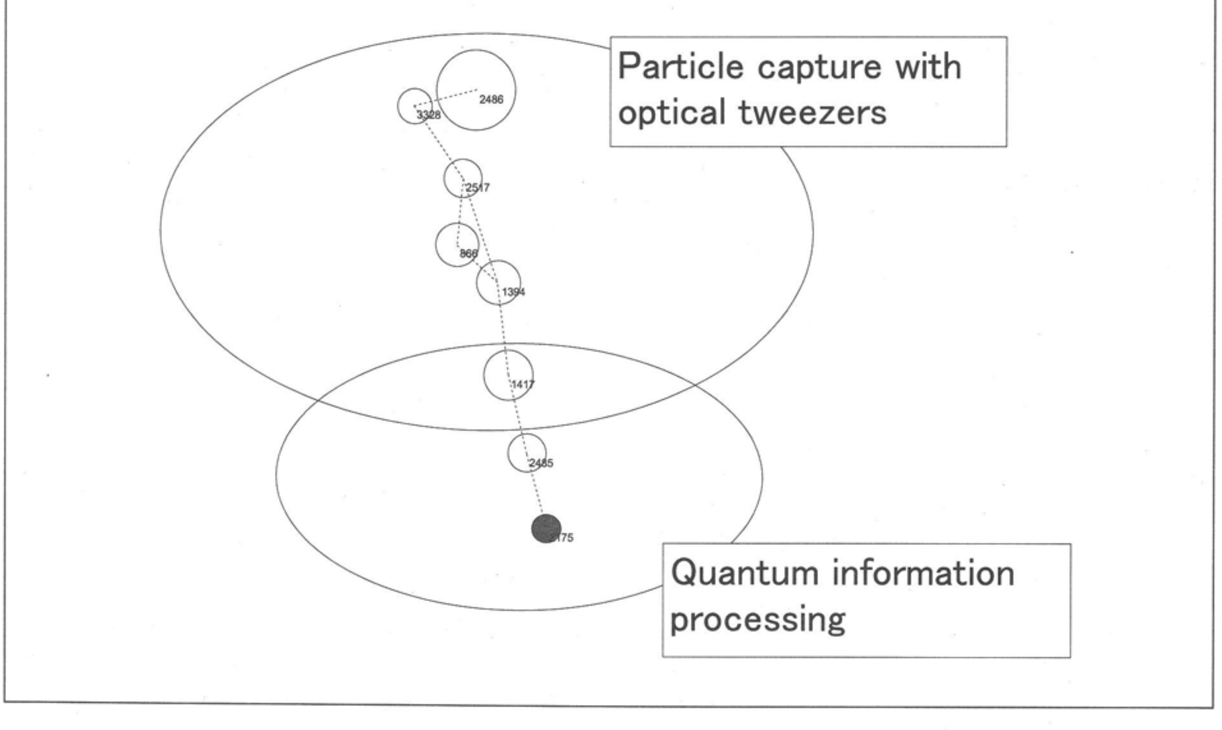
Name of RA	Ferromagnetic semiconductor spintronics	RA ID	55

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
12(6)	85(22)	2428	8605	2002.8

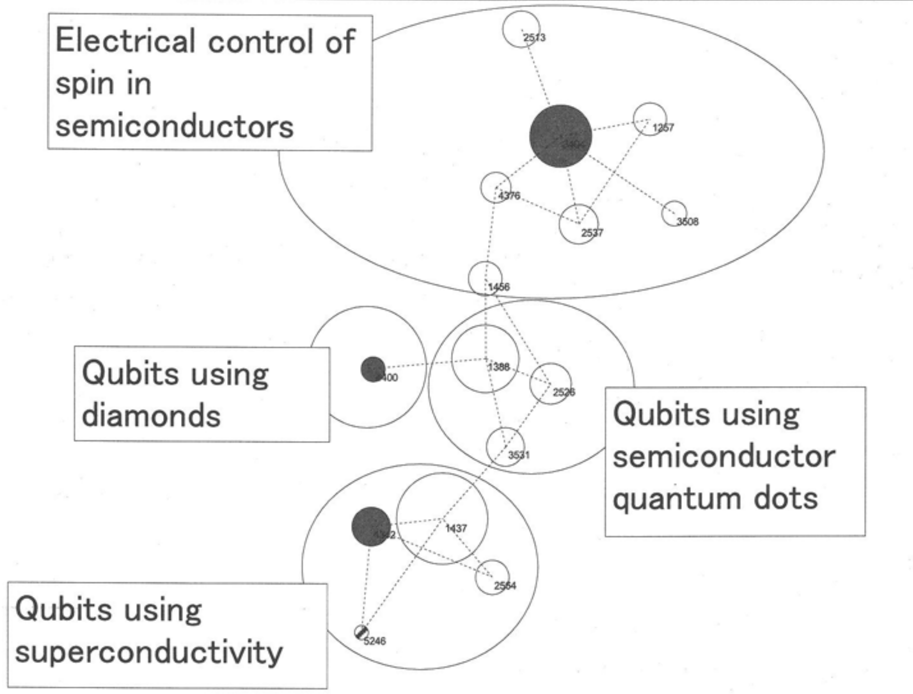


Name of RA	Quantum information control with multidimensional photon	RA ID	56

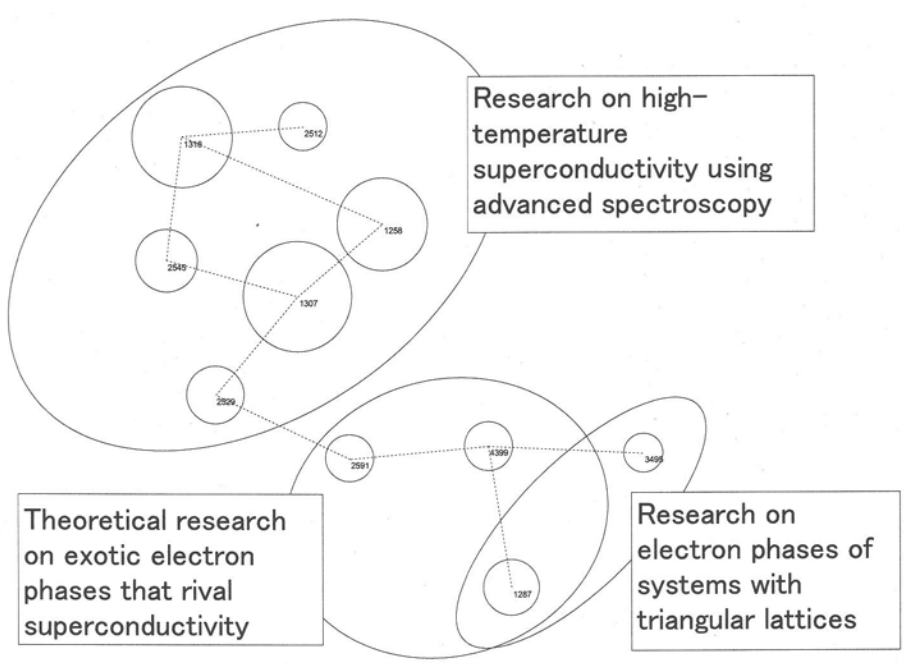
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(1)	26(6)	1375	2282	2002.8



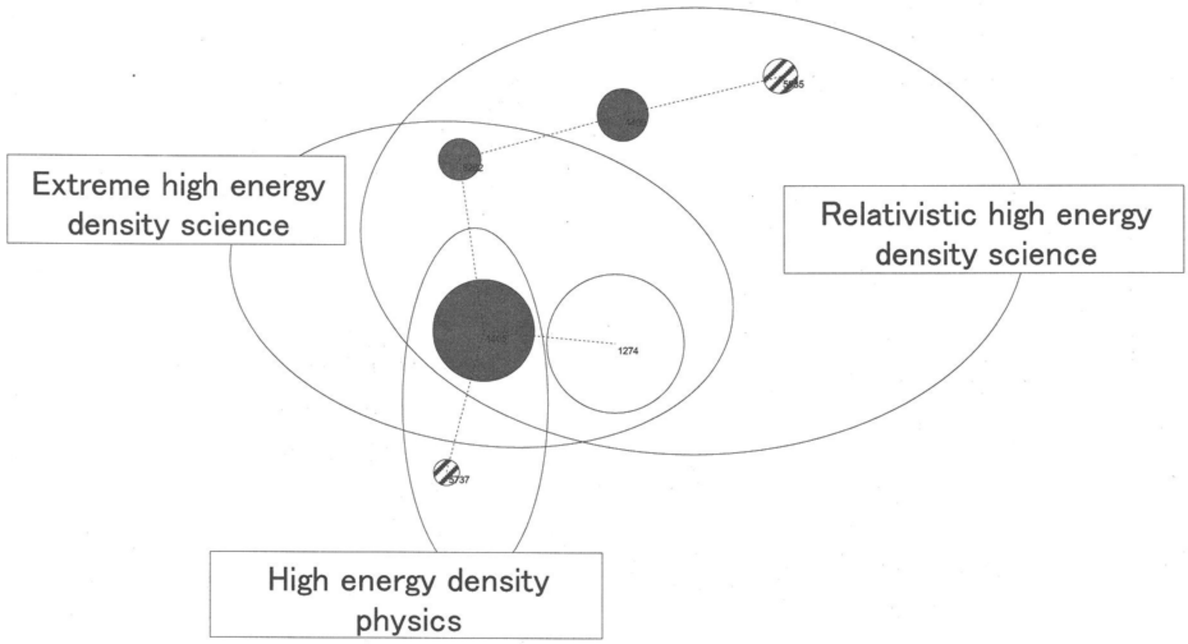
Name of RA	Electrical control of spin in semiconductors / quantum computer using solid state components		RA ID	57
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
15(3)	106(19)	2547	7692	2004.2



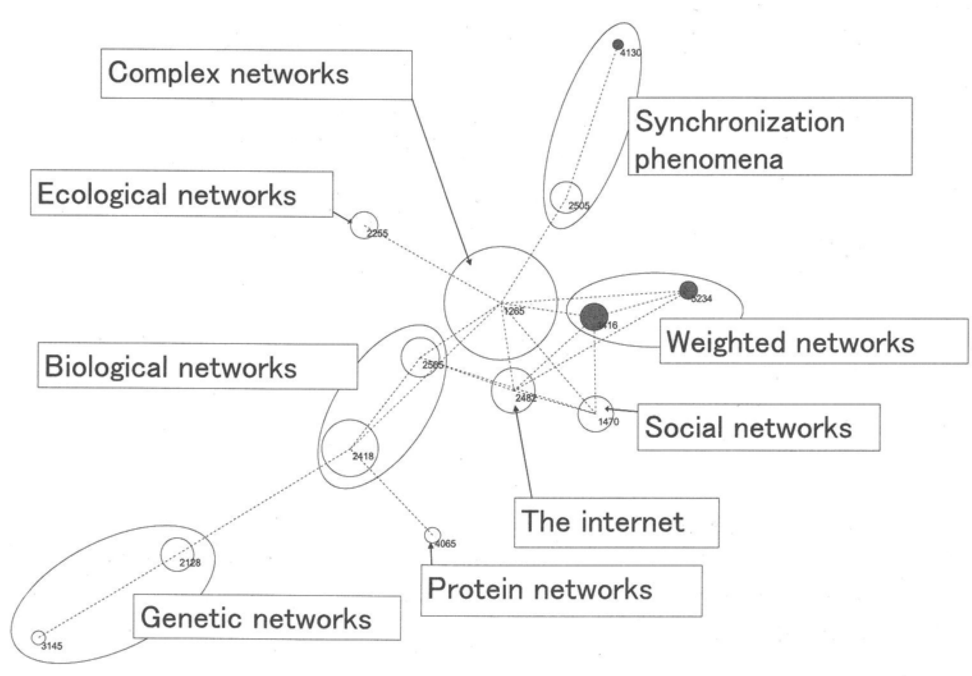
Name of RA	High-temperature superconductivity spectroscopy / new electron phase		RA ID	58
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
10(0)	45(20)	2050	4259	2002.9



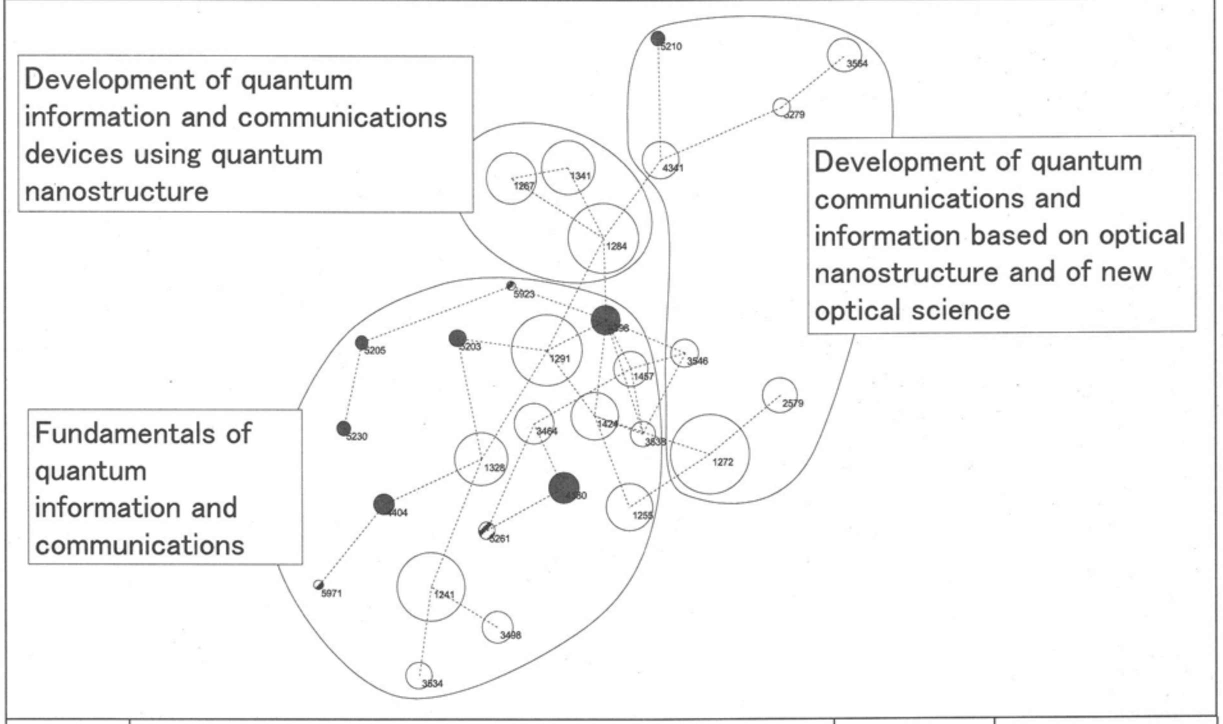
Name of RA	High energy density science	RA ID	59	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(3)	28(8)	625	1361	2004.2



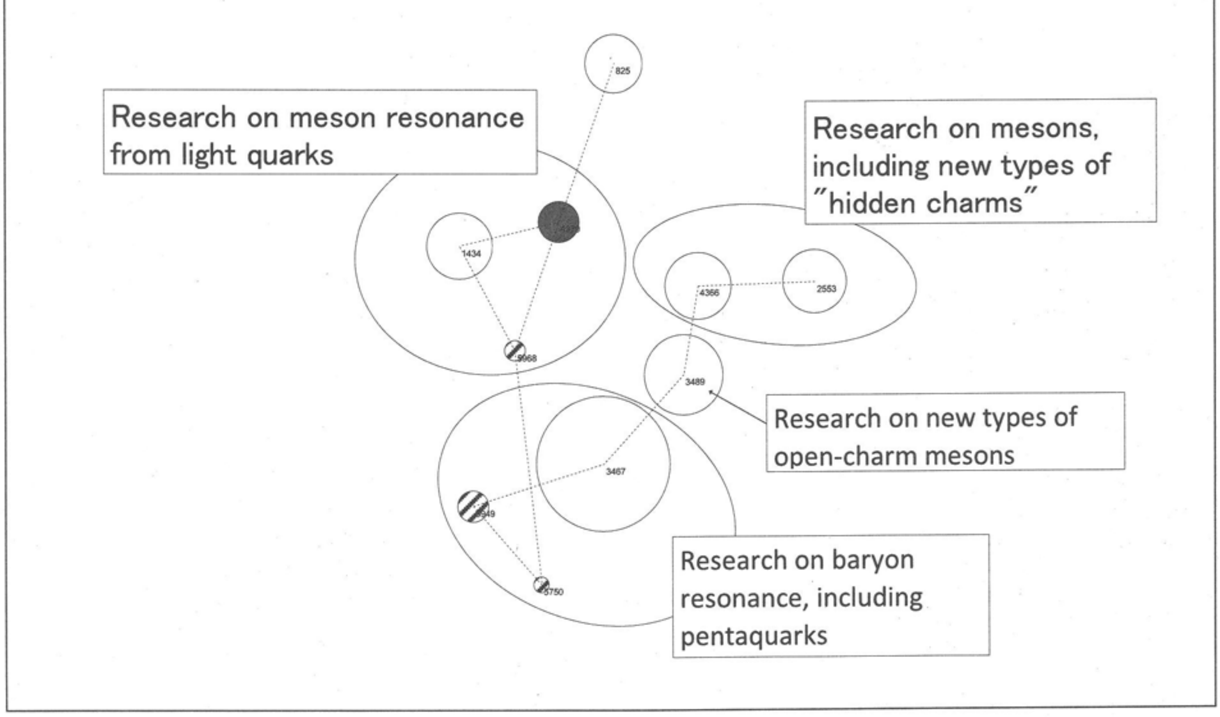
Name of RA	Complex networks	RA ID	60	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13(3)	55(1)	3206	8101	2003.1



Name of RA	Quantum information/communication, optical nanoscience		RA ID	61
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
29(7)	162(16)	4771	12680	2003.7

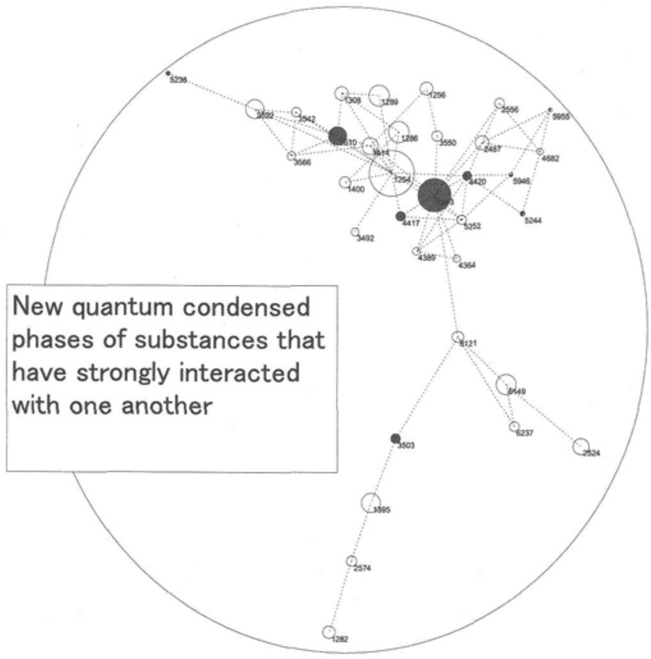


Name of RA	Hadron spectroscopy		RA ID	62
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
10(1)	90(20)	1368	6792	2003.9



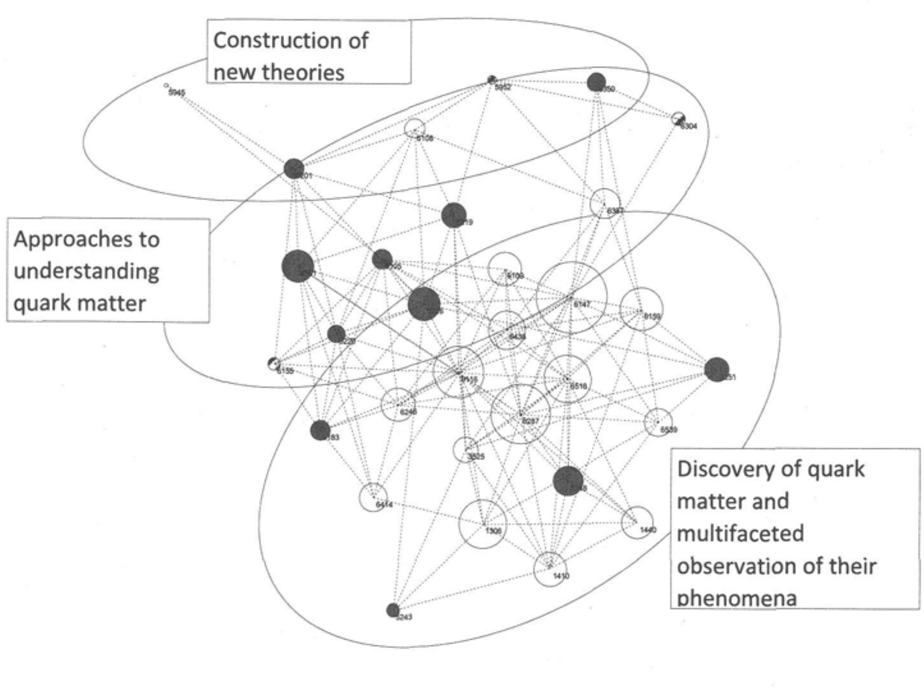
Name of RA	New quantum condensed phase where substances strongly interact with each other	RA ID	63

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
34(6)	241(11)	5996	22778	2003.5



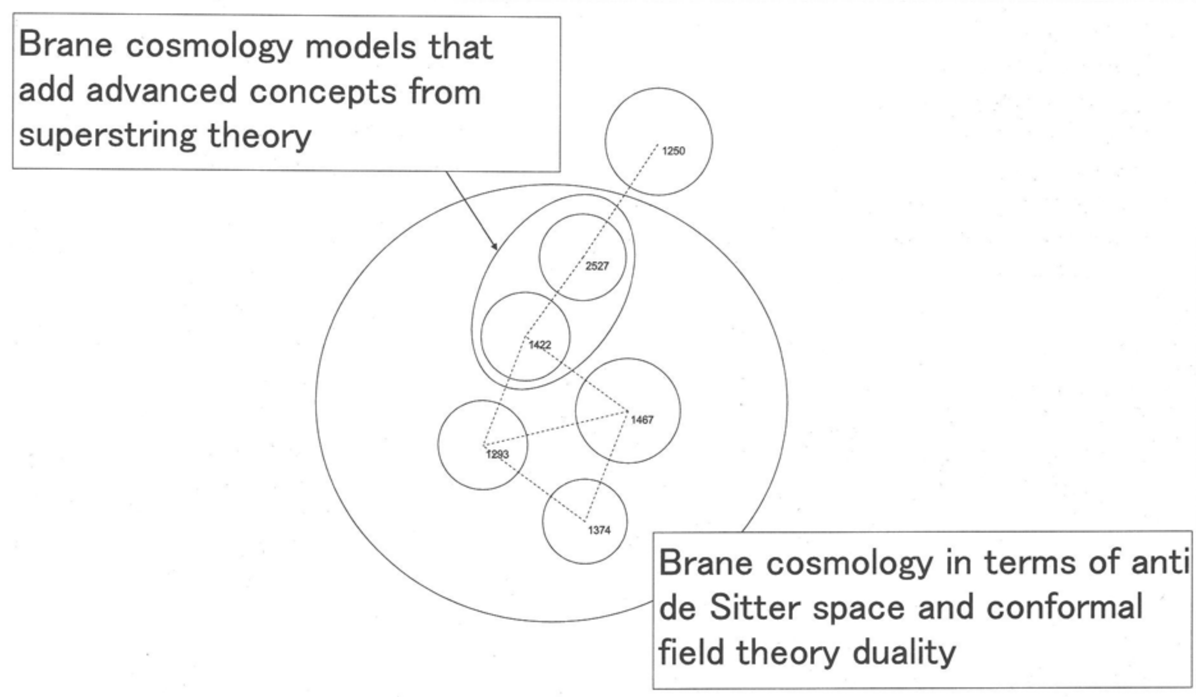
Name of RA	Search for quark matter through high-energy nuclear collision	RA ID	64

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
31(11)	134(14)	2280	10101	2003.5



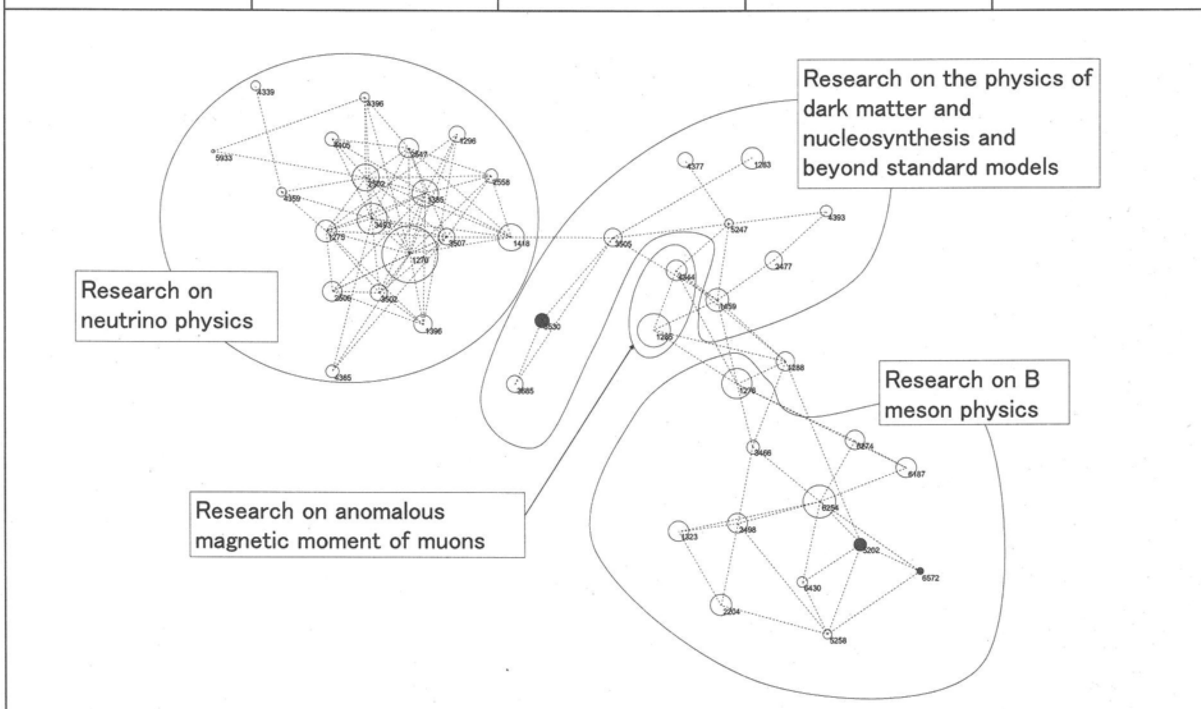
Name of RA	Brane cosmology from the perspective of duality of anti de sitter space and conformal field theory	RA ID	65

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(0)	17(6)	800	1482	2001.4



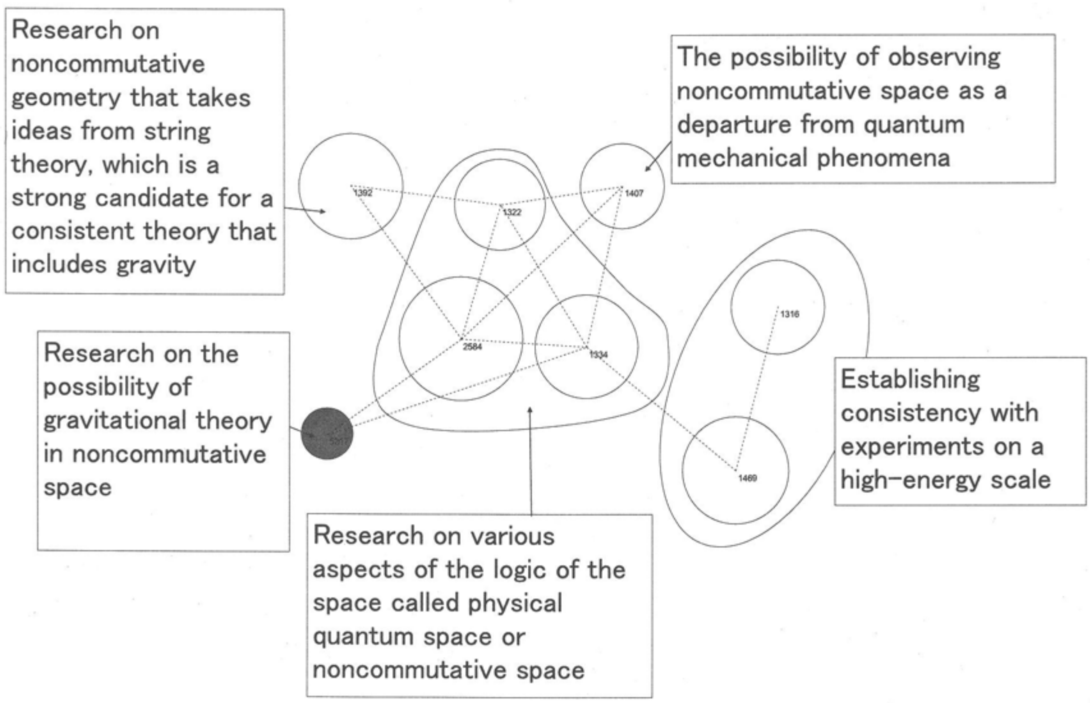
Name of RA	Explore physics beyond the standard model from flavor physics of B meson and neutrino, dark matter and muon anomalous magnetic efficiency	RA ID	66

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
43(3)	265(46)	6302	23338	2003.4



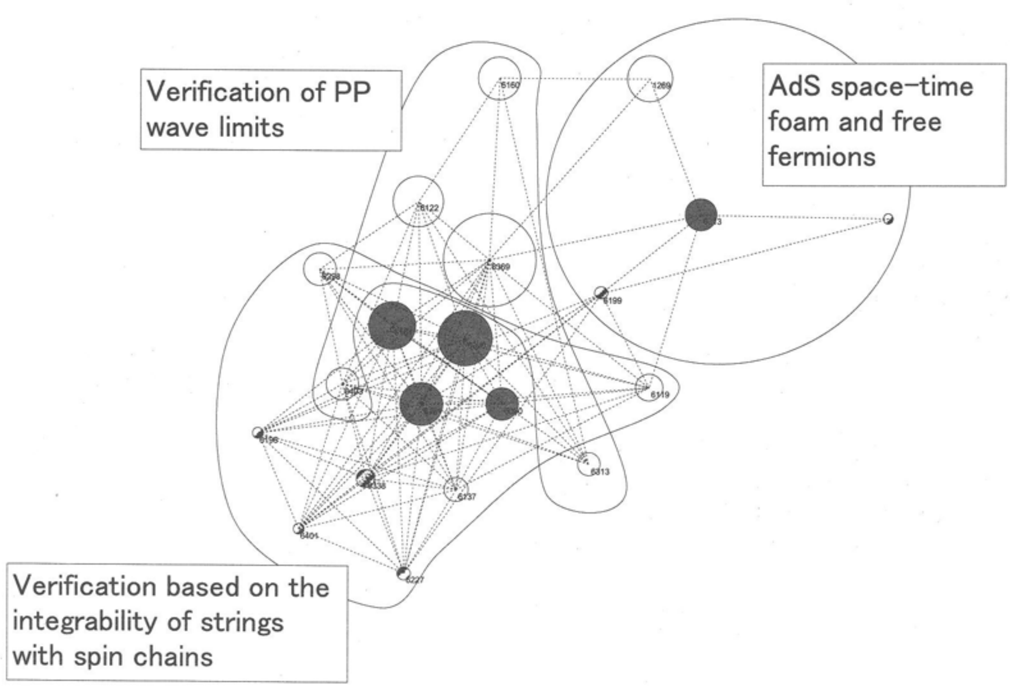
Name of RA	Field theory on noncommutative space	RA ID	67

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(1)	36(1)	1509	3611	2002.2

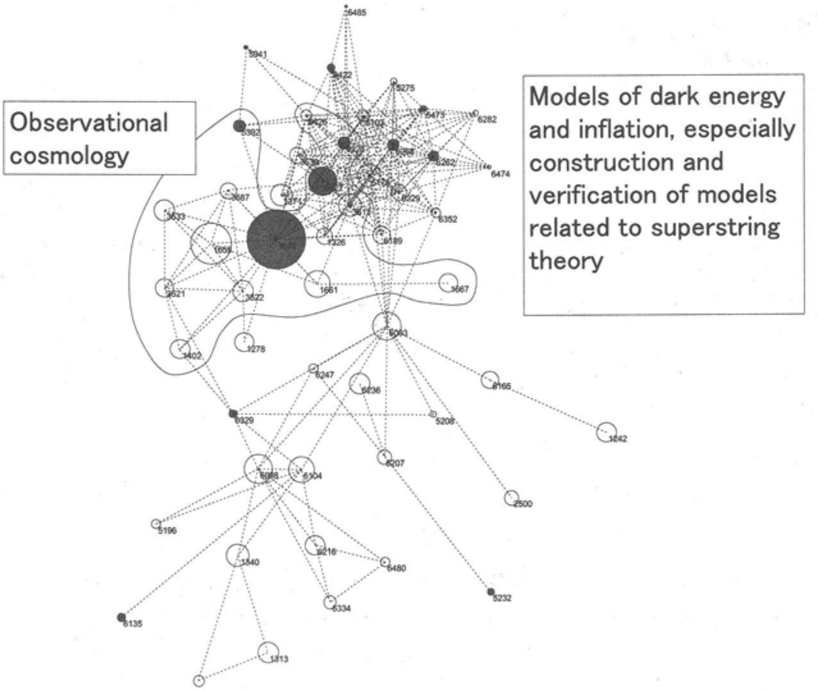


Name of RA	Verification and integrability of AdS/CFT correspondence	RA ID	68

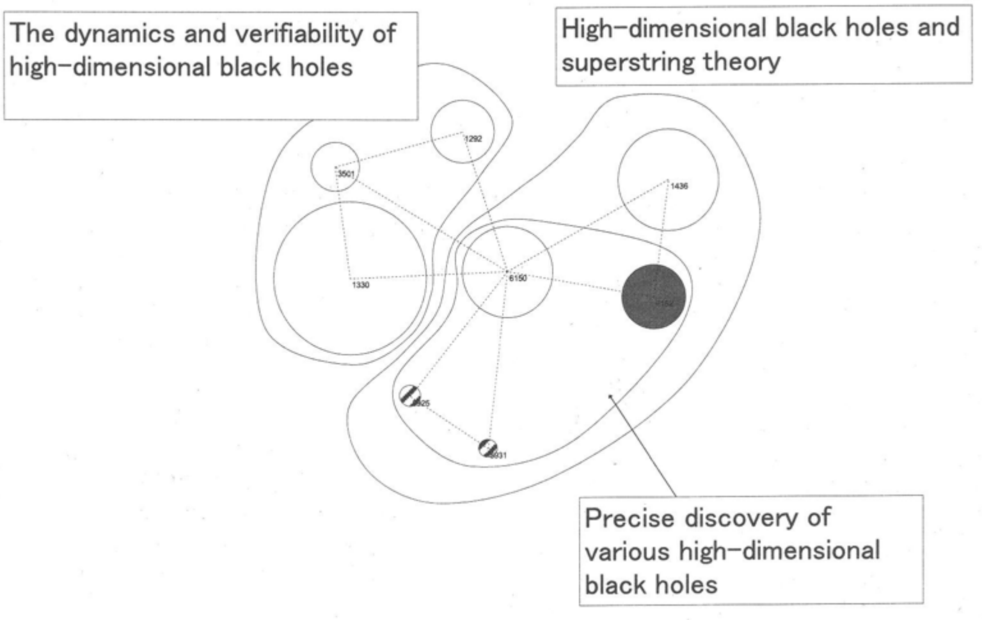
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
20(5)	78(1)	1091	5923	2003.9



Name of RA	Observational cosmology and an elementary model for it		RA ID	69
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
52(11)	415(40)	10189	40267	2003.3

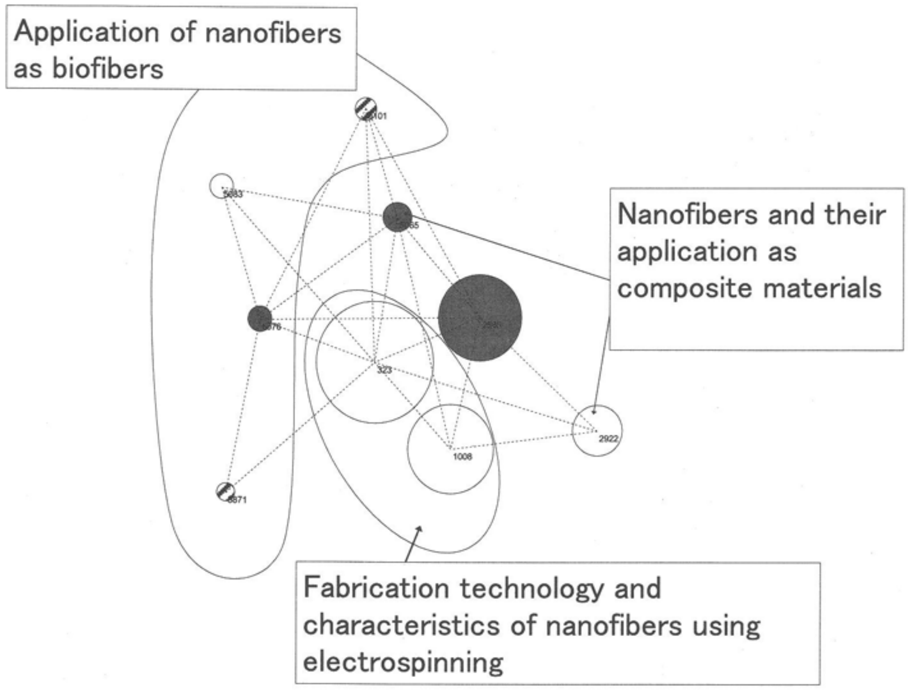


Name of RA	High-dimensional black holes		RA ID	70
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(1)	79(8)	1164	3942	2004.0



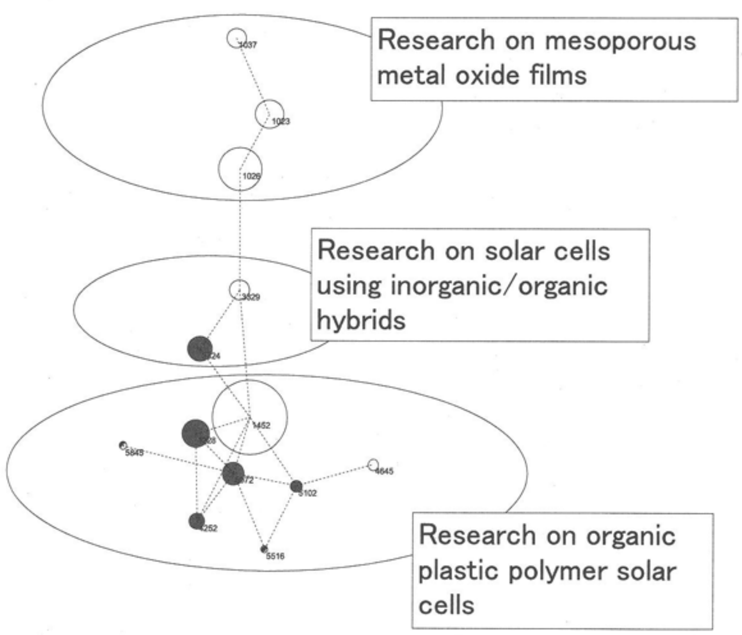
Name of RA	Nanofiber technology with the electro-spinning process and tissue engineering research	RA ID	71

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9(3)	49(1)	1058	3318	2003.5

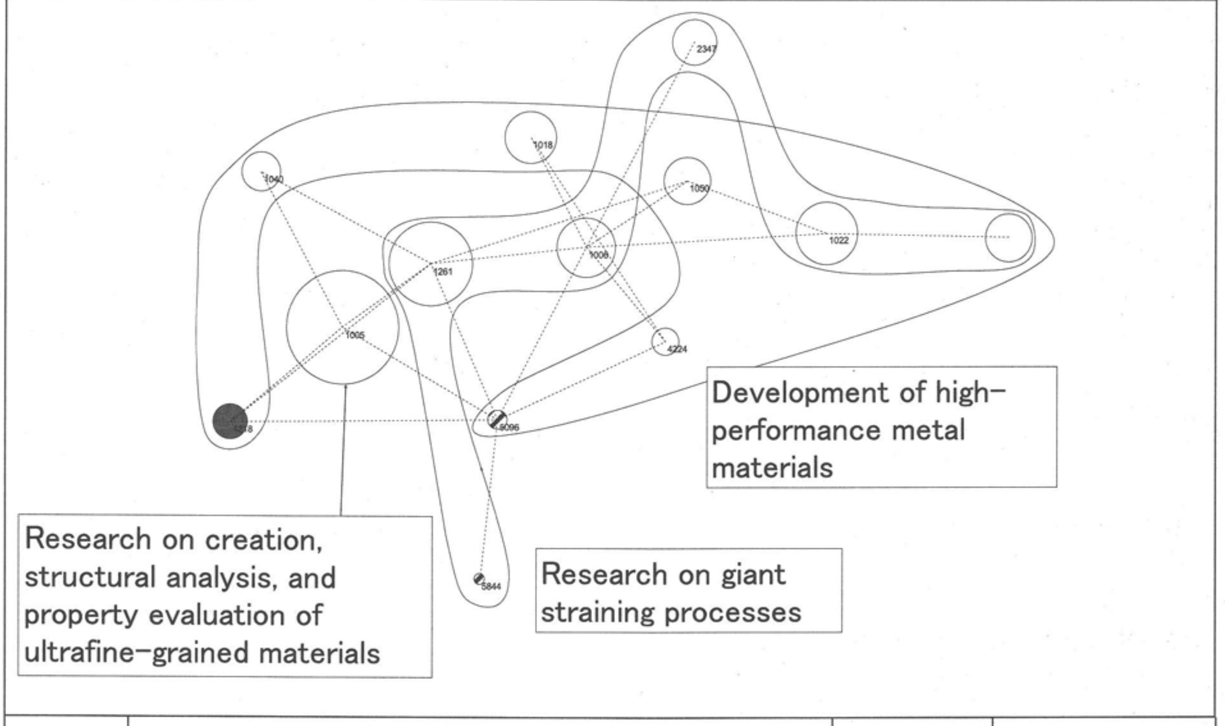


Name of RA	Study of solar cells using inorganic oxides, organic-inorganic hybrids or organic polymers	RA ID	72

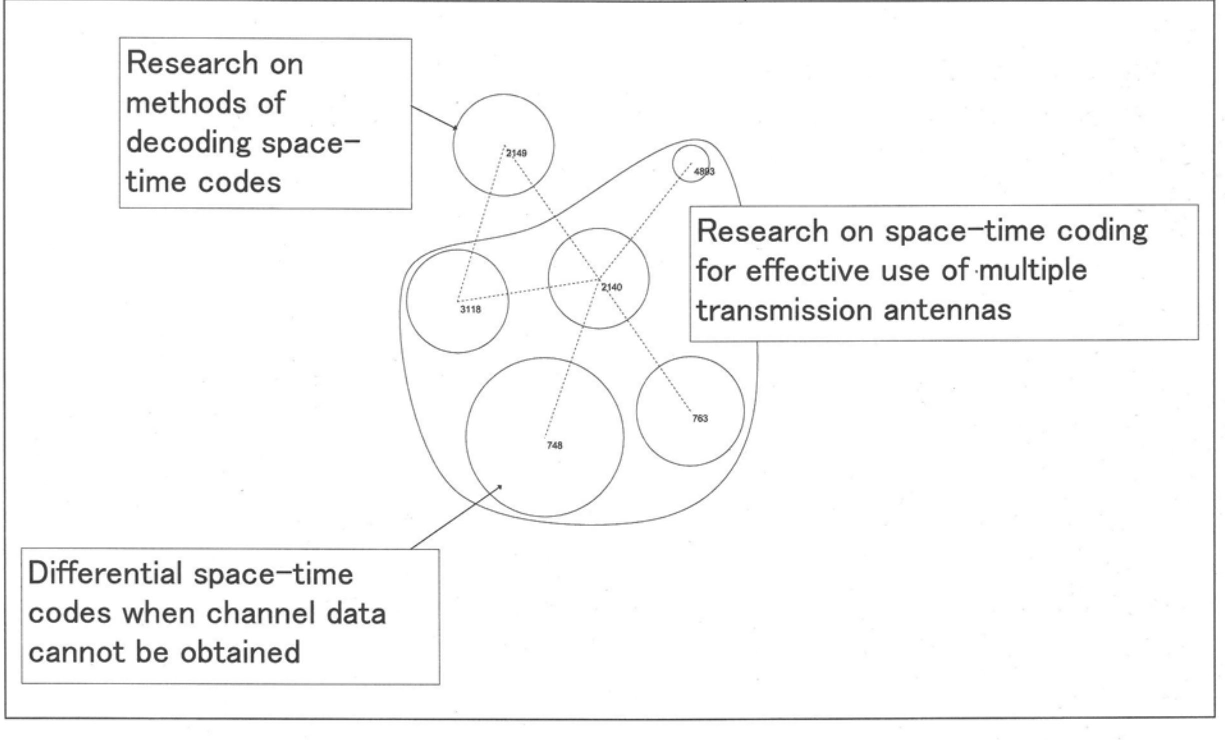
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13(5)	50(0)	1992	4066	2003.7



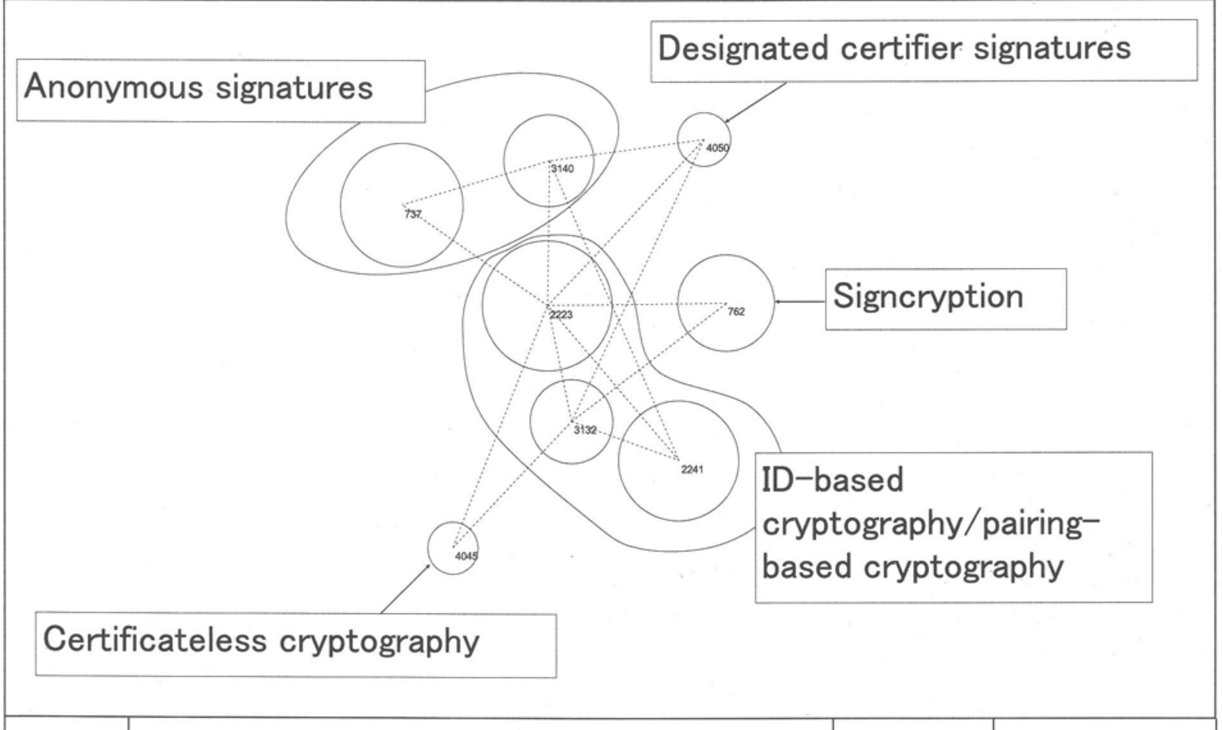
Name of RA	Ultra fine crystal grain / macrostrain process		RA ID	73
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13(1)	83(16)	1541	4253	2003.5



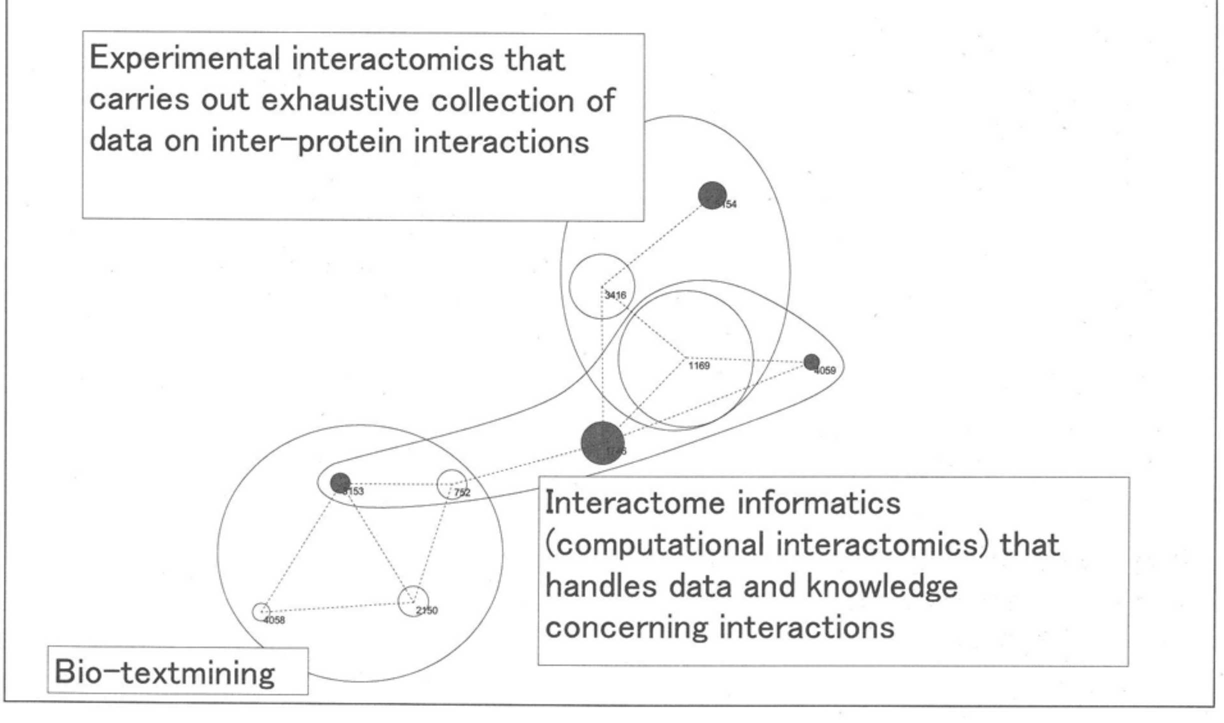
Name of RA	Space-time code		RA ID	74
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(0)	15(0)	416	660	2002.7



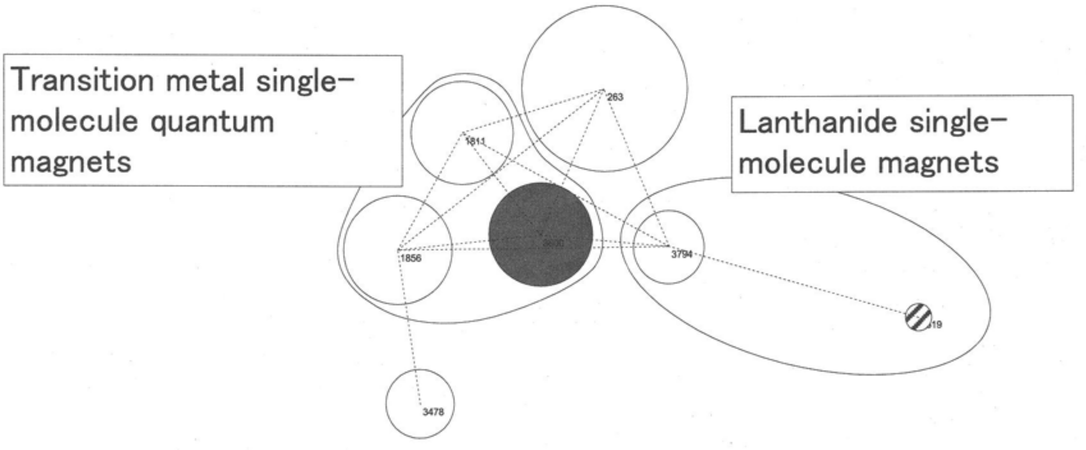
Name of RA	Multifunctional signature / multifunctional coding	RA ID	75	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(0)	37(2)	524	1191	2002.9



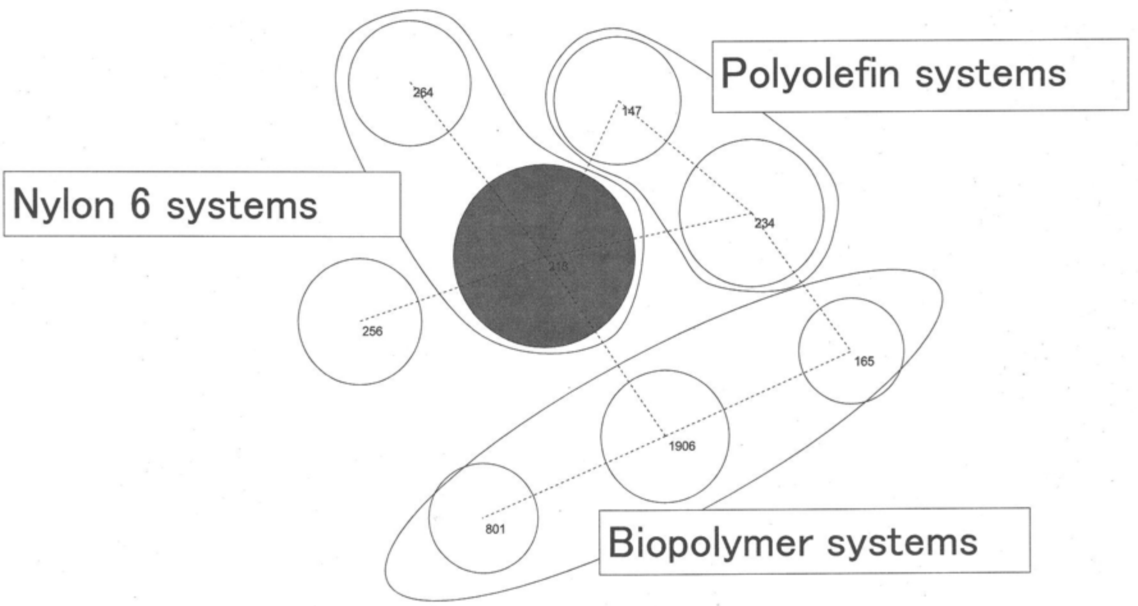
Name of RA	Interactome analysis	RA ID	76	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9(4)	51(4)	3127	6036	2004.0



Name of RA	Molecule-based nano-quantum magnet	RA ID	77	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7(1)	32(4)	836	1892	2003.6

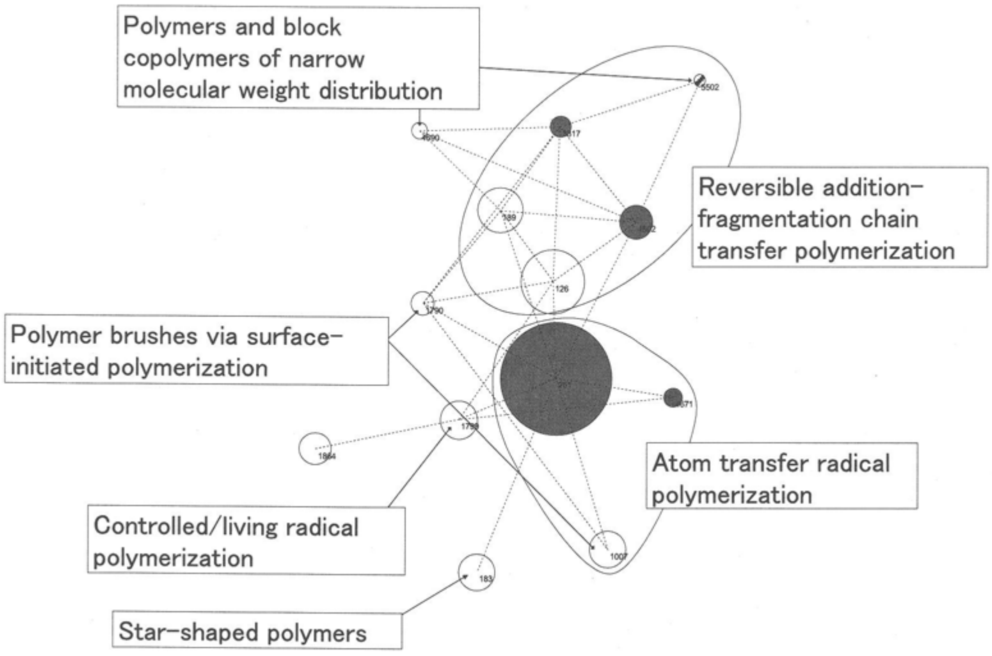


Name of RA	Macromolecule nanocomposite	RA ID	78	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(1)	21(7)	1181	2052	2001.8



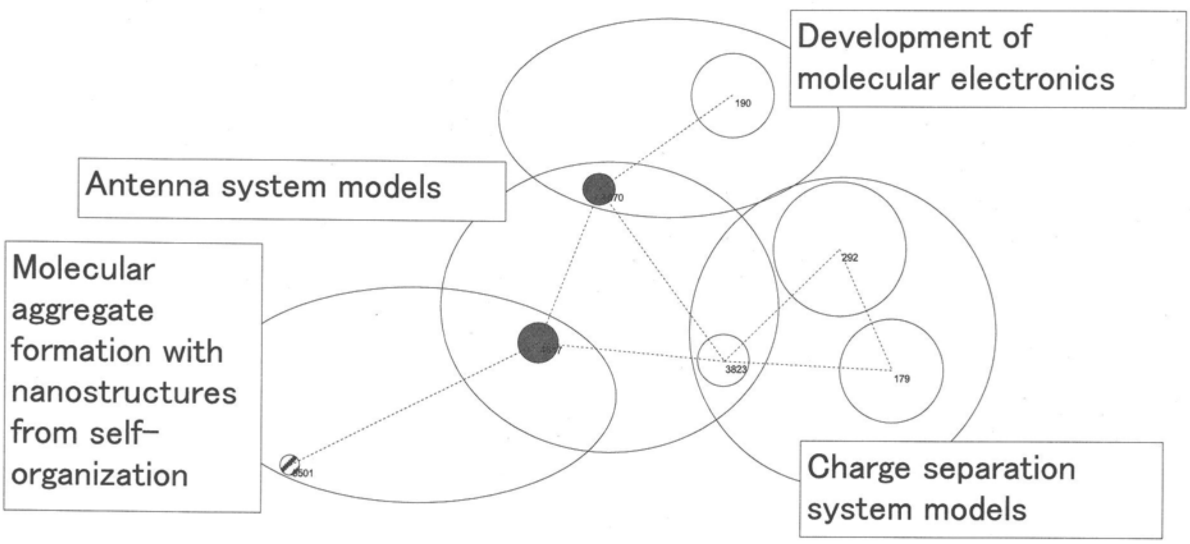
Name of RA	Living radical polymerization	RA ID	79

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13(4)	63(7)	2550	7018	2003.2

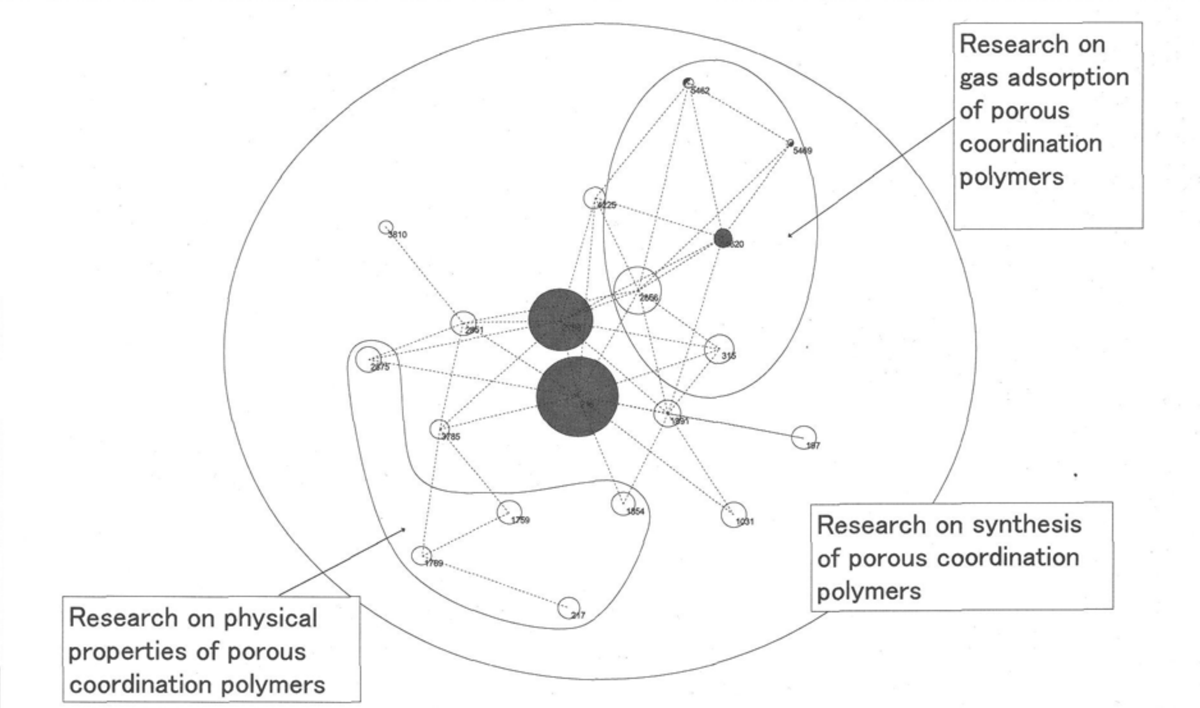


Name of RA	Construction of artificial photosynthesis model mimicking antenna system and charge separation system	RA ID	80

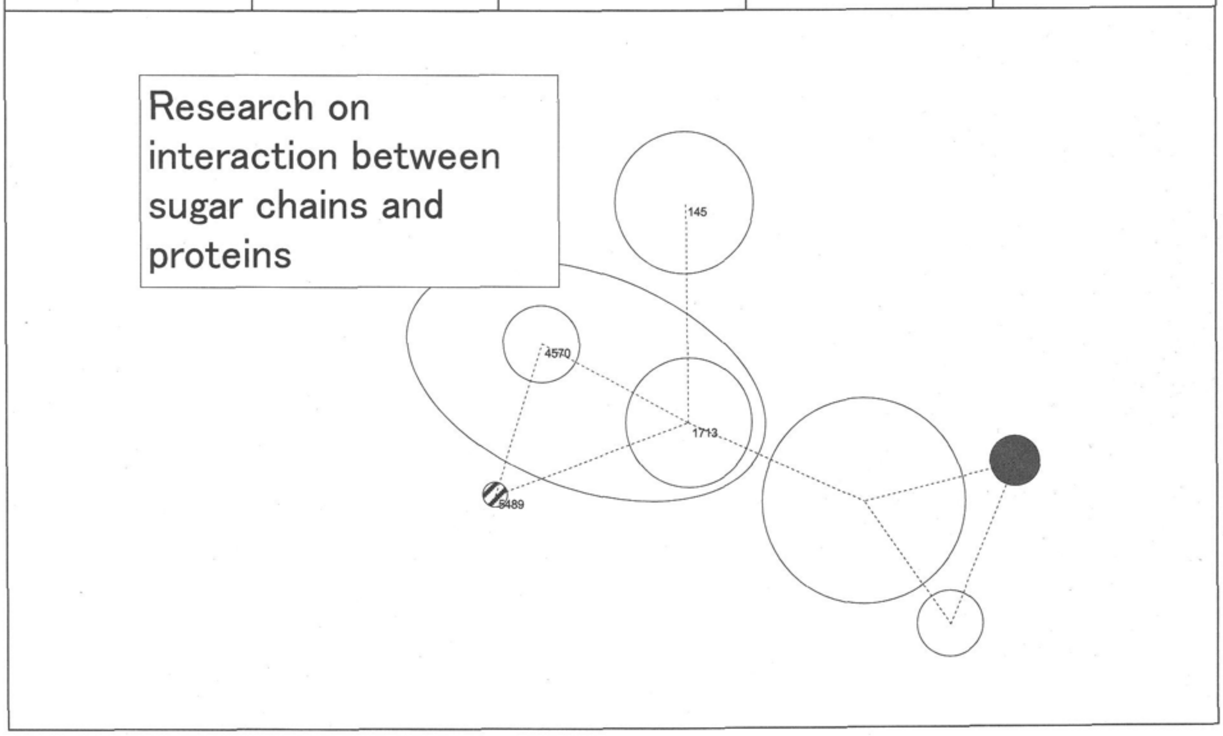
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7(2)	20(16)	1046	1826	2003.0



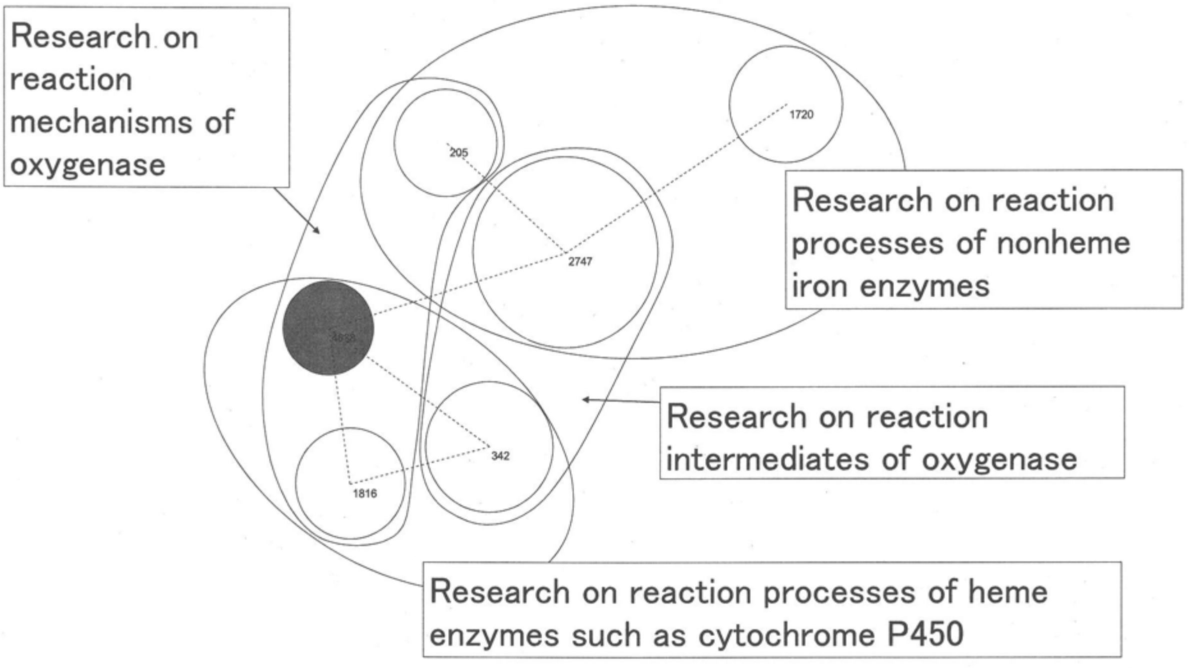
Name of RA	Porous coordination polymer		RA ID	81
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
19(3)	67(4)	3629	8835	2003.5



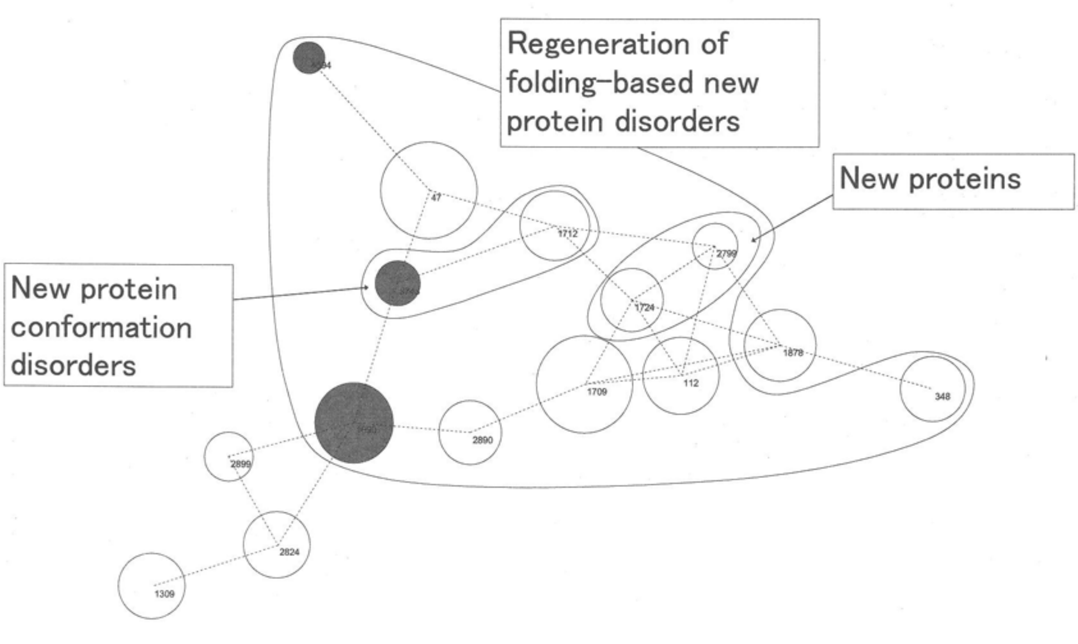
Name of RA	Retrieval of binding specificity of sugar chain recognition protein by neoglycolipid sugar chain microarray		RA ID	82
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7(1)	55(1)	1563	3983	2004.1



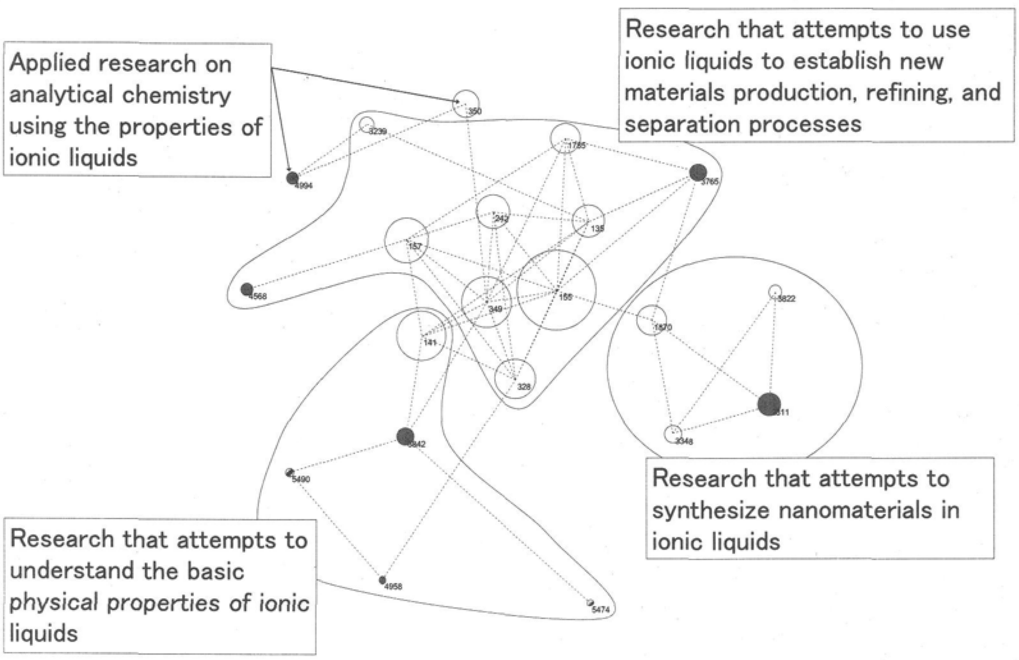
Name of RA	Activation of oxygen molecule by metalloenzyme		RA ID	83
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(1)	29(0)	913	2005	2003.6



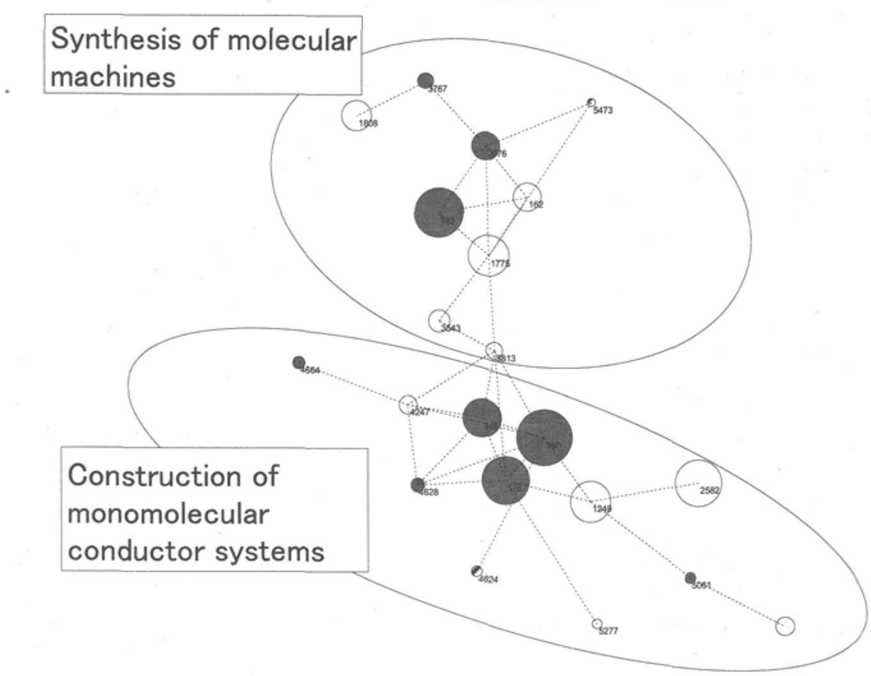
Name of RA	Protein folding		RA ID	84
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
15(3)	45(1)	2020	3653	2003.1



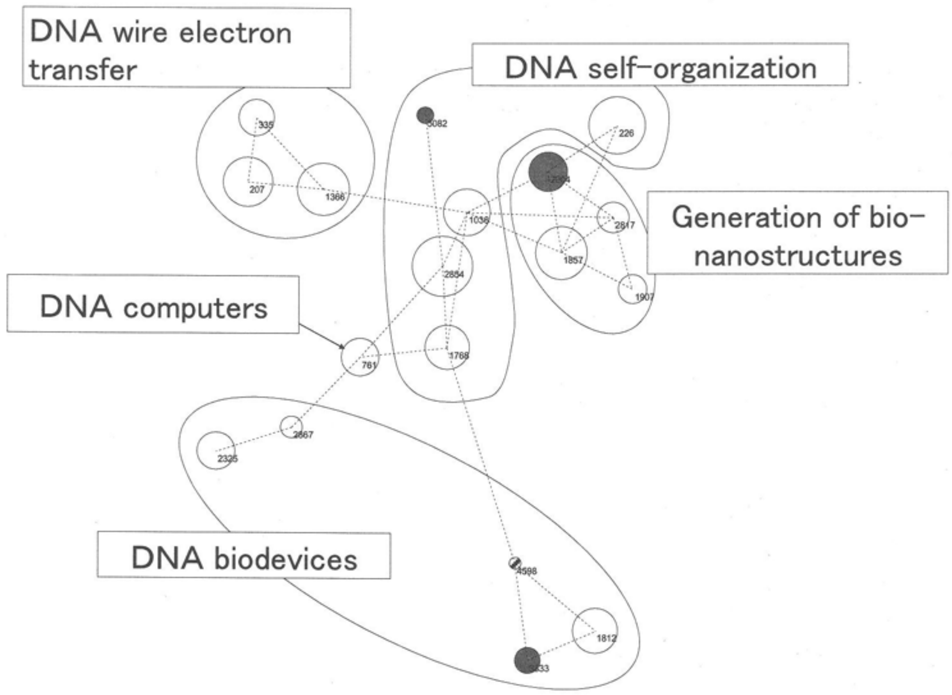
Name of RA	Ionic liquid		RA ID	85
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
21(6)	103(10)	3217	9708	2003.2



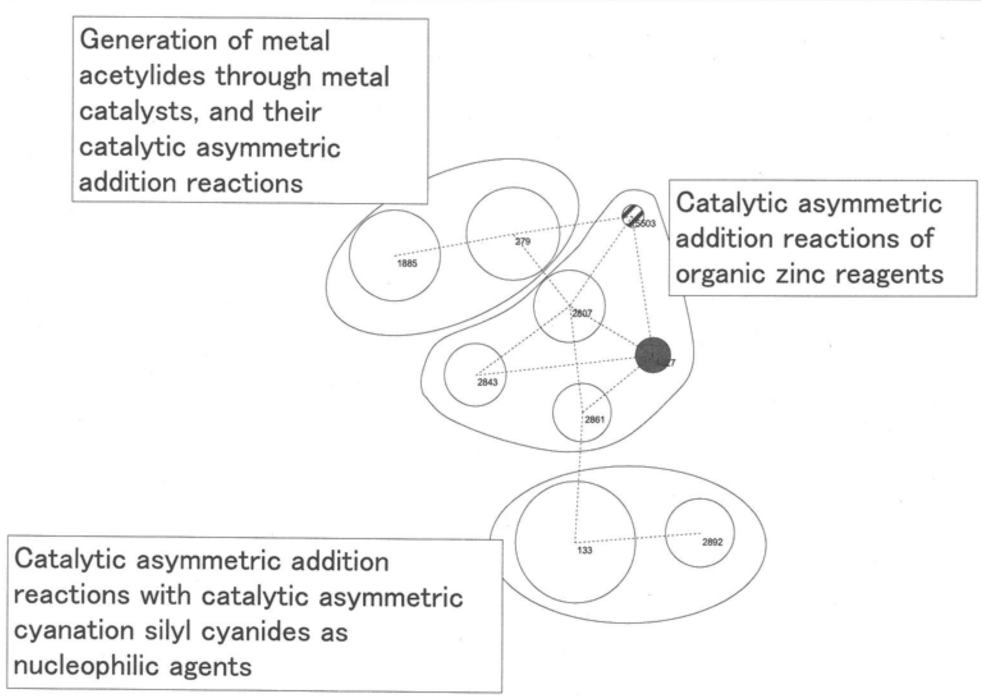
Name of RA	Study on supramolecular nanodevice by molecular machine and single-molecule conductor		RA ID	86
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
21(9)	95(1)	4138	9254	2003.5



Name of RA	DNA-nanomaterial and nanodevice		RA ID	87
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
18(3)	91(1)	3275	6940	2003.3

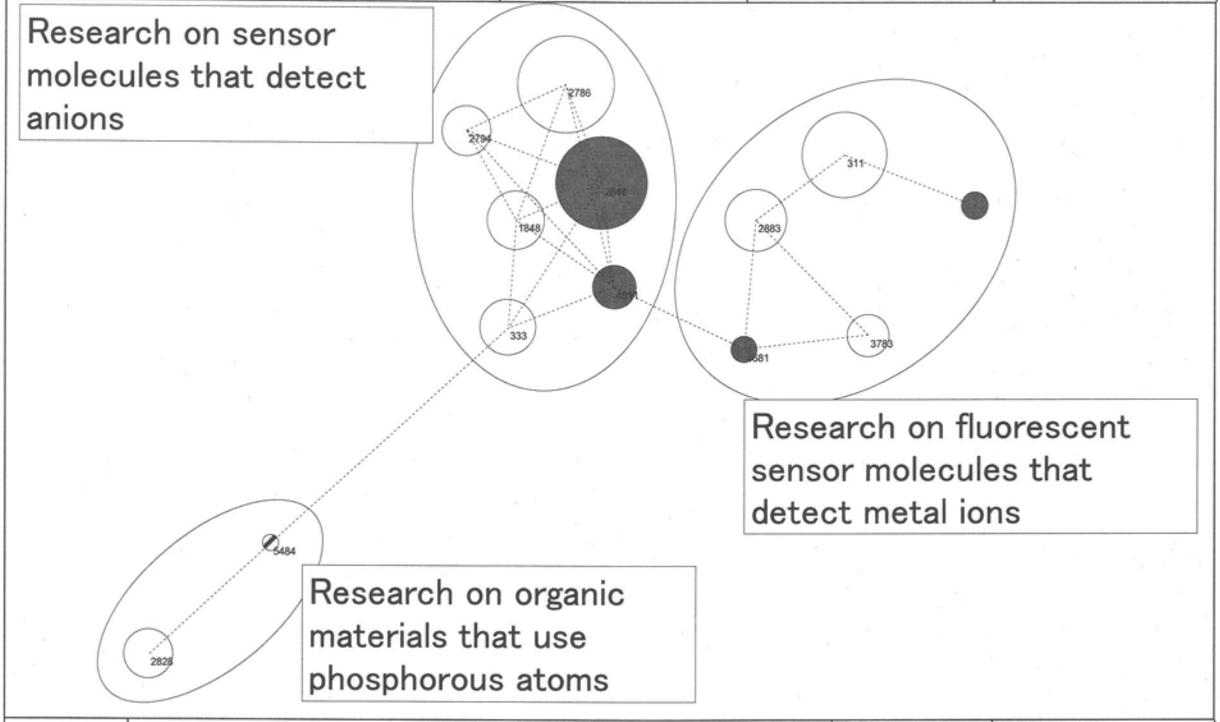


Name of RA	Catalytic asymmetric addition reaction of carbon nucleophile		RA ID	88
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9(1)	34(2)	971	2023	2003.4



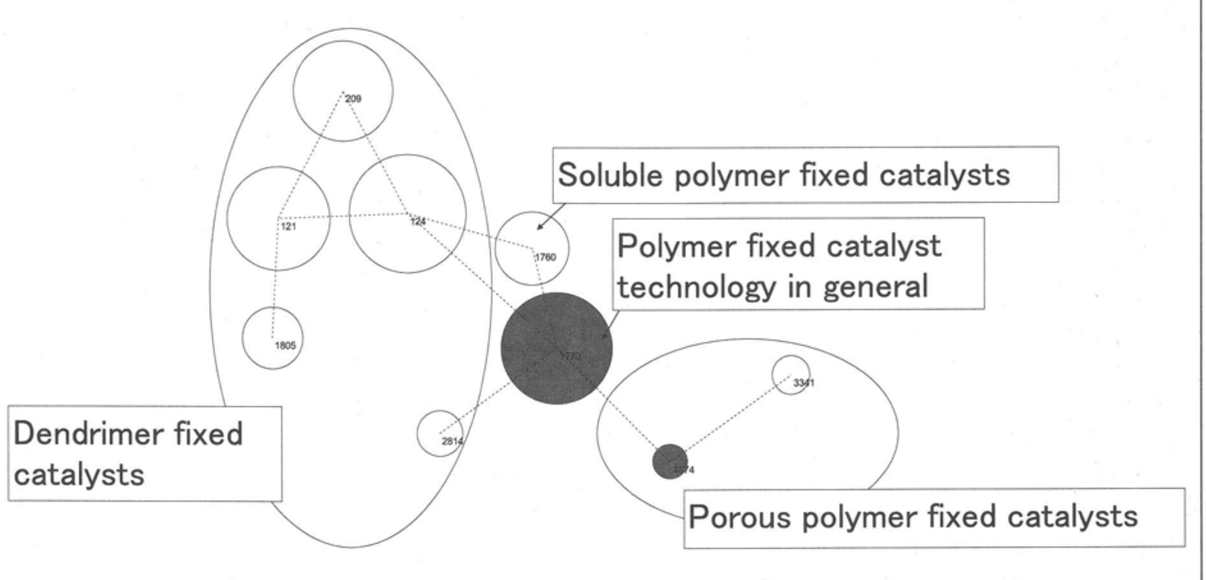
Name of RA	Bioimaging probe	RA ID	89

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13(4)	56(7)	1434	3157	2004.0

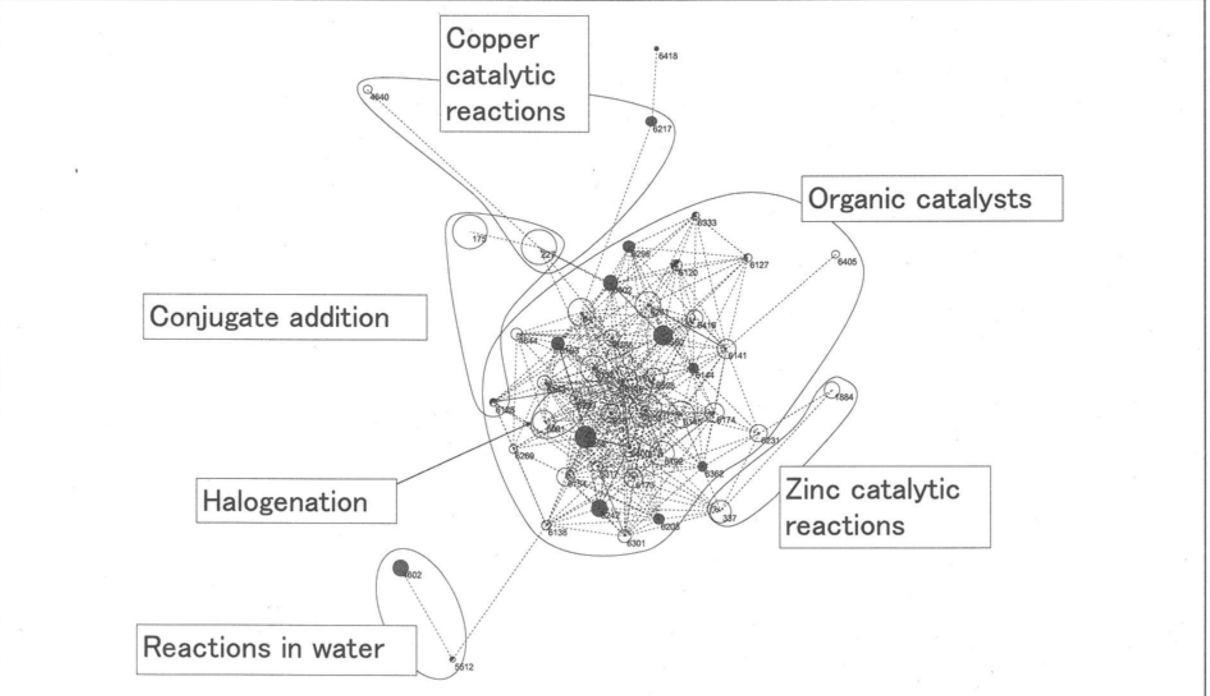


Name of RA	Synthetic polymer-immobilized catalyst technology	RA ID	90

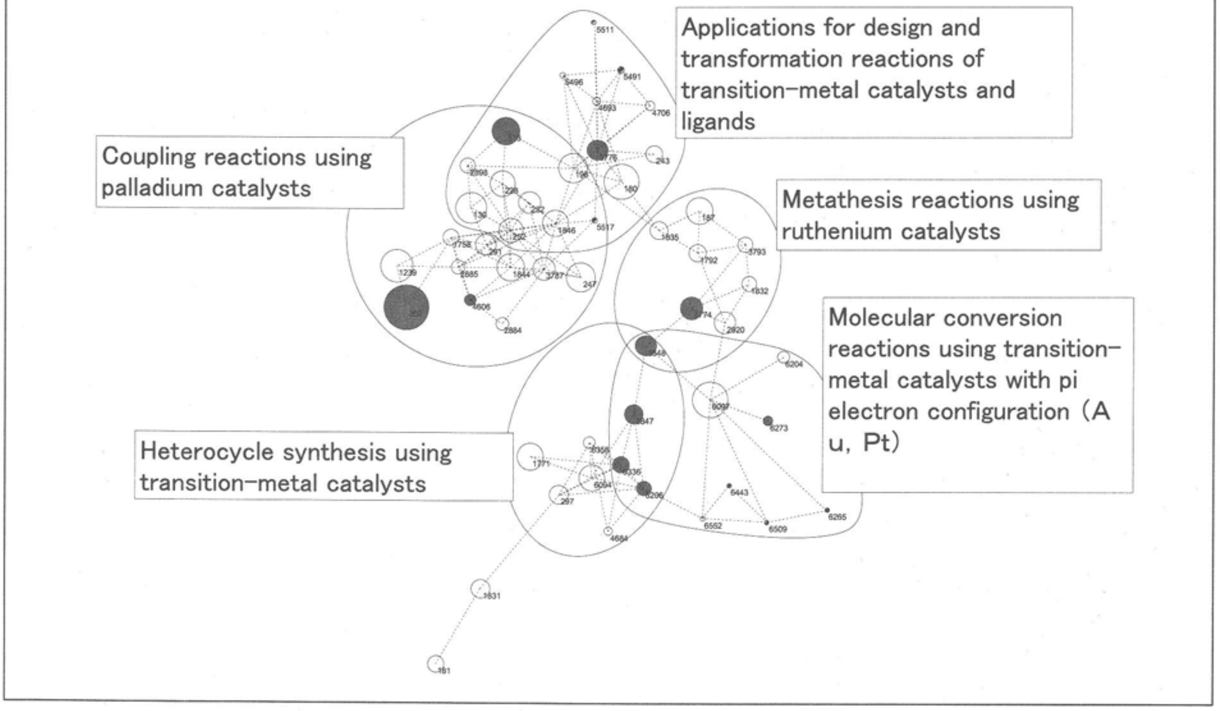
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9(2)	26(11)	1951	3711	2002.3



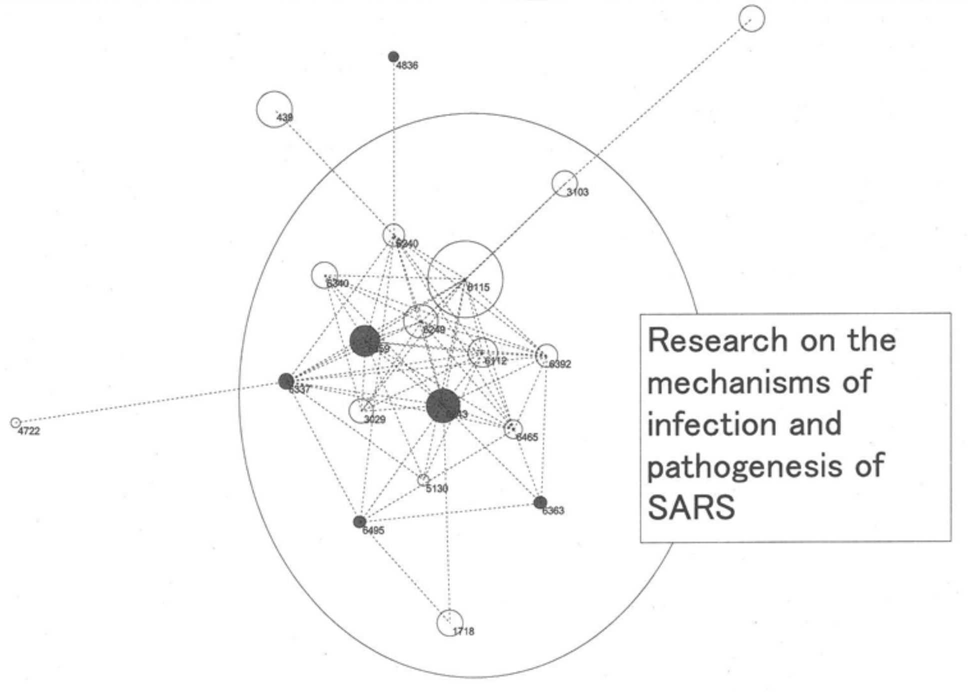
Name of RA	Catalytic asymmetric synthesis		RA ID	91
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
48(11)	205(37)	2988	12788	2004.1



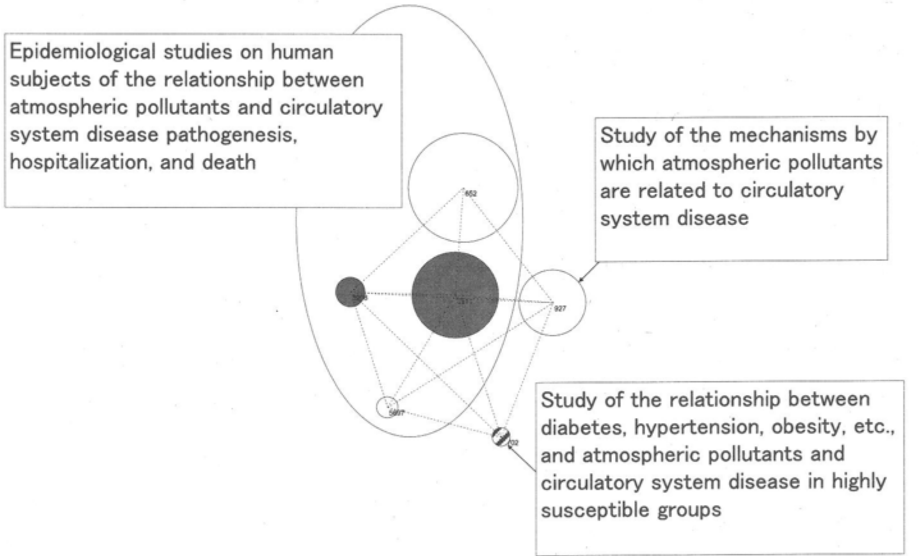
Name of RA	Molecular conversion reaction using transition metal catalyst		RA ID	92
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
52(10)	244(10)	6652	17175	2003.7



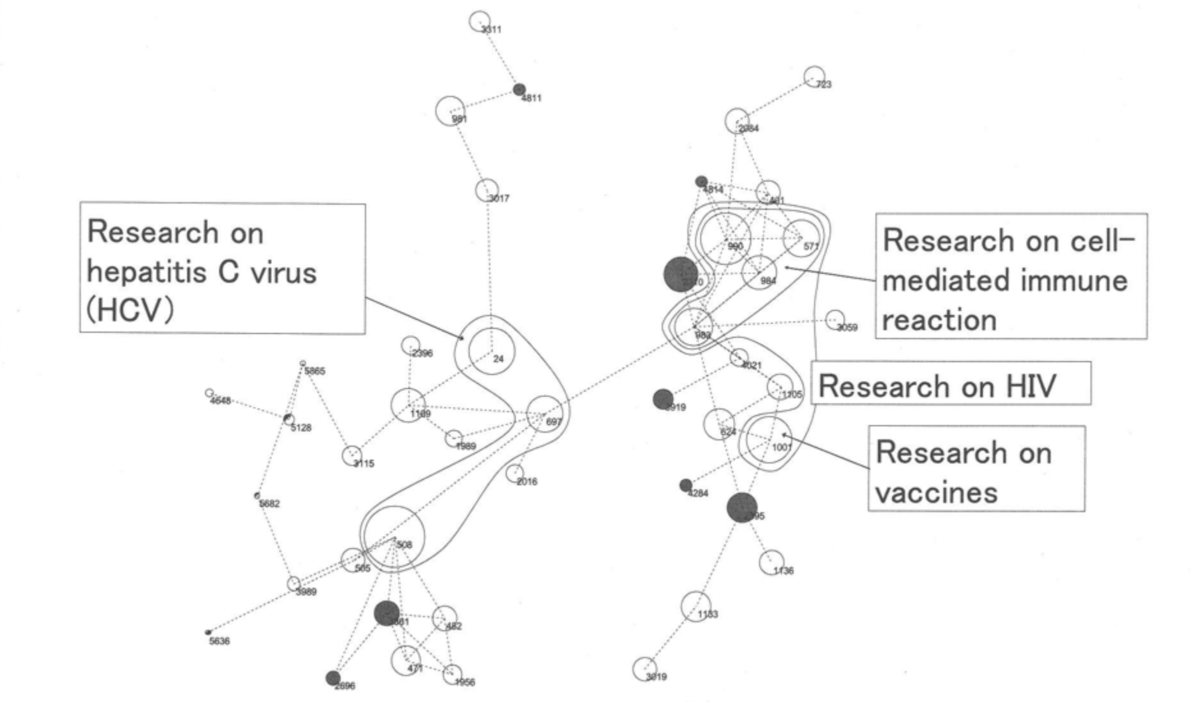
Name of RA	Pathogenic mechanism and preventive/therapeutic method of severe acute respiratory syndrome (SARS)	RA ID	93	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
20(6)	77(4)	3363	12772	2003.5



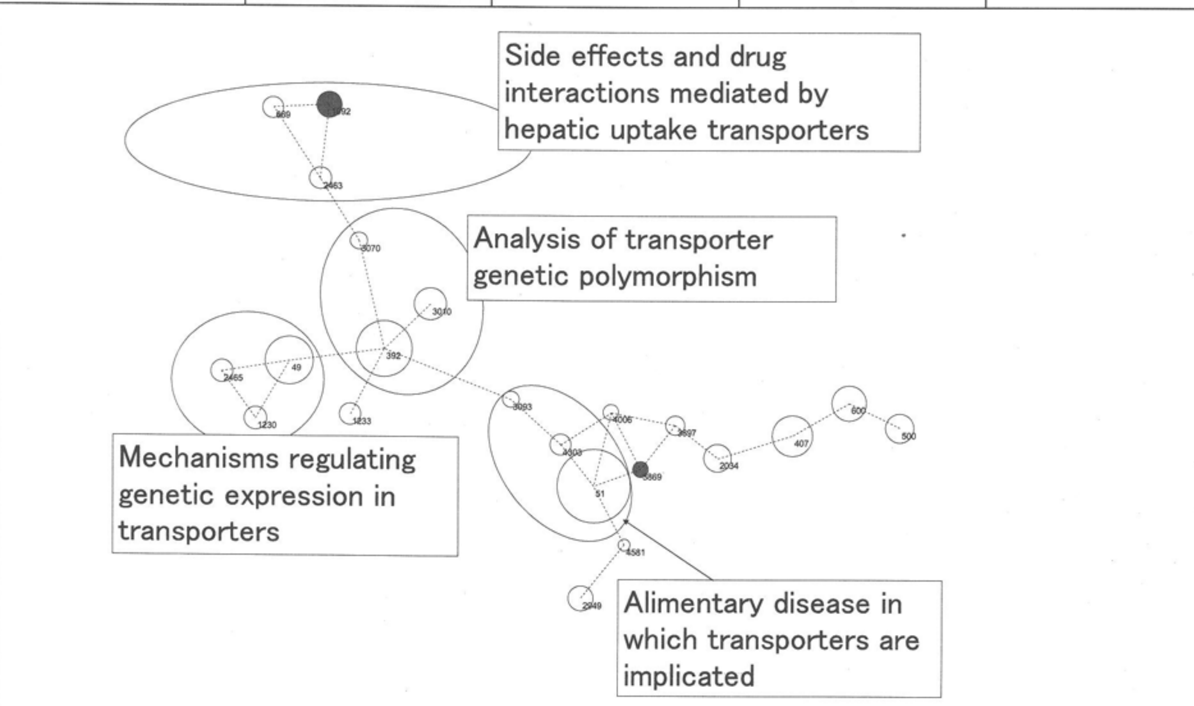
Name of RA	Epidemiological study about the effect of air pollution (especially particle-like substances) on cardiovascular disease	RA ID	94	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(2)	13(0)	444	727	2004.1



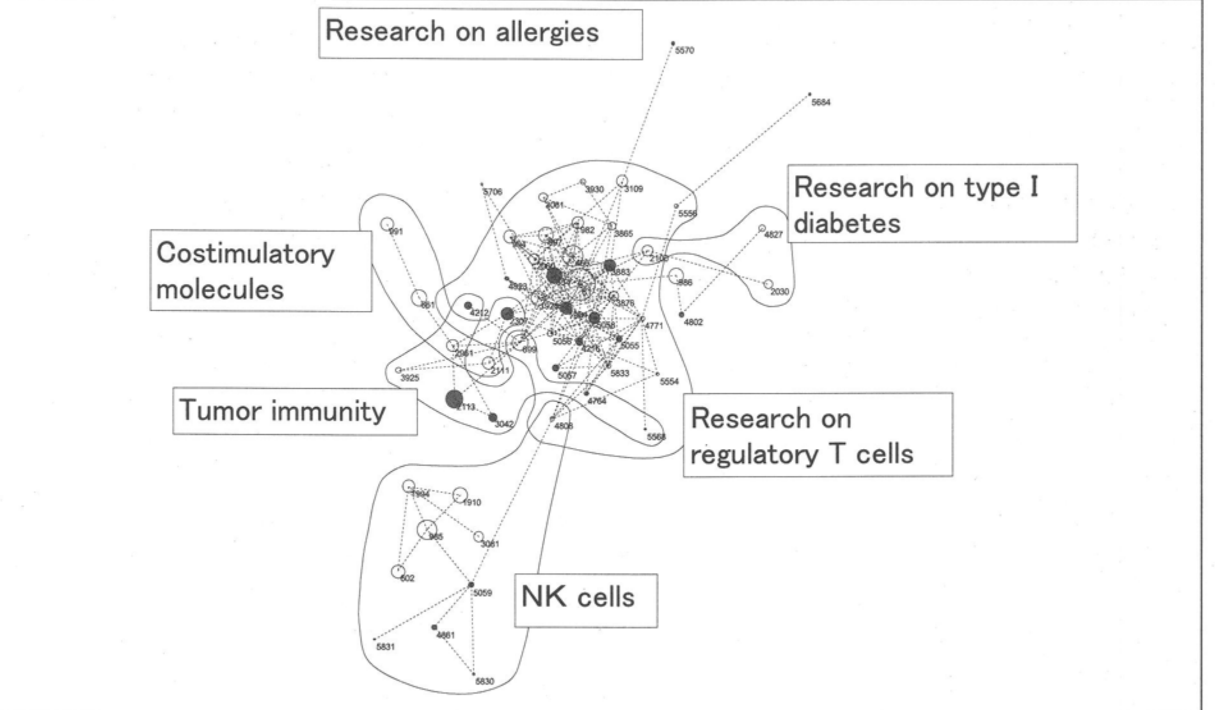
Name of RA	Study on HCV and HIV	RA ID	95	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
44(8)	185(5)	10743	26987	2002.9



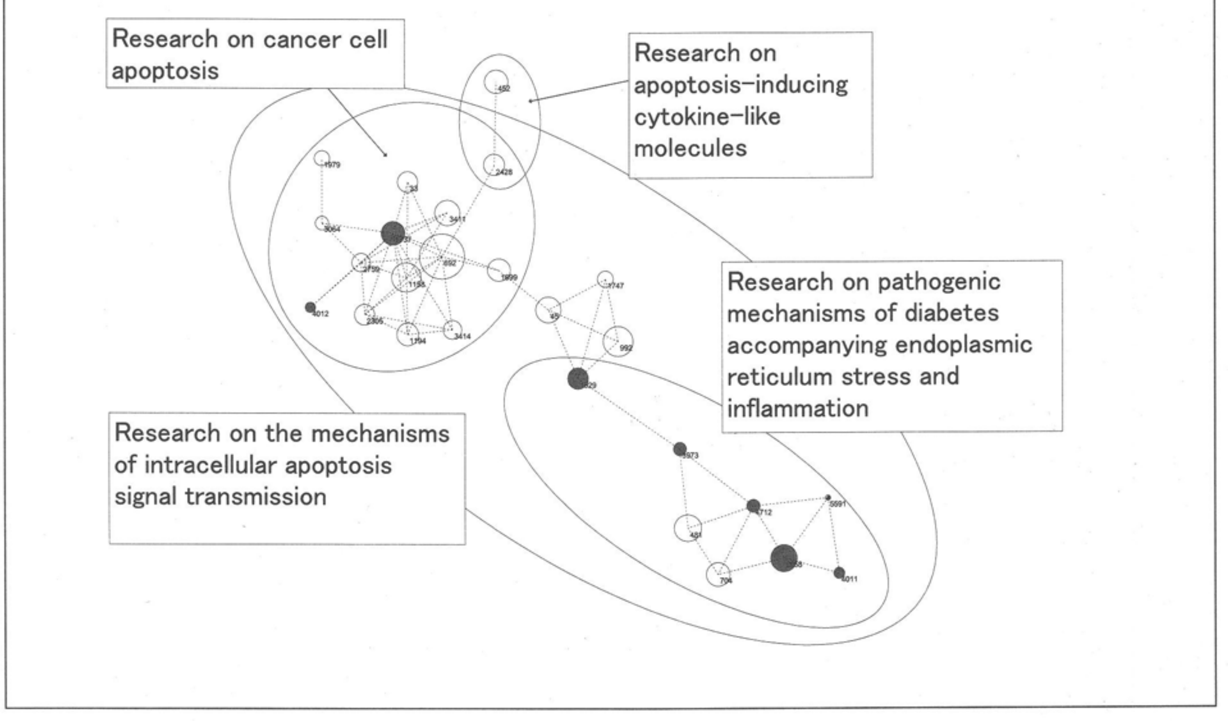
Name of RA	Elucidation of in-vivo function of drug transporter in human	RA ID	96	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
22(2)	136(18)	7416	19592	2002.9



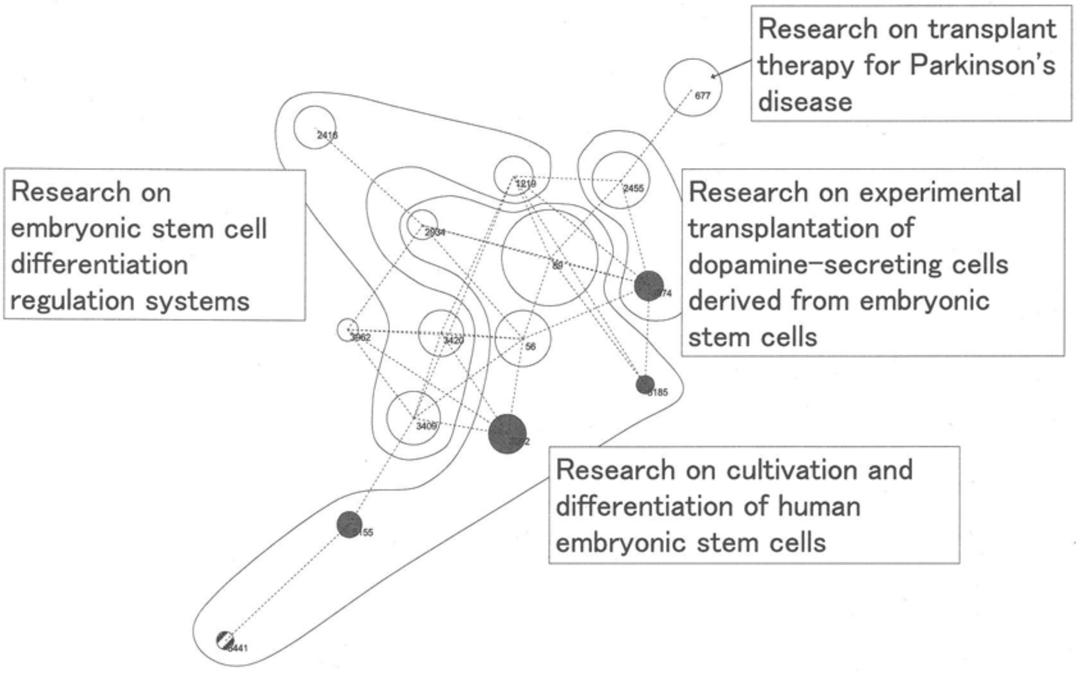
Name of RA	Suppression of immune reaction centered on foxp3-positive, CD25-positive and CD4-positive regulatory t cells		RA ID	97
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
56(15)	209(10)	8319	28424	2003.6



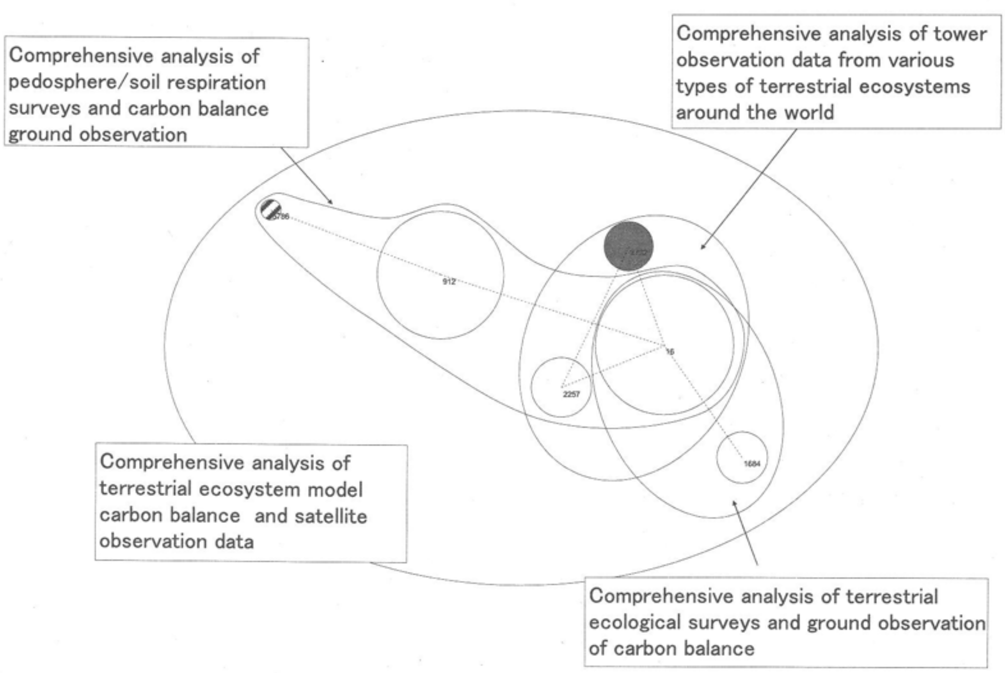
Name of RA	Apoptosis (cell death) and inflammation		RA ID	98
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
26	71(9)	6164	112844	2002.5



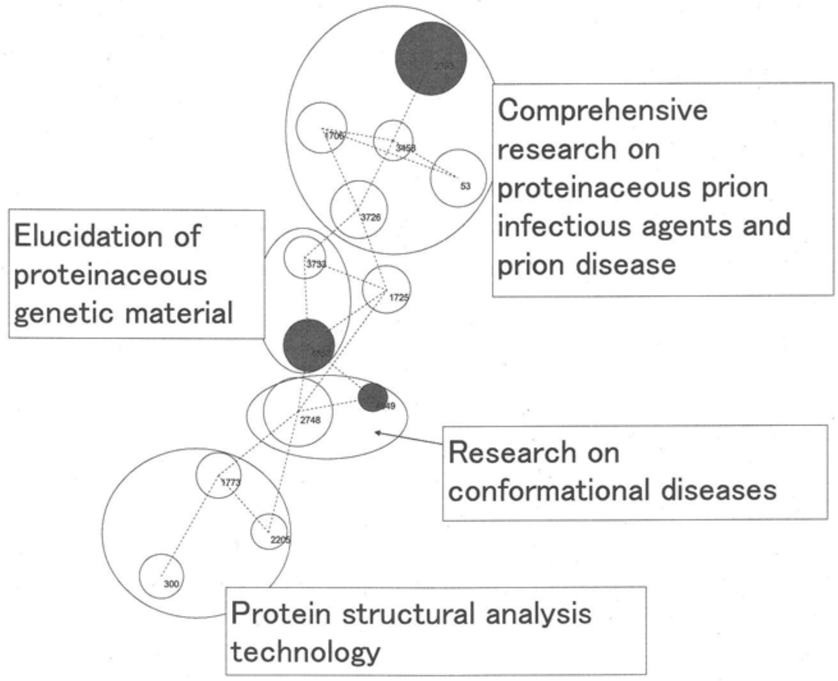
Name of RA	Embryonic stem cell / neural induction		RA ID	99
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
15(4)	72(3)	3759	9361	2003.5



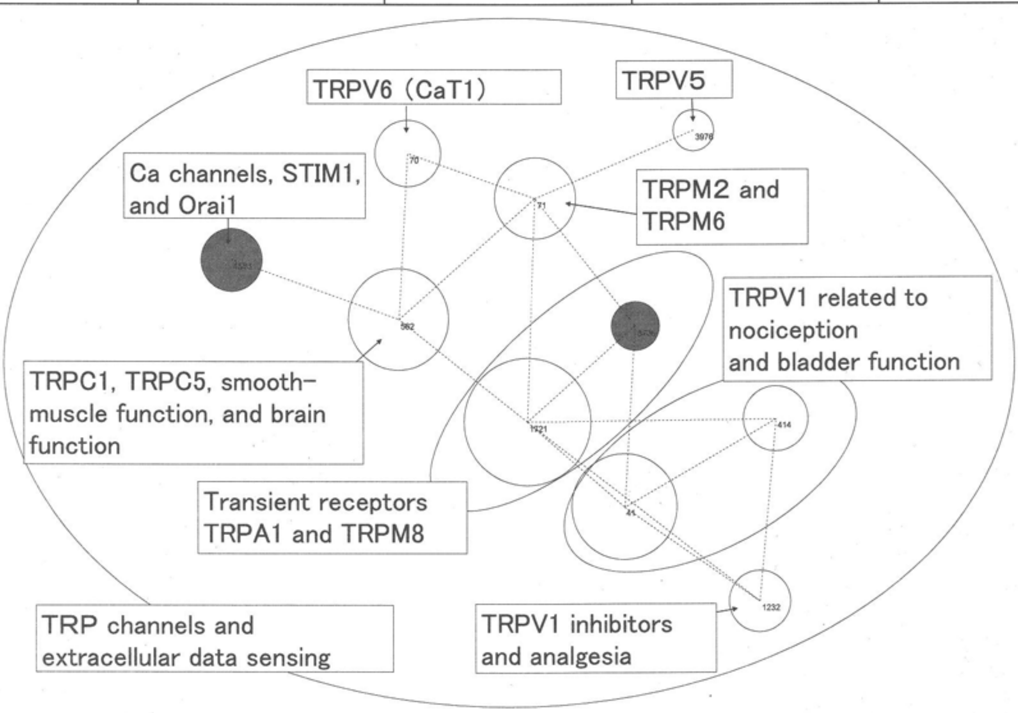
Name of RA	Study on exchange between atmosphere and continental ecosystem of CO_2 and others		RA ID	100
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(1)	17(0)	771	1243	2003.1



Name of RA	Proteinous infectious agent / new paradigm for genetic material		RA ID	101
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13(3)	34(0)	1825	3390	2003.6

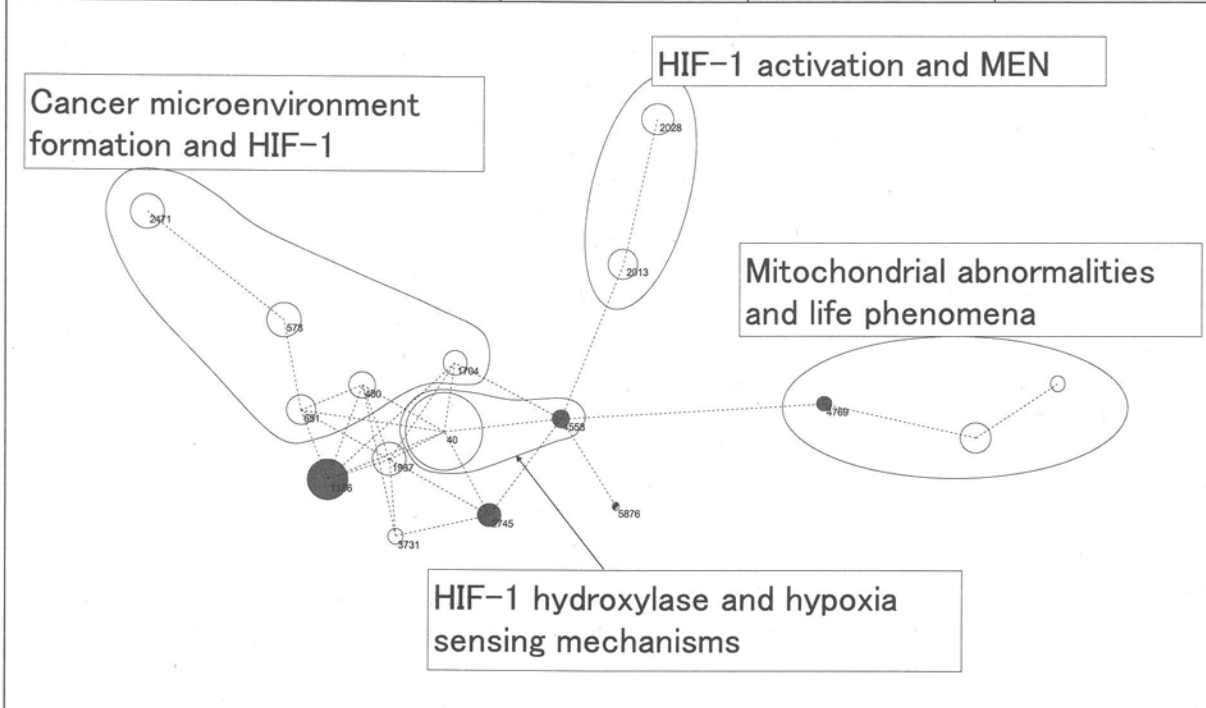


Name of RA	Physiological function of TRP channel		RA ID	102
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
10(2)	58(6)	2274	5883	2003.2



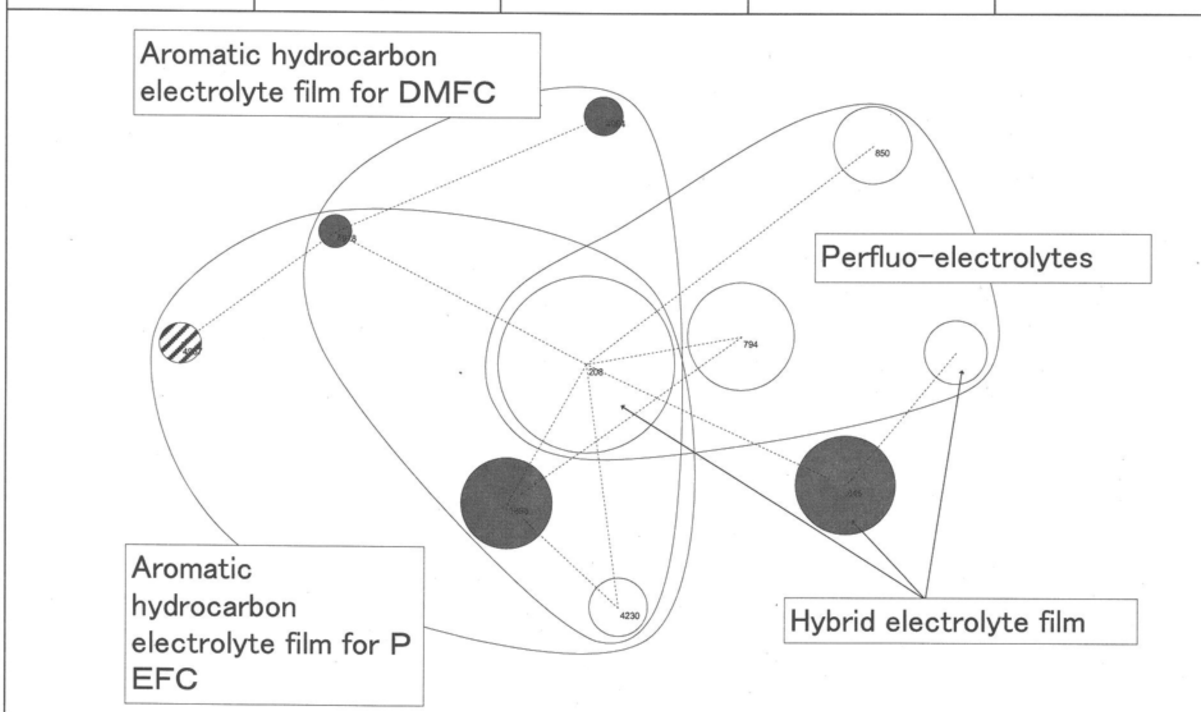
Name of RA	Activation of hypoxia-inducible factor 1 and formation of tumor microenvironment	RA ID	103

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
17(4)	68(6)	3738	10408	2003.0

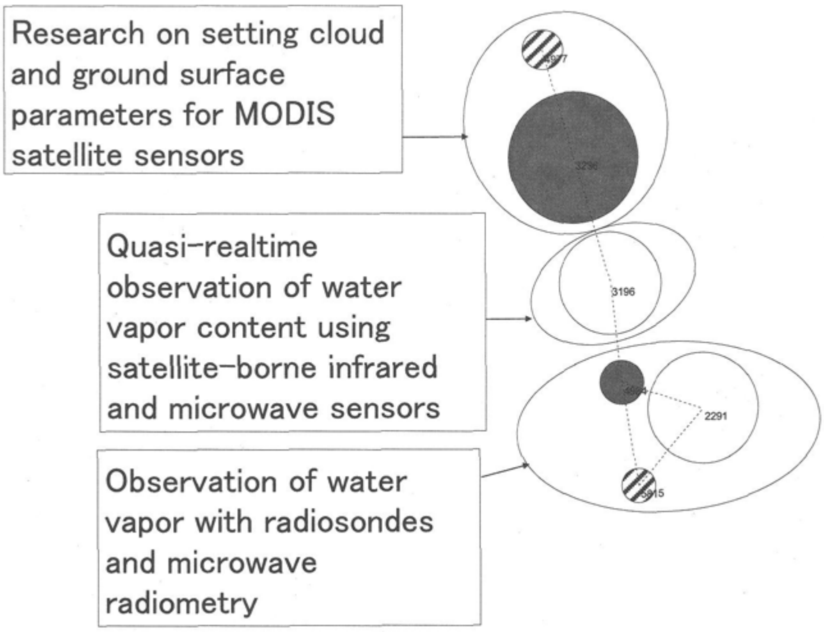


Name of RA	Solid macromolecule type fuel cell / macromolecular electrolyte film	RA ID	104

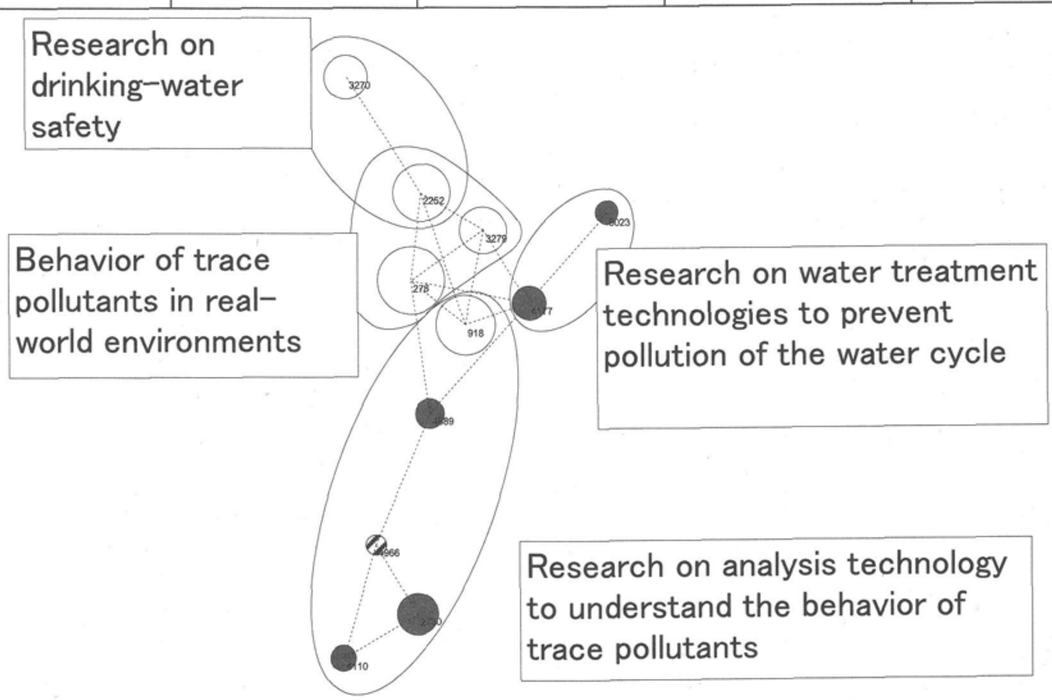
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
10(4)	22(6)	891	1486	2003.2



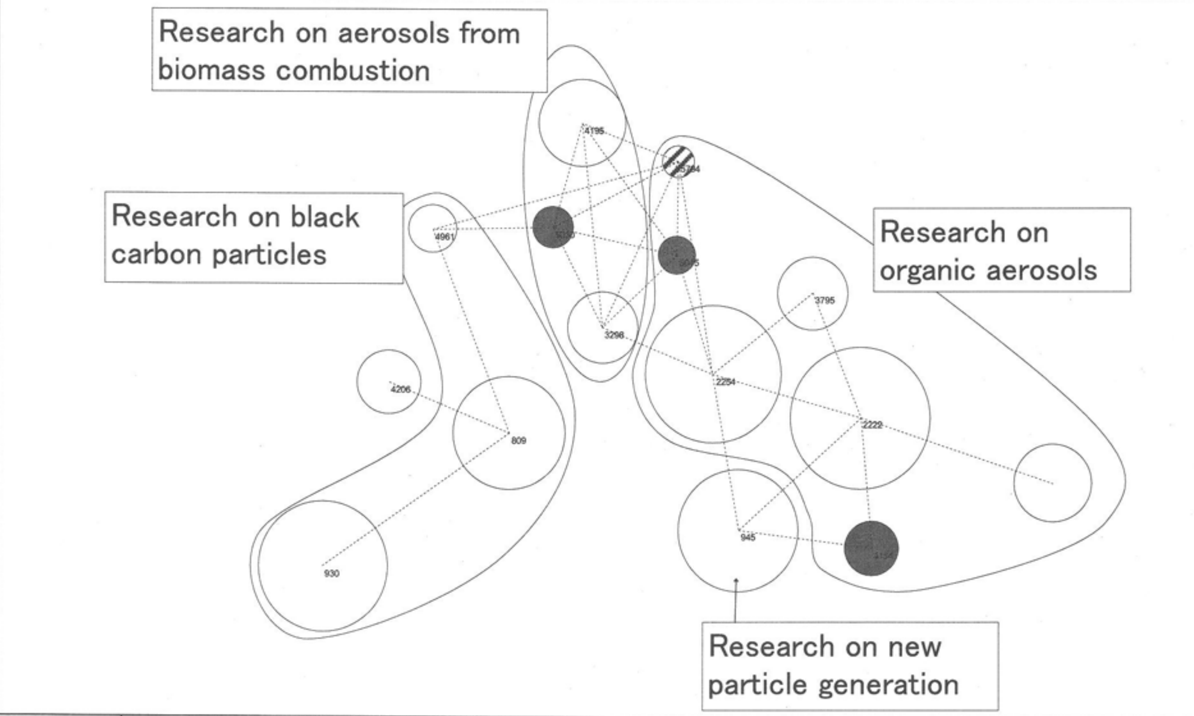
Name of RA	Quantification of water vapor, clouds, aerosol and albedo based on satellite and ground-based observation		RA ID	105
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(2)	18(0)	370	611	2004.3



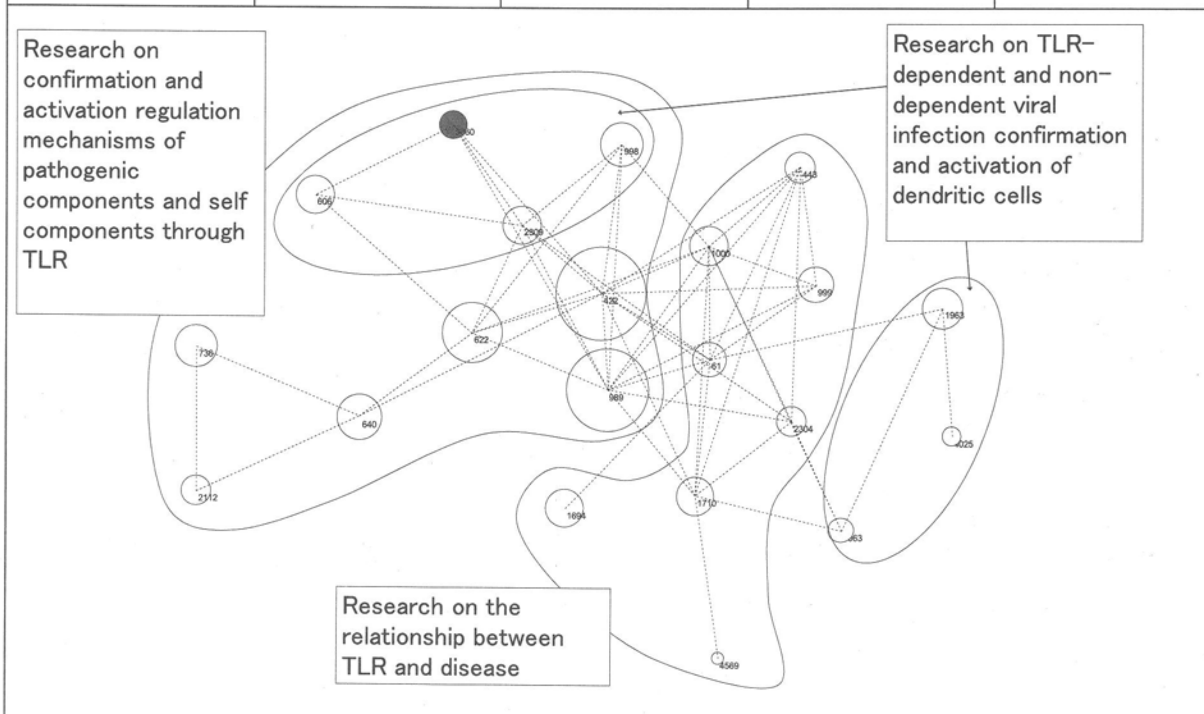
Name of RA	Water environment		RA ID	106
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
11(5)	30(0)	808	1442	2003.6



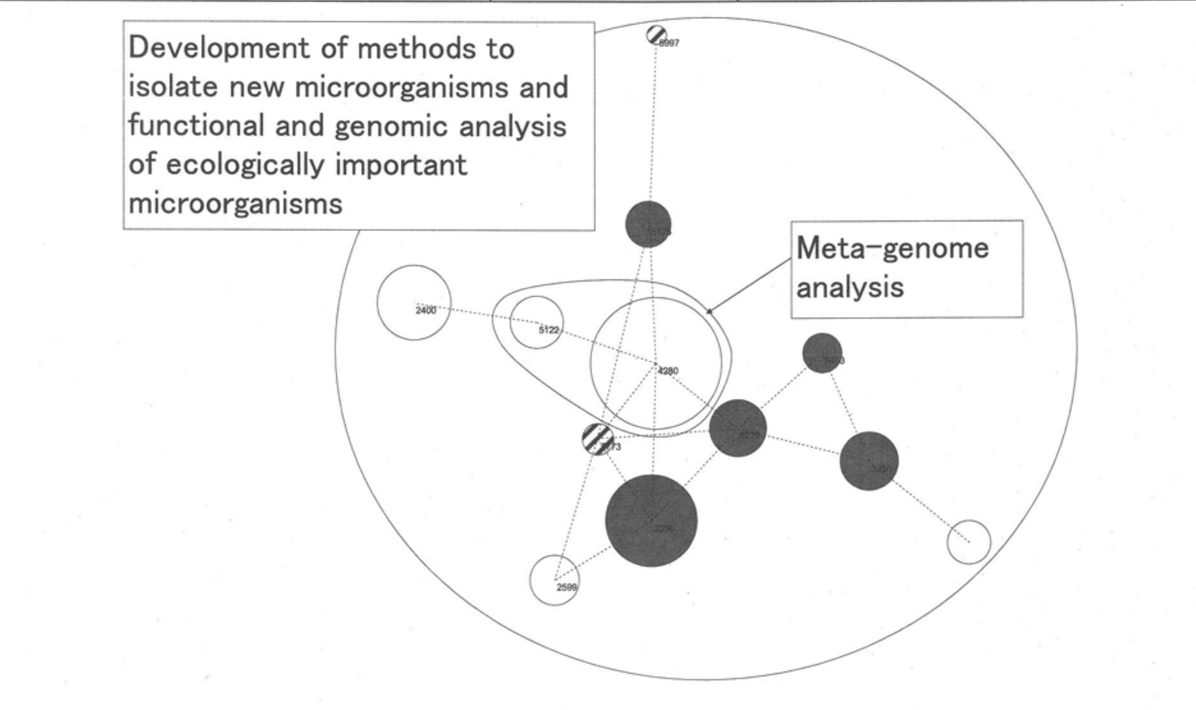
Name of RA	Aerosol		RA ID	107
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
15(3)	84(1)	1565	3451	2003.9



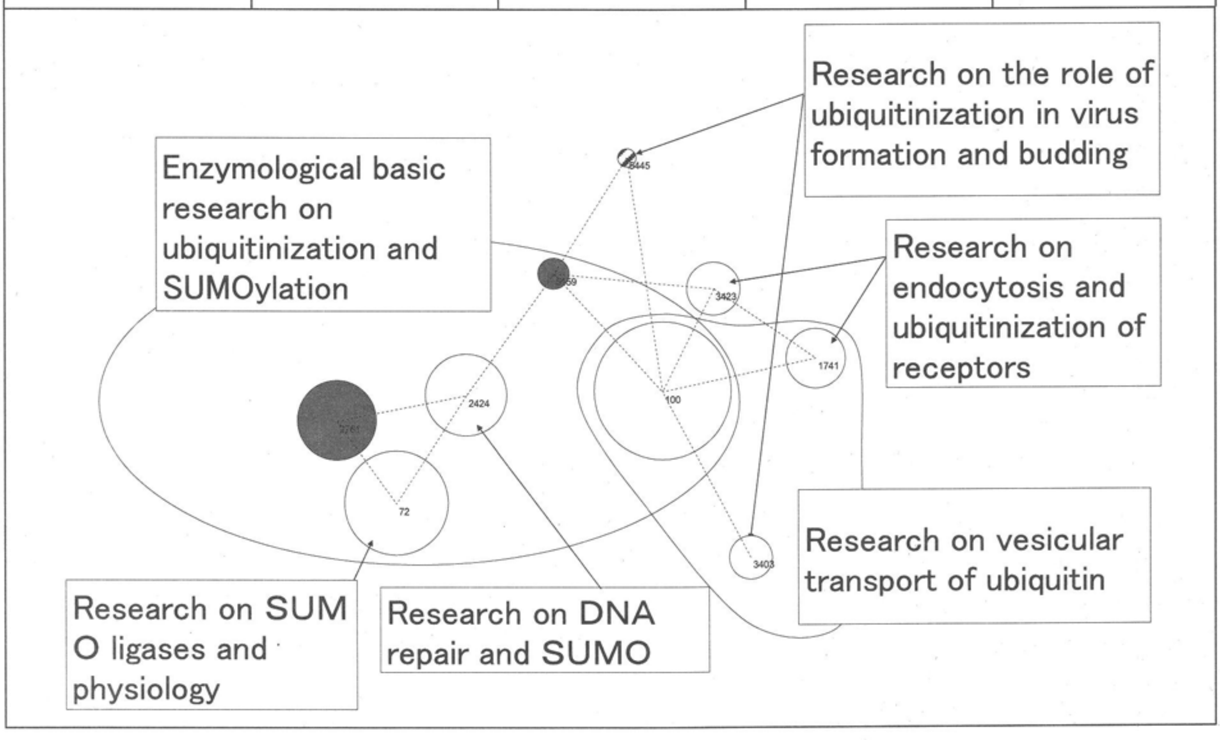
Name of RA	Innate immunity		RA ID	108
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
21(1)	133(51)	7323	22662	2003.2



Name of RA	Microbiodiversity		RA ID	109
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
12(5)	31(1)	1135	1970	2004.5

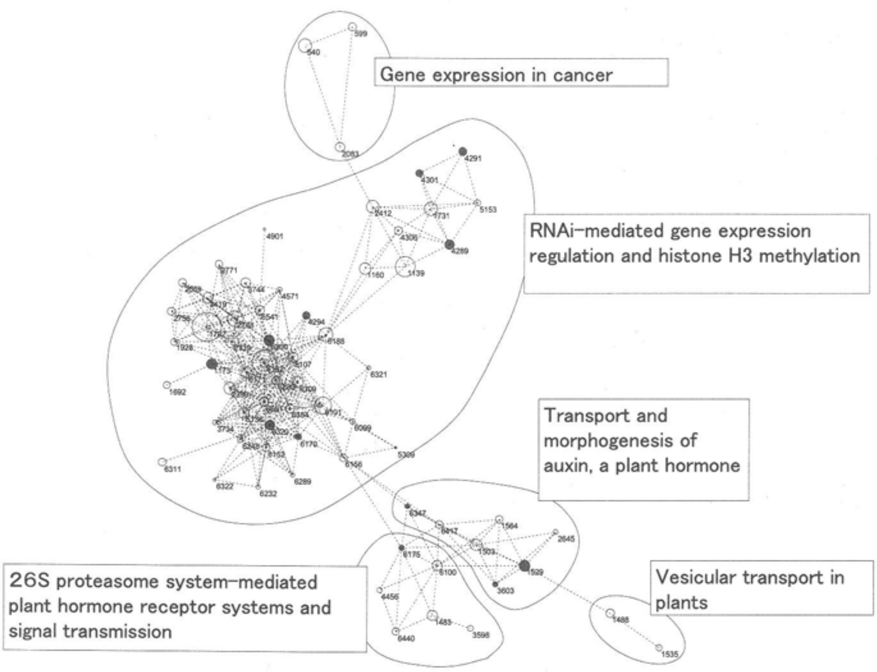


Name of RA	Study on ubiquitination and sumoylation of protein		RA ID	110
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9(2)	44(0)	2804	6908	9(2)



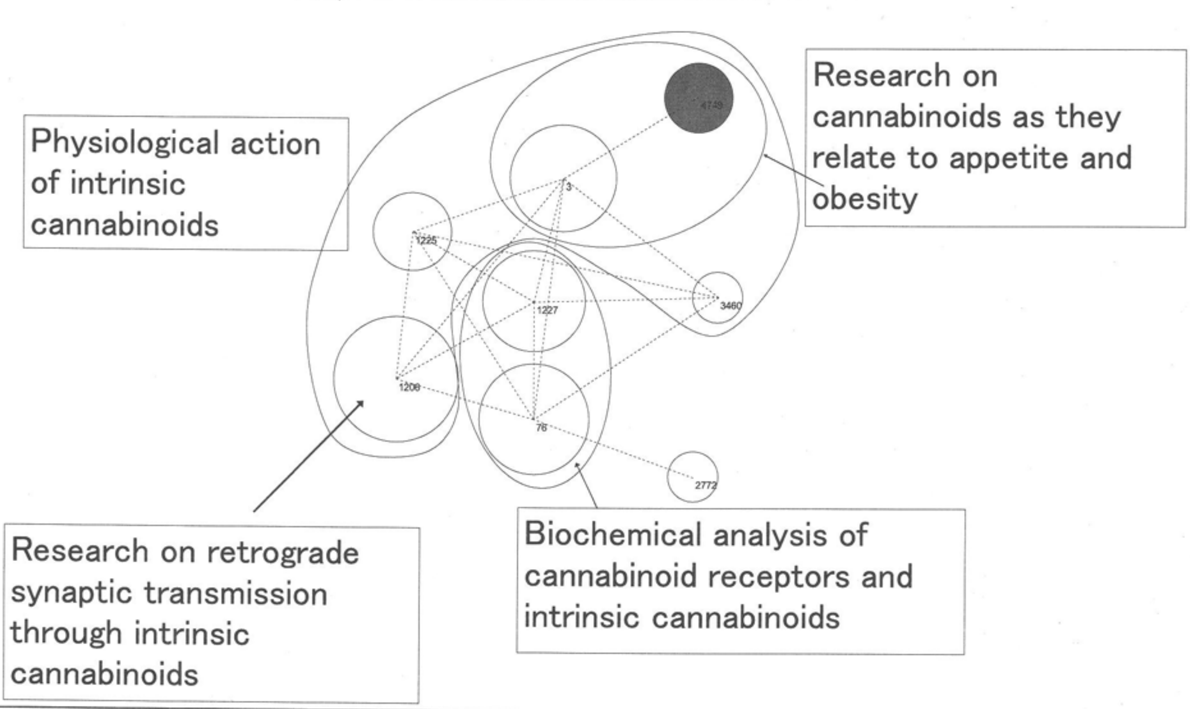
Name of RA	Multi-hierarchical regulatory mechanism of life phenomena	RA ID	111

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
67(12)	380(30)	13610	52771	2003.5



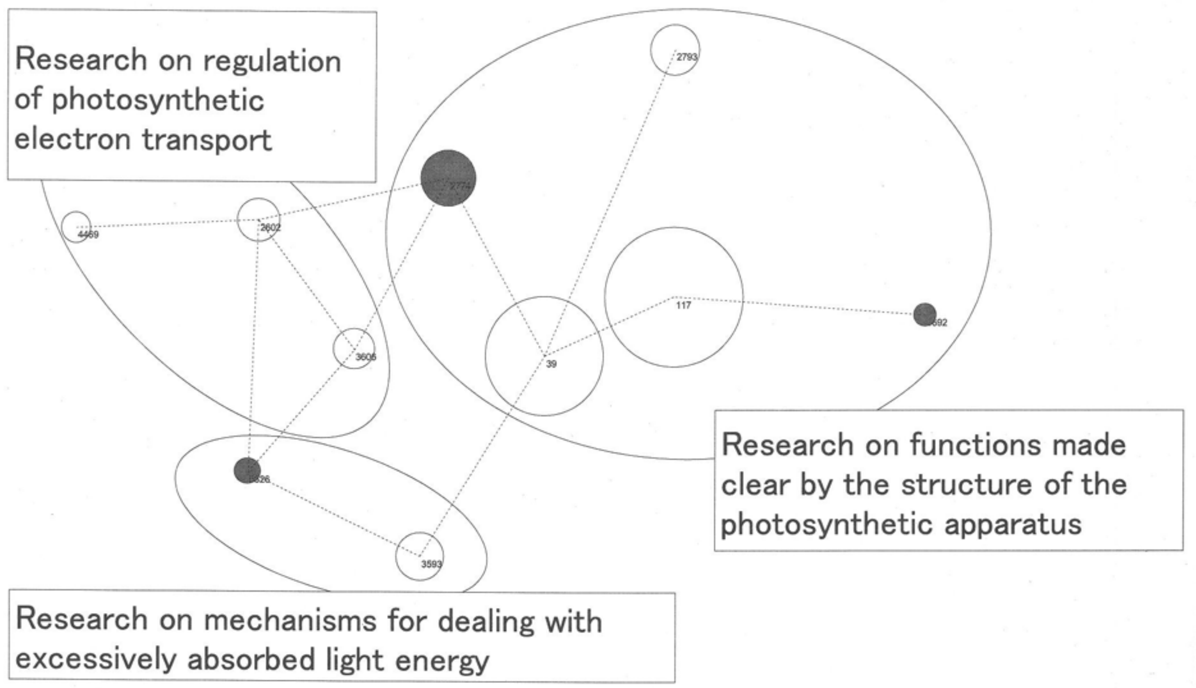
Name of RA	Molecular mechanism and physiological role of endogenous cannabinoid signal	RA ID	112

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8(1)	48(4)	1806	4514	2003.7



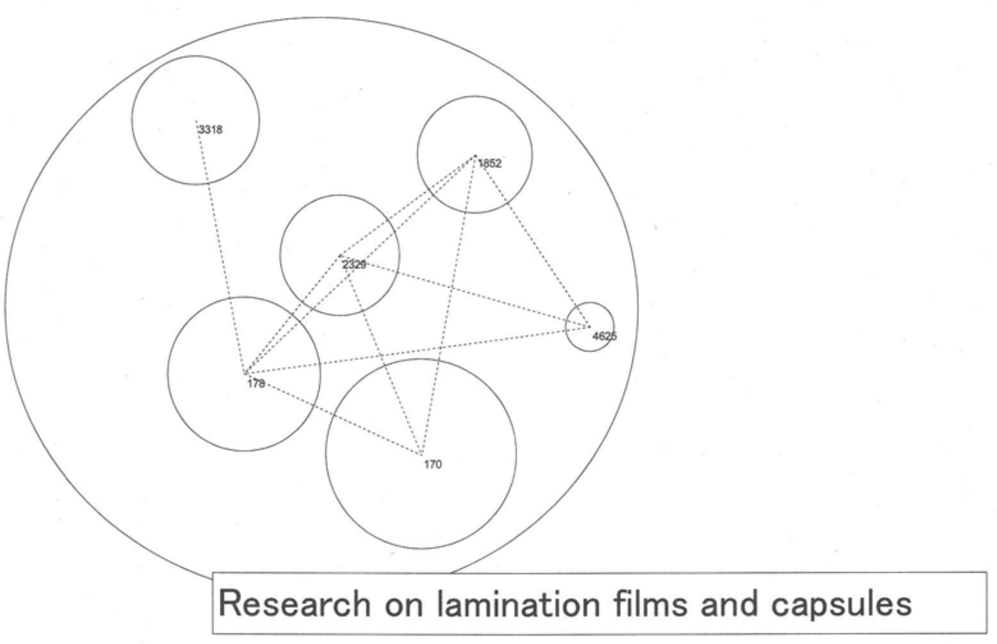
Name of RA	Photosynthetic light reaction apparatus / structure, function and regulation	RA ID	113

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
10(3)	26(5)	1902	3417	2003.7

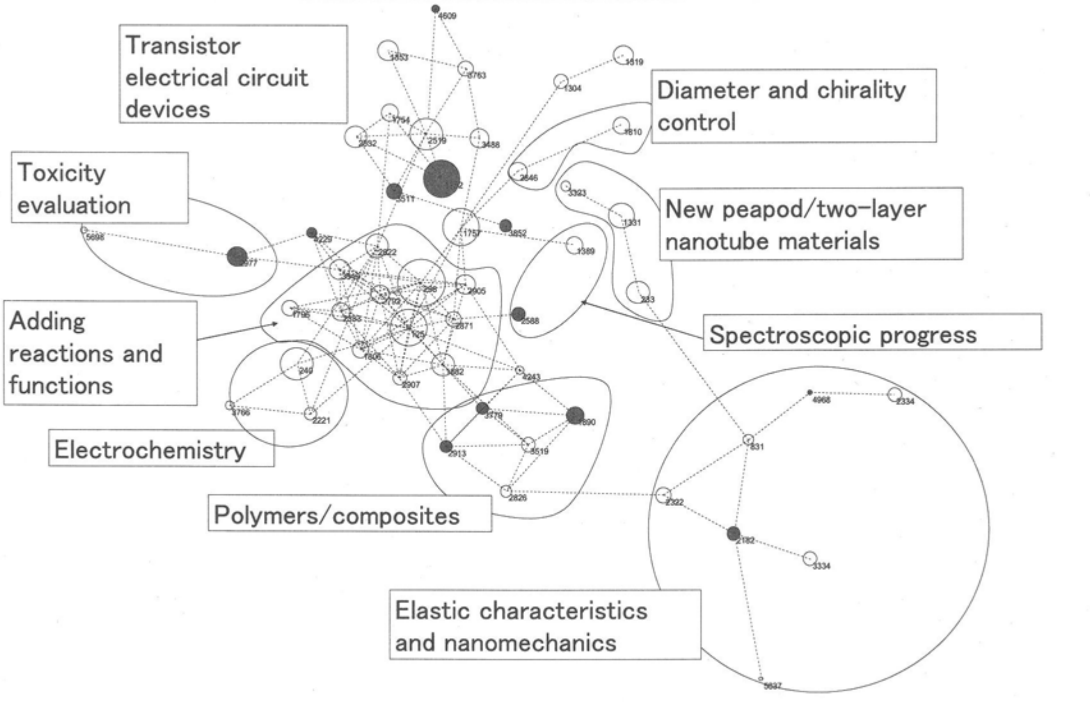


Name of RA	Study of laminated film and capsule	RA ID	114

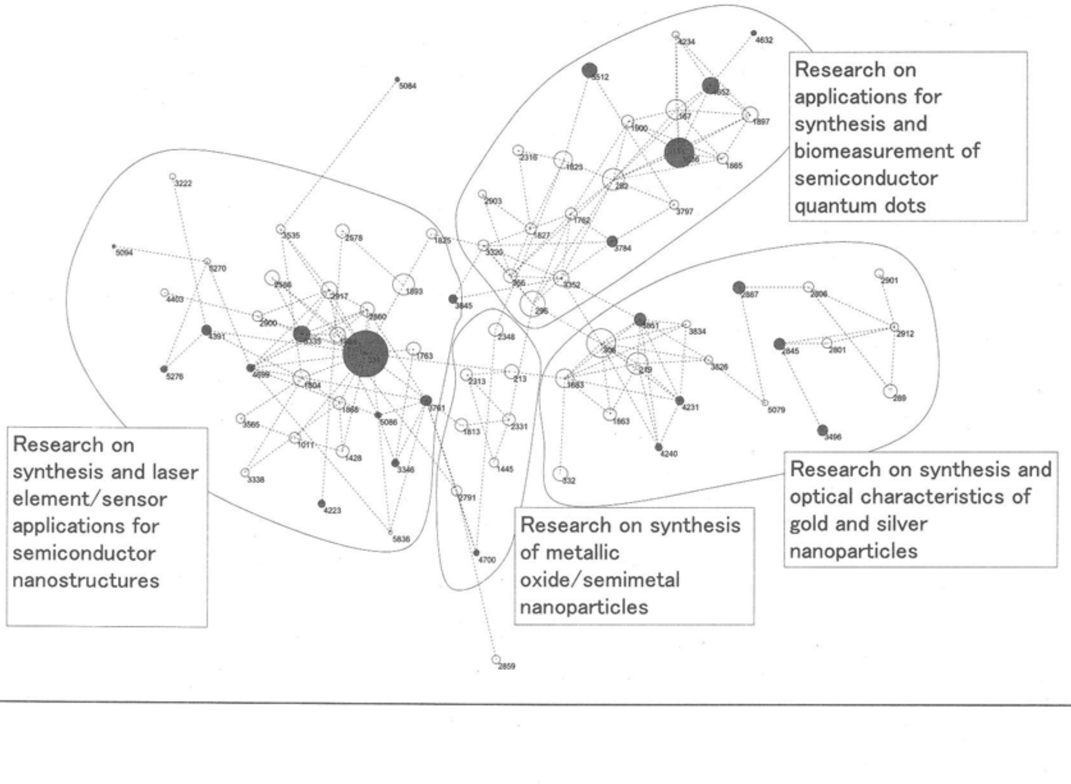
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6(0)	33(0)	930	2083	2003.1



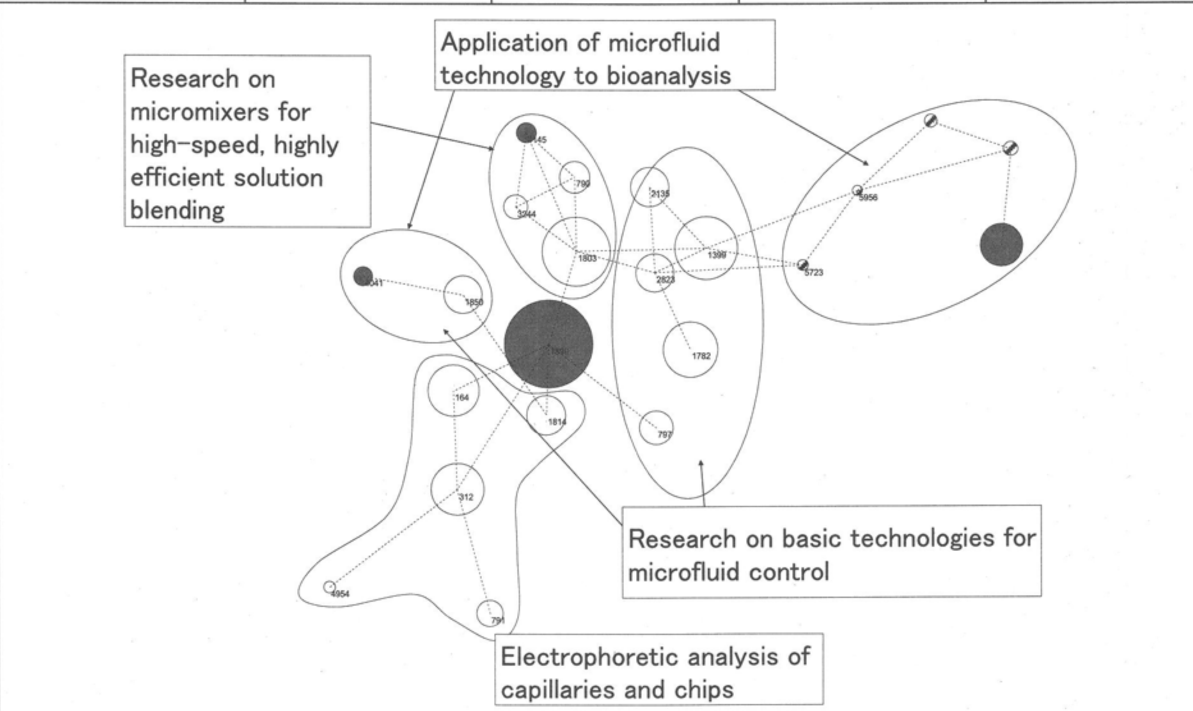
Name of RA	Carbon nanotube synthesis and device evaluation		RA ID	115
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
51(12)	235(20)	7109	21232	2003.3



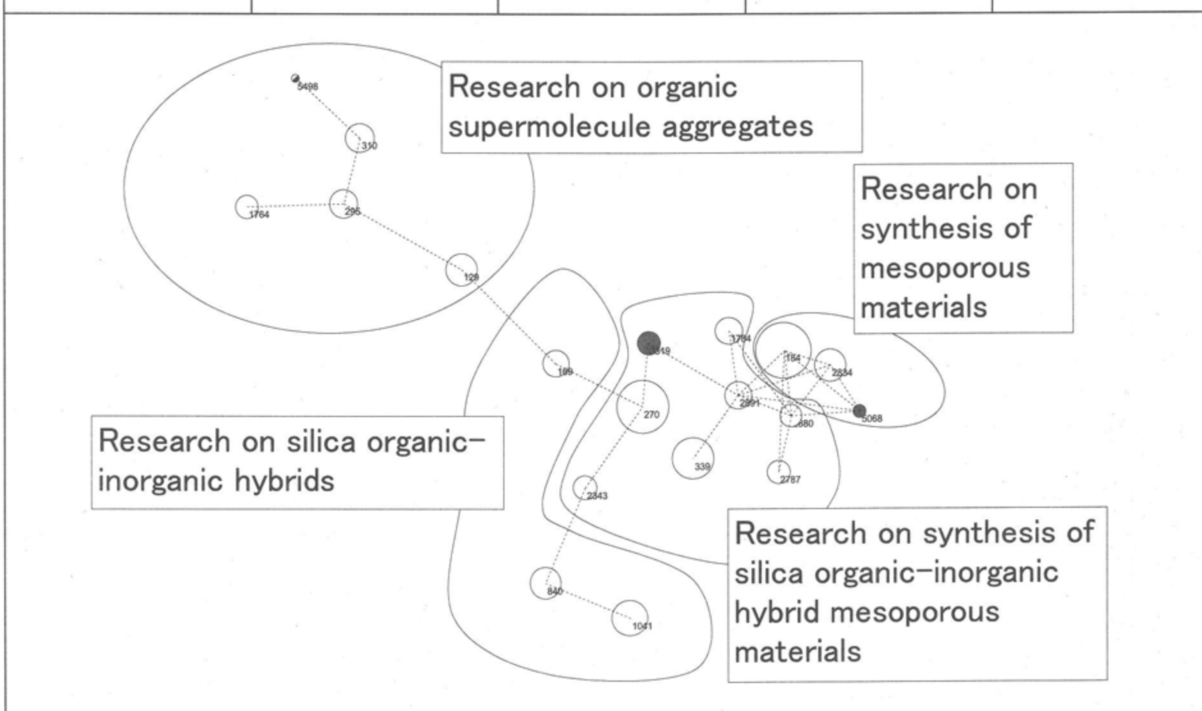
Name of RA	Study on synthesis and optical application of metal and metal oxide nanoparticle/nanostructure		RA ID	116
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
81(24)	264(7)	10422	27102	2003.3



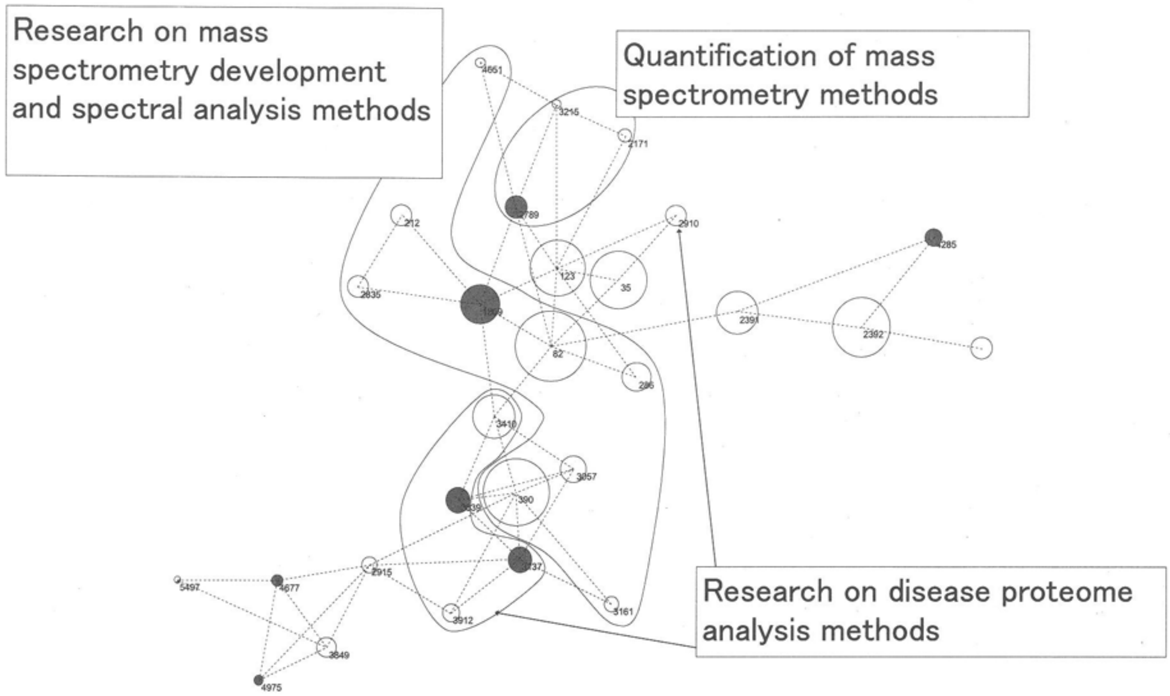
Name of RA	Micro-bio system and micro chemical system		RA ID	117
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
22(4)	78(7)	2471	5079	2003.4



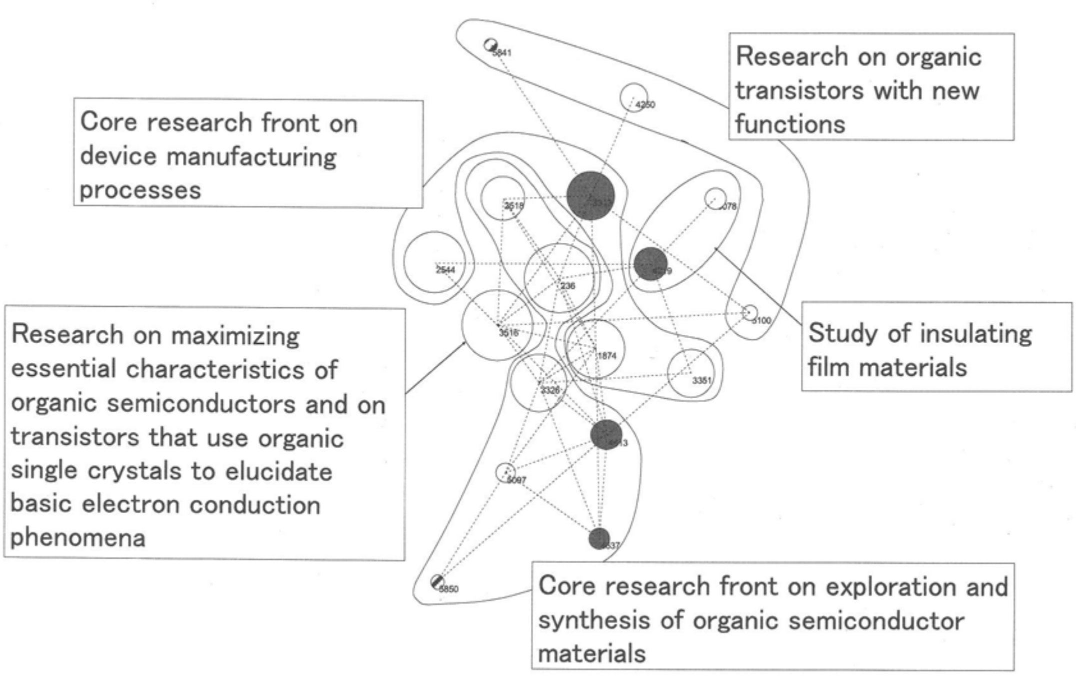
Name of RA	Mesoporous material / silica organic-inorganic hybrid material / organic supramolecular complex		RA ID	118
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
19(2)	76(14)	2537	5160	2002.7



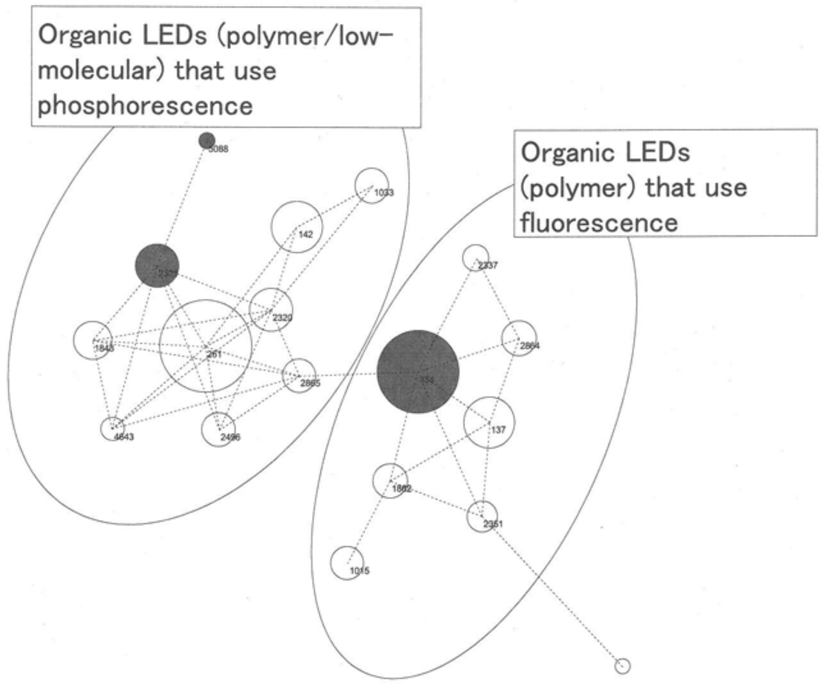
Name of RA	Isotope labeling / quantitative mass spectrometry / protein analysis	RA ID	119	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
28(7)	84(3)	5547	12509	2002.9



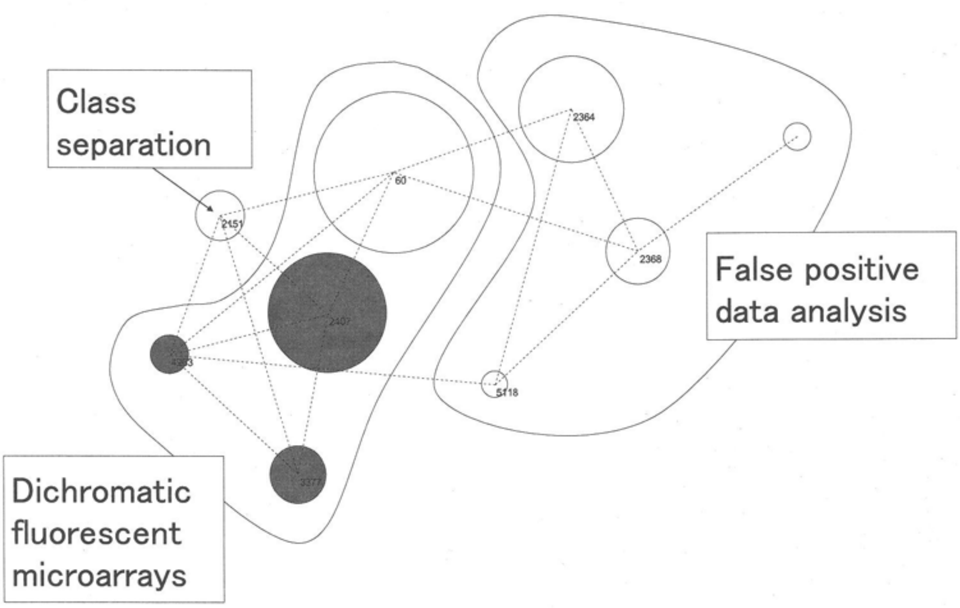
Name of RA	Organic transistor / improvement in performance and function	RA ID	120	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
17(4)	69(6)	1320	3139	2004.1



Name of RA	Polymer organic led and phosphorescent organic LED	RA ID	121	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
18(3)	89(6)	2538	7364	2002.8

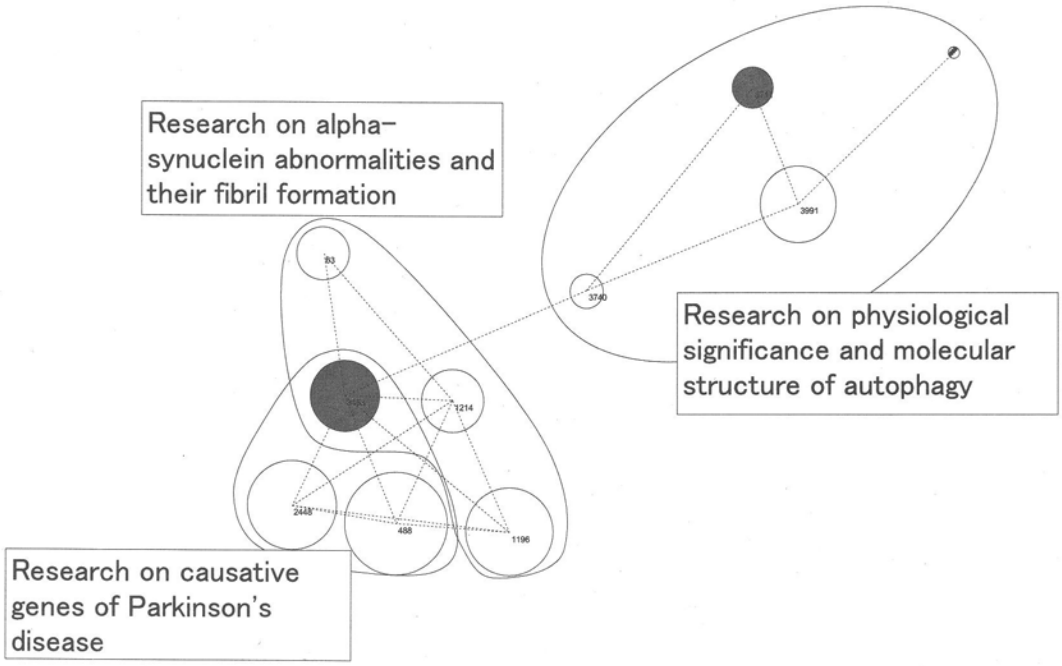


Name of RA	Bioinformatics / transcriptome	RA ID	122	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9(3)	23(0)	1433	2306	2002.8



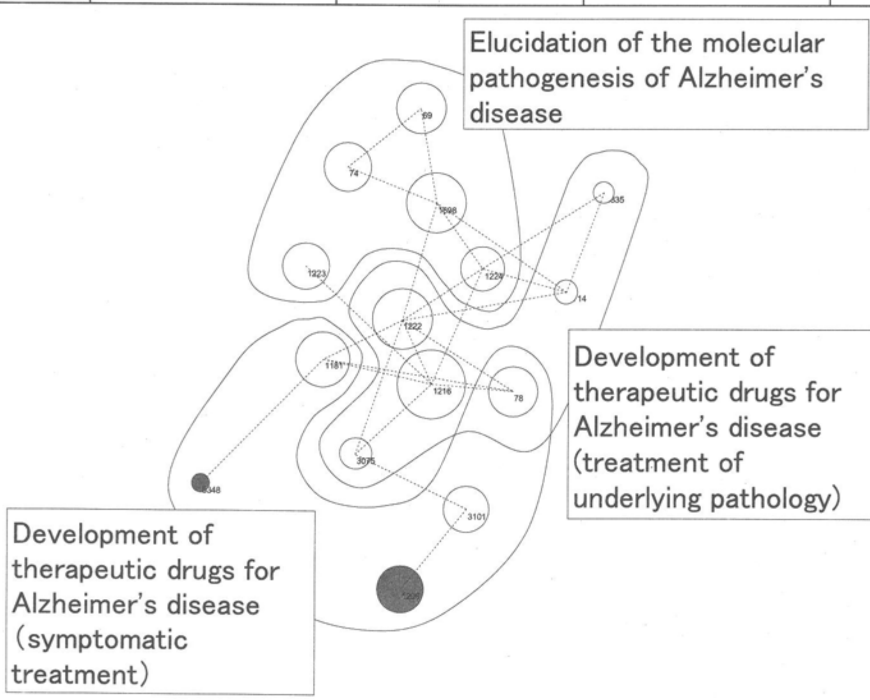
Name of RA	Pathogenesis and pathology of parkinson's disease and intracellular quality control mechanism by autophagy	RA ID	123

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
10(2)	71(19)	3073	7866	2003.9



Name of RA	Molecular pathology and therapy of alzheimer's disease	RA ID	124

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
15(2)	68(3)	4241	9988	2002.8

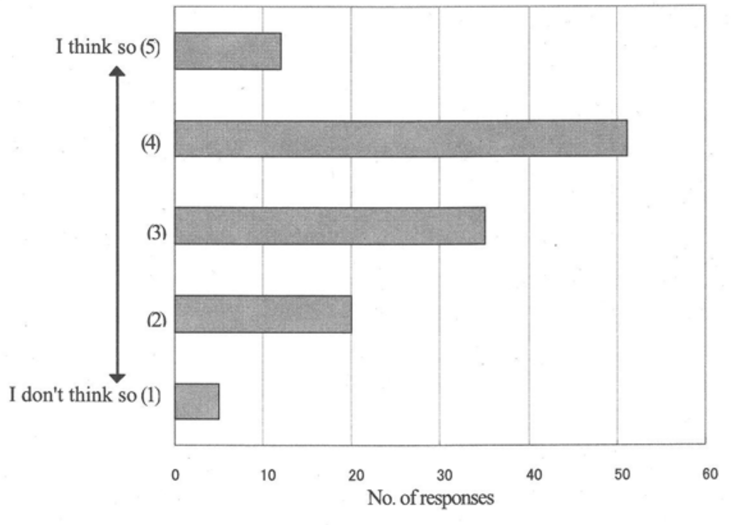


3. Questionnaire Survey on hot research areas

Those who carried out content analysis of the hot research areas were surveyed regarding development in their relevant areas since the second half of the 1990s and in the five years after the survey period.

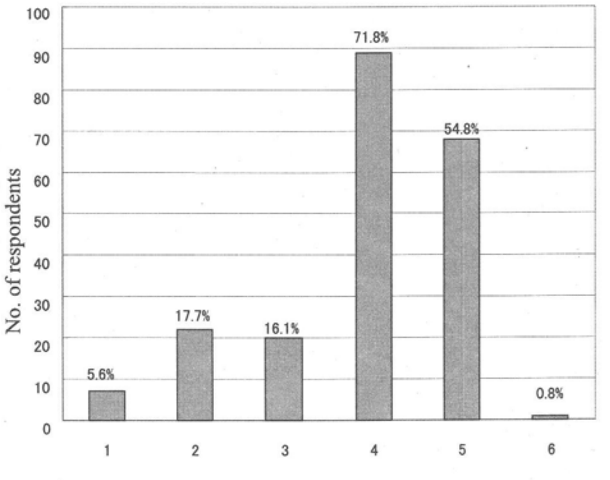
Before the first question, they were asked to evaluate on a scale of 1 ("I don't think so") to 5 ("I think so") whether the Individual Research Area Map for their hot research areas appropriately visualizes the internal structure of the research area. The results were as in Figure 1. They indicate that the visualization of hot research areas in this study is generally close to the frontline sense of researchers.

Figure 1: Evaluation of the visualization of hot research areas



The first question asked what changes respondents think took place over the 10 years from the latter half of the 1990s to 2001–2006 (the survey's subject period), with answers selected from the categories below. Multiple answers were permissible. The results were as in Figure 2.

Figure 2: Past changes in the hot research areas

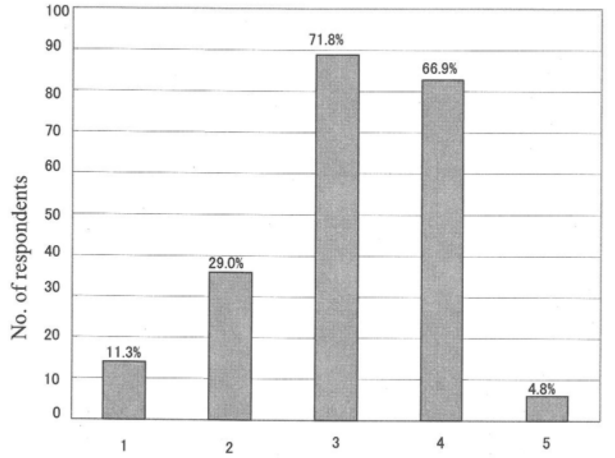


1. During the latter half of the 1990s, it was part of a somewhat larger research area, and as research subsequently advanced, it became an independent research area.
2. During the latter half of the 1990s, research was carried out separately, but as research subsequently advanced, it tended to fuse and form a research area.
3. During the latter half of the 1990s, this kind of research area was not recognized, but as it subsequently advanced, a research area formed.
4. During the latter half of the 1990s, a precursor research area existed, and as research subsequently advanced, the amount of related research increased rapidly.
5. During the latter half of the 1990s, a precursor research area existed, but as research subsequently advanced, the quality of the research changed.
6. During the latter half of the 1990s, a precursor research area existed, was considered important, and many papers were published in the area, so research has not changed quantitatively or qualitatively.

A characteristic of the 124 hot research areas handled in this study is that over the past 10 years, the volume of research has increased, while at the same time, the quality has changed. In addition, there are hot research areas that formed when different research communities merged, and others that formed through research communities developed while carrying out research that had not been recognized as a research area. In other words, our method does not address only research areas that have a high number of papers published and are already important, it also analyzes research areas that have the ability to create scientific dynamism and change.

The second question asked what changes respondents think will take place over the period from 2006 through 2010, with answers selected from the categories below. Multiple answers were permissible. The results were as in Figure 3.

Figure 3: Future changes in the hot research areas



1. It will probably divide into multiple research areas.
2. It will probably fuse with another research area.
3. A quantitative expansion of research will probably occur.
4. A qualitative change in research will probably occur.
5. There will probably be no noteworthy quantitative expansion of or qualitative change in research.

Respondents expected most of the hot research areas to change over the coming five years. Fewer than 5 percent of them indicated they expected no noteworthy quantitative expansion or qualitative change in research. Regarding the means of change, for both quantitative expansion and qualitative change, it is notable that expectations for fusion are high at almost 30 percent, compared with less than 20 percent giving that answer for the first question (on the process of past change).

Next, the study examined the relationship between responses to the first question (past changes in the research areas) and the second question (future changes). Because multiple responses are possible for both questions, the total values do not match the number of hot research areas.

Figure 4: Future changes expected in hot research areas judged as "1. During the latter half of the 1990s, it was part of a somewhat larger research area, and as research subsequently advanced, it became an independent research area"

Future 1: Divide	2
Future 2: Fuse	2
Future 3: Quantitative expansion	6
Future 4: Qualitative change	5
Future 5: No change	1

Figure 5: Future changes expected in hot research areas judged as "2. During the latter half of the 1990s, research was carried out separately, but as research subsequently advanced, it tended to fuse and form a research area"

Future 1: Divide	2
Future 2: Fuse	13
Future 3: Quantitative expansion	17
Future 4: Qualitative change	14
Future 5: No change	1

Figure 6: Future changes expected in hot research areas judged as "3. During the latter half of the 1990s, this kind of research area was not recognized, but as it subsequently advanced, a research area formed"

Future 1: Divide	1
Future 2: Fuse	5
Future 3: Quantitative expansion	15
Future 4: Qualitative change	15
Future 5: No change	1

Figure 7: Future changes expected in hot research areas judged as "4. During the latter half of the 1990s, a precursor research area existed, and as research subsequently advanced, the amount of related research increased rapidly"

Future 1: Divide	11
Future 2: Fuse	25
Future 3: Quantitative expansion	67
Future 4: Qualitative change	60
Future 5: No change	3

Figure 8: Future changes expected in hot research areas judged as "5. During the latter half of the 1990s, a precursor research area existed, but as research subsequently advanced, the quality of the research changed"

Future 1: Divide	9
Future 2: Fuse	19
Future 3: Quantitative expansion	50
Future 4: Qualitative change	50
Future 5: No change	2

Figure 9: Future changes expected in hot research areas judged as "6. During the latter half of the 1990s, a precursor research area existed, was considered important, and many papers were published in the area, so research has not changed quantitatively or qualitatively"

Future 1: Divide	0
Future 2: Fuse	0
Future 3: Quantitative expansion	0
Future 4: Qualitative change	0
Future 5: No change	1

For expected changes in the hot research areas as well, "quantitative expansion" and "qualitative change" were often selected. "Quantitative expansion" and "qualitative change" reflect changes in the status of communities related to the hot research areas (the number of people involved, the backgrounds of participating researchers, etc.). These can be expected to create dynamic change in new sciences, and to be reflected in frequent changes to the Science Map.

4. Field distribution of core papers making up hot research areas

- Academic Disciplines Relation Map is depicted using the data of field distribution of 124 hot research areas.

- The Figures below show the field distribution (by percentage) of the core papers that comprise the 124 hot research areas derived for this study. For each hot research area, the field with the highest percentage of core papers is shaded. In the case of "Drug-eluting stents (ID1)," for example, every core paper falls into the "clinical medicine" category, so the percentage for that field is 100 percent and it is shaded on this figure.

- ID of hot research areas that are shaded are inter/multi-disciplinary in this study. Inter/multi-disciplinary research areas as used here are those hot research areas in which core papers do not exceed 60 percent in any field. In the case of "Pathogenic mechanism and preventive/therapeutic method of severe acute respiratory syndrome (SARS; ID93)," for example, the field with the highest percentage of its core papers is clinical medicine, but it only accounts for 54.5 percent, so it is considered an inter/multi-disciplinary area.

Research area ID	Research area	Agricultural science	Biology/ biochemistry	Chemistry	Clinical medicine	Computer science	Economics/ management	Engineer-ing	Environment/ ecology	Earth science
1	Drug-eluting stent	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
2	Stage classification, treatment algorithm and outcome prediction of hepatocarcinoma	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
3	Basic and clinical study on antitumor effect of histone deacetylase (HDAC) inhibitors	0.0	6.3	0.0	87.5	0.0	0.0	0.0	0.0	0.0
4	Biodefense by blood coagulation regulatory system	0.0	5.6	0.0	94.4	0.0	0.0	0.0	0.0	0.0
5	Deep mycosis	0.0	0.0	0.0	86.7	0.0	0.0	0.0	0.0	0.0
6	Study on highly pathogenic avian influenza subtype H5N1	0.0	0.0	0.0	77.1	0.0	0.0	0.0	0.0	0.0
7	Bone metabolism control by drug and its clinical application	0.0	9.4	0.0	89.1	0.0	0.0	0.0	0.0	0.0
8	History of effect and adverse effect of hormone replacement therapy (HRT)	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
9	Thromboembolism study	0.0	0.0	0.0	98.6	0.0	0.0	0.0	0.0	0.0
10	Conventional infectious diseases / resistant bacterial infectious diseases	0.0	0.0	0.0	61.0	0.0	0.0	0.0	0.0	0.0
11	Control of lymphocyte-activating organ dysfunction by antibody therapy and others	0.0	0.5	0.0	91.4	0.0	0.0	0.0	0.0	0.0
12	Study on risk assessment, therapeutic effect, and diagnostic method for cardiac diseases	0.0	0.0	0.0	97.4	0.0	0.0	0.0	0.0	0.0
13	Drug therapy of diabetes / thiazolidine derivatives	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
14	Arteriosclerosis, abnormal lipid metabolism and abnormal carbohydrate metabolism affecting the onset of acute coronary syndrome, and inhibitory effect of hypolipidemic agents and proglycemic agents on the onset of acute coronary syndrome	0.0	10.8	0.0	86.2	0.0	0.0	0.0	0.0	0.0
15	Ghrelin / function and pathophysiological significance	0.0	34.5	0.0	62.1	0.0	0.0	0.0	0.0	0.0
16	Hormone therapy / breast cancer prevention	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
17	Molecular targeting therapy / type III tyrosine kinase-related tumor	0.0	2.5	1.3	94.9	0.0	0.0	0.0	0.0	0.0
18	Basic and clinical study on antibody therapy for HER2 (human epidermal growth factor receptor 2) positive breast cancer	0.0	10.5	0.0	89.5	0.0	0.0	0.0	0.0	0.0
19	Obesity and diabetes	0.0	24.3	0.0	61.8	0.0	0.0	0.0	0.0	0.0
20	New development in molecular therapy targeting EGFR mutations and others	0.0	1.1	0.0	98.9	0.0	0.0	0.0	0.0	0.0
21	Study on regulation of tissue stem cell by extracellular environment and characteristics of cancer stem cell	0.0	3.7	0.0	77.8	0.0	0.0	0.0	0.0	0.0
22	Cancer / gene expression profiling analysis	0.0	6.5	0.0	90.3	0.0	0.0	0.0	0.0	0.0
23	Biological elucidation and clinical application of damaged tissue repair mechanism	0.0	3.1	0.0	92.7	0.0	0.0	0.0	0.0	0.0
24	Elucidation of behavior principle of ion/water channel molecule	0.0	61.2	10.2	0.0	0.0	0.0	0.0	0.0	0.0
25	Genome-wide gene expression analysis and expression regulatory function analysis	0.0	19.2	0.0	0.0	11.5	0.0	0.0	0.0	0.0
26	Histone diversity and life phenomena	0.0	11.4	0.0	8.6	0.0	0.0	0.0	0.0	0.0
27	Plant functional genomics study	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	Plant cell proteome analysis	0.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	Plant-microorganism interaction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	Light environment response control / flower bud formation mechanism in plant	0.0	2.9	2.0	0.0	0.0	0.0	0.0	1.0	0.0
31	Redox regulation	0.0	18.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	Inducible defense mechanism in plant	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0
33	Environmental stress response / metabolic profiling / cellular structure and phospholipid metabolism in plant	0.5	1.8	6.8	1.8	3.2	0.0	4.1	0.0	0.0
34	Plant defense against infection / plant immunity	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	Environmental pollution study of bromine flame retardant made mainly of polybrominated diphenylethers (PBDEs)	2.5	0.0	0.0	0.0	0.0	0.0	0.0	95.0	0.0
36	Assistive technology for detection, prediction and countermeasure of animal and plant activity change caused by climate change	0.0	0.0	0.0	0.0	0.0	0.0	0.0	94.7	2.6
37	Biodiversity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	96.3	0.0
38	Climatic effect of air pollutant and mineral dust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	96.0
39	Earth history	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	96.2
40	Gamma-ray burst and relative celestial explosion phenomenon	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0
41	Formation and evolution of the galaxy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42	Solid macromolecule type fuel cell / mass and heat transfer	0.0	0.0	11.4	0.0	0.0	0.0	88.6	0.0	0.0
43	Nitride semiconductor transistor / high-voltage and high-frequency application	0.0	0.0	0.0	0.0	0.0	0.0	94.7	0.0	0.0
44	Integrated comprehension of brain function by neuron-glia interaction	0.0	10.5	0.0	5.3	0.0	0.0	0.0	0.0	0.0
45	Visceral sensation and neural mechanism of emotion and empathy	0.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Immunology	Materials science	mathematics	Microbiology	Molecular biology/ genetics	Multiple areas	Neuroscience, ethology	Pharma-ceutical science/toxicology	Physics	Plant/animal science	Psychiatry/psychology	Social science/general	Space science
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	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	6.3	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	0.0	0.0	0.0	0.0	0.0	0.0
2.2	0.0	0.0	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	17.1	0.0	2.9	0.0	0.0	0.0	2.9	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	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	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	37.3	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0
6.3	0.0	0.0	0.0	0.0	0.0	0.9	0.9	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	0.0	2.6	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	0.0	0.0	0.0	3.1	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	0.0	3.4	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	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	1.3	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	0.0	0.0	0.0	0.0	0.0	0.0
1.7	0.0	0.0	0.0	9.2	0.0	2.9	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	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	18.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	3.1	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	0.0	0.0	0.0	0.0	28.6	0.0	0.0	0.0
0.0	0.0	0.0	0.0	69.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	80.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	2.9	2.9	0.0	0.0	0.0	94.3	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.0	0.0	0.0	0.0
0.0	0.0	0.0	16.0	2.0	0.0	0.0	0.0	0.0	82.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	94.1	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81.6	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.1	0.0	0.0	0.0
0.0	0.5	0.0	0.5	0.5	0.0	0.0	2.7	0.0	77.8	0.0	0.0	0.0
0.8	0.0	0.0	5.6	4.0	0.0	0.0	0.0	0.0	88.7	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	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	2.6	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	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	0.0
0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	18.2	0.0	0.0	0.0	77.3
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	99.4
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	0.0	0.0	0.0	0.0	0.0	0.0	5.3	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	84.2	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	70.6	0.0	0.0	0.0	23.5	0.0	0.0

Research area ID	Research area	Agricultural science	Biology/ biochemistry	Chemistry	Clinical medicine	Computer science	Economics/ management	Engineer-ing	Environment/ ecology	Earth science
46	Decision-making neuroscience	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	Kinetics of AMPA receptor and spine morphology in synaptic plasticity	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48	Cause analysis and therapy development for psychiatric and nerve disease	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0
49	Functional analysis of human brain and drug therapy of psychiatric disease	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0
50	Structural analysis of the production process from the perspective of a network	0.0	0.0	0.0	0.0	0.0	7.1	0.0	0.0	0.0
51	Economic environment surrounding businesses	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
52	Metamaterials	0.0	0.0	0.0	0.0	10.6	0.0	24.2	0.0	0.0
53	Superconductive properties of magnesium diboride and its application	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
54	Attosecond quantum dynamics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55	Ferromagnetic semiconductor spintronics	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0
56	Quantum information control with multidimensional photon	0.0	0.0	0.0	0.0	7.7	0.0	7.7	0.0	0.0
57	Electrical control of spin in semiconductors / quantum computer using solid state	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
58	High-temperature superconductivity spectroscopy / new electron phase	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
59	High energy density science	0.0	0.0	0.0	0.0	0.0	0.0	25.0	0.0	0.0
60	Complex networks	0.0	0.0	0.0	0.0	18.2	0.0	3.6	1.8	0.0
61	Quantum information/communication, optical nanoscience	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0
62	Hadron spectroscopy	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0
63	New quantum condensed phase where substances strongly interact with each other	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
64	Search for quark matter through high-energy nuclear collision	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0
65	Brane cosmology from the perspective of duality of anti de sitter space and conformal field theory	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
66	Explore physics beyond the standard model from flavor physics of B meson and neutrino, dark matter and muon anomalous magnetic efficiency	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0
67	Field theory on noncommutative space	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	Verification and integrability of AdS/CFT correspondence	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
69	Observational cosmology and an elementary model for it	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70	High-dimensional black holes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71	Nanofiber technology with the electro-spinning process and tissue engineering research	0.0	2.0	22.4	0.0	0.0	0.0	0.0	0.0	0.0
72	Study of solar cells using inorganic oxides, organic-inorganic hybrids or organic polymers	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0
73	Ultra fine crystal grain / macrostrain process	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0
74	Space-time code	0.0	0.0	0.0	0.0	86.7	0.0	13.3	0.0	0.0
75	Multifunctional signature / multifunctional coding	0.0	0.0	0.0	0.0	94.6	0.0	5.4	0.0	0.0
76	Interactome analysis	0.0	11.8	0.0	0.0	74.5	0.0	0.0	0.0	0.0
77	Molecule-based nano-quantum magnet	0.0	0.0	90.6	0.0	0.0	0.0	0.0	0.0	0.0
78	Macromolecule nanocomposite	0.0	0.0	76.2	0.0	0.0	0.0	9.5	0.0	0.0
79	Living radical polymerization	0.0	0.0	95.2	0.0	0.0	0.0	3.2	0.0	0.0
80	Construction of artificial photosynthesis model mimicking antenna system and charge separation system	0.0	0.0	95.0	0.0	0.0	0.0	5.0	0.0	0.0
81	Porous coordination polymer	0.0	0.0	86.6	0.0	0.0	0.0	3.0	0.0	0.0
82	Retrieval of binding specificity of sugar chain recognition protein by neoglycolipid sugar chain microarray	0.0	12.7	85.5	0.0	0.0	0.0	0.0	0.0	0.0
83	Activation of oxygen molecule by metalloenzyme	0.0	20.7	79.3	0.0	0.0	0.0	0.0	0.0	0.0
84	Protein folding	0.0	28.9	62.2	0.0	0.0	0.0	0.0	0.0	0.0
85	Ionic liquid	0.0	3.9	84.5	0.0	0.0	0.0	9.7	0.0	0.0
86	Study on supramolecular nanodevice by molecular machine and single-molecule conductor	0.0	0.0	71.6	0.0	0.0	0.0	0.0	0.0	0.0
87	DNA-nanomaterial and nanodevice	0.0	1.1	72.5	0.0	2.2	0.0	0.0	0.0	0.0
88	Catalytic asymmetric addition reaction of carbon nucleophile	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
89	Bioimaging probe	0.0	1.8	98.2	0.0	0.0	0.0	0.0	0.0	0.0
90	Synthetic polymer-immobilized catalyst technology	0.0	0.0	92.3	0.0	0.0	0.0	0.0	0.0	0.0

Immunology	Materials science	mathematics	Microbiology	Molecular biology/ genetics	Multiple areas	Neuroscience/ ethology	Pharma-ceutical science/toxicology	Physics	Plant/animal science	Psychiatry/ps ychology	Social science/general	Space science
0.0	0.0	0.0	0.0	0.0	0.0	84.6	0.0	0.0	0.0	15.4	0.0	0.0
0.0	0.0	0.0	0.0	4.5	0.0	90.9	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	10.5	1.2	68.6	0.0	0.0	0.0	16.3	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	13.8	1.5	0.0	0.0	81.5	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	92.9	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.2	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
0.0	9.4	0.0	0.0	0.0	0.0	0.0	0.0	87.1	0.0	0.0	0.0	0.0
0.0	3.8	3.8	0.0	0.0	0.0	0.0	0.0	76.9	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0	0.0	0.0	0.0	0.0
0.0	0.0	1.8	0.0	1.8	3.6	0.0	0.0	69.1	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.8	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	96.7	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.2	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.8	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	96.2	0.0	0.0	0.0	1.9
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.2	0.0	0.0	0.0	2.8
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	87.5	0.0	0.0	0.0	12.3
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
0.0	61.2	0.0	4.1	0.0	0.0	0.0	4.1	6.1	0.0	0.0	0.0	0.0
0.0	70.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0
0.0	85.5	0.0	0.0	0.0	0.0	0.0	0.0	13.3	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	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
0.0	0.0	0.0	0.0	13.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.4	0.0	0.0	0.0	0.0
0.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	1.6	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	10.4	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	0.0	0.0	0.0	1.8	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	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.9	0.0	0.0	0.0	0.0
0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0
0.0	15.4	0.0	1.1	0.0	1.1	0.0	0.0	6.6	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	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
0.0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Research area ID	Research area	Agricultural science	Biology/ biochemistry	Chemistry	Clinical medicine	Computer science	Economics/ management	Engineer-ing	Environment/ ecology	Earth science
91	Catalytic asymmetric synthesis	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
92	Molecular conversion reaction using transition metal catalyst	0.0	0.4	98.4	0.0	0.0	0.0	0.0	0.0	0.0
93	Pathogenic mechanism and preventive/therapeutic method of severe acute respiratory syndrome (SARS)	0.0	9.1	0.0	54.5	0.0	0.0	0.0	0.0	0.0
94	Epidemiological study about the effect of air pollution (especially particle-like substances) on cardiovascular disease	0.0	0.0	0.0	53.8	0.0	0.0	0.0	46.2	0.0
95	Study on HCV and HIV	0.0	3.2	1.1	48.6	0.0	0.0	0.0	0.0	0.0
96	Elucidation of in-vivo function of drug transporter in human	0.0	8.1	0.0	53.7	0.0	0.0	0.0	0.0	0.0
97	Suppression of immune reaction centered on foxp3-positive, CD25-positive and CD4-positive regulatory t cells	0.0	0.5	0.0	58.9	0.0	0.0	0.0	0.0	0.0
98	Apoptosis (cell death) and inflammation	0.0	26.8	0.0	42.3	0.0	0.0	0.0	0.0	0.0
99	Embryonic stem cell / neural induction	0.0	19.4	0.0	54.2	0.0	0.0	0.0	0.0	0.0
100	Study on exchange between atmosphere and continental ecosystem of CO2 and others	41.2	0.0	0.0	0.0	0.0	0.0	0.0	41.2	11.8
101	Proteinous infectious agent / new paradigm for genetic material	0.0	55.9	17.6	8.8	0.0	0.0	2.9	0.0	0.0
102	Physiological function of TRP channel	0.0	50.0	0.0	8.6	0.0	0.0	0.0	0.0	0.0
103	Activation of hypoxia-inducible factor 1 and formation of tumor microenvironment	0.0	39.7	8.8	26.5	0.0	0.0	0.0	0.0	0.0
104	Solid macromolecule type fuel cell / macromolecular electrolyte film	0.0	0.0	36.4	0.0	0.0	0.0	54.5	0.0	0.0
105	Quantification of water vapor, clouds, aerosol and albedo based on satellite and ground-based observation	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	50.0
106	Water environment	13.3	0.0	20.0	0.0	0.0	0.0	23.3	43.3	0.0
107	Aerosol	0.0	0.0	6.0	0.0	0.0	0.0	27.4	19.0	47.6
108	Innate immunity	0.0	7.5	0.0	36.8	0.0	0.0	0.0	0.0	0.0
109	Microbiodiversity	0.0	9.7	0.0	0.0	0.0	0.0	0.0	19.4	0.0
110	Study on ubiquitination and sumoylation of protein	0.0	27.3	0.0	2.3	0.0	0.0	0.0	0.0	0.0
111	Multi-hierarchical regulatory mechanism of life phenomena	0.0	19.7	0.3	11.6	0.5	0.0	0.0	0.0	0.0
112	Molecular mechanism and physiological role of endogenous cannabinoid signal	2.1	16.7	0.0	16.7	0.0	0.0	0.0	0.0	0.0
113	Photosynthetic light reaction apparatus / structure, function and regulation	0.0	42.3	11.5	0.0	0.0	0.0	0.0	0.0	0.0
114	Study of laminated film and capsule	0.0	3.0	57.6	0.0	0.0	0.0	3.0	0.0	0.0
115	Carbon nanotube synthesis and device evaluation	0.0	0.4	49.4	1.3	1.7	0.0	6.8	1.3	0.0
116	Study on synthesis and optical application of metal and metal oxide nanoparticle/nanostructure	0.0	1.9	56.4	0.8	0.0	0.0	0.8	0.0	0.0
117	Micro-bio system and micro chemical	0.0	6.4	42.3	0.0	24.4	0.0	16.7	0.0	0.0
118	Mesoporous material / silica organic-inorganic hybrid material / organic supramolecular complex	0.0	0.0	55.3	0.0	0.0	0.0	2.6	0.0	0.0
119	Isotope labeling / quantitative mass spectrometry / protein analysis	0.0	11.9	41.7	13.1	4.8	0.0	13.1	0.0	0.0
120	Organic transistor / improvement in performance and function	0.0	0.0	27.5	0.0	0.0	0.0	1.4	0.0	0.0
121	Polymer organic led and phosphorescent organic LED	0.0	0.0	37.1	0.0	0.0	0.0	1.1	0.0	0.0
122	Bioinformatics / transcriptome	0.0	13.0	0.0	0.0	30.4	0.0	0.0	0.0	0.0
123	Pathogenesis and pathology of parkinson's disease and intracellular quality control mechanism by autophagy	0.0	22.5	0.0	14.1	0.0	0.0	0.0	0.0	0.0
124	Molecular pathology and therapy of alzheimer's disease	0.0	22.1	5.9	11.8	0.0	0.0	0.0	0.0	0.0

Immunology	Materials science	mathematics	Microbiology	Molecular biology/ genetics	Multiple areas	Neuroscience, ethology	Pharma-ceutical science/toxicology	Physics	Plant/animal science	Psychiatry/psychology	Social science/general	Space science
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	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
1.3	0.0	0.0	28.6	1.3	0.0	0.0	0.0	0.0	5.2	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	0.0
17.3	0.0	0.0	28.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
11.0	0.0	0.0	0.0	2.9	0.0	0.0	24.3	0.0	0.0	0.0	0.0	0.0
37.8	0.0	0.0	1.0	1.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.6	0.0	0.0	0.0	21.1	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	16.7	0.0	9.7	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0	0.0
0.0	0.0	0.0	2.9	5.9	0.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	8.6	0.0	27.6	5.2	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	14.7	0.0	1.5	8.8	0.0	0.0	0.0	0.0	0.0
0.0	9.1	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	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	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45.9	0.0	0.0	5.3	3.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	48.4	0.0	3.2	0.0	0.0	0.0	19.4	0.0	0.0	0.0
0.0	0.0	0.0	15.9	54.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3	0.0	0.0	3.7	35.0	1.3	0.0	0.0	0.0	27.6	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	31.3	33.3	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	46.2	0.0	0.0	0.0
0.0	36.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	15.7	0.0	0.0	0.0	0.0	0.0	1.7	21.7	0.0	0.0	0.0	0.0
0.0	30.3	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.0	0.0	0.0	0.0
0.0	3.8	0.0	0.0	0.0	1.3	0.0	0.0	5.1	0.0	0.0	0.0	0.0
0.0	42.1	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	0.0	10.7	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	46.4	0.0	0.0	0.0	0.0	0.0	0.0	24.6	0.0	0.0	0.0	0.0
0.0	46.1	0.0	0.0	0.0	0.0	0.0	0.0	15.7	0.0	0.0	0.0	0.0
0.0	0.0	47.8	0.0	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	1.4	18.3	1.4	42.3	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	4.4	0.0	47.1	5.9	0.0	0.0	1.5	1.5	0.0

Acknowledgments

Experts in Japan were asked to perform the content analysis of the 124 hot research areas. We would like to express our sincere gratitude for their cooperation.

In addition, the following 10 experts were kind enough to cooperate with interviews covering an overview of the research areas as a whole. We express our sincere gratitude to them as well.

Hiroshi IMAHORI	Professor	Kyoto University
Kiyotaka OKADA	Director-General	National Institute for Basic Biology
Taro KAWAI	Associate Professor	Osaka University
Kenji KANGAWA	Director General	National Cardiovascular Center
Shinichi KIKUCHI	Assistant Professor	Keio University
Shinichi NOJIRI	Professor	Nagoya University
Tamio HAYASHI	Professor	Kyoto University
Kiichi HIROTA	Assistant Professor	Kyoto University
Makoto MATSUOKA	Professor	Nagoya University
Yuji MATSUDA	Professor	Kyoto University

The Institute for Future Technology carried out selection of the researchers who performed content analysis of the 124 research areas, communicated with the researchers, commissioned them, and collected the results. We are grateful for their assistance.

Interviews covering an overview of the research areas as a whole research area were made possible by science and technology research grants (18-113, Ayaka SAKA) from the Watanabe Memorial Foundation for the Advancement of Technology. We are grateful for their assistance.

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(As of March 31, 2008)

Science Map 2006

Study on Hot Research Areas (2001-2006) by Bibliometric Method

June 2008

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