NISTEP REPORT No.100

Science Map 2004

- Study on Hot Research Areas (1999-2004) by
Bibliometric Method -

NISTEP REPORT No.95 (2005) Follow-up

March 2007

Science and Technology Foresight Center
National Institute of Science and Technology Policy (NISTEP)

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- Study on Hot Research Areas (1999-2004) by bibliometric method -

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Contents

III. Results of content analysis of 133 research area

List of research areas

Overview

1. Objectives

The objective of this study is to understand and track the recent evolution of science focusing on basic research activities. Specific objectives of this study are as follows:

(1) Development of a “Science Map” which provides a bird’s eye view of current science activities; and

(2) Identification of “hot research areas” (RAs) and understanding of chronological change in such areas.

This study offers information with insights into the search for the factors to be considered in promoting basic research activities in the future and the direction of the measures, through, for example, the understanding of relations between inter/multi-disciplinary research and traditional disciplines.

2. Methodology

The foundation of the methodology is to understand RAs by extracting RAs through bibliometric analysis and content analysis of the established RAs.

(1) As a start of the bibliometric analysis, we used highly cited papers (approximately 47000) meeting a criterion of the top 1% by year and 22 field (such as clinical medicine, plant and animal science, chemistry, and physics), based on total citations in the six years from 1999 to 2004.

(2) RAs with a certain size were identified through two steps to cluster highly cited papers (papers → Research Fronts [RFs] → Research Areas [RAs]). The term “co-citation” used here refers to a form of citation in which a set of papers is simultaneously cited by other papers. The papers frequently co-cited are thought to have common research subjects. Thus, it is possible to obtain a cluster of papers with similarities in research pursuits by categorizing those strongly connected by co-citation. This study designates the papers which play a central role in RAs as “core papers” and the papers which cite the core papers as “citing papers”. A set of papers obtained through the first clustering, a database of RFs (5350 RFs) was retrieved form the Essential Science Indicators (ESI) database of Thomson Scientific Inc.

(3) This study adopted a new method by redesigning the method originally developed in the Study on Rapidly-Developing Research Areas (NISTEP REPORT No.95) (May 2005, research subjects are documents for six years from 1997 to 2002). The categorization in the second step was improved with the awareness of three issues, namely 1) to obtain stable clusters for time-series analysis, 2) to further clarify the concept of RAs, and 3) to avoid fragmentation of similar RAs. As a result, 133 RAs were extracted and analyzed a content of each RA..

3. Main results

3-1 Map of 133 RAs

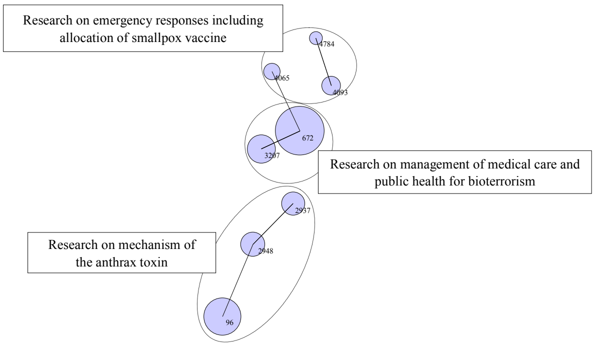
The following three maps were developed concerning 133 RAs:

1) Individual RA map, showing what research themes each of the 133 RAs consists of;

2) Relation map with traditional disciplineshowing how 133 RAs are related to traditional disciplines; and

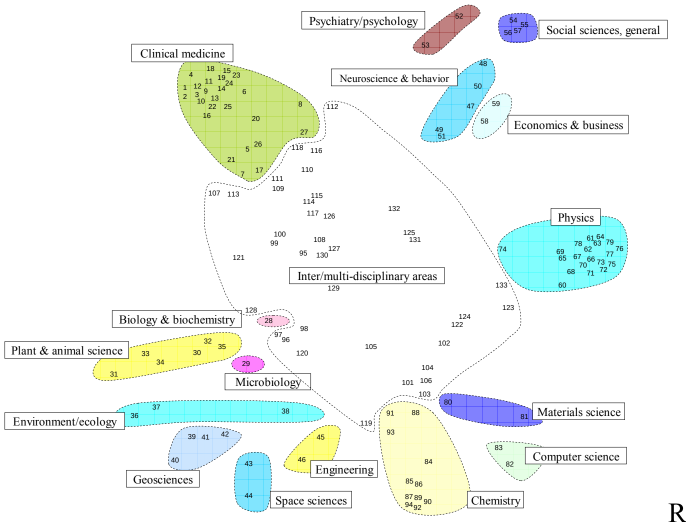
3) Correlation map, depicting the strength of the relationship among 133 RAs.

The Individual RA map is a graphic image of clusters of RFs with strong co-citation ties, which constitute RAs. Japan leads the world in some RAs: with approximately 60% of core papers being published in Japan, such as “Superconductors with anisotropic gaps (ID 71)”. “Research on countermeasures to Bioterrorism (ID 7)” is the evolution of RAs which appeared in the study of the Report 2005. It is found in this study from the analysis of the individual RA map that this area has been expanded to make it more comprehensive with addition of the method of provision of emergency vaccination and the research on medical and public hygiene management to previous research on anthrax.



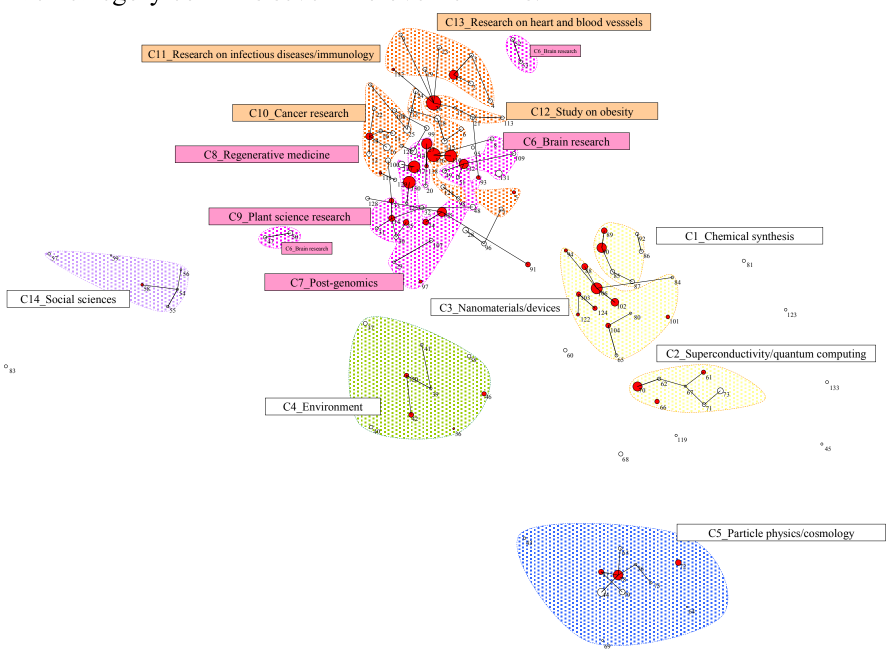
Individual RA map（Example: ID 7 “Research on countermeasures to Bioterrorism”）

The Relation map with traditional disciplines is a map showing the relations with 22 fields (traditional disciplines), including physics, chemistry and clinical medicine. The papers in 22 fields with similarities were clustered together on the map. This map allows us to see the relations between the established 133 RAs and the traditional disciplinesuch as basic biology, clinical medicine, chemistry and physics. About one third or 42 RAs are in life science-related areas, among which 27 RAs are in clinical medicine. And 37 RAs have been extracted from the areas of physics, chemistry and engineering, materials science and computer science (physics/chemistry-related areas) and 7 RAs from environment/ecology and geosciences. Although small in number, space science, social science and general studies have also been extracted. About 30% (39 RAs) have been found in the inter/multi-disciplinary areas. In other words, it is fair to conclude that RAs in today’s scientific activities consist of life science-related areas, physics/science-related areas and inter/multi-disciplinary areas, with each accounting for about 30%. Furthermore, it is also found that the more rapidly a RA is developing (having four or more RFs with rapidly increasing number of citations), the more prominent the inter/multi-disciplinary character is.



Relation map with traditional disciplines

The Correlation map clusters RAs with strong co-citation relations, focusing on how strong the co-citation relations of the 133 RAs are. Based on the analysis results of the individual RA map, the RAs with similar contents on the map are categorized into 14 categories, namely *chemical synthesis, superconductivity/quantum computing, nano materials/devices, environment, particle physics/cosmology, brain research, post-genomics, regenerative medicine, plant science research, cancer research, research on infectious diseases/immunology, study of obesity, research on heart and blood vessels,* and *social sciences*. Each category contains several to over ten RAs.



Correlation map

The *healthcare-related* category (*C10*-13) is placed at the top of the correlation map of RAs, and comes below the more basic category of *life science* (*C6*-9). In the boundary zone, there is a category with characteristics of both. At the right of the map, there are two categories (*C1*, *C2*) related to chemistry and physics, and the category (*C3*) related to nanoscience comes in between. The category of *particle physics/cosmology* (*C5*) is a physics-related category with a highly independent nature. Below *life science* and to the left of *nanoscience* comes the category of *environment* (*C4*).

Furthermore, current trends in scientific activities can be observed; for example, there is a strong relation between *study of obesity* and *research on heart and blood vessels*; *research on infectious diseases/immunology* is strongly related to various other RAs in the life science-related category, demonstrating a highly inter/multi-disciplinary nature; and *brain research* consists of molecular biology-related areas, as well as of RAs associated with *research on heart and blood vessels* and of cognitive science areas, which is closely related to *social sciences*.

What attracts our attention is that several RAs are positioned in between *nano materials/devices* and the *life science-related* category, and there is a possibility that these RAs will develop into *nanoscience* and *life science* integrated category.

3-2 Characteristics of research activities in Japan and other major countries observed in the RAs

Observing the strengths and weaknesses of Japan's research from the Relation map with traditional disciplines, the share of core papers of Japan accounts for 9% or more (the share of Japan in the entire 133 RAs is 9 %.) in many areas such as physics, chemistry, plant and animal sciences, and materials science, demonstrating the strong presence of Japan. On the other hand, the areas with a more than 9% share are few in engineering, environment/ecology, and cosmology. The presence of Japan is not observed at all in the areas of psychiatry/psychology, social sciences/general, and economics & business.

In the 39 RAs with a strong inter/multi-disciplinary nature, there are areas with a core-paper share exceeding 9%, confirming the result of the previous study in 2005 that Japan is not necessarily weak in inter/multi-disciplinary areas.

At the same time, Japan does not have any core papers in more than 20% of the entire RAs. Note that the ratio is large when compared to that of about 10% for the U.K. or Germany.

3-3 Characteristics of scientific activities in major countries observed in the RAs

Portfolio analysis was conducted on the share of major countries in terms of core papers and citing papers in each of the 14 categories of the Correlation map. The United States has the largest share at 61%, followed by 13% for Germany, 12% for the U.K., 9% for Japan, 7% for France, 3% for China, and 2% for Korea. More than 50% of Japan's core papers are in the areas related to physics and chemistry, life science-related areas and healthcare related areas, each comprising about 20%. It is characteristic that in the U.S., Germany, the U.K., and France, life science and healthcare-related categories account for approximately 50% and environment maintains a certain share. Particularly in the U.S. and U.K., social science has a certain presence. In Korea, physics/chemistry-related categories account for nearly 70%. In China, the share of healthcare-related categories is large, which exhibits a similarity to the U.S.

With respect to the share in citing papers, the difference among categories is large in Japan, whereas it is small in the U.K., Germany and France. In other words, the number of researchers involved in "hot" RAs varies greatly among categories in Japan, while a certain size of researcher group exists in each category in the U.K., Germany and France.

3-4 Chronological change in RAs

Since this study has redesigned the analysis method, a strict comparison with the previous study of 2005 may not be possible. Still, time-series analysis was performed on the RAs. The entire 133 RAs extracted for this study were compared to the previous study. As a result, 32 RAs (Type 1) were newly identified in this study, 45 RAs (Type 2) were identified as a continuation from the previous study, and 18 RAs (Type 3) emerged as a result of integration of several RAs of the previous study. From this, it is found that frontline scientific research is dynamically changing, and aspects of RAs have changed in a short time. Particularly, among the newly identified RAs (Type 1), there are RAs involved in the occurrence of avian influenza and Severe Acute Respiratory Syndrome (SARS), which shook the world in 2003. It is found that this method enables the understanding of RAs which attract much attention and have rapidly developed in the past year or two.

Furthermore, by comparing the individual RA maps, it is found to be possible to visually identify what changes have occurred over time. Besides the above-mentioned example of the "Research on countermeasures to Bioterrorism (ID 7)", in the research of the "Development of statistics method for microarray data processing (ID 125)", it is found that research developed with an emphasis on mathematics has grown to influence a wide range of areas in a short period of time.

4. Political implications

4-1 Importance of inter/multi-disciplinary areas

A considerable number of "hot" RAs have inter/multi-disciplinary characters as found from the fact that about 30% of 133 RAs are in inter/multi-disciplinary research. According to this study, the RAs to which more than 90% of the core papers belong in specific traditional disciplines are less than one third of the total. It is also found that rapidly developing RAs have stronger inter/multi-disciplinary characters. Japan has already taken a policy to promote inter/multi-disciplinary research programs, but it is still important to steadfastly promote this approach. This study has found that a number of RAs with more than a 9% share, *i.e.* the average in Japan, are in inter/multi-disciplinary research. A comparison with the previous study, though the method is different, also shows the same results, suggesting a continuation of this tendency. In other words, a considerable number of Japanese researchers publish the world's leading papers in the inter/multi-disciplinary RAs and it is an essential task to develop a supporting system to encourage many researchers to take on these inter/multi-disciplinary challenges.

4-2 Importance of public research and development/support in accordance with the development of scientific research

Three patterns are recognized from the overview of RAs: RAs newly identified after the previous study (Type 1), continuously developing RAs (Type 2), and integrated RAs (Type 3), demonstrating a drastic change in a short period of time. It is also found that the elements within RAs are also changing in the Type 2 and Type 3 RAs. It is observed that a change in RAs occurs quite rapidly, particularly when *life science-related* research is involved. Unfortunately, Japan has little presence in these areas. At funding agencies of the U.S., a program director in charge of the RA is entitled to allocate the budget for pioneering research projects on an as needed basis. It is necessary in Japan to consider establishment of a support system to appropriately respond to the changes in scientific research.

4-3 Effectiveness of periodic observation of RAs by Science Map

This study has established a new methodology to map dealing with state of science by bibliometric analysis and to comprehensively understand scientific research mainly in natural science. At the RA level, the trends in research activity of different countries exhibit different strengths.

The 3rd Science and Technology Basic Plan stipulates that a certain amount of resources shall be allocated to steadily promote basic research that would bring about diverse wisdom and innovation. Basic research includes the studies based on free ideas and the studies aiming for future applications in line with the policies. In terms of basic research promotion, the former is excluded from the principle of issue selection and resource concentration; however, the government needs to confirm a steady progress in science through the observation of the research balance and the situations of inter/multi-disciplinary research. In other words, periodic observations by this method that describe the conditions of basic science in the recent past, from the viewpoint of scientific papers, will be an effective benchmark for the long-term policy for basic science promotion, and in some cases, will be a good reference for reviewing the policies. Nonetheless, it is necessary to pay special attention to the fact that there is a difference in paper production activities of researchers even in basic science and this method alone does not necessarily enable a holistic understanding of scientific activities.

1 Objectives

1-1 Objectives and stance of this study

Science and technology policies in developed nations have become even more mission-oriented and are expected to have a greater impact on the economy, society and public life. In the 3rd Science and Technology Basic Plan which has been in effect since 2006, the issue of how the accomplishments of public research and development and related support activities have benefited the public in the end is increasingly recognized. At the same time, several studies[1] have evidenced that it is necessary to continue promoting basic science since it plays an important role in generating impact as a basis for science and technology.

Bibliometric analysis is used as one of the indicators to measure basic scientific activities. Publication tendencies of academic papers have been analyzed by area, providing useful information pertaining to the quality of papers of different countries and portfolios about publications.

However, through the area-level macro analysis of papers, it is not easy to understand the qualitative change in scientific research itself. For instance, let us take the development of quantum mechanics into account. The main issue at the beginning of the 20th century was to understand the behavior of electrons within atoms, and each scientist tackled this task. Today, at the beginning of 21st century, scientists attempt to control each electron within a device, thereby generating impacts on society, the economy and public life as nanoscience. In order to understand such dynamic scientific trends, analysis beyond the academic realm is necessary. Furthermore, capturing of scientific activities by area enables the understanding about specific scientific contents and therefore is thought to be an effective tool to understand the qualitative change in scientific research.

In addition, relations among the RAs are also changing. A number of inter/multi-disciplinary areas are emerging, including nanoscience and bioinformatics, etc. Despite the fact that awareness of importance of these areas was increasingly being recognized, there was no methodological prescription to quantitatively analyze inter/multi-disciplinary research. It is fair to say that inter/multi-disciplinary research has traditionally been expressed with the simple combination of names of existing areas. Therefore, the establishment of the methodology to systematically understand the inter/multi-disciplinary areas may serve as a tool to objectively understand scientific activities. Two factors are necessary to that end: one, the overview of RAs; and two, the most recent scientific knowledge.

Based on the awareness described above, this study aims to develop a Science Map that enables a comprehensive understanding of current science and search for the issues involved in the promotion of future science and uncover clues to solve the issues. The Study on Rapidly-developing Research Areas (NISTEP REPORT No.95) reports that a new method has already been developed that combines “bibliometric analysis” and “content analysis” with the purpose to discover high profile and rapidly-developing RAs mainly in basic science (hereinafter referred to as “developing areas”), as well as to understand scientific activities in Japan in these developing areas.

This study is the second one based on the method specified in the NISTEP REPORT No.95 with the aim to continuously accumulate data and grasp the chronological changes. At the same time, information was shared with the Organization for Economic Cooperation and Development (OECD) to

[1] Analysis of Socio-Economic Impact of Science and Technology (NISTEP REPORT No.89) Benchmarking Research & Development Capacity in Japan (NISTEP REPORT No.90)

comprehensively understand science, highlighting basic science, in addition to rapidly developing RAs. Revision was made on the study method developed in the NISTEP REPORT No.95 to use it for science and technology indicators to keep up to date on the international research trends. In other words, the data obtained in this study serve as a starting point for future accumulation of data.

1-2 Flow of the study

In this study, we tried to objectively understand the scientific areas by combining the "establishment of RAs through bibliometric analysis (hereinafter referred to as "bibliometric analysis")" and "content analysis on established RAs (hereinafter referred to as "content analysis")".

First, a method was developed to have a bird's eye view of scientific areas highlighting basic research. Specifically, focusing on academic papers which are the output of basic research, a method was developed to establish and extract RAs by bibliometric analysis. This bibliometric analysis yielded 133 RAs.

Next, content analysis was performed on the obtained RAs (naming and defining of RAs).

Then, examination on the percentage share of papers and time-series analysis in each of the RAs of the U.S., U.K., Germany, France, Korea and China were performed. Through these analyses, the tendency of the overall characteristics in scientific research during the period between 1999 and 2004 and the weight of Japan's presence in each RA were observed.

This report documents results derived from joint research between the National Institute of Science and Technology Policy (NISTEP) and the Organization of Economic Cooperation (OECD). The establishment and analysis of RAs serving as a fundamental database of this research were prepared by NISTEP. In specific terms, it includes identification of 133 RAs through co-citation analysis, mapping of individual RAs, and content analysis of individual RAs. Both NISTEP and OECD, based on the data on 133 RAs, pursued the development of science, technology, and innovation indicators: specifically, the development of a map showing a holistic view of current scientific activities and identification of 14 categories based on 133 RAs. This report includes the extraction of individual RAs, mapping and content analyses, among others. With respect to analysis of inter/multi-disciplinary areas in each category, the share analysis of OECD members, and social network analysis to co-authorship among institutions in specific categories are documented in a report[2] published by OECD.

[2] OECD STI Working Paper 2007/1

2. Methodology

In the present day, when scientific research is continuously evolving, we consider it necessary to have a holistic view of overall science and to identify newly developing RAs as quickly as possible, such as nanoscience, in order to implement flexible science and technology policy measures. However, since an understanding of the latest RAs requires highly advanced and specialized knowledge, it is not easy to have an overview of overall scientific research.

This study focuses on "scientific papers" that are the output of research activities and attempts to objectively understand scientific areas by combining "establishment of RAs by bibliometric analysis" and "content analysis on the established RAs". The development of a method is required to make three points possible and to establish such a method that will continuously provide objective data useful for policy formulation. The three points are:

- Holistic analysis of overall research, without being confined to specific areas;
- Objective analysis of RAs based on statistical information; and
- Sustainable analysis using the same method.

The methodology is explained in this chapter.

2-1 Bibliometric analysis

(1) Database used for analysis

This study used the bibliometric database: namely, the Essential Science Indicator (hereinafter referred to as "ESI") of Thomson Scientific Inc. for the establishment of RAs by bibliometric analysis. ESI contains the constant data of the most recent 10 years and covers 10 million bibliographic information items listed in more than 8,500 academic journals of the world.

ESI contains the following data as unique and comprehensive data concerning the trend and statistics of scientific research activities:

- Citation ranking of scientists, papers, research institutes, countries, and journals;
- Data on the highly cited papers of the past 10 years; and
- Data on the so-called RFs, or highly co-cited papers associated with co-citation.

Out of the above, "RFs" are used for this study.

Below is the list of 22 fields in ESI of Thomson Scientific Inc., that categorizes academic journals into 22 fields (Table 1). <u>This study identifies the following 22 fields as "traditional disciplines"</u>.

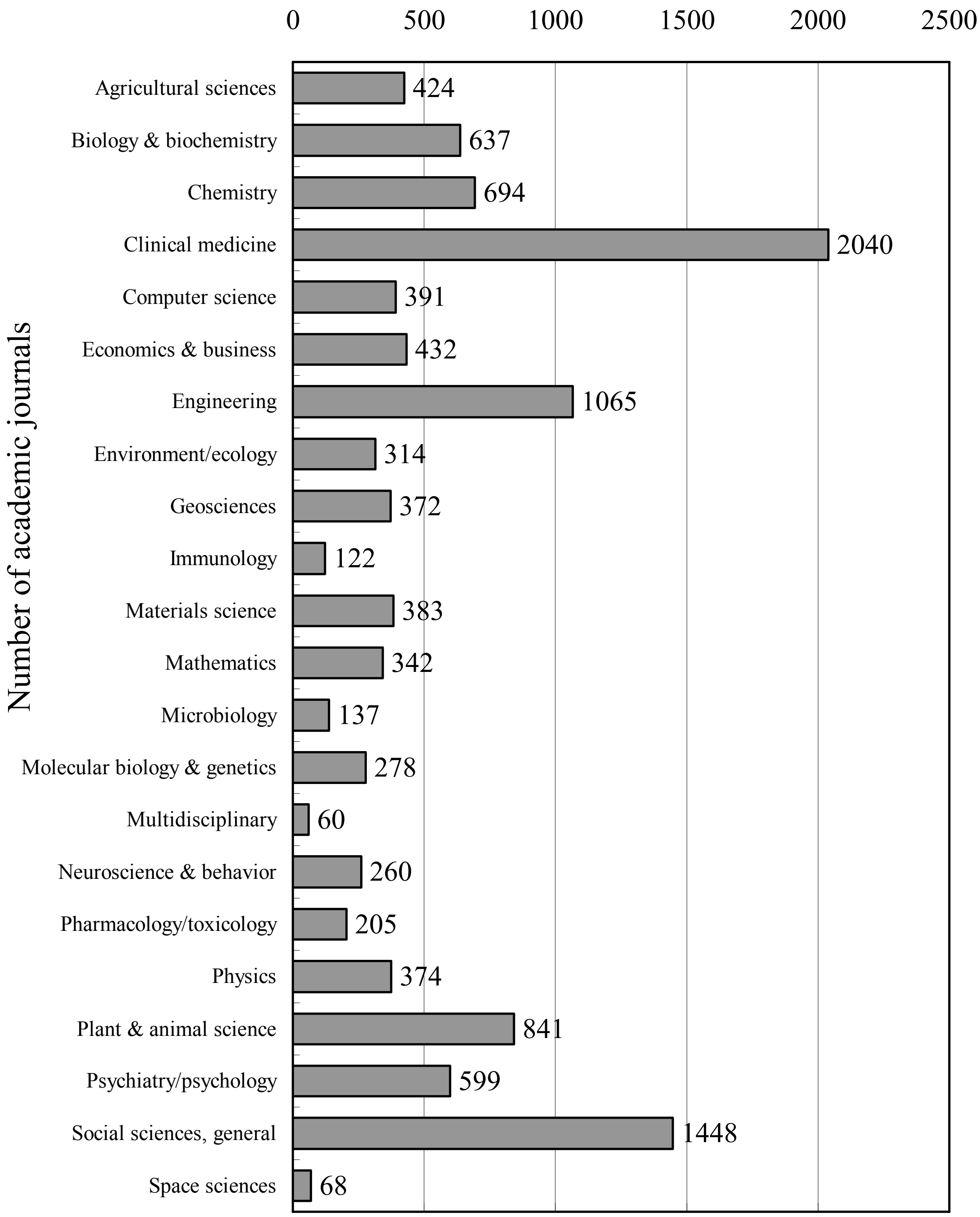
Table 1: 22 fields in ESI

Agricultural sciences	Economics & business	Materials science	Neuroscience & behavior	Social sciences, general
Biology & biochemistry	Engineering	Mathematics	Pharmacology/toxicology	Space sciences
Chemistry	Environment/ecology	Microbiology	Physics	
Clinical medicine	Geosciences	Molecular biology & genetics	Plant & animal science	

Source: "Essential Science Indicators," by Thomson Scientific.

The twenty-two fields and distribution of the number of academic journals in each discipline are shown in Figure 2. Although there are differences in the number of academic journals among different disciplines, data include a wide range of fields, such as clinical medicine, physics, engineering and social sciences. The Science and Technology Foresight Center of NISTEP has confirmed that ESI lists major academic journals for life science, information and telecommunications, environment, and nanotechnology/material among the priority disciplines of the 3rd Science and Technology Basic Plan.

Table 2: Twenty-two fields and distribution of the number of academic journals in each discipline (as of March, 2003)



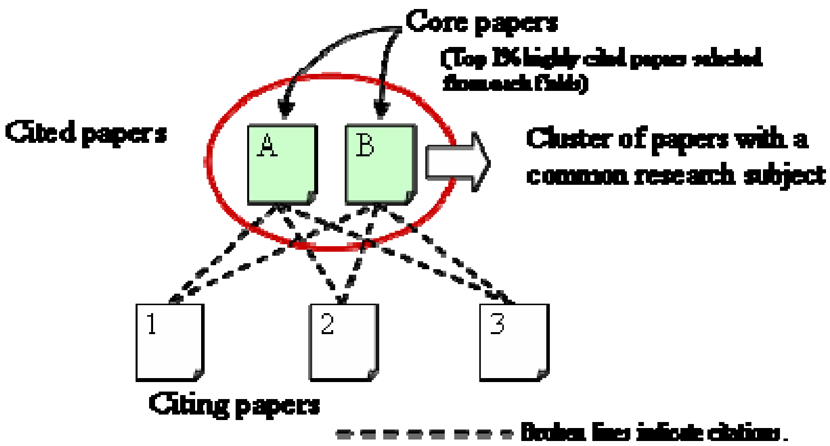
Source: "Essential Science Indicators," by Thomson Scientific.

(2) Clustering of papers by co-citation relations

Knowledge in cutting-edge research is transmitted through frequent information exchange among researchers. The exchange takes various forms and citation of scientific papers is one of the major ways to enable knowledge flow. Citation tendency of a RA reflects how the RA is constructed and how it is related to others. Therefore, understanding of the citation tendency of papers and major papers that make up a RA enables examination of the trend of the RAs.

Paying attention to this aspect, papers were clustered in this study based on co-citation relations. <u>Co-citation here is a form of citation in which a set of papers is simultaneously cited by other papers.</u> The activity of co-citation is represented in Figure 3.

Figure 3: Activity of co-citation



In Figure 3, papers A and B are simultaneously cited (co-cited) by papers 1, 2 and 3. The papers co-cited by many papers are thought to have some sort of relationship regarding their contents (common subject, common methodology, etc.), and successive clustering of papers using the frequency of co-citation yields a cluster of papers related to a common research subject. Co-citation analysis in this study uses the following formula to evaluate co-citation frequencies for papers A and B. We can conclude that a co-citation relation is in place and a “RF (RF)” is formed if the value of the formula (2) falls on or above the 0.3 threshold.

$$N_{AB} \geq 2$$

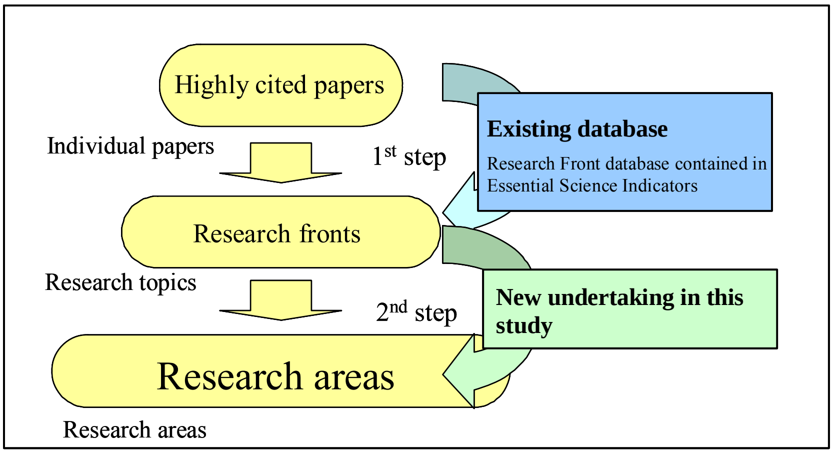
$$N_{norm} = N_{AB} / \sqrt{N_A N_B} \quad \text{…Equation (1)}$$

$$N_{norm} \geq 0.3 \quad \text{…Equation (2)}$$

N_{AB} indicates the number of co-citations and N_A and N_B indicate the number of papers citing the papers A and B, respectively. N_{norm} indicates the normalized number of co-citations. The larger the value of N_{norm} is, the more frequently the citations take place. The right-hand member indicates the geometric mean between the percentage of the paper N_{AB} which is co-cited by both paper A and paper B among the papers citing the paper A (N_A), and the percentage of the paper N_{AB} which is co-cited by both paper A and paper B among the papers citing the paper B (N_B). For example, for the sake of simplification, taking the case of $N_A = N_B$, if 30% of papers citing the paper A co-cite the paper B, the papers A and B form a RF.

In this study, papers were clustered in two steps via co-citation analysis. Clusters of papers obtained through the first and second clustering are referred to as "RFs" and "RAs", respectively. Figure 4 provides a picture of the interrelation among highly cited papers, RFs and RAs.

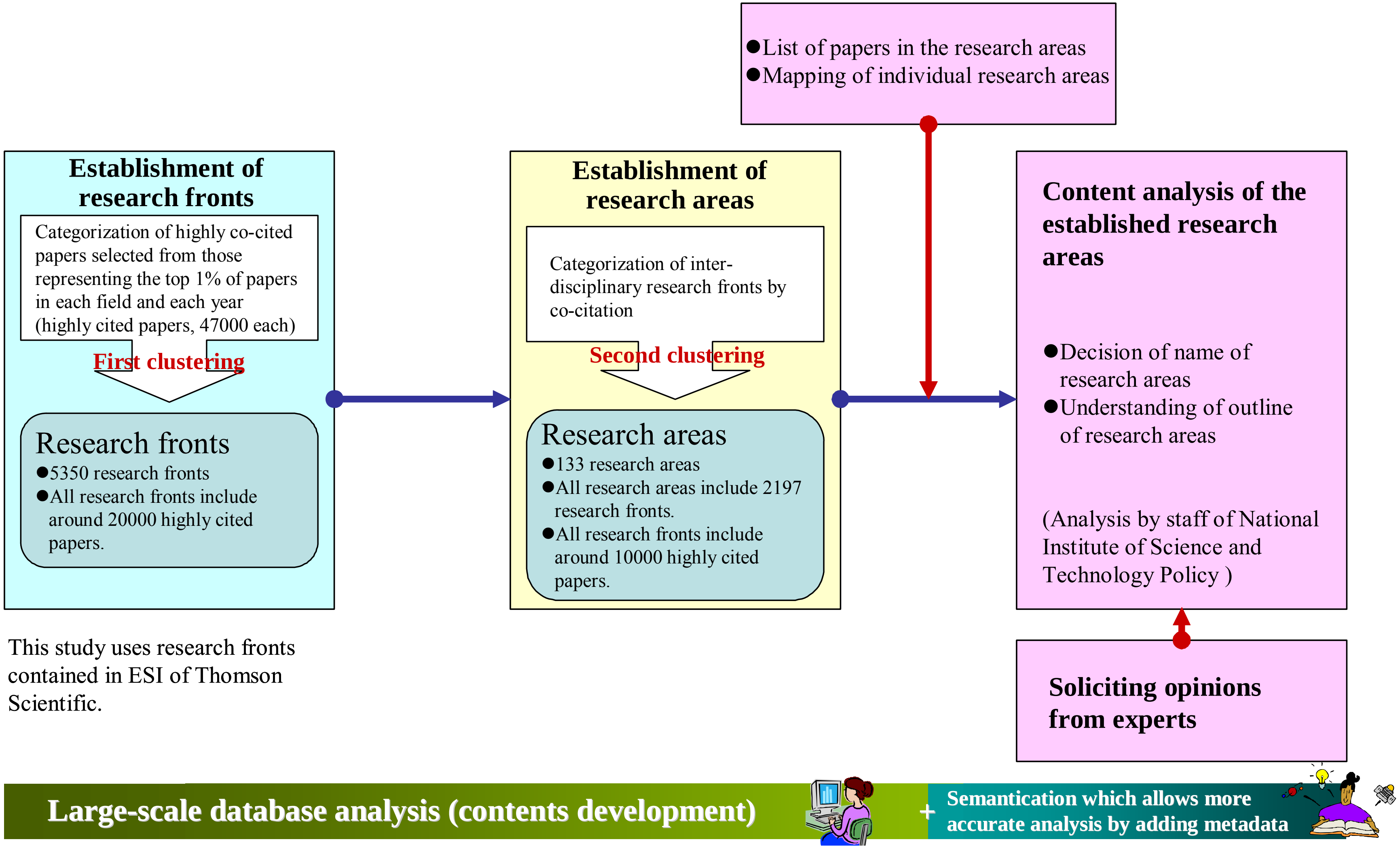
Figure 4: Interrelation among highly cited papers, RFs and RAs



(3) Procedures to understand research areas by bibliometric method

Figure 5 shows the procedures to understand RAs by bibliometric method. In this study, we attempt to grasp RAs by combining "establishment of RAs by bibliometric analysis" and "content analysis of the established RAs". In the meantime, this study reviewed the method of bibliometric analysis based on the issues that surfaced in the previous study. The details of the study are shown in 2-2 and 2-3.

Figure 5: Overall system of study



2-2 Details of bibliometric analysis

(1) Establishment of Research Fronts

This study uses RFs contained in ESI of Thomson Scientific Inc. The identification of 133 areas described in this report was conducted using the 2004 database (1994-2004). The 2002 database (1997-2002), which was used for the previous study, was used for time-series analysis. The outline of the database is shown in Table 6.

Meanwhile, the identification of RAs by bibliometric analysis based on the 2004 database is explained below.

Table 6: Outline of RFs of ESI

(2004 database: this study)

Version of the database	Updated data of March 1, 2005
Publication dates of papers used to establish RAs	January 1999 – December 2004
Total number of RFs	5350 fronts
Number of core papers which constitute RFs	21411 papers

(2002 database: present study)

Version of the database	Updated data of March 1, 2003
Publication dates of papers used to establish RAs	January 1997 – December 2002
Total number of RFs	5221 fronts
Number of core papers which constitute RFs	21183 papers

Below is the summary of the mechanism for formation of RFs (RFs). RFs are the papers listed in ESI and consist of highly cited papers included in the top 1% threshold by field (22 fields, such as agricultural science, biology/biochemistry, chemistry, clinical medicine) and by year based on citations. As a reference, Table 7 shows the threshold values of citation frequencies for highly cited papers during the period from January 1994 to December 2004 listed in the updated data of March 2005 (database on the citation frequencies as of December 2004). Generally, the older the year of publication is, the higher the threshold value is. An interfiled comparison shows that the threshold value for life science-related areas is high. Table 8 is the real number of highly cited papers during the same period; the total number of highly cited papers is 47218 in the target period of this study, *i.e.* the period between 1999 and 2004.

As a parameter for clustering highly cited papers, the threshold of the normalized co-citation was set at 0.3, and the maximum cluster and minimum cluster sizes at 50 and 2, respectively. Figure 9 illustrates the progress of clustering, in terms of time sequence. As the relevant RF advances, the number of papers linked with co-citation increases and so does the number of core papers. In the meantime, RFs of ESI are revised every two months as needed, and the number of core papers fluctuates. There are cases where a RF disappears or splits up.

Table 7: Criteria for highly cited papers (top 1%)
(Threshold values vary in each year and each field)

Number of citations of the papers published between January 1994 and December 2004 to be eligible for highly cited papers											
Field	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Agricultural sciences	63	58	52	50	48	43	37	25	16	9	3
Biology & biochemistry	223	207	193	182	155	129	103	76	51	27	6
Chemistry	109	100	94	84	77	69	58	41	31	15	5
Clinical medicine	171	164	143	131	116	100	84	63	43	22	5
Computer science	49	49	45	39	38	31	24	21	15	6	
Economics & business	103	86	70	64	54	38	33	20	13	6	3
Engineering	50	45	42	41	35	30	25	19	12	7	3
Environment/ecology	118	96	95	76	76	62	50	36	23	11	4
Geosciences	118	107	98	88	78	63	51	36	22	12	4
Immunology	296	267	238	199	196	157	131	105	70	45	8
Materials science	65	58	57	51	48	43	37	27	19	10	3
Mathematics	47	41	38	33	28	25	18	14	9	5	
Microbiology	164	149	155	137	124	103	83	63	43	23	5
Molecular biology & genetics	398	350	318	303	266	226	189	139	97	47	11
Multidisciplinary	51	53	60	87	69	88	82	71	76	39	12
Neuroscience & behavior	242	219	210	182	156	137	109	86	52	23	6
Pharmacology/toxicology	127	120	99	103	83	78	66	53	38	17	4
Physics	113	105	106	89	82	73	63	48	32	17	5
Plant & animal science	86	83	74	71	61	52	43	36	23	11	4
Psychiatry/psychology	139	122	105	92	84	72	55	40	25	12	4
Social sciences, general	55	52	46	43	37	32	26	19	13	7	3
Space sciences	154	145	133	132	113	113	84	75	48	31	9

Source: "Essential Science Indicators," by Thomson Scientific.

Note: Data from 1999 are used in this study. Data between 1994 and 1998 are presented as a reference. Some columns are left blank (computer science and mathematics in 2004) because if the threshold of the top 1% is less than 2, no papers are eligible for highly cited papers.

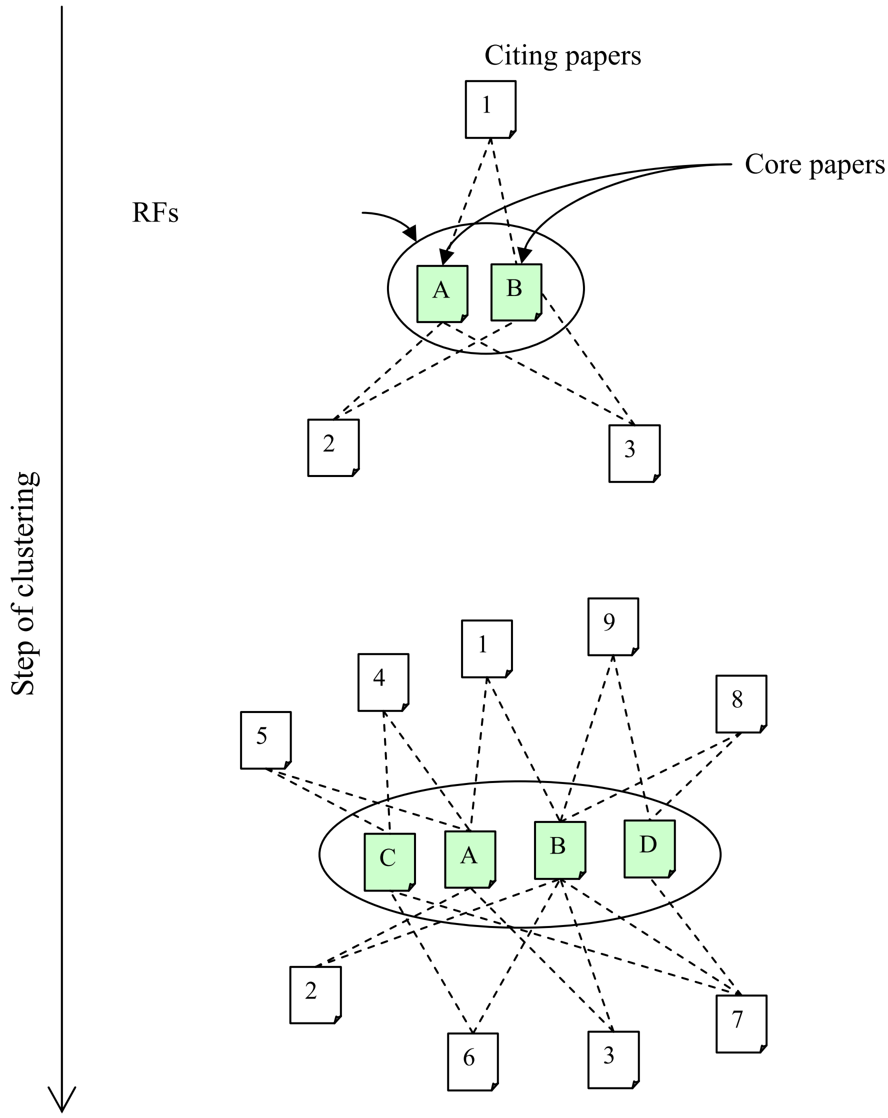
Table 8: Number of highly cited papers (top1%)

Number of highly cited papers (top1%) between January 1994 and December 2004											
Field	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Agricultural sciences	122	131	131	134	141	133	133	141	140	178	92
Biology & biochemistry	494	490	500	487	505	504	488	506	502	510	574
Chemistry	798	852	895	873	904	928	909	949	992	1136	820
Clinical medicine	1444	1493	1542	1612	1671	1678	1641	1686	1695	1795	1743
Computer science	130	126	134	122	135	145	164	156	158	323	
Economics & business	101	108	122	121	123	126	128	127	137	128	61
Engineering	557	573	605	583	611	628	609	656	689	645	328
Environment/ecology	146	154	162	172	173	178	179	197	208	233	223
Geosciences	173	180	186	182	190	217	214	214	220	244	241
Immunology	101	107	108	105	113	120	111	113	106	108	107
Materials science	219	249	286	289	305	316	317	346	345	379	289
Mathematics	160	168	174	166	182	181	204	181	218	196	
Microbiology	126	128	131	129	128	133	121	132	136	136	164
Molecular biology & genetics	204	221	214	223	223	228	231	232	230	246	261
Multidisciplinary	42	36	35	32	32	30	33	19	17	23	26
Neuroscience & behavior	207	224	240	254	249	259	253	252	246	297	229
Pharmacology/toxicology	139	131	142	132	135	143	139	136	146	157	169
Physics	681	705	712	729	759	755	741	786	829	877	818
Plant & animal science	409	428	428	423	450	462	453	432	440	517	382
Psychiatry/psychology	171	189	195	188	189	189	190	195	189	200	191
Social sciences, general	309	342	329	312	327	312	316	335	308	292	252
Space sciences	92	93	97	92	88	103	104	103	118	113	106
Total	6825	7128	7368	7360	7633	7768	7678	7894	8069	8733	7076

Source: "Essential Science Indicators," by Thomson Scientific.

Note: Data from 1999 are used in this study. The total number of papers from 1997 to 2002 is 47218. Data between 1994 and 1998 are presented as a reference. Some columns are left blank (computer science and mathematics in 2004) because if the threshold of the top 1% is less than 2, no papers are eligible for highly cited papers.

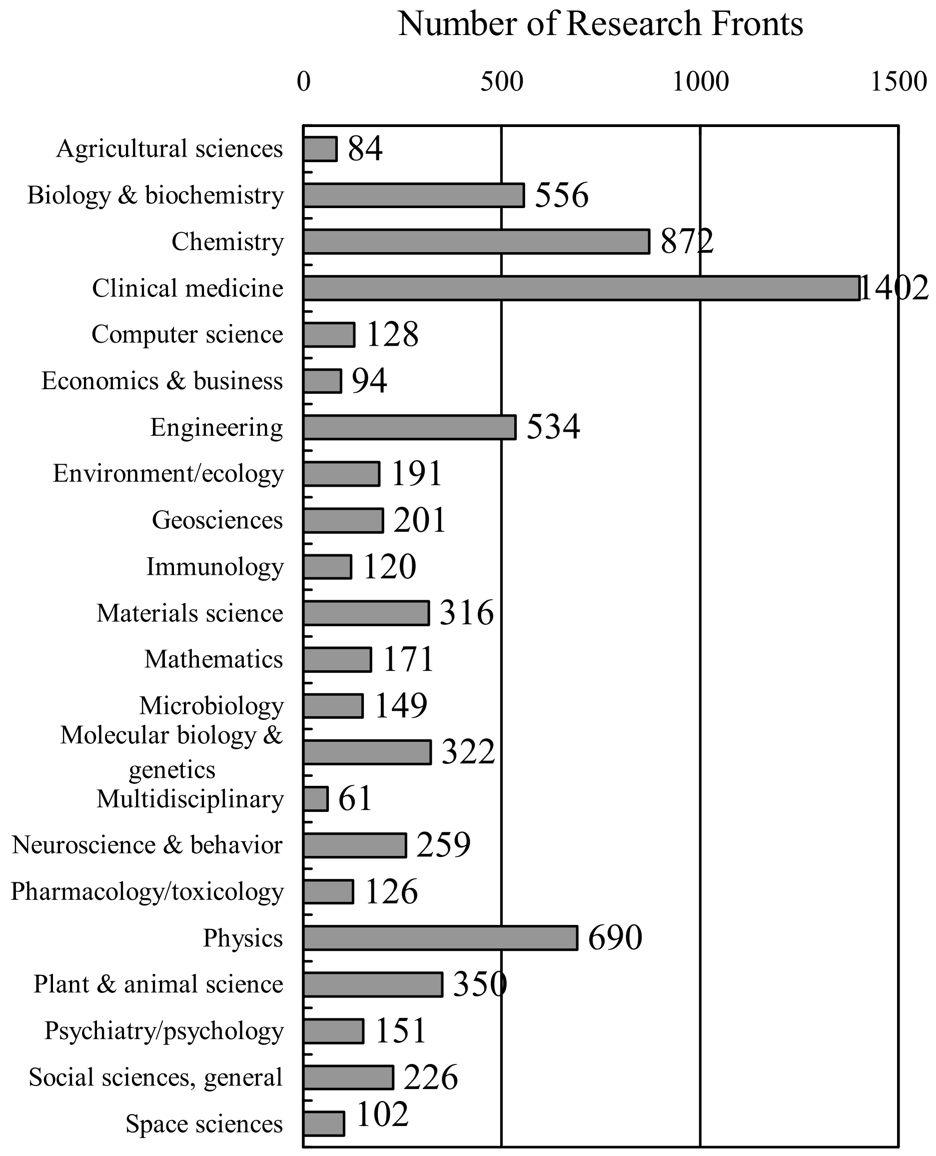
Figure 9: Pattern diagram of the mechanism of the development of RFs
(The broken lines indicate citations.)



In the data of March 2005, there were 5350 RFs and 21411 core papers in 22 fields. Highly cited papers in the RFs account for nearly 50% of the total of highly cited papers (47218) in the period from 1999 to 2004, the period covered in this study. The coverage rate is the same as in the previous study.
With respect to the fields of RFs, we first examined the distribution of 22 fields of core papers which comprise a RF, and designated the fields with the highest percentage of core papers as a primary group and the fields with the 2nd highest as a secondary group, making the belonging to multiple fields possible. Figure 10 shows the distribution (the 2004 database) of RFs by field. The field with the highest number is

clinical medicine, followed by chemistry, physics, biology/biochemistry, and engineering in that order.

Figure 10: Distribution of RFs by field (the 2004 database)



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: There are 5350 RFs, among which 1462 are distributed in two or more fields (total: 7015). All data in Figure 10 is shown as total.

Each RF is marked with an identification code named "Front ID", containing the following information:

(i) Key words of RFs obtained by frequency analysis of technical terms which appear in the titles of core papers;

(ii) Number of core papers comprising RFs;

(iii) Year of publication of each core paper;

(ix) Number of citations of core papers;

(x) Average rate of increase in citations of each core paper; and

(xi) Slope of regression line (of x).

Average rate of increase in citations is determined by the following formula:

$$\frac{1}{N-1}\sum_{i=1}^{N-1}\frac{y_{i+1}-y_i}{y_i}\times 100$$

Here, y_i denotes the number of citations per core paper in the "i" th year, where N=6 since this study uses the data for 6 years. For instance, it is 200% if the number of citations was 5 in 2003 and 15 in 2004. The slope of the regression line was obtained by the slope of a linear function.

Some RFs are treated as independent due to the low frequency of co-citations with each of the others although similar research activities are undertaken. Table 11 shows the examples of RFs that contain the keyword "carbon nanotube" (hereinafter referred to as CNT). Front ID4673 is the RF dealing with the application of CNT to molecular-scale electronics, and Front ID4682 is the RF dealing with the practical use of CNT as a biosensor. Among the total of 5350 RFs, 61 RFs contain the keyword CNT.

Table 12 shows examples of papers belonging to the Front ID4682. As it shows, detailed journal information is available.

Table 11: Example of RFs (related to carbon nanotubes)

Front ID	Keywords of RFs	Number of core papers	Average year of publication of core papers	Number of citations of core papers	Average rate of increase	Slope of regression line
4667	SINGLE-WALLED CARBON NANOTUBES USING FLUORESCENCE; METALLIC SINGLE-WALLED CARBON NANOTUBES; SEMICONDUCTING SINGLE-WALLED CARBON NANOTUBES; SINGLE-WALLED CARBON NANOTUBES SYNTHESIZED; SINGLE-WALLED CARBON NANOTUBE SPECTROSCOPY	12	2003.3	283	251.39	15.08
4673	SINGLE-WALLED CARBON NANOTUBES; FUNDAMENTAL ELECTRONIC PROPERTIES; MOLECULAR ELECTRONICS; APPLICATIONS	2	2003	94	84.85	14
4682	HIGHLY SPECIFIC ELECTRONIC BIOSENSORS; ENZYME-COATED CARBON NANOTUBES; SPECIFIC PROTEIN BINDING USING NANOTUBE FET DEVICES; ELECTRONIC DETECTION; SINGLE-MOLECULE BIOSENSORS	3	2003	104	377.78	22.67
4683	ALIGNED CARBON NANOTUBES; ALIGNED ZNO NANORODS; PERIODIC ARRAYS; NANOSENSOR ARRAYS; PHOTONIC CRYSTALS	2	2003.5	23	233.33	7
4734	COATING SINGLE-WALLED CARBON NANOTUBES; MULTIWALLED CARBON NANOTUBES; ELECTRONIC DEVICE APPLICATIONS; COVALENT COUPLING; QUANTUM DOTS	2	2003	35	725	14.5

Source: "Essential Science Indicators" by Thomson Scientific.

Table 12: Example of core papers (related to Front ID 4682)

Paper title	Journal name	Volume number	Number of citations	First author
Noncovalent functionalization of carbon nanotubes for highly specific electronic biosensors	PROC NAT ACAD SCI USA	100: (9) 4984-4989 APR 29 2003	45	Chen, RJ
Enzyme-coated carbon nanotubes as single-molecule biosensors	NANO LETT	3: (6) 727-730 JUN 2003	35	Besteman, K
Electronic detection of specific protein binding using nanotube FET devices	NANO LETT	3: (4) 459-463 APR 2003	24	Star, A

Source: "Essential Science Indicators" by Thomson Scientific.

(2) Establishment of research areas

In order to establish RAs with a certain size and dimension, we grasp the relationship among similar RFs and cluster them into categories. The basis for the method of the previous and this study is to establish RAs encompassing wider notions than RFs.

The issues that surfaced in the previous study and the issues observed in the analysis by the previous method concerning the database subject to this study are summarized to the following three points. In order to respond to these issues, we tried to improve the method of bibliometric analysis for this study. However, the issue C, *i.e.* the issue of clustering of papers with an outstanding number of citations, is excluded from the target of redesigning the method because it is an inevitable issue for conducting co-citation analysis.

A. Issue of stability for time-series analysis

According to the results of time-series analysis conducted as a trial in the previous study, 80% of developing areas consisting of 5 or fewer RFs among the 153 developing areas obtained from the 2002 database disappeared from the RAs in the 2004 database obtained by the previous method. This indicates that the RAs consisting of a small number of RFs are unstable for time-series analysis, and it is necessary to improve the stability in order to analyze the continuous progress of RAs for this study.

B. Issue of the size of RAs

In the previous study, there was a distribution of the size of RAs in which one RA is perceived as a large conceptual unit whereas another as individual and specific research. In specific terms, since the threshold for clustering was set at 0 in the previous study, RFs with extremely weak co-citation relations were clustered together, and the fields with more than 50 RFs were divided into smaller categories with RFs below 50, so there emerged a number of categories with similarities to each other.

C. Issue of clustering of papers with the outstanding number of citations

Co-citation analysis evaluates the strength of linkage of papers by the equation (1). The equation (1) is a normalized formula for co-citation used in many studies. However, there was a case where a paper was not included in a cluster although the paper was cited by outstanding number of documents, indicating a huge contribution of the paper to the development of the field.

$$N_{\mathrm{norm}} = N_{\mathrm{AB}} / \sqrt{N_{\mathrm{A}} N_{\mathrm{B}}} \qquad \text{… Equation (1)}$$

RAs can be obtained by clustering of RFs. Specifically, we analyze co-citation relations among RFs by treating a RF as a hypothetical paper. Base on this, the RFs were clustered at a specific level of co-citation. The clustering of RFs depends on the three parameters shown in Table 13.

Table 13: Parameters for clustering

Parameters	Contents
Threshold of co-citation	Parameters indicating the strength of co-citation relations: the higher the value, the stronger the co-citation relations
Maximum number of RF	Maximum number of RFs in a RA
Minimum number of RF	Minimum number of RFs in a RA

Thus, we reviewed the following three points in order to address the issues A and B.

1) In order to allow stable time-series analysis, the study was performed on the RAs with 6 or more RFs.
2) With the aim to further clarify the concept of RAs, the threshold value for clustering of RAs was set to 0.1. In the previous study, the threshold was 0.
3) In order to avoid small segmentation of RAs, the maximum number of RFs in a RA is set at 100. The maximum number was 50 in the previous study.

In addition to the above, the policy for the selection of RAs subject to content analysis is set forth in 4) below.

4) The concept of a RA has been changed from the previous study of a "RA with more than 2 RFs whose papers are cited by a rapidly increasing number of papers" to "all the RAs obtained through clustering (a RA is composed of 6 or more RFs)".

At the time of the previous study, a request was made by the Council for Science and Technology Policy to shed light on rapidly developing RAs, so a method was chosen that emphasizes an increasing number of fronts. However, the objective of this study is to take a bird's eye view of overall research activities based on the mutual relations among and integration of RAs. Thus, we added policy 4). In the meantime, we listed the number of RFs with a rapidly growing number of citations (see the next section) to be used as a reference for content analysis, in order to allow comparison with the previous study.

Table 14 shows examples of RAs. As RFs, RAs are also categorized with ID codes, which record keywords of RAs obtained by the frequency analysis of the titles of core papers, the number of RFs which comprise a RA, the average year of publication, the number of citations, and the number of co-citations (total) of the entire core papers belonging to RFs which comprise a RA. RA ID102 in Table 14 indicates the areas associated with CNT. This category includes 50 RAs containing the keyword of CNT out of the entire 61 RAs. From this fact, it is clear that RFs that deal with similar research have been grouped together.

The result of clustering is shown in Table 15. The number of highly cited papers published during the period between 1999 and 2004, which make up the population for clustering, is 47218. As a result of the first stage clustering, 5350 RFs were obtained, which contain 21411 highly cited papers. One hundred and thirty-three RAs were obtained by the second stage clustering, which include 2197 RFs and 10504 highly cited papers. This accounts for 41.0% of the total RFs and 22.2% of the total number of highly cited papers.

Table 14: Examples of RAs

RA ID	Group of fragmented keywords describing the details of RAs	Number of RFs	Average year of publication of core papers	Number of citations	Number of co-citations (total)
48	ampa receptor subunits controls synaptic trafficking underlying plasticity; stargazin control synaptic ampa receptor number; subunit-specific rules governing ampa receptor trafficking; synaptic nmda receptor activation; hippocampal long-term synaptic plas	15(2)	2000.7	6911	2899
102	carbon nanotube modified glassy carbon electrodes; single-walled carbon nanotubes using fluorescence; single-walled carbon nanotubes using binary (fe; single-walled 4 angstrom carbon nanotubes aligned; 4 angstrom single-walled carbon nanotubes	50(15)	2001.5	17077	6014
49	huntington's disease transgenic mice; huntington's disease protein interacts; early huntington's disease; motor neuron disease; polyglutamine disease	7(1)	2001.3	3305	1666
5	severe acute respiratory syndrome coronavirus spike protein expressed; coronavirus associated severe acute respiratory syndrome (sars); severe acute respiratory syndrome coronavirus 3c-like proteinase; severe acute respiratory syndrome (sars) coronavirus;	19(5)	2003.6	5112	1143
103	high efficiency dye-sensitized nanocrystalline solar cells based; quasi-solid-state dye-sensitized tio2 solar cells; dye-sensitized nanacrystalline tio2 solar cells; dye-sensitized nanocrystalline solar cells employing; dye-sensitized solid-state solar ce	14(4)	2001.4	4706	2186

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

Table 15: Result of clustering

	Number of RAs	Number of RFs	Number of highly cited papers
Before clustering			47,218
First stage clustering		5,350	21,411
Second stage clustering	133	2,197	10,504

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

(3) Identification of rapidly-developing Research Areas

The following policies enable one to identify rapidly developing RAs with an increasing number of citations among 133 RAs established by bibliometric analysis. These correspond to the extraction/analysis method of RAs adopted in the previous study.

First, in order to extract RFs with a rapidly increasing number of cited papers (hereinafter referred to as "rapidly increasing fronts"), we counted the number of citations of core papers included in each of the 5350 RFs during the period from 1999 to 2004, and then calculated the rate of increase in the number of citations and the slope of the regression line by RF.

With respect to the fields of RFs, we examined 22 fields of core papers and the areas with the highest percentage of core papers were grouped into the primary group and the second highest into the secondary group, which allows multiple belongings (see 2-2 (1)). In accordance with this policy, the rate of increase in the number of citations of RFs that belong to each of the 22 fields and the mean slope of the regression line were calculated (the result of 2004 data is shown in Table 16).

Out of the RFs, we extracted those exceeding the average rate of increase and the mean slope of the regression line in each area. Figure 17 shows the distribution of RFs by field with above/below average values (2004 database). In each field, 1015 (total: 1229) RFs or about 20% exceed the average values for both items. In the case of RFs that belong to a number of fields, if one RF exceeds the average in one field, it is identified as a rapidly increasing front.

The ranking of RAs was made in descending order of the number of citations. This study includes 43 RAs with more than 4 rapidly increasing fronts and 41 RAs with 2-3 rapidly increasing fronts, out of 133 RAs obtained from bibliometric analysis. The number of rapidly increasing fronts is listed as a reference in Section I of III Reference (Result of content analysis of RAs).

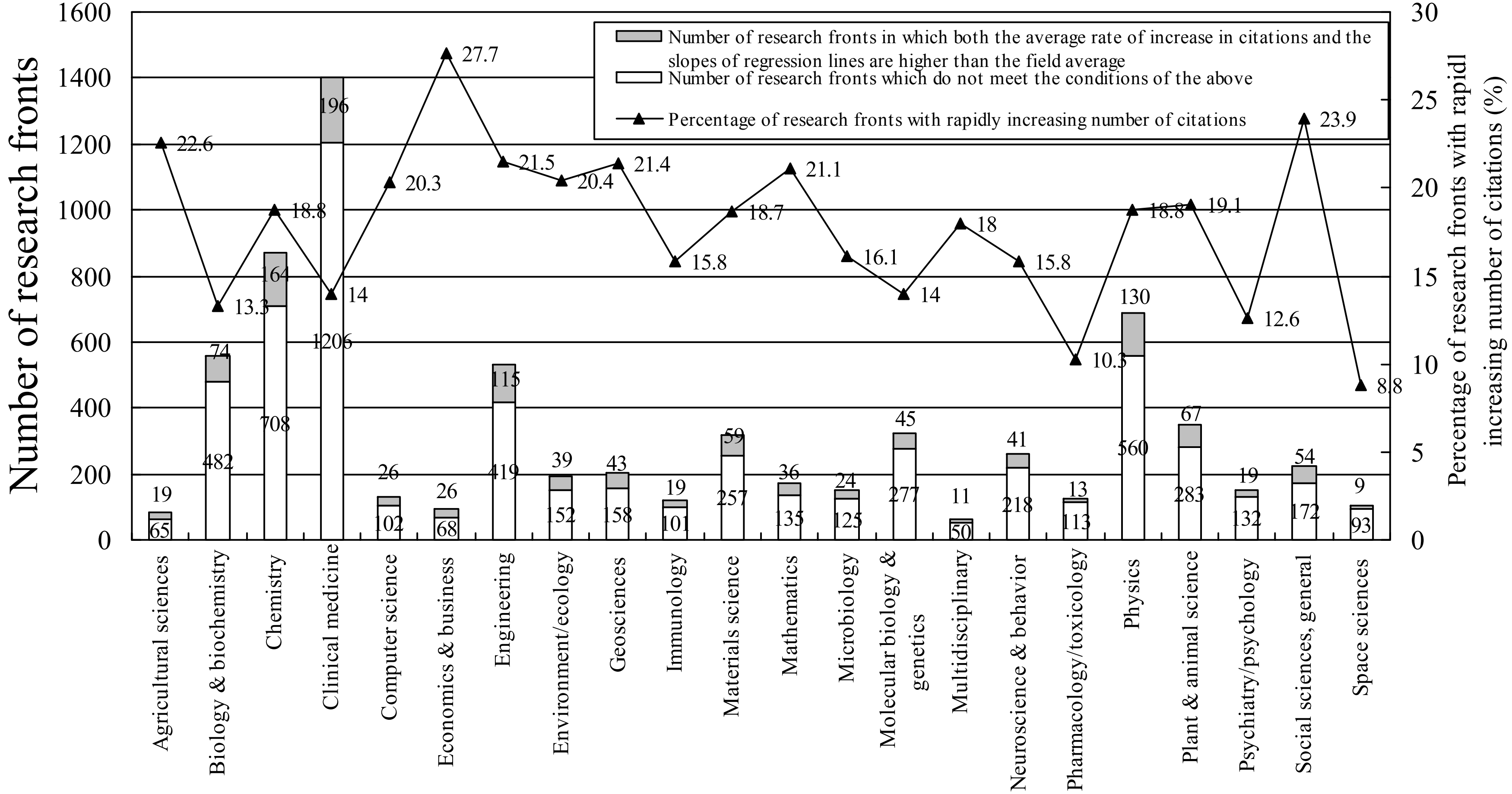
In this study, average values by field were adopted for the purpose of extracting rapidly increasing fronts. This is because many RFs that are cited more frequently than other fields, such as those associated with biology/biochemistry, clinical medicine, and life science, tend to be extracted if the average of all fields is used as a threshold value. Therefore, we extracted rapidly increasing fronts evenly from all the fields by adopting the average of each field.

Table 16: Average rate of increase in the number of citations of core papers which constitute RFs, and average slopes of regression lines by field (the 2004 database)

Fields	Number of RFs	Average number of core papers in RFs	Average rate of increase in RFs by field	Average slopes of regression lines by field
Agricultural sciences	84	4.0	93.4	3.4
Biology & biochemistry	556	5.4	197.6	10.3
Chemistry	872	4.8	168.0	6.5
Clinical medicine	1402	4.2	215.0	11.0
Computer science	128	3.8	181.9	4.9
Economics & business	94	3.2	108.0	3.1
Engineering	534	4.1	136.0	3.4
Environment/ecology	191	4.1	158.5	5.7
Geosciences	201	3.7	133.7	5.0
Immunology	120	5.5	186.9	12.1
Materials science	316	5.2	143.2	5.7
Mathematics	171	3.5	109.2	2.3
Microbiology	149	4.6	205.7	10.2
Molecular biology & genetics	322	5.9	239.6	15.4
Multidisciplinary	61	7.5	157.3	9.2
Neuroscience & behavior	259	4.3	209.4	9.9
Pharmacology/toxicology	126	6.0	248.0	8.4
Physics	690	5.6	151.3	5.7
Plant & animal science	350	4.7	144.1	4.9
Psychiatry/psychology	151	3.7	194.3	6.2
Social sciences, general	226	3.3	125.0	3.1
Space sciences	102	5.0	157.1	13.3

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

Figure 17: Distribution of RFs with increasing citations in each field (the 2004 database)



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

2-3 Method of content analysis of the established Research Areas

In this study, we conducted content analysis on categorized RAs by co-citation. The following two points were developed as a database for analysis.

- List of papers in the RAs (information pertaining to titles of core papers belonging to RFs, and keywords and abstracts of RFs obtained by the frequency analysis on core paper titles and abstracts)
- Individual RA map

(1) List of papers in the Research Areas

We have compiled a list of information on core papers belonging to each RA as shown in Table 18.

Table 18: Examples of list of papers in the RAs (part of RA ID102)

List of Papers

Research Area ID	Research Area Name	# of RFs
386	carbon nanotube modified glassy carbon electrodes; single-walled carbon nanotubes using fluorescence; single-walled carbon nanotubes using binary (fe; single-walled 4 angstrom carbon nanotubes aligned; 4 angstrom single-walled carbon nanotubes	50

Research Front ID	Keywords of Research Front	# of Core Papers	Total Citations
126	LITHIUM MULTIWALLED CARBON NANOTUBES; SINGLE-WALLED CARBON NANOTUBES; ELECTROCHEMICAL STORAGE; ELECTROCHEMICAL INTERCALATION	2	157

	Core Paper Title	Journal	Issued Year	Citations	First Author
Chem	Electrochemical storage of lithium multiwalled carbon nanotubes	CARBON	37: (1) 61-69 1999	96	Frackowiak, E
Chem	Electrochemical intercalation of single-walled carbon nanotubes with lithium	CHEM PHYS LETT	307: (3-4) 153-157 JUL 2 1999	89	Gao, B

Research Front ID	Keywords of Research Front	# of Core Papers	Total Citations
203	SINGLE-WALLED CARBON NANOTUBES; ALKALI-DOPED CARBON NANOTUBES; FINITE-DIAMETER CARBON NANOTUBE ROPES; CARBON NANOTUBE ARRAYS; IDEALIZED CARBON SLIT PORES	9	766

	Core Paper Title	Journal	Issued Year	Citations	First Author
Chem	Hydrogen storage in single-walled carbon nanotubes at room temperature	SCIENCE	286: (5442) 1127-1129 NOV 5 1999	403	Liu, C
Chem	High H-2 uptake by alkali-doped carbon nanotubes under ambient pressure and moderate temperatures	SCIENCE	285: (5424) 91-93 JUL 2 1999	286	Chen, P
Phys	Hydrogen adsorption and cohesive energy of single-walled carbon nanotubes	APPL PHYS LETT	74: (16) 2307-2309 APR 19 1999	282	Ye, Y
Chem	Molecular simulation of hydrogen adsorption in single-walled carbon nanotubes and idealized carbon slit pores	J CHEM PHYS	110: (1) 577-586 JAN 1 1999	154	Wang, QY
Phys	Hydrogen storage in single-walled carbon nanotubes	APPL PHYS LETT	76: (20) 2877-2879 MAY 15 2000	95	Lee, SM
Chem	Monte Carlo simulations of H-2 physisorption in finite-diameter carbon nanotube ropes	CHEM PHYS LETT	320: (3-4) 352-358 APR 7 2000	87	Williams, KA
Chem	Physisorption of hydrogen on microporous carbon and carbon nanotubes	J PHYS CHEM B	102: (52) 10894-10898 DEC 24 1998	81	Rzepka, M
Chem	Optimization of carbon nanotube arrays for hydrogen adsorption	J PHYS CHEM B	103: (23) 4809-4813 JUN 10 1999	71	Wang, QY
Engi	Molecular modeling of adsorptive energy storage: Hydrogen storage in single-walled carbon nanotubes	IND ENG CHEM RES	38: (12) 4647-4655 DEC 1999	36	Gordon, PA

Research Front ID	Keywords of Research Front	# of Core Papers	Total Citations
210	FREE-STANDINGSINGLE-WALLED CARBON NANOTUBES; ENHANCED CVD APPROACH; EXTENSIVE NANOTUBE NETWORKS; DIRECTED GROWTH; DIRECTIONALITY	2	111

	Core Paper Title	Journal	Issued Year	Citations	First Author
Chem	Directed growth of free-standingsingle-walled carbon nanotubes	J AM CHEM SOC	121: (34) 7975-7976 SEP 1 1999	77	Cassell, AM
Mate	An enhanced CVD approach to extensive nanotube networks with directionality	ADVAN MATER	12: (12) 890-894 JUN 16 2000	67	Franklin, NR

Research Front ID	Keywords of Research Front	# of Core Papers	Total Citations
213	SINGLE-WALL CARBON NANOTUBES; SINGLE-WALLED CARBON NANOTUBES; CATALYTIC CHEMICAL VAPOR DEPOSITION (CCVD) METHOD; LARGE SCALE CVD SYNTHESIS; CATALYTIC DECOMPOSITION	5	346

	Core Paper Title	Journal	Issued Year	Citations	First Author
Chem	Large scale CVD synthesis of single-walled carbon nanotubes	J PHYS CHEM B	103: (31) 6484-6492 AUG 5 1999	174	Cassell, AM
Chem	Large-scale synthesis of single-wall carbon nanotubes by catalytic chemical vapor deposition (CCVD) method	CHEM PHYS LETT	317: (1-2) 83-89 JAN 28 2000	111	Colomer, JF
Chem	A scalable CVD method for the synthesis of single-walled carbon nanotubes with high catalyst productivity	CHEM PHYS LETT	322: (5) 321-326 MAY 26 2000	96	Su, M
Chem	Controlled production of single-wall carbon nanotubes by catalytic decomposition of CO on bimetallic Co-Mo catalysts	CHEM PHYS LETT	317: (3-5) 497-503 FEB 4 2000	87	Kitiyanan, B
Chem	Synergism of Co and Mo in the catalytic production of single-wall carbon nanotubes by decomposition of CO	CARBON	39: (4) 547-558 2001	53	Alvarez, WE

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

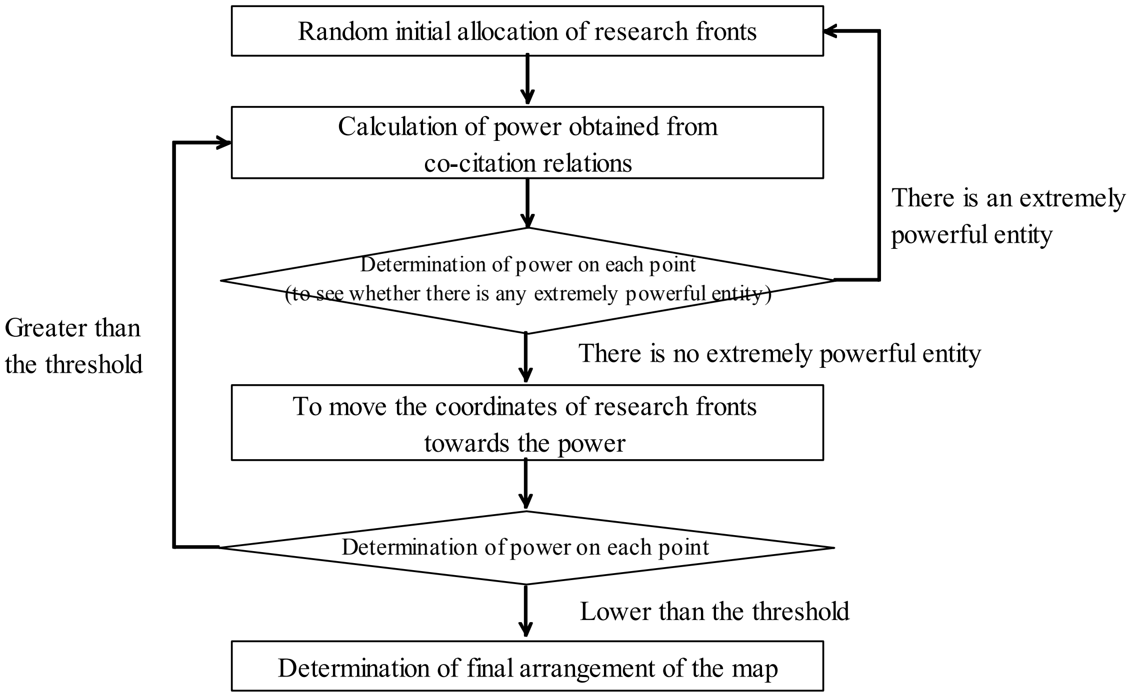
(2) Mapping of individual Research Areas

A map of individual RAs of the established 133 RAs was developed in order to visualize the relationships among RFs which constitute a RA.

The map was created by a gravity model. Figure 19 is a flow chart of the development of a map of individual RAs. First, RFs are randomly plotted in the two-dimensional space (one circle indicates a RF). After that, RFs are moved incrementally in the direction of the net force calculated by co-citation relations. In doing so, the size of the circle was not taken into consideration; instead, each RF was considered as a dot representing the center of the circle. At each step, the average force affecting each dot is calculated and when the power affecting each dot is extremely large, mapping was redone with a new initial setting. The final allocation was obtained when the average force on each dot reached its minimum value. In the map of individual RAs, only relative location of RFs is important, and no specific significance is attached to the mere location of each dot, whether it is at the left or right, or at the top or bottom.

The force on each dot is calculated by the sum of the attractive force and repulsive force based on the co-citation relations. The attractive force between a pair of RFs is proportional to the product of the normalized co-citation frequency, N_{norm}, and the physical distance between RFs is r (See §2-1 for the definition of N_{norm}). Therefore, if a pair of co-cited RFs is distant, a strong attractive force is generated. On the other hand, a repulsive force is proportional to the quotient of the normalized maximum number of co-citations, $N_{\mathrm{norm}}^{\max}$, divided by r^2. Therefore, the closer two RFs get, the stronger the repulsive force becomes. The normalized maximum value of citation frequency $N_{\mathrm{norm}}^{\max}$ is the value of the strongest co-citation relations between RFs in a RA; the maximum value of this parameter is 1.

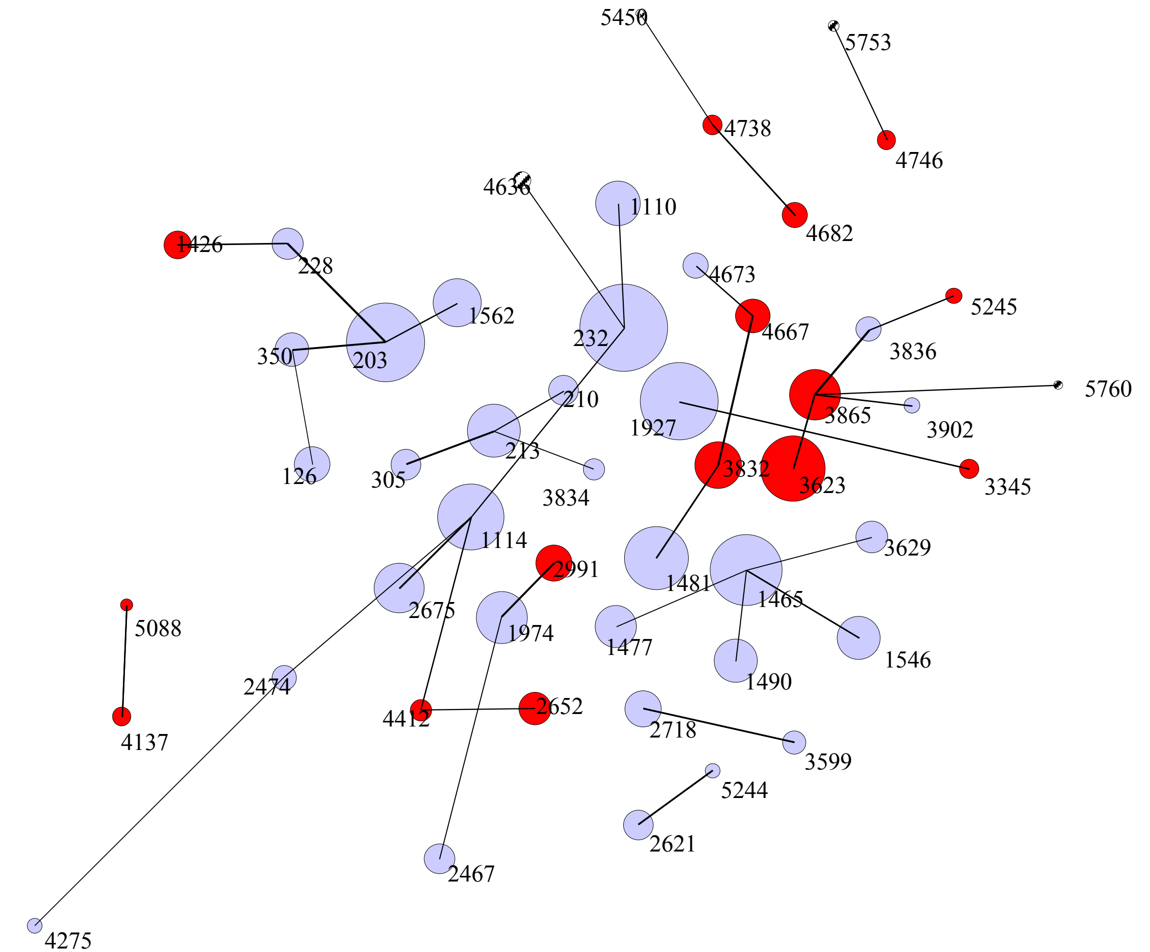
Figure 19: Flow chart of the development of a map of individual RAs



A map of individual RAs associated with the "Carbon Nanotube" obtained from the gravity model is shown in Figure 20 for reference. The following is an explanation of the map of individual RAs.

- A circle drawn on the map corresponds to one RF.
- The number next to a circle indicates the ID number of the corresponding RF.
- The area of a circle is proportional to the number of citations of core papers that constitute a RF.
- Dark color indicates the RFs that has prominent increase in citations of core papers (See §2-4 for the criteria of dark colored RFs).
- Diagonal lines in the circle indicate the RFs newly identified in 2004.
- The circles representing RFs are closely placed when the co-citation relation is strong and placed far apart when the relation is weak.
- RFs having the strongest co-citation relations are connected with lines.

Figure 20 : Example of map of individual RAs (RA ID102)



ID	Keyword
126	LITHIUM MULTIWALLED CARBON NANOTUBES
203	SINGLE-WALLED CARBON NANOTUBES
210	FREE-STANDINGSINGLE-WALLED CARBON NANOTUBES
213	SINGLE-WALL CARBON NANOTUBES
228	HYDROGEN ADSORPTION
232	POLYMER-WRAPPED SINGLE-WALLED CARBON NANOTUBES
305	SINGLE-WALLED CARBON NANOTUBES
350	ELECTROCHEMICAL STORAGE
1110	CARBON NANOTUBE MODIFIED GLASSY CARBON ELECTRODES
1114	CARBON NANOTUBE EPOXY COMPOSITES
1426	MECHANICALLY PREPARED NANOSTRUCTURED GRAPHITE
1465	CARBON NANOTUBE INTRAMOLECULAR JUNCTIONS
1477	GROWING Y-JUNCTION CARBON NANOTUBES
1481	ISOLATED SINGLE-WALL CARBON NANOTUBES
1490	SUPERCONDUCTIVITY
1546	MULTI-WALL CARBON NANOTUBES
1562	SINGLE WALL CARBON NANOTUBE BUNDLES
1927	SINGLE-WALLED CARBON NANOTUBES
1974	CARBON NANOTUBE ENCAPSULATED FULLERENES
2467	BORON NITRIDE FULLERENE MATERIALS
2474	CARBON NANOTUBE-METAL-OXIDE NANOCOMPOSITES
2621	DOABLE RESONANT RAMAN SCATTERING
2652	UNUSUALLY HIGH THERMAL CONDUCTIVITY
2675	SINGLE WALL CARBON NANOTUBES
2718	SINGLE-WALLED 4 ANGSTROM CARBON NANOTUBE ARRAYS
2991	CLEAN DOUBLE-WALLED CARBON NANOTUBES SYNTHESIZED
3345	SUB-PPM NO2 GAS DETECTION
3599	SINGLE-WALLED 4 ANGSTROM CARBON NANOTUBES
3623	LOGIC GATES
3629	NANOTUBE ELECTRON WAVEGUIDE
3832	INDIVIDUAL SINGLE-WALLED CARBON NANOTUBES
3834	SINGLE-WALLED CARBON NANOTUBES
3836	AMBIPOLAR NANOTUBE FIELD EFFECT TRANSISTORS
3865	CARBON NANOTUBE FIELD-EFFECT TRANSISTORS USING TOP GATE
3902	CARBON NANOTUBE TRANSISTOR ARRAYS
4137	ATOMISTIC-BASED FINITE DEFORMATION MEMBRANE
4275	POLYPROPYLENE USING ATOMIC FORCE MICROSCOPY
4412	CARBON NANOTUBE COMPOSITES
4636	IN SITU ATOM TRANSFER RADICAL POLYMERIZATION
4667	SINGLE-WALLED CARBON NANOTUBES USING FLUORESCENCE
4673	SINGLE-WALLED CARBON NANOTUBES
4682	HIGHLY SPECIFIC ELECTRONIC BIOSENSORS
4738	CARBON NANOTUBES FUNCTIONALIZED
4746	CARBON NANOTUBE NANOELECTRODE ARRAY
5088	STRUCTURAL MECHANICS APPROACH
5244	CARBON NANOTUBE SCIENCE
5245	SEMICONDUCTING CARBON NANOTUBES
5450	SEMICONDUCTING SINGLE-WALLED CARBON NANOTUBES
5753	CARBON NANOTUBE NANOELECTRODE ARRAYS
5760	SCHOTTKY-BARRIER CARBON NANOTUBE TRANSISTORS

(3) Content analysis of Research Areas

As described above, content analysis was conducted on each RA, upon developing a list of papers in RAs and a map of individual RAs.

Information on RFs and RAs obtained by bibliometric analysis is just bibliographical information (see Table 18). We conducted semantic processing for more accurate analysis by adding more information (metadata) from which the contents of research could be obtained. The process of adding metadata is called "content analysis" in this study.

For content analysis, specialized knowledge is required on a given each RA. Therefore, the analysis was performed at the Science and Technology Foresight Center of NISTEP. Specifically, the analysis was conduced from the following viewpoints, and the names were given to RAs and the RAs were textualized.

1) Names of RAs

Names that accurately describe the contents of RAs are given.

2) Explanation of RAs

As the explanation of a RA, an "Outline of areas" shall be given. This item shall be linked with 3) Interpretation of a map of individual areas, as closely as possible.

(Outline of the areas)

A general explanation is given on RAs and research contents of RFs that constitute a research. The contents of RFs are described in accordance with either the following (1) or (2):

(1) When a group of RFs with similar contents can be presented, the contents shall be itemized.

(2) When it is difficult to present groups, the contents of RFs considered important (those linked with many RFs, or those with a rapidly increasing number of citations, etc.) in the RA shall be itemized.

3) Interpretation of a map of individual areas

Contents of RFs are described in accordance with either the following (1) or (2) of the "map of individual RAs". This item shall be linked with 2) Explanation of RAs, as closely as possible.

(1) When a group of RFs with similar contents in the map of individual RAs can be presented, the relevant group of RFs shall be parenthesized and its contents shall be described in the map of individual RAs.

(2) When it is difficult to present a group of RFs in the map of individual RAs, RFs that are considered important (those linked with many RFs or those with a rapidly increasing number of citations, etc.) shall be illustrated and their contents shall be described in the map of individual RAs.

(4) Soliciting opinions from external experts on content analysis of Research Areas

Since RAs obtained in this study are highly advanced areas, it requires much care for interpretation of the results. Thus, we have solicited opinions from external experts as to whether the interpretations concluded by the Science and Technology Foresight Center of NISTEP were appropriate, whether the map of individual RAs was sufficiently valid from the perspective of experts, and whether new knowledge could be obtained from the individual research map.

Specifically, we asked experts to verify the following four points, by presenting them with a "content analysis of RAs", "map of individual RAs" and "list of papers in RAs".

1) **Names of RAs**
To verify the name of RAs appropriately describes the contents of the RAs.
To suggest a revised name if it is necessary.

2) **Explanation**
To check the explanation of RAs appropriately describes the contents of the RAs.

3) **Map of individual RAs**
To verify whether descriptions of the individual RA map and clustering of RFs appropriately describes the contents of the areas.

4) **Other**
Whether the map of RAs is sufficiently valid, and whether any new knowledge can be obtained from the map of RAs, from the perspective of experts.

Among the opinions from the experts, the Secretariat reflected the comments on the 1) revision of names of RAs, 2) explanation of RAs, and 3) revision of interpretation of the map of RAs in the content analysis on an as needed basis. With respect to the comments for item 4) Other, we will use them as a reference when conducting studies in the future.

(5) Results of content analysis of Research Areas

We obtained the results of the content analysis of RAs as shown in Table 21, by conducting operations of the above mentioned (3) and (4), and based on Table 18 and Figure 20. We then developed a chart to illustrate the contents by RA (See. III Results of contents analysis of research areas)

Figure 21: Example of results of content analysis of RAs (RA ID102)

Name of RA	Basic and applied research on carbon nanotubes	Area ID	102

Statistical information on RA

Number of RFs (Number of those with rapidly increasing citations)	Number of core papers	Number of citations	Number of co-citations (total)	Average year of publication of core papers
50 (15)	245	6014	17077	2001.5

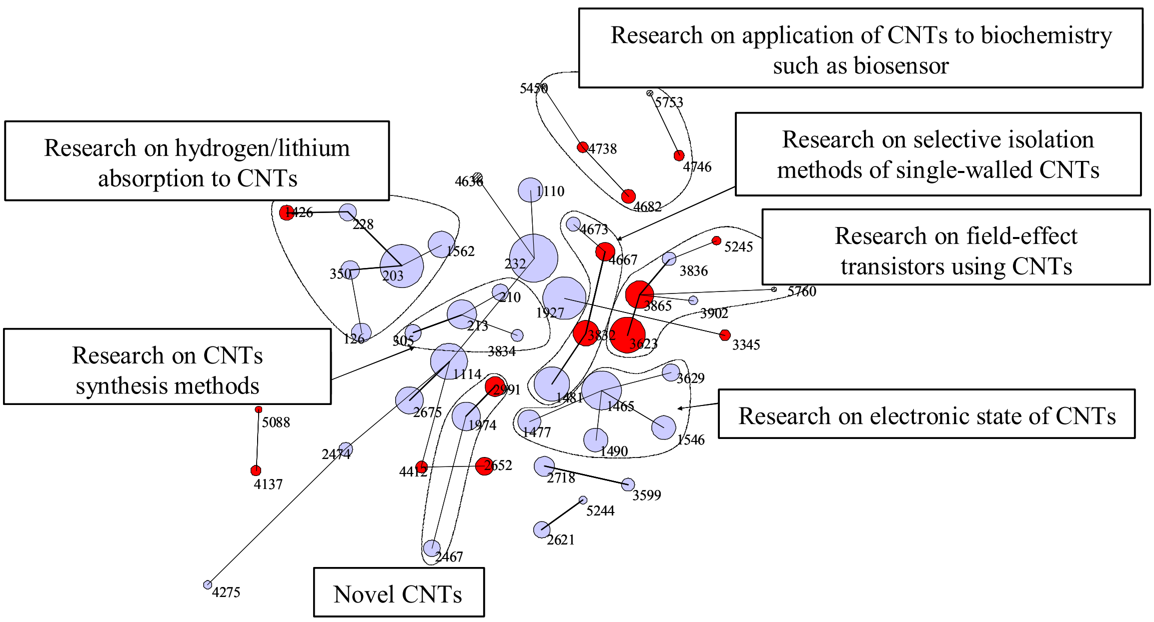
Explanation of RAs

The Carbon Nanotube (hereinafter referred to as CNT) consists of a tube-shaped material made of carbon, and there are monolayer CNT and multilayer CNT. The size of the monolayer CNT is specified to be from 0.4 to several nm in diameter and from several μm to several hundred μm in length, but some are of several mm in length. Due to such physical properties as flexibility in geometric configuration and change in electrical characteristics, it is one of the representative materials in the realm of nanotechnology. This area of research consists of RFs ranging from basic physical properties to application of CNT. Major contents of the RAs are as follows:

- ◆ Research on fabrication method of CNT
- ◆ Research on selective isolation method of monolayer CNT
- ◆ Newly synthesized CNT (2-layerCNT, fullerene-encapsulated CNT, and composites with BN, etc.)
- ◆ Research on electron states and mechanical properties of CNT
- ◆ Research on hydrogen or lithium storage in CNT
- ◆ Research chemical sensors using CNT
- ◆ Research on field effect transistors using CNT
- ◆ Research on CNT modification using polymers and composite materials using CNT
- ◆ Research on application of CNT to biochemistry, such as biosensors

10 years after the discovery by a Japanese research team, basic research to seek out fabrication methods and on electronic states which were quite active at the beginning are now virtually at a standstill in terms of progress in achievements, although a good number of research projects are still being done. Compared to a similar material, fullerene, which attracted attention of researchers in the same period, the characteristic of CNT research is that investigation of its applicability has indeed been extremely active in recent years.

Map of individual RAs



Keywords of RFs

ID	Keyword
126	LITHIUM MULTIWALLED CARBON NANOTUBES
203	SINGLE-WALLED CARBON NANOTUBES
210	FREE-STANDINGSINGLE-WALLED CARBON NANOTUBES
213	SINGLE-WALL CARBON NANOTUBES
228	HYDROGEN ADSORPTION
232	POLYMER-WRAPPED SINGLE-WALLED CARBON NANOTUBES
305	SINGLE-WALLED CARBON NANOTUBES
350	ELECTROCHEMICAL STORAGE
1110	CARBON NANOTUBE MODIFIED GLASSY CARBON ELECTRODES
1114	CARBON NANOTUBE EPOXY COMPOSITES
1426	MECHANICALLY PREPARED NANOSTRUCTURED GRAPHITE
1465	CARBON NANOTUBE INTRAMOLECULAR JUNCTIONS
1477	GROWING Y-JUNCTION CARBON NANOTUBES
1481	ISOLATED SINGLE-WALL CARBON NANOTUBES
1490	SUPERCONDUCTIVITY
1546	MULTI-WALL CARBON NANOTUBES
1562	SINGLE WALL CARBON NANOTUBE BUNDLES
1927	SINGLE-WALLED CARBON NANOTUBES
1974	CARBON NANOTUBE ENCAPSULATED FULLERENES
2467	BORON NITRIDE FULLERENE MATERIALS
2474	CARBON NANOTUBE-METAL-OXIDE NANOCOMPOSITES
2621	DOABLE RESONANT RAMAN SCATTERING
2652	UNUSUALLY HIGH THERMAL CONDUCTIVITY
2675	SINGLE WALL CARBON NANOTUBES
2718	SINGLE-WALLED 4 ANGSTROM CARBON NANOTUBE ARRAYS

ID	Keyword
2991	CLEAN DOUBLE-WALLED CARBON NANOTUBES SYNTHESIZED
3345	SUB-PPM NO2 GAS DETECTION
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5760	SCHOTTKY-BARRIER CARBON NANOTUBE TRANSISTORS

3 133 Research Areas

In Chapter 3, the following three types of Science Maps were developed concerning the 133 RAs obtained by the method introduced in the previous chapter.

1) Individual RA map illustrating what themes each of the 133 RAs addresses;
2) Relation map with traditional disciplines illustrating the relationship between the 133 RAs and traditional disciplines; and
3) Correlation map illustrating the strength of mutual relations among the 133 RAs.

The development and analysis results of these maps are described below.

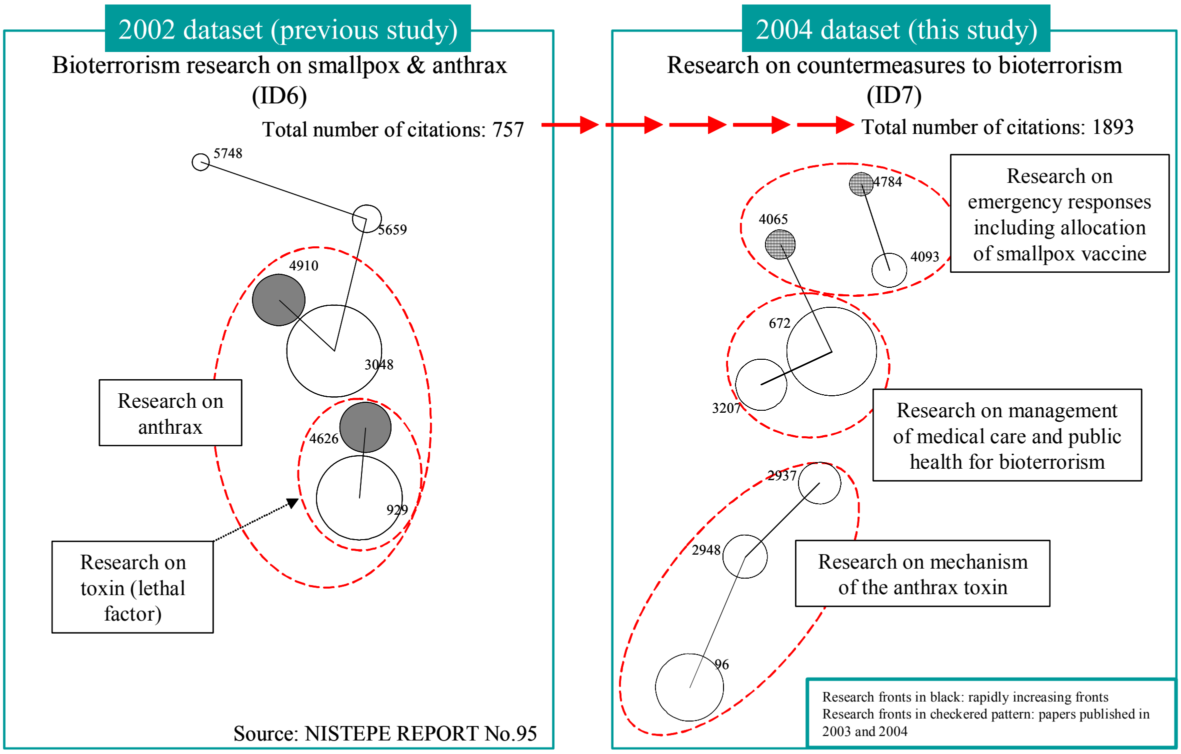
3-1 Analysis of the Individual RA map

(1) Time-series analysis by comparing maps of individual Research Areas

Figure 22 shows the comparison of individual RA map by extracting bio-terrorism-related RAs from the previous and this study. Papers subject to this study are those entered into the database during the period from January 1999 to December 2004. Papers subject to the previous study are those entered into the database during the period from 1997 to 2002, from which it is clear that many papers were already published less than a year after the terrorist attacks of 2001.

The “Bioterrorism research on smallpox & anthrax” of the previous study is composed of 6 RFs and 26 core papers. The “research on countermeasures to bioterrorism” in this study consisted of 8 RFs and 22 core papers. Among them 11 core papers are overlapping ones. The degree of commonality is 0.45. The difference between papers of the previous study and those of this study is that this study includes the papers published in 2003 and 2004. The RFs containing these papers were then analyzed and it was found that the research was conducted on effective use of emergency smallpox vaccination, etc. The research on bioterrorism had previously been on the bacteria, but the developments in recent years have been based on the clinical and social perspectives regarding how to respond to actual emergency situations. The RFs with a rapidly increasing number of citations (rapidly developing RF) were 2 in the previous study but there were none in this study.

Figure 22: Change in RAs related to bioterrorism



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

(2) Analysis of time-series change in citing papers

The following two cases show the result of time-series analysis of changes in citing papers conducted with the aim to explore the qualitative change in individual RAs. Each figure here indicates the average change that occurred in 3 years.

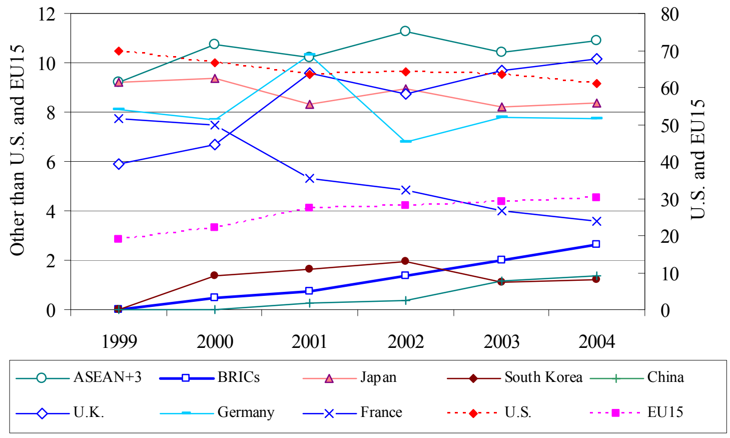
- **RA ID118: Research on multipotency and differentiation mechanism of stem cells in the cardiovascular system, cancer and embryos.**

Figure 23 shows the result of analysis on the multipotency and differentiation mechanism of stem cells in the cardiovascular system, cancer and embryos. The United States had the highest share during the period from 1999 to 2004 (Figure 23 (a)). The share of Japan was about 9% in 1999 but has gradually declined. During this period, the share of the BRICs countries (Brazil, Russia, India and China) has increased, reaching the level of France in 2004.

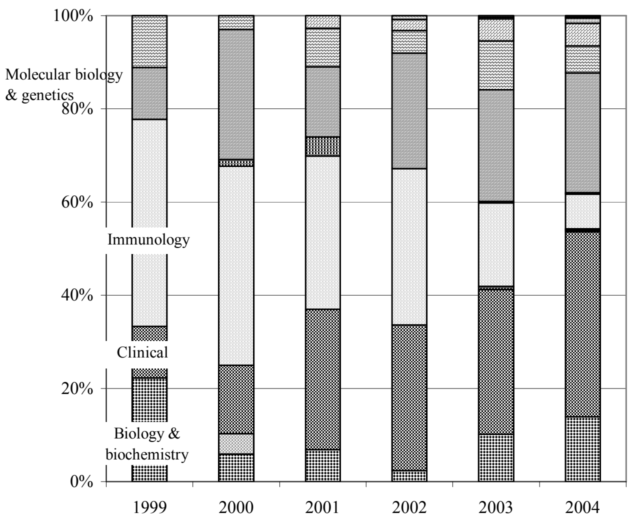
Papers on this research were initially published in immunology journals, and the percentage of publications in clinical medicine increased drastically after 2001 (Figure 23 (b)). When an area comparison is made between core papers and citing papers, it is clear that core papers are mainly in clinical medicine, immunology, and molecule biology/genetics, whereas the areas of citing papers cover a wide range of science fields (Figure 23 (c)). These results suggest that the research on the multipotency and differentiation mechanism of stem cells in the cardiovascular system, cancer and embryos has impacts on other fields.

Figure 23: Analysis result of "Research on multipotency and differentiation mechanism of stem cells in cardiovascular system, cancer, and embryos"

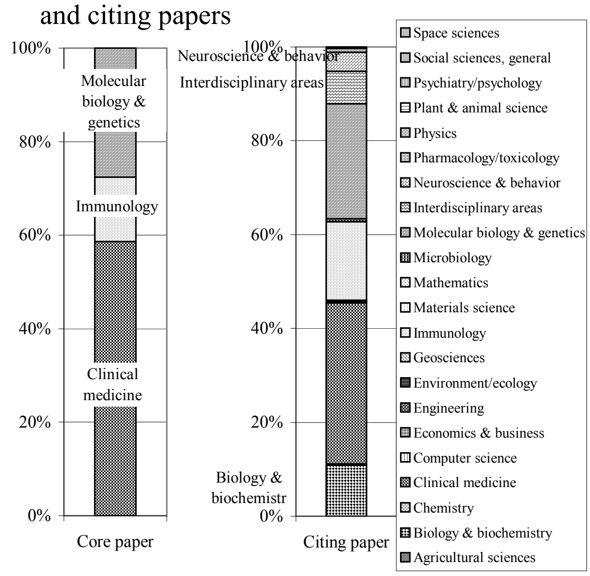
(a) Share in citing papers by country



(b) Share of fields in citing papers by year



(c) Distribution of fields in core papers and citing papers



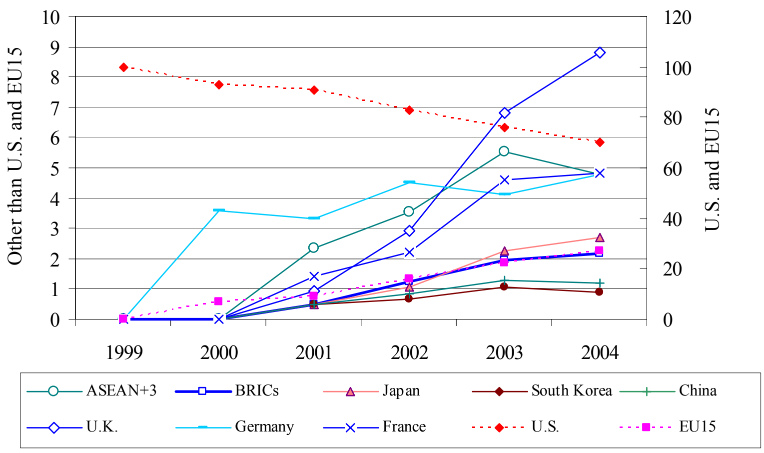
Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

- **RA ID125: Development of statistics method for microarray data analysis**

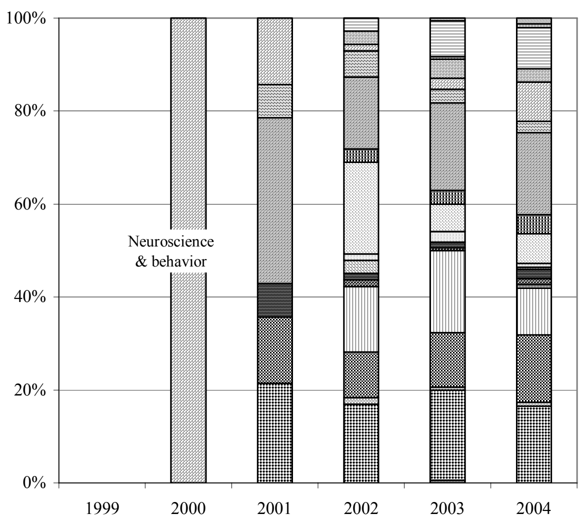
Figure 24 shows the result of analysis of RAs of the development of statistics method for microarray data analysis. The U.S. holds the majority of the shares but U.K., France and Germany are rapidly expanding their shares. On the other hand, Japan has been left far behind these countries. From the chronological change in citing papers, it is observed that citing papers used to be solely in the traditional discipline of neuroscience/behavior but they now consist of many fields (Figure 24(b)). Figure 24(c) is the ratio of core papers and citing papers of 22 fields in six years. Nearly half of the core papers are on mathematics and some are on biology/biochemistry, clinical medicine, and computer science. In the meantime, citing papers include mathematics as well as 19 other fields, showing diversity.

Figure 24: Analysis results of "Development of statistics method for microarray data analysis"

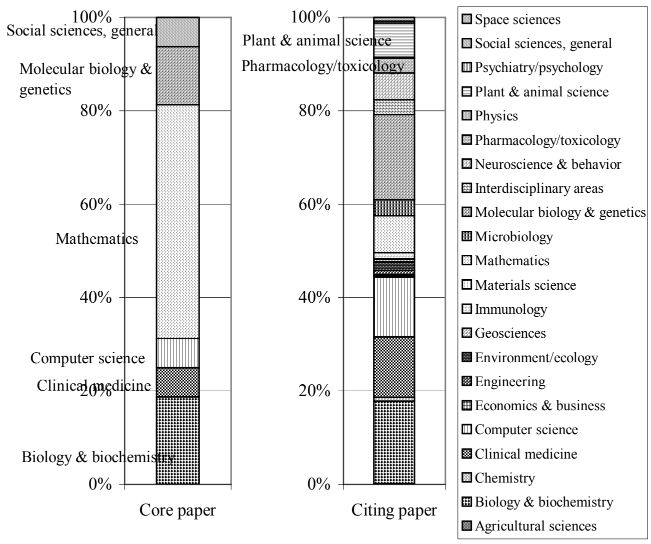
(a) Share in citing papers by countries



(b) Share of fields in citing papers by year



(c) Distribution of fields in core papers and citing papers



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

3-2 Mapping and analysis of relations with traditional disciplines

The relation map with traditional disciplines analyzes how the 133 RAs are related to traditional disciplines in order to understand the trend of science focusing on basic research.

(1) Mapping of relations with traditional disciplines

Next, the map that visually represents the relationship between RAs and traditional disciplines is shown in Figure 25. The numerical figure on the map is the RA ID assigned to each RA in a database and the names of RAs corresponding to the ID numbers are also listed on the map.

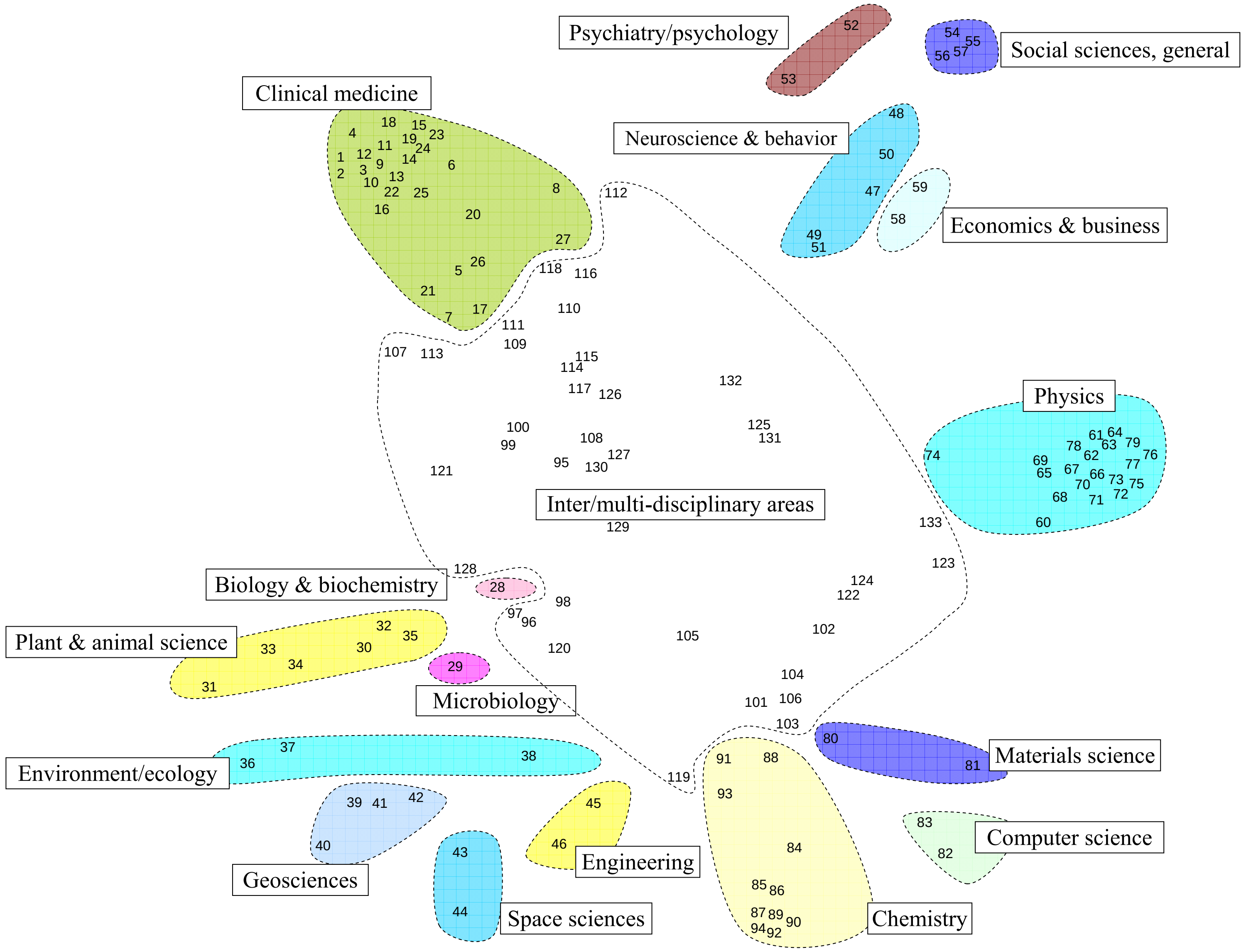
Here, in order to elucidate the relationship between the traditional disciplines and the 133 RAs, we compared the distribution of 22 fields of core papers that constitute RAs. We then made arrangements when entire components are most stable by moving each RA using a gravity model in which an attractive force is generated between RAs with a similar ratio of distribution. Therefore, the RAs with similar distribution of core papers tend to be clustered together. Meanwhile, the relative locations of RAs are what is important, and no specific significance is attached to the location of each dot, whether it is at the left or right, or at the top or bottom. The data on the 22 fields of core papers which constitute RAs are based on Reference 2 (Distribution of core papers which constitute RAs).

RAs outside of the dotted circles drawn at the center of the map of relations with traditional disciplines are the RAs with more than 60% of core papers belonging to any of the 22 fields. On the other hand, the ones inside the circle are interdisciplinary/multidisciplinary areas which do not belong to any specific field. The RAs with a pink shade on the map indicate the areas with more than 15% of Japanese papers: the orange shade with 9%<15%, the yellow one with 4%<9%, and the light blue one with 0%<4%, while the unshaded region has 0% of Japanese papers. The average percentage of Japanese papers in the 133 RAs is 9%.

In Figure 26, the ratio occupied by core papers in each RA was calculated and the RA encircled with a dotted line. For instance, the range within the "~ 40 %" line indicates the areas with less than 40% core papers belonging to any of the 22 fields. The RAs which belong solely to the traditional discipline (the areas outside of "~ 99 %") are physics, chemistry, geosciences, plant/animal science, clinical medicine, and social sciences/general. In addition, most of the RAs have inter/multi-disciplinary character, although in varying degrees.

Figure 25: Relation map with traditional disciplines

- This figure is depicted by a gravity model. In this model, attractive forces work between RAs having a similar field distribution of core papers.
- Roughly 30%, or 39, of the areas have been classified as inter/multi-disciplinary areas because their core papers belong to no specific science field. Many of them are new RAs, with a recent average publication year. Also, Japan has been performing well in these areas.
- Japan's presence is relatively large in the RAs whose core papers mainly belong to physics, chemistry, and plant and animal sciences.



Field	ID	Name of research areas
Clinical medicine	1	Research on medical examination of colorectal cancer
	2	Clinical treatment of severe sepsis and septic shock
	3	Cardiac resynchronization therapy for intractable heart failure
	4	Diversity of arrhythmia-related genes
	5	Research on SARS and avian influenza
	6	Research on allergy therapy
	7	Research on countermeasures to bioterrorism
	8	Therapy of multiple sclerosis
	9	Development of imaging techniques for cardiovascular system
	10	Cancer therapy with angiogenesis inhibitor
	11	Research on multiple myeloma therapy
	12	Research on diseases for which Rituxan is effective
	13	Research on osteoclastic mechanism
	14	Research on cancer therapy
	15	Clinical trial of therapeutic agent for cardiovascular disease
	16	Research on molecular pathogenesis and leukemia therapy
	17	Functional analysis of peroxisome proliferator-activated receptor
	18	Autoimmune disease
	19	Prevention of post-coronary angioplasty restenosis with drug-eluting stents
	20	Gene therapy targeting hematopoietic stem cells and its side effects
	21	Molecular mechanism of adipocytokines and the onset of metabolic syndrome
	22	Research on breast cancer therapy
	23	Research on venous thromboembolism therapy
	24	Clinical research on COX-2 inhibitor as anti-inflammatory drug
	25	Effects of COX-2 inhibitor against cancer
	26	Signal transducing molecules associated with lifestyle-related diseases
	27	Stem cell therapy on nervous, hematopoietic, and cardiovascular system

Field	ID	Name of research areas
Biology & biochemistry	28	Structures and functions of G-protein-coupled receptor
Microbiology	29	Utility of agrobacterium-mediated genetic engineering and the genomic character
Plant & animal science	30	Plant genome research
	31	Functional analysis on abscisic acid, a plant hormone
	32	Dynamics and regulation of cytoskeleton
	33	Analysis of mechanism of regulation of plant growth
	34	Stress response in plants
	35	Study of biological clock
Environment/ecology	36	Environment pollution and risk of persistent organic halide pollutants
	37	Study on biodiversity in plants
	38	Aquatic pollution by toxic chemical compounds
Geosciences	39	Carbon cycle in south Pacific Ocean
	40	North Atlantic Oscillation and climate change
	41	Research on paleoclimate
	42	Effects of aerosol and air pollutant on climate and atmospheric circulation model
Space sciences	43	Mars exploration
	44	Large-scale structure of the universe
Engineering	45	Research on meshless finite element method
	46	Research on spectroanalysis

Field	ID	Name of research areas
Inter/multi-disciplinary areas	95	Signal conduction of the lysophospholipids receptors
	96	Water and iron transport mechanism in organism
	97	Molecular phylogenetic analysis
	98	Research on infection mechanism of HIV
	99	Signal transduction in metabolic pathway
	100	Hypoxia-inducible factor and tumorigenesis
	101	Nanocomposites consisting of inorganic nano materials and organic polymers
	102	Basic and applied research on carbon nanotubes
	103	High-efficiency dye-sensitised solar cell
	104	Synthesis of nano-structures form microstructure with microparticles and polymers
	105	Research on proteome
	106	Development of nanostructure and its application to molecular devices
	107	Genome analyses of Helicobacter pylori and Mycobacterium tuberculosis

Field	ID	Name of research areas
Inter/multi-disciplinary areas	108	Research on molecular mechanism of sex hormone receptors against cancer
	109	Research on prion diseases
	110	Research on infection mechanism and therapy of HCV and HIV
	111	Cancer therapy with histone deacetylase inhibitor
	112	Intake of soy- and plant-derived estrogen/isoflavone and its effects on age-associated diseases
	113	Ghrelin; its mechanism of action
	114	Molecular mechanism of PI3/Akt signal transduction pathway
	115	Genetic diagnosis and therapy of Crohn's disease
	116	Research on immune system
	117	Research on molecular mechanism in apoptosis
	118	Research on multipotency and differentiation mechanism of stem cells in cardiovascular system, cancer, and embryos
	119	Development and application of proton-exchange membrane fuel cells
	120	Research on global carbon cycle

Field	ID	Name of research areas
Inter/multi-disciplinary areas	121	Signal transduction in immune system
	122	Research on high performance organic thin film transistor
	123	High-dielectric gate insulating technology for semiconductor integrated circuits
	124	Research on high efficiency organic LED
	125	Development of statistics method for microarray data analysis
	126	Function study of mammalian TOR
	127	Molecular mechanism of DNA damage and repair
	128	Nucleocytoplasmic traffic and cell function
	129	Mechanism of control of life-span
	130	Research on epigenetic transcriptional regulation
	131	TRP channel and cellular senses
	132	Research on Alzheimer's disease and Parkinson's disease
	133	Research on nitride compound semiconductor

Field	ID	Name of research areas
Neuroscience & behavior	47	Brain function imaging of cognitive psychological phenomena
	48	Glutamate receptors in plasticity brain
	49	Research on neurodegenerative mechanism in Huntington's disease based on transgenic mice
	50	Visual stimulation and oscillatory brain activities
	51	Mechanism of molecules involved in formation of brain
Psychiatry/ psychology	52	Clinical trials for phobias, mood disorders and anxiety disorders
	53	Early diagnostics and therapy of schizophrenia
Social sciences, general	54	Law and behavioral science
	55	Political power and human rights
	56	Research on intellectual property right problems
	57	Study on local economy and regional integration
Economics & business	58	Research on corporate governance
	59	Research on venture capital

Field	ID	Name of research areas
Physics	60	Stability and vitrification of supercooled liquid
	61	Physical attributes and material process of MgB2
	62	Quantum computing devices
	63	Noncommutative field theory and super string theory
	64	Baryon consisting of five quarks
	65	Photonic crystal and devices
	66	Spintronics
	67	Physics in high-temperature superconductor junctions
	68	Basic and applied research on ultra-short-pulse laser
	69	Relativistic astronomy and gravity waves
	70	Quantum electronics and its application to quantum information processing
	71	Superconductors with anisotropic gaps
	72	Quantum chromodynamics
	73	Bi-based high-temperature superconductors
	74	Network analysis and its application to genome, social-network, and infection transmission
	75	Super string theory and spatiotemporal physics
	76	Quantum gravity
	77	Neutrino oscillation and creation of material universe
	78	Cosmic microwave background fluctuation and inflationary cosmology
	79	Supersymmetry and CP violation
Materials science	80	Formation of nanostructures based on block copolymers
	81	Research on plastic deformation in nano-crystals
Computer science	82	Application of cryptographic technologies to digital information distribution
	83	Research on modulation schemes for ultra-wideband communications
Chemistry	84	Catalytic activity of gold clusters
	85	Dendrimer research
	86	High performance catalysis for olefin polymerization
	87	Research on living free-radical polymerization
	88	Metal-organic hybrid porous materials
	89	Catalytic asymmetric synthesis
	90	Organic synthesis and its application to a sustainable society
	91	Chemical-/bio-system with microchips
	92	Metal-organic complex and its catalytic activity
	93	Drug discovery research
	94	Detection of negative ions by chemical methods

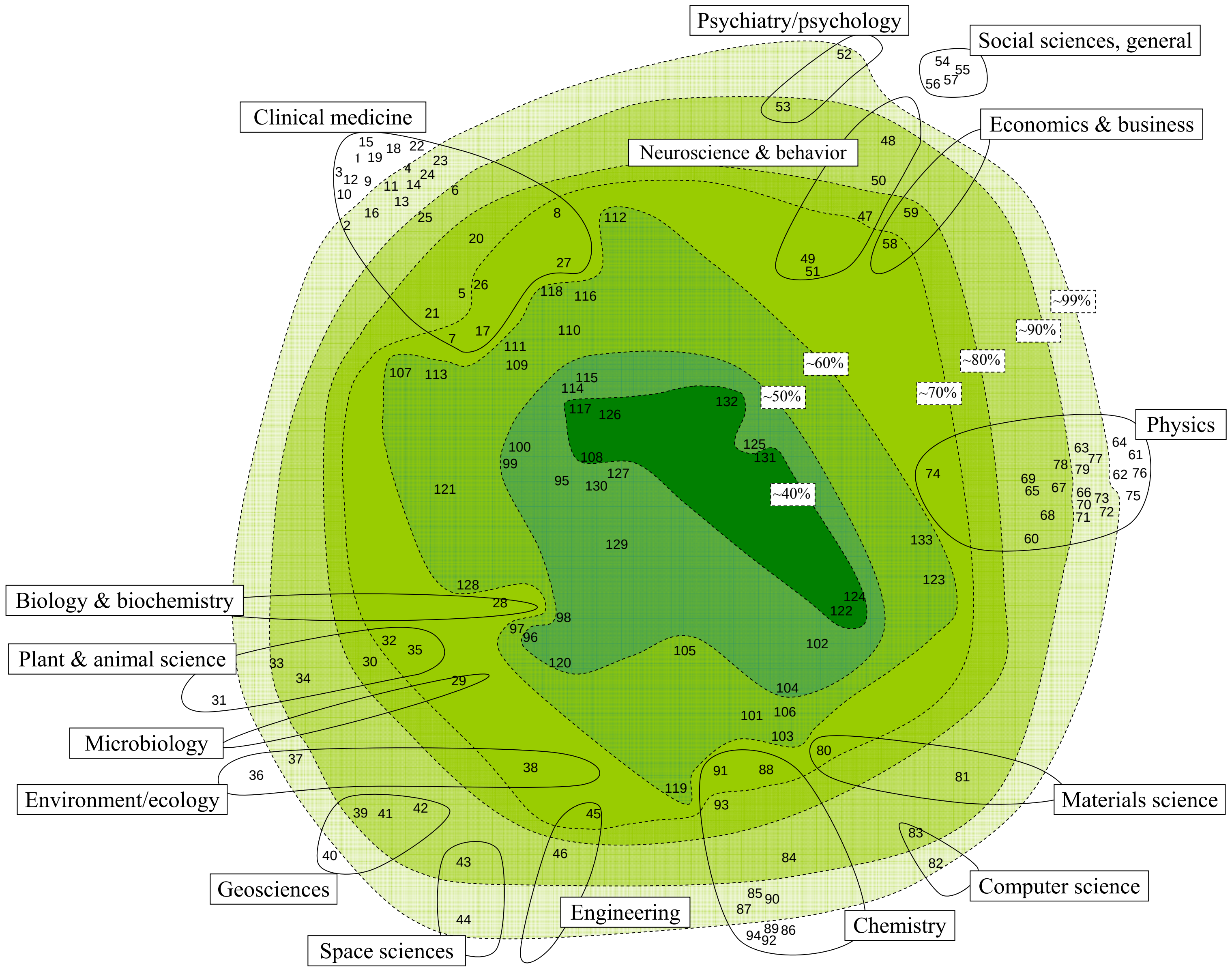
The ratio of Japanese papers in core papers

- 15% ~
- 9% ~ 15%
- 4% ~ 9%
- 0% ~ 4%
- 0%

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Figure 26: Relation map with traditional disciplines (degree of integration)

- This figure is depicted by a gravity model. In this model, attractive forces work between RAs having a similar field distribution of core papers.
- By calculating an occupancy rate (by field) of RAs in core papers, the RAs are circled with dotted lines. For instance, the area inside the ~40% line shows that there are no fields with an occupancy rate exceeding 40%.
- RAs in which more than 90% of the core papers are confined to specific traditional disciplines are less than one third of all the areas, and thus many RAs are composed of integrated traditional disciplines.



Field	ID	Name of research areas
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	4	Diversity of arrhythmia-related genes
	5	Research on SARS and avian influenza
	6	Research on allergy therapy
	7	Research on countermeasures to bioterrorism
	8	Therapy of multiple sclerosis
	9	Development of imaging techniques for cardiovascular system
	10	Cancer therapy with angiogenesis inhibitor
	11	Research on multiple myeloma therapy
	12	Research on diseases for which Rituxan is effective
	13	Research on osteoclastic mechanism
	14	Research on cancer therapy
	15	Clinical trial of therapeutic agent for cardiovascular disease
	16	Research on molecular pathogenesis and leukemia therapy
	17	Functional analysis of peroxisome proliferator-activated receptor
	18	Autoimmune disease
	19	Prevention of post-coronary angioplasty restenosis with drug-eluting stents
	20	Gene therapy targeting hematopoietic stem cells and its side effects
	21	Molecular mechanism of adipocytokines and the onset of metabolic syndrome
	22	Research on breast cancer therapy
	23	Research on venous thromboembolism therapy
	24	Clinical research on COX-2 inhibitor as anti-inflammatory drug
	25	Effects of COX-2 inhibitor against cancer
	26	Signal transducing molecules associated with lifestyle-related diseases
	27	Stem cell therapy on nervous, hematopoietic, and cardiovascular system

Field	ID	Name of research areas
Biology & biochemistry	28	Structures and functions of G-protein-coupled receptor
Microbiology	29	Utility of agrobacterium-mediated genetic engineering and the genomic character
Plant & animal science	30	Plant genome research
	31	Functional analysis on abscisic acid, a plant hormone
	32	Dynamics and regulation of cytoskeleton
	33	Analysis of mechanism of regulation of plant growth
	34	Stress response in plants
	35	Study of biological clock
Environment/ ecology	36	Environment pollution and risk of persistent organic halide pollutants
	37	Study on biodiversity in plants
	38	Aquatic pollution by toxic chemical compounds
Geosciences	39	Carbon cycle in south Pacific Ocean
	40	North Atlantic Oscillation and climate change
	41	Research on paleoclimate
	42	Effects of aerosol and air pollutant on climate and atmospheric circulation model
Space sciences	43	Mars exploration
	44	Large-scale structure of the universe
Engineering	45	Research on meshless finite element method
	46	Research on spectroanalysis

Field	ID	Name of research areas
Neuroscience & behavior	47	Brain function imaging of cognitive psychological phenomena
	48	Glutamate receptors in plasticity brain
	49	Research on neurodegenerative mechanism in Huntington's disease based on transgenic mice
	50	Visual stimulation and oscillatory brain activities
	51	Mechanism of molecules involved in formation of brain
Psychiatry/ psychology	52	Clinical trials for phobias, mood disorders and anxiety disorders
	53	Early diagnostics and therapy of schizophrenia
Social sciences, general	54	Law and behavioral science
	55	Political power and human rights
	56	Research on intellectual property right problems
	57	Study on local economy and regional integration
Economics & business	58	Research on corporate governance
	59	Research on venture capital

Field	ID	Name of research areas
Physics	60	Stability and vitrification of supercooled liquid
	61	Physical attributes and material process of MgB2
	62	Quantum computing devices
	63	Noncommutative field theory and super string theory
	64	Baryon consisting of five quarks
	65	Photonic crystal and devices
	66	Spintronics
	67	Physics in high-temperature superconductor junctions
	68	Basic and applied research on ultra-short-pulse laser
	69	Relativistic astronomy and gravity waves
	70	Quantum electronics and its application to quantum information processing
	71	Superconductors with anisotropic gaps
	72	Quantum chromodynamics
	73	Bi-based high-temperature superconductors
	74	Network analysis and its application to genome, social-network, and infection transmission
	75	Super string theory and spatiotemporal physics
	76	Quantum gravity
	77	Neutrino oscillation and creation of material universe
	78	Cosmic microwave background fluctuation and inflationary cosmology
	79	Supersymmetry and CP violation
Materials science	80	Formation of nanostructures based on block copolymers
	81	Research on plastic deformation in nano-crystals
Computer science	82	Application of cryptographic technologies to digital information distribution
	83	Research on modulation schemes for ultra-wideband communications
Chemistry	84	Catalytic activity of gold clusters
	85	Dendrimer research
	86	High performance catalysis for olefin polymerization
	87	Research on living free-radical polymerization
	88	Metal-organic hybrid porous materials
	89	Catalytic asymmetric synthesis
	90	Organic synthesis and its application to a sustainable society
	91	Chemical-/bio-system with microchips
	92	Metal-organic complex and its catalytic activity
	93	Drug discovery research
	94	Detection of negative ions by chemical methods

Field	ID	Name of research areas
Inter/multi-disciplinary areas	95	Signal conduction of the lysophospholipids receptors
	96	Water and iron transport mechanism in organism
	97	Molecular phylogenetic analysis
	98	Research on infection mechanism of HIV
	99	Signal transduction in metabolic pathway
	100	Hypoxia-inducible factor and tumorigenesis
	101	Nanocomposites consisting of inorganic nano materials and organic polymers
	102	Basic and applied research on carbon nanotubes
	103	High-efficiency dye-sensitised solar cell
	104	Synthesis of nano-structures form microstructure with microparticles and polymers
	105	Research on proteome
	106	Development of nanostructure and its application to molecular devices
	107	Genome analyses of Helicobacter pylori and Mycobacterium tuberculosis

Field	ID	Name of research areas
Inter/multi-disciplinary areas	108	Research on molecular mechanism of sex hormone receptors against cancer
	109	Research on prion diseases
	110	Research on infection mechanism and therapy of HCV and HIV
	111	Cancer therapy with histone deacetylase inhibitor
	112	Intake of soy- and plant-derived estrogen/isoflavone and its effects on age-associated diseases
	113	Ghrelin; its mechanism of action
	114	Molecular mechanism of PI3/Akt signal transduction pathway
	115	Genetic diagnosis and therapy of Crohn's disease
	116	Research on immune system
	117	Research on molecular mechanism in apoptosis
	118	Research on multipotency and differentiation mechanism of stem cells in cardiovascular system, cancer, and embryos
	119	Development and application of proton-exchange membrane fuel cells
	120	Research on global carbon cycle

Field	ID	Name of research areas
Inter/multi-disciplinary areas	121	Signal transduction in immune system
	122	Research on high performance organic thin film transistor
	123	High-dielectric gate insulating technology for semiconductor integrated circuits
	124	Research on high efficiency organic LED
	125	Development of statistics method for microarray data analysis
	126	Function study of mammalian TOR
	127	Molecular mechanism of DNA damage and repair
	128	Nucleocytoplasmic traffic and cell function
	129	Mechanism of control of life-span
	130	Research on epigenetic transcriptional regulation
	131	TRP channel and cellular senses
	132	Research on Alzheimer's disease and Parkinson's disease
	133	Research on nitride compound semiconductor

The ratio of Japanese papers in core papers

- 15% ~
- 9% ~ 15%
- 4% ~ 9%
- 0% ~ 4%
- 0%

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

(2)Relationship between traditional disciplines and the 133 Research Areas

The results of categorization of the 133 RAs by field are shown in Figures 27, 28, and 29. Here, the distribution of the 22 fields of core papers which constitute RAs was first analyzed; then, the ones with more than 60% of core papers were determined as the fields of RAs. Any area with a percentage less than 60% was considered as one with no bias toward a specific field, and was placed under an interdisciplinary/multidisciplinary category.

The field distribution of 133 RAs is described below. There are 42 RAs related to Life science, such as clinical medicine and plant/animal science, among which more than half, or 27 RAs, are in the area of clinical medicine. Thirty-seven RAs are in chemistry, physics, engineering and materials science, and there are 7 RAs in geosciences.

Although small in number, cosmology, and social sciences/general are also included. Furthermore, approximately 30% of the 133 areas or 39 RAs are in inter/multi-disciplinary areas.

Table 27: Life science-related RAs

Field	Name of research area	Field	Name of research area
Clinical medicine	Research on medical examination of colorectal cancer	Clinical medicine	Research on breast cancer therapy
	Clinical treatment of severe sepsis and septic shock		Research on venous thromboembolism therapy
	Cardiac resynchronization therapy for intractable heart failure		Clinical research on COX-2 inhibitor as anti-inflammatory drug
	Diversity of arrhythmia-related genes		Effects of COX-2 inhibitor against cancer
	Research on SARS and avian influenza		Signal transducing molecules associated with lifestyle-related diseases
	Research on allergy therapy		Stem cell therapy on nervous, hematopoietic, and cardiovascular system
	Research on countermeasures to bioterrorism	Neuroscience & behavior	Brain function imaging of cognitive psychological phenomena
	Therapy of multiple sclerosis		Glutamate receptors in plasticity brain
	Development of imaging techniques for cardiovascular system		Research on neurodegenerative mechanism in Huntington's disease based on transgenic mice
	Cancer therapy with angiogenesis inhibitor		Visual stimulation and oscillatory brain activities
	Research on multiple myeloma therapy		Mechanism of molecules involved in formation of
	Research on diseases for which Rituxan is effective	Psychiatry/ psychology	Clinical trials for phobias, mood disorders and anxiety disorders
	Research on osteoclastic mechanism		Early diagnostics and therapy of schizophrenia
	Research on cancer therapy	Biology & biochemistry	Structures and functions of G-protein-coupled receptor
	Clinical trial of therapeutic agent for cardiovascular disease	Microbiology	Utility of agrobacterium-mediated genetic engineering and the genomic character
	Research on molecular pathogenesis and leukemia therapy	Plant & animal science	Plant genome research
	Functional analysis of peroxisome proliferator-activated receptor		Functional analysis on abscisic acid, a plant hormone
	Autoimmune disease		Dynamics and regulation of cytoskeleton
	Prevention of post-coronary angioplasty restenosis with drug-eluting stents		Analysis of mechanism of regulation of plant growth
	Gene therapy targeting hematopoietic stem cells and its side effects		Stress response in plants
	Molecular mechanism of adipocytokines and the onset of metabolic syndrome		Study of biological clock

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

Table 28: RAs related to chemistry, physics, engineering, materials science, environment/ecology, and geosciences

Field	Name of research area	Field	Name of research area
Environment/ ecology	Environment pollution and risk of persistent organic halide pollutants	Physics	Super string theory and spatiotemporal physics
	Study on biodiversity in plants		Quantum gravity
	Aquatic pollution by toxic chemical compounds		Neutrino oscillation and creation of material universe
Geosciences	Carbon cycle in south Pacific Ocean		Cosmic microwave background fluctuation and inflationary cosmology
	North Atlantic Oscillation and climate change		Supersymmetry and CP violation
	Research on paleoclimate	Materials science	Formation of nanostructures based on block
	Effects of aerosol and air pollutant on climate and atmospheric circulation model		Research on plastic deformation in nano-crystals
Space sciences	Mars exploration	Computer science	Application of cryptographic technologies to digital information distribution
	Large-scale structure of the universe		Research on modulation schemes for ultra-wideband communications
Engineering	Research on meshless finite element method	Chemistry	Catalytic activity of gold clusters
	Research on spectroanalysis		Dendrimer research
Physics	Stability and vitrification of supercooled liquid		High performance catalysis for olefin polymerization
	Physical attributes and material process of MgB2		Research on living free-radical polymerization
	Quantum computing devices		Metal-organic hybrid porous materials
	Noncommutative field theory and super string theory		Catalytic asymmetric synthesis
	Baryon consisting of five quarks		Organic synthesis and its application to a sustainable society
	Photonic crystal and devices		Chemical-/bio-system with microchips
	Spintronics		Metal-organic complex and its catalytic activity
	Physics in high-temperature superconductor junctions		Drug discovery research
	Basic and applied research on ultra-short-pulse laser		Detection of negative ions by chemical methods
	Relativistic astronomy and gravity waves	Social sciences, general	Law and behavioral science
	Quantum electronics and its application to quantum information processing		Political power and human rights
	Superconductors with anisotropic gaps		Research on intellectual property right problems
	Quantum chromodynamics		Study on local economy and regional integration
	Bi-based high-temperature superconductors	Economics & business	Research on corporate governance
	Network analysis and its application to genome, social-network, and infection transmission		Research on venture capital

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

Table 29: Inter-/multi-disciplinary RAs

Field	Name of research area	Field	Name of research area
Inter/multi-disciplinary areas	Signal conduction of the lysophospholipids receptors	Inter/multi-disciplinary areas	Genetic diagnosis and therapy of Crohn's disease
	Water and iron transport mechanism in organism		Research on immune system
	Molecular phylogenetic analysis		Research on molecular mechanism in apoptosis
	Research on infection mechanism of HIV		Research on multipotency and differentiation mechanism of stem cells in cardiovascular system, cancer, and embryos
	Signal transduction in metabolic pathway		Development and application of proton-exchange membrane fuel cells
	Hypoxia-inducible factor and tumorigenesis		Research on global carbon cycle
	Nanocomposites consisting of inorganic nano materials and organic polymers		Signal transduction in immune system
	Basic and applied research on carbon nanotubes		Research on high performance organic thin film transistor
	High-efficiency dye-sensitised solar cell		High-dielectric gate insulating technology for semiconductor integrated circuits
	Synthesis of nano-structures form microstructure with microparticles and polymers		Research on high efficiency organic LED
	Research on proteome		Development of statistics method for microarray data analysis
	Development of nanostructure and its application to molecular devices		Function study of mammalian TOR
	Genome analyses of Helicobacter pylori and Mycobacterium tuberculosis		Molecular mechanism of DNA damage and repair
	Research on molecular mechanism of sex hormone receptors against cancer		Nucleocytoplasmic traffic and cell function
	Research on prion diseases		Mechanism of control of life-span
	Research on infection mechanism and therapy of HCV and HIV		Research on epigenetic transcriptional regulation
	Cancer therapy with histone deacetylase inhibitor		TRP channel and cellular senses
	Intake of soy- and plant-derived estrogen/isoflavone and its effects on age-associated diseases		Research on Alzheimer's disease and Parkinson's disease
	Ghrelin; its mechanism of action		Research on nitride compound semiconductor
	Molecular mechanism of PI3/Akt signal transduction pathway		

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

Reflecting the characteristics of the database, half of the 133 RAs are associated with Life science and healthcare. No RAs have been established belonging to the fields of agricultural science, immunology, molecular biology/genetics, pharmacology/toxicology, and mathematics. This may be attributed to the fact that RAs with a certain number of core papers were selected, and the RAs, such as mathematics, with a small number of core papers were left out. In such cases, the role of mathematics can be measured through the distribution of core papers on mathematics in the selected RAs. As a result of the analysis, it can be concluded that traditional disciplinesuch as agricultural science, immunology, molecular biology/genetics, pharmacology/toxicology and mathematics, have foundational elements and are components of RAs since many of the papers on the traditional disciplines are included in core papers of the 133 RAs.

(3)Characteristics of core papers in 133 Research Areas

Figure 30 shows the recent top 15 RAs obtained from the calculation of the average year of publication of core papers which constitute RAs. Interestingly enough, about half of the RAs are in the inter/multi-disciplinary areas.

Table 30: Top 15 RAs with recent average publication year of core papers

Name of research areas	Field	Number of core papers	Average year of publication of core papers
Baryon consisting of five quarks	Physics	39	2003.7
Research on SARS and avian influenza	Clinical medicine	83	2003.6
Relativistic astronomy and gravity waves	Physics	29	2003.0
Super string theory and spatiotemporal physics	Physics	71	2002.6
Environment pollution and risk of persistent organic halide pollutants	Environment/ecology	28	2002.6
Research on high performance organic thin film transistor	Inter/multi-disciplinary areas	59	2002.5
Prevention of post-coronary angioplasty restenosis with drug-eluting stents	Clinical medicine	50	2002.3
Function study of mammalian TOR	Inter/multi-disciplinary areas	33	2002.2
Signal transduction in immune system	Inter/multi-disciplinary areas	30	2002.2
Nucleocytoplasmic traffic and cell function	Inter/multi-disciplinary areas	19	2002.1
Research on multipotency and differentiation mechanism of stem cells in cardiovascular system, cancer, and embryos	Inter/multi-disciplinary areas	29	2002.1
Catalytic activity of gold clusters	Chemistry	32	2002.1
Genetic diagnosis and therapy of Crohn's disease	Inter/multi-disciplinary areas	44	2002.0
Quantum gravity	Physics	41	2002.0
Research on epigenetic transcriptional regulation	Inter/multi-disciplinary areas	268	2002.0

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

(4) Characteristics of Research Fronts in 133 Research Areas

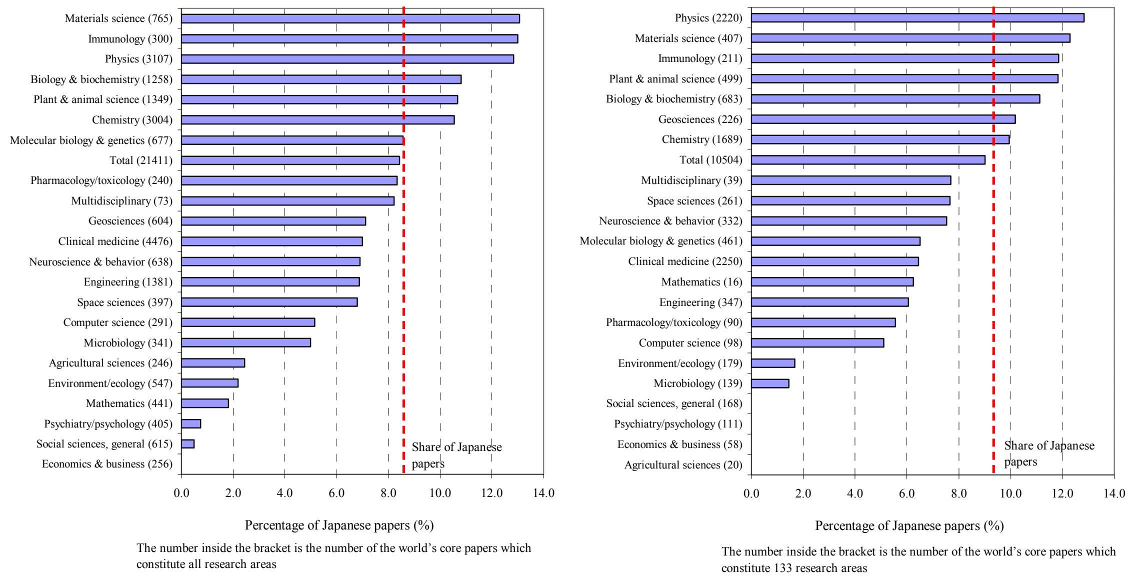
In the analysis of 133 RAs, there are no explicit fields to which agricultural science, immunology, molecular biology/genetics, pharmacology/toxicology and mathematics belong. Thus, with an aim to examine the presence of Japan in these fields we analyzed the percentage of Japanese papers by field: specifically, core papers (about 20,000) which are the components of RFs and core papers (about 10,000) which are the components of the 133 RAs (Figure 31). From Figure 31(a), it is clear that the number of core papers which are the components of the overall RFs is not 0 except for the field of economics/business. The strength of Japan is found in the fields in materials science, immunology and physics. Figure 31(b) indicates that Japan has a strong presence in physics, materials science and immunology in terms of the core papers which are the components of the 133 RAs.

A notable point here is that the percentage of Japanese papers in immunology is large. Since no RA belonging to this field was established, these papers must be included in the inter/multi-disciplinary areas.

In mathematics and geosciences, the percentage of Japanese papers in the 133 RAs is larger than those in the overall RFs. On the other hand, in agricultural science, molecular biology/genetics, pharmacology/toxicology, and microbiology, the percentage of Japanese papers in the 133 RAs is lower than those in RFs.

Figure 31: Percentage of Japanese papers for all core papers

(a) All RFs (b) 133 RAs

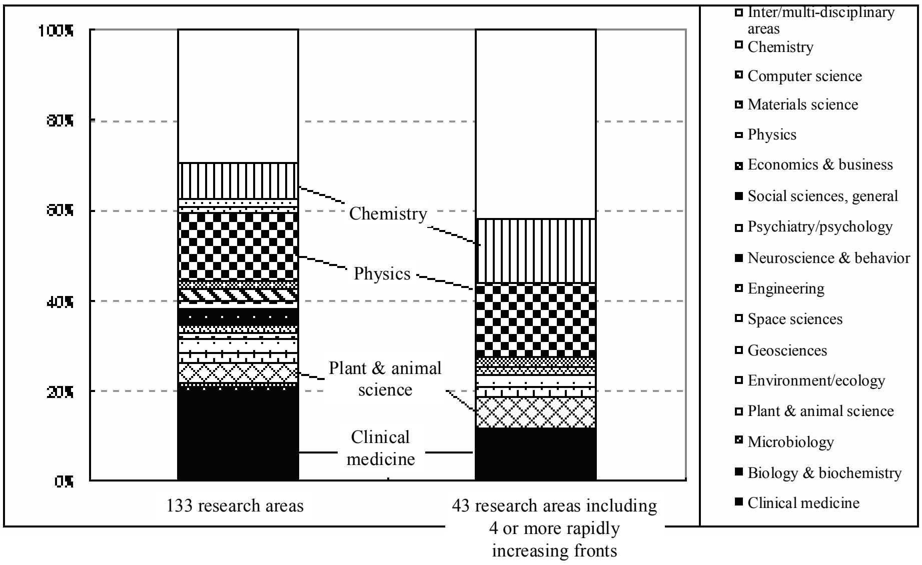


Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

(5) Relationship between 133 Research Areas and rapidly-developing Research Areas

Among the 133 RAs, 42 RAs contain 4 RFs with rapidly increasing number of citations (rapidly developing RFs) and 41RAs contain 2 or 3 rapidly developing RFs. About 60% of RAs can be classified into rapidly-developing RAs, the category established in the previous study. In Figure 32, we made a comparison between the 133 RAs and 43 RAs which contain more than 4 rapidly developing RFs. It is found that about 40% of RAs which contain more than 4 rapidly developing RFs are in the inter/multi-disciplinary areas.

Figure 32: Field comparison between 133 RAs and the RAs with four or more rapidly increasing fronts



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

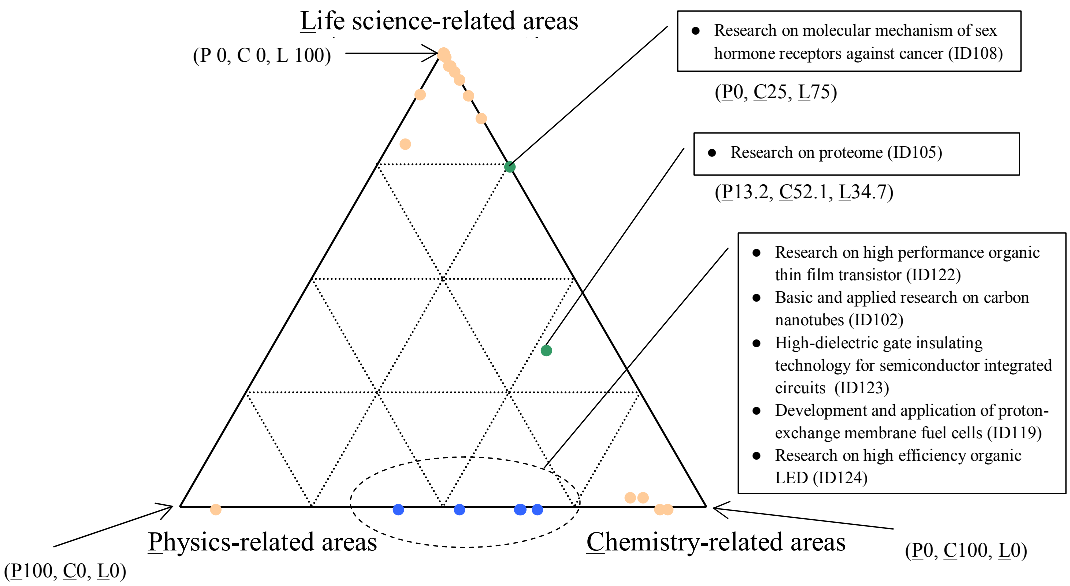
(6) Characteristics of inter/multi-disciplinary areas

With the purpose to examine the characteristics of inter/multi-disciplinary areas, the percentage of fields of core papers in 39 RAs categorized in inter/multi-disciplinary areas (as shown in Figure 29) are plotted on three axes: namely *Life science*-related areas, physics-related areas, and chemistry-related areas (as shown in Figure 33). Among the 22 fields of ESI, 10 fields[1] such as clinical medicine, plant and animal science, and biochemistry are classified as Life science-related areas; physics, mathematics and engineering as physics-related areas; and chemistry and materials science as chemistry-related areas.

First, inter/multi-disciplinary areas of physics-related areas and chemistry-related areas include the following: “Research on high performance organic thin-film transistors (ID122)”; “Basic and applied research on carbon nanotubes (ID 102)”; “High-dielectric gate insulating technology for semiconductor integrated circuits (ID 123)”; “Development and application of proton-exchange membrane fuel cells (ID 119)”; and “Research on high-efficiency organic LED (ID 124)”.

“Protenome (ID 105)” is classified into inter/multi-disciplinary areas of physics- related areas, chemistry-related areas and Life science-related areas.

Figure 33: Three axes plot of the RAs related to Life science, physics and chemistry

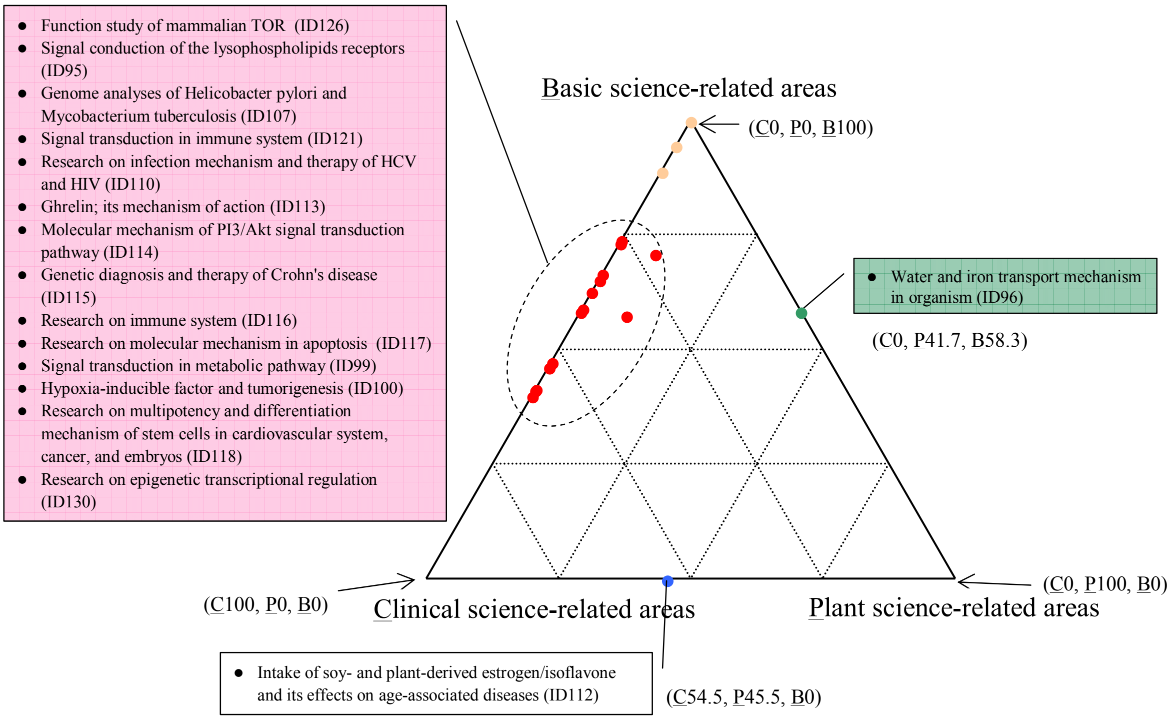


Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

Life science-related areas are further plotted on three axes in Figure 34: basic science-related, clinical science-related, and plant science-related areas. Many RAs are plotted on basic-related and clinical-related areas; thus it is assumed that Life science-related inter/multi-disciplinary areas have entered the stage of translational research, envisioning the application to practical medicine, from the stage of laboratory experiments. Also, RAs on phenomena observed in various living matter were plotted between basic science-related and plant science-related areas such as “Water and ionic transport mechanisms in organisms (ID 96)”. The “Intake of soy- and plant-derived estrogen/isoflavone and its effects on age-associated diseases (ID 112)” was plotted between plant science-related and clinical science-related areas.

[1] 10 fields are classified as life science related areas: namely, agricultural science, biology/biochemistry, clinical medicine, immunology, microbiology, molecular biology, genetics, neuroscience/behavior, pharmacology/toxicology, and psychiatry/psychology.

Figure 34: Three axes plot of the RAs related to basic science, clinical science and plant science



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

(7) Presence of Japan in 133 Research Areas

The percentage of Japanese core papers which constitute RAs can be considered as one of the indicators to assess the presence of Japan. The result of the examination on the percentage of Japanese core papers and the presence of Japan is described below. Figure 35 shows the RAs with Japanese papers of more than 9%. If the institution which an author (several authors in many cases) of a paper represents is a Japanese institution, the paper is counted as a Japanese paper.

- **RAs with relatively high Japanese presence**

Among the 133 RAs, Japanese presence is relatively high in physics, chemistry, plant/animal science and materials science. Japan is doing well in inter/multi-disciplinary areas.

In 13 RAs among the 20 areas of physics, the percentage of Japanese papers exceeds 9% (in 9 of them over 15%). The RA with the highest percentage is "Superconductors with anisotropic gaps (ID 70)", with approximately 60% of Japanese papers, the highest among the 133 RAs.

In chemistry, the percentage of Japanese papers exceeds 9% in 7 RAs out of 11.
"High performance catalysis for olefin polymerization (ID 86)" and "Catalytic asymmetric synthesis (ID 89)" exceeds 15%.

In plant and animal science of Life science-related areas, the percentage of Japanese papers exceeds 9% in 3 RAs out of 6. Particularly, in the research of "Functional analysis on abscisic acid, a plant hormone (ID 31)", the percentage is high at 24%. In the area of "Molecular mechanism of adipocytokines and the onset of metabolic syndrome (ID 21), the percentage of Japanese papers is high at about 40%.

In the 16 areas of inter/multi-disciplinary areas, the percentage of Japanese papers exceeds 9%. Generally, Japan is believed to be weak in inter/multi-disciplinary areas. However, both the previous and this study confirmed that Japan maintains a certain level of presence in these areas.

Table 35: RAs in which the presence of Japan is high

Name of research areas	Number of core papers	Number of Japanese papers	Percentage of Japanese papers
Superconductors with anisotropic gaps	44	27	61
Bi-based high-temperature superconductors	85	39	46
Molecular mechanism of adipocytokines and the onset of metabolic syndrome	67	29	43
Relativistic astronomy and gravity waves	29	12	41
High performance catalysis for olefin polymerization	43	17	40
Ghrelin; its mechanism of action	51	20	39
High-efficiency dye-sensitised solar cell	79	27	34
Research on plastic deformation in nano-crystals	58	18	31
Physics in high-temperature superconductor junctions	18	5	28
Spintronics	79	21	27
Functional analysis on abscisic acid, a plant hormone	33	8	24
Catalytic asymmetric synthesis	170	37	22
Study of biological clock	122	26	21
Cancer therapy with histone deacetylase inhibitor	15	3	20
Nanocomposites consisting of inorganic nano materials and organic polymers	43	8	19
Supersymmetry and CP violation	154	28	18
Analysis of mechanism of regulation of plant growth	109	19	17
Signal conduction of the lysophospholipids receptors	24	4	17
Physical attributes and material process of MgB2	61	10	16
Quantum computing devices	31	5	16
Baryon consisting of five quarks	39	6	15
Neutrino oscillation and creation of material universe	135	20	15
Research on neurodegenerative mechanism in Huntington's disease based on transgenic mice	28	4	14
Genetic diagnosis and therapy of Crohn's disease	44	6	14
Effects of COX-2 inhibitor against cancer	53	7	13
Research on immune system	329	43	13
Application of cryptographic technologies to digital information distribution	23	3	13
Research on osteoclastic mechanism	39	5	13
Effects of aerosol and air pollutant on climate and atmospheric circulation model	143	18	13
Photonic crystal and devices	24	3	13
Genome analyses of Helicobacter pylori and Mycobacterium tuberculosis	25	3	12
Research on molecular mechanism in apoptosis	219	26	12
Noncommutative field theory and super string theory	77	9	12
Quantum chromodynamics	181	21	12
Detection of negative ions by chemical methods	44	5	11
Metal-organic hybrid porous materials	103	11	11
Basic and applied research on carbon nanotubes	245	26	11
Research on multipotency and differentiation mechanism of stem cells in cardiovascular system, cancer, and embryos	29	3	10
Formation of nanostructures based on block copolymers	20	2	10
Research on nitride compound semiconductor	30	3	10
Research on living free-radical polymerization	71	7	10
Research on medical examination of colorectal cancer	21	2	10
TRP channel and cellular senses	116	11	9
Catalytic activity of gold clusters	32	3	9
Chemical-/bio-system with microchips	97	9	9
Molecular mechanism of DNA damage and repair	76	7	9
Intake of soy- and plant-derived estrogen/isoflavone and its effects on age-associated diseases	22	2	9
Function study of mammalian TOR	33	3	9
Research on Alzheimer's disease and Parkinson's disease	215	19	9
Structures and functions of G-protein-coupled receptor	46	4	9

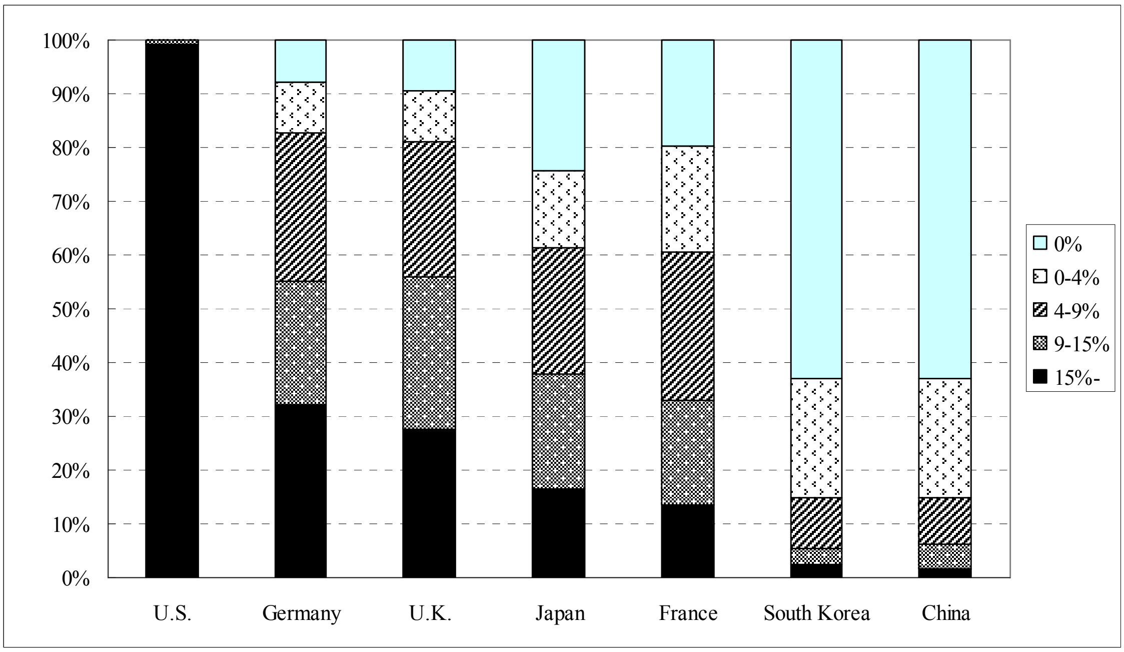
Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

- **RAs with relatively low Japanese presence**

In the RAs of engineering, environment/ecology and cosmology, only a small number of them have the percentage of Japanese papers exceeding 9%, indicating the low presence of Japan. No presence is detected in fields of psychiatry/psychology, social sciences/general and economics.

Figure 36 shows RA distribution of the share of papers in the 133 RAs in each country. Japan have no shares in more than 20% of RAs, which is relatively high compared to that of the U.S. (0%), and Germany and the U.K. (both about 10%).

Figure 36: Distribution of RAs by the share of papers in each country



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

3-3 Mapping and analysis of correlation of RAs

The purpose of the Correlation map is to show and analyze how strong the correlation among the 133 RAs is, and to understand the trends in science focusing on basic research.

(1) Mapping of Correlation of RAs

We developed a map showing correlations among RAs (Correlation map), using co-citation relations among the RAs (Figure 37). A gravity model is used for developing the correlation map, as in the case of the map of individual RAs. Each circle represents a RA and the size of the circle corresponds to the number of citations. RAs linked by strong co-citation relations are clustered together. In the correlation map, RAs with the strongest co-citation relations and with the correlation values greater than the threshold are linked with full lines. With this correlation map, we attempt to have a bird's eye view of current scientific activities. In the meantime, the RA of ID82, Cryptographic application technology is not included in this map because there are no co-citation relations with other RAs.

Next, the 133 RAs were classified into the following 14 categories based on the result of content analysis of each RA on the map, namely, *chemical synthesis(C1), superconductivity/quantum computing(C2), nanomaterials/devices(C3), environment(C4), particle physics/cosmology(C5), brain research (C6), post-genomics(C7), regenerative medicine(C8), plant science research(C9), cancer research(C10), research on infectious diseases/immunology(C11), study on obesity(C12), research on heart and blood vessels(C13), and social sciences(C14).* The classification of categories is the concept of a so-called traditional research genre and the boundary of a category cannot be quantitatively specified, so the dependency on analysts is unavoidable.

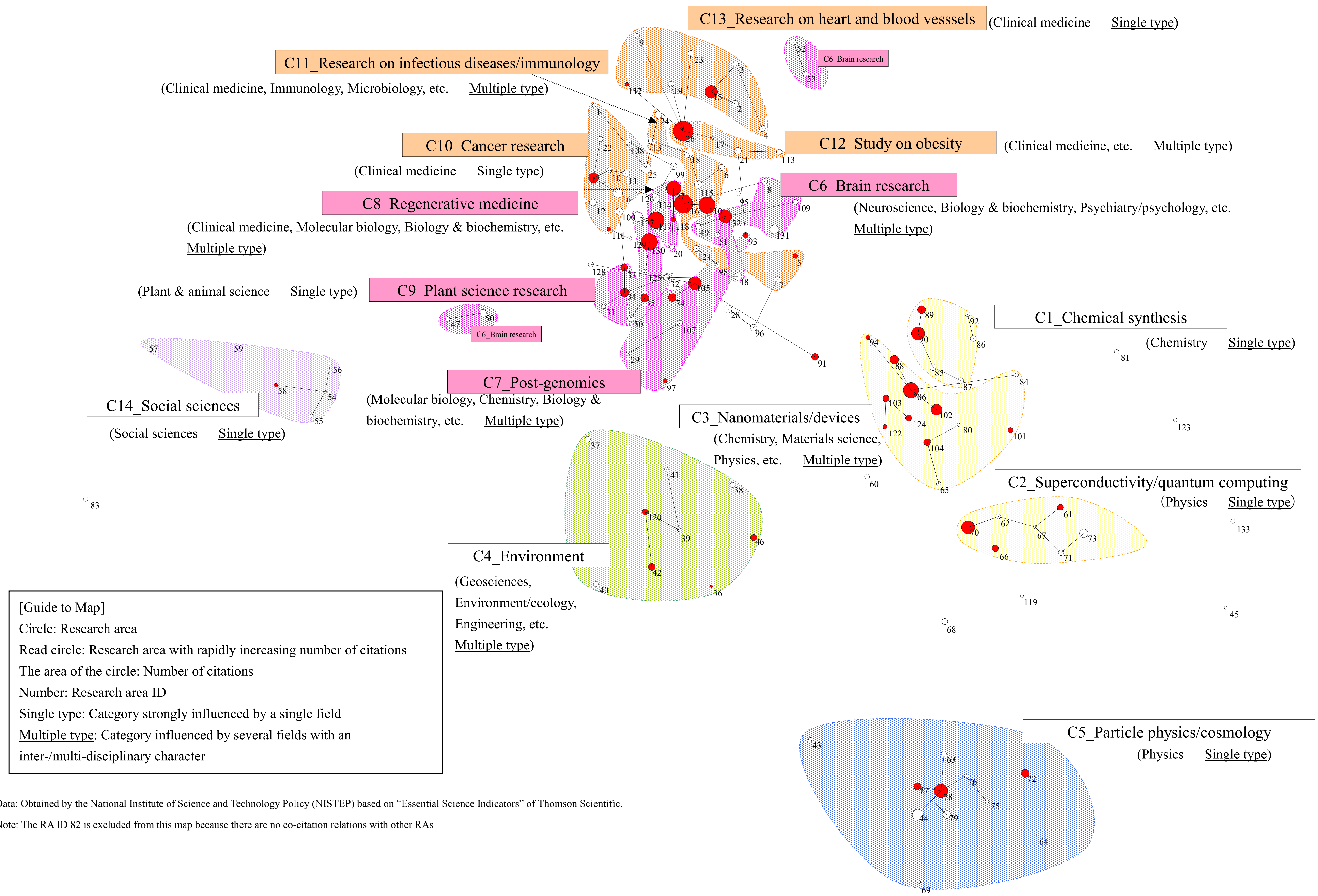
When the arrangements on a correlation map or full lines connecting RAs are compared with the categories, it is found they do not necessarily correspond to each other. For instance, five lines are projected from the "Signal transducing molecules associated with lifestyle-related diseases (ID 26)" of the *study on obesity(C12)*. However, four RAs out of these are classified into *research on heart and blood vessels(C13)*, instead of *C12*. Considering the state of current basic science drawn on the correlation map, it can be assumed that there is a strong relation between *study on obesity* and *research on heart and blood vessels*, and the research activities are conducted within that framework.

Brain research (C6) appears at three different locations on the correlation map. In other words, it is suggested that brain research in general terms consists of brain research associated with molecular biology, brain research related to *research on heart and blood vessels(C13)*, and cognitive science-related brain research which is closely related to *social sciences(C14)*.

It is suggested from the correlation map that the *research on infectious diseases/immunology(C11)* has strong relations with various other RAs in the life science-related category.

In other words, it is fair to say that one can trace the development trends of the latest research activities by comparing the correlation map with the categories.

Figure 37: Correlation map



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: The RA ID 82 is excluded from this map because there are no co-citation relations with other RAs

Table 38: Categories of 133 RAs

Field	Category name	Sub-category	ID	Name of research area
Nanotechnology/materials	C1_Chemical synthesis		85	Dendrimer research
			86	High performance catalysis for olefin polymerization
			87	Research on living free-radical polymerization
			89	Catalytic asymmetric synthesis
			90	Organic synthesis and its application to a sustainable society
			92	Metal-organic complex and its catalytic activity
	C2_Superconductivity/ quantum computing		61	Physical attributes and material process of MgB2
			62	Quantum computing devices
			66	Spintronics
			67	Physics in high-temperature superconductor junctions
			70	Quantum electronics and its application to quantum information processing
			71	Superconductors with anisotropic gaps
			73	Bi-based high-temperature superconductors
	C3_Nano materials/devices		65	Photonic crystal and devices
			80	Formation of nanostructures based on block copolymers
			84	Catalytic activity of gold clusters
			88	Metal-organic hybrid porous materials
			94	Detection of negative ions by chemical methods
			101	Nanocomposites consisting of inorganic nano materials and organic polymers
			102	Basic and applied research on carbon nanotubes
			103	High-efficiency dye-sensitised solar cell
			104	Synthesis of nano-structures form microstructure with microparticles and polymers
			106	Development of nanostructure and its application to molecular devices
			122	Research on high performance organic thin film transistor
			124	Research on high efficiency organic LED
	Others		45	Research on meshless finite element method
			60	Stability and vitrification of supercooled liquid
			68	Basic and applied research on ultra-short-pulse laser
			81	Research on plastic deformation in nano-crystals
			119	Development and application of proton-exchange membrane fuel cells
			123	High-dielectric gate insulating technology for semiconductor integrated circuits
			133	Research on nitride compound semiconductor
C4_Evvironment			36	Environment pollution and risk of persistent organic halide pollutants
			37	Study on biodiversity in plants
			38	Aquatic pollution by toxic chemical compounds
			39	Carbon cycle in south Pacific Ocean
			40	North Atlantic Oscillation and climate change
			41	Research on paleoclimate
			42	Effects of aerosol and air pollutant on climate and atmospheric circulation model
			46	Research on spectroanalysis
			120	Research on global carbon cycle
C5_Particle physics/ cosmology			43	Mars exploration
			44	Large-scale structure of the universe
			63	Noncommutative field theory and super string theory
			64	Baryon consisting of five quarks
C5_Particle physics/ cosmology			69	Relativistic astronomy and gravity waves
			72	Quantum chromodynamics
			75	Super string theory and spatiotemporal physics
			76	Quantum gravity
			77	Neutrino oscillation and creation of material universe
			78	Cosmic microwave background fluctuation and inflationary cosmology
			79	Supersymmetry and CP violation
Life science	C6_Brain research		8	Therapy of multiple sclerosis
			48	Glutamate receptors in plasticity brain
			49	Research on neurodegenerative mechanism in Huntington's disease based on transgenic mice
			51	Mechanism of molecules involved in formation of brain
			109	Research on prion diseases
			131	TRP channel and cellular senses
			132	Research on Alzheimer's disease and Parkinson's disease
			47	Brain function imaging of cognitive psychological
			50	Visual stimulation and oscillatory brain activities
			52	Clinical trials for phobias, mood disorders and anxiety
			53	Early diagnostics and therapy of schizophrenia
	C7_Post-genomics	Genome/bioinfomatics	29	Utility of agrobacterium-mediated genetic engineering and the genomic character
			74	Network analysis and its application to genome, social-network, and infection transmission
			97	Molecular phylogenetic analysis
			107	Genome analyses of Helicobacter pylori and Mycobacterium tuberculosis
			125	Development of statistics method for microarray data analysis
			127	Molecular mechanism of DNA damage and repair
			130	Research on epigenetic transcriptional regulation
		Proteomics	93	Drug discovery research
			105	Research on proteome
	C8_Regenerative medicine		20	Gene therapy targeting hematopoietic stem cells and its side effects
			27	Stem cell therapy on nervous, hematopoietic, and cardiovascular system
			114	Molecular mechanism of PI3/Akt signal transduction pathway
			117	Research on molecular mechanism in apoptosis
			118	Research on multipotency and differentiation mechanism of stem cells in cardiovascular system, cancer, and embryos
	C9_Plant science research		30	Plant genome research
			31	Functional analysis on abscisic acid, a plant hormone
			32	Dynamics and regulation of cytoskeleton
			33	Analysis of mechanism of regulation of plant growth
			34	Stress response in plants
			35	Study of biological clock
	Others		28	Structures and functions of G-protein-coupled receptor
			91	Chemical-/bio-system with microchips
			95	Signal conduction of the lysophospholipids receptors
			96	Water and iron transport mechanism in organism
			99	Signal transduction in metabolic pathway
			128	Nucleocytoplasmic traffic and cell function
			129	Mechanism of control of life-span
Healthcare	C10_Cancer research		1	Research on medical examination of colorectal cancer
			10	Cancer therapy with angiogenesis inhibitor
			11	Research on multiple myeloma therapy
			12	Research on diseases for which Rituxan is effective
			14	Research on cancer therapy
			16	Research on molecular pathogenesis and leukemia therapy
			22	Research on breast cancer therapy
			25	Effects of COX-2 inhibitor against cancer
			100	Hypoxia-inducible factor and tumorigenesis
			108	Research on molecular mechanism of sex hormone receptors against cancer
			111	Cancer therapy with histone deacetylase inhibitor
			126	Function study of mammalian TOR
	C11_Research on infectious diseases/ immunology		5	Research on SARS and avian influenza
			6	Research on allergy therapy
			7	Research on countermeasures to bioterrorism
			13	Research on osteoclastic mechanism
			18	Autoimmune disease
			24	Clinical research on COX-2 inhibitor as anti-inflammatory
			98	Research on infection mechanism of HIV
			110	Research on infection mechanism and therapy of HCV and HIV
			115	Genetic diagnosis and therapy of Crohn's disease
			116	Research on immune system
			121	Signal transduction in immune system
	C12_Study of obesity		17	Functional analysis of peroxisome proliferator-activated
			21	Molecular mechanism of adipocytokines and the onset of metabolic syndrome
			26	Signal transducing molecules associated with lifestyle-related diseases
			113	Ghrelin; its mechanism of action
	C13_Research on heart and blood vessels		2	Clinical treatment of severe sepsis and septic shock
			3	Cardiac resynchronization therapy for intractable heart failure
			4	Diversity of arrhythmia-related genes
			9	Development of imaging techniques for cardiovascular system
			15	Clinical trial of therapeutic agent for cardiovascular disease
			19	Prevention of post-coronary angioplasty restenosis with drug-eluting stents
			23	Research on venous thromboembolism therapy
			112	Intake of soy- and plant-derived estrogen/isoflavone and its effects on age-associated diseases
C14_Social sciences			54	Law and behavioral science
			55	Political power and human rights
			56	Research on intellectual property right problems
			57	Study on local economy and regional integration
			58	Research on corporate governance
			59	Research on venture capital
Others			82	Application of cryptographic technologies to digital information distribution
			83	Research on modulation schemes for ultra-wideband communications

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

(2) Characteristics of Correlation map

The result of field distribution of papers which are the components of categories (data not shown) is incorporated into the correlation map of Figure 37 (refer to the brackets in the Figure). For example, it is shown that the core papers of *chemical synthesis (C1)* mainly consist of chemistry papers.

The categories *C1 – C3* are located at the center of Figure 37, showing the presence of RAs related to *Nanotechnology/materials*. The *chemical synthesis (C1)* includes 6 RAs. The main research objectives of the areas in this category are research and development of catalysts that promote effective chemical reactions and synthesis of new materials. Many of the core papers constituting these RAs are listed in chemical journals. The *superconductivity/quantum computing (C2)* consists of 7 RAs. Core papers in this category mainly consist of physics papers. There is the category *nanomaterials/devices (C3)* in between *C1* and *C2*, containing 12 RAs. Core papers in this category consist of papers on chemistry, materials science, and physics, exhibiting an inter/multi-disciplinary character. Thus, an integrated category, *C3*, is placed in between the chemistry-related *C1* and Physics-related *C3*, showing that <u>the location on the correlation map describes the characteristics of RAs</u>.

Environment(C4) has 9 RAs and is placed at the center of the correlation map. From the positions in the map, it is clear that this category has a certain level of co-citation relations with *Life science*, *healthcare*, and *Nanotechnology/materials*. Core papers in this category are composed of geosciences, *environment*/ecology and engineering, having no inconsistency with positional relations on the map, which shows that the category of *environment* has an inter/multi-disciplinary character. This category includes such RAs as *environment*al changes, chemical substances and biodiversity.

Particle physics/cosmology (C5) extends to the bottom right of the correlation map. Since it is placed away from other categories, the research on *particle physics/cosmology* has limited correlation with other categories. Core papers in this category consist only of physics and space sciences. Taking into consideration the positional relations on the correlation map, it is suggested that the flow of knowledge between *C5* and other RAs is quite limited.

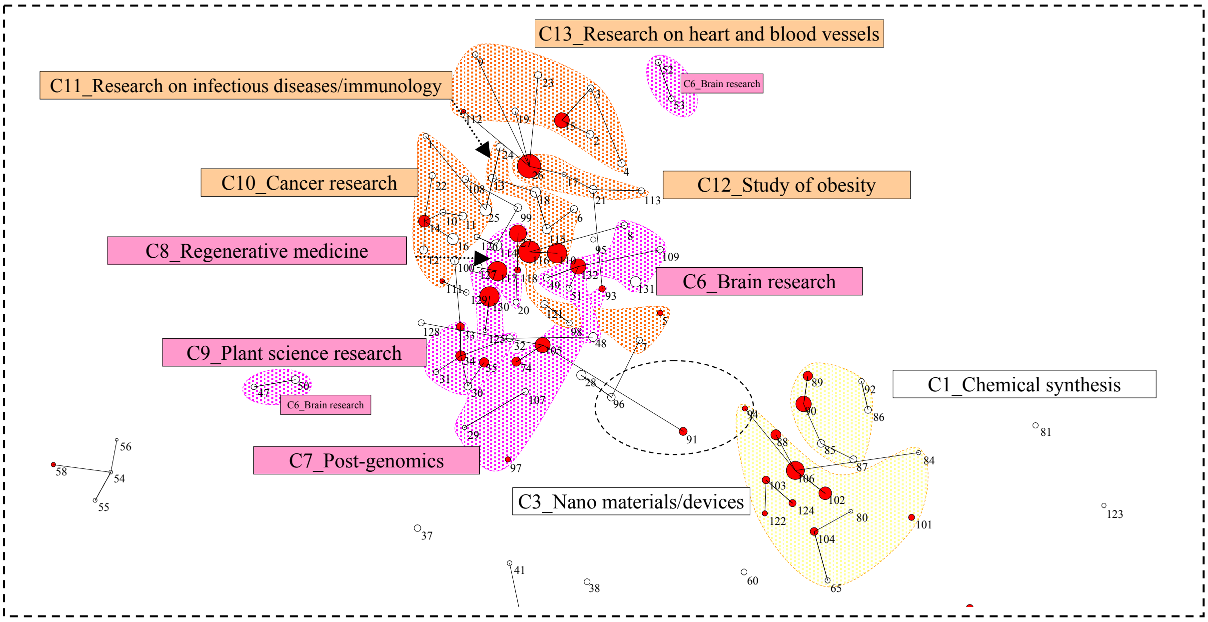
RAs at the top center of the correlation map are RAs related to *Life science* and *healthcare* (Figure 37: Figure 39 is the expanded map). Due to the complexity of the relations among RAs, it is not easy to have a definite classification of these categories. Roughly however, the upper half of Figure 39 is the RAs related to *healthcare* and the bottom half is the RAs related to *Life science*.

"Life science-related category" includes 38 RAs, which can be divided into 4 categories: namely, *C6-brain research, C7-post genomics, C8-regenerative medicine,* and *C9-plant science research*. "*Healthcare-related category"* is composed of 35 RAs, which can also be divided into 4 categories: *C10-cancer research, C11-research on infectious diseases / immunology, C12-study on obesity, and C13-research on heart and blood vessels*.

With respect to the components of core papers in *Life science-related categories*, *C9-plant science research* is the only area that is strongly influenced by a single field, whereas *C6-brain study, C7-post-genemics, and C8-regenerative medicine* consist of various fields of basic biology. In the *healthcare related categories*, *C10-cancer research, C12-study on obesity, and C13-research on heart and blood vessels* are strongly influenced by the fields of clinical medicine. The category *C11-research on infectious diseases and immunology* consists of the papers on immunology and microbiology, in addition to those on clinical medicine. When details of positional relations on the map are closely examined, *C8-regenerative medicine* and *C11-research on infectious diseases and immunology* are placed halfway between the *Life science-related categories* and *healthcare-related categories*. This position corresponds to the characteristic of inter/multi-disciplinary areas that core papers of *C8* and *C11* consist of papers in various fields.

An interesting point is that one can see that *C3-nanomaterials/devices* is slightly gravitated toward *Life* *science-related categories*. This means that there is a weak co-citation relation between *C3* and *Life science-related categories*. However, at present, this relation is not strong enough to create a RA on the map. Considering the movement in the future, it is predicted that a RA related to nanobiology will be formed in the area of the dotted circle on the correlation map of Figure 39. In fact, there is a RA of "Chemical/bio-systems with microchips (ID 91)" within the circle. The research objective of this RA is the development of microchips that promote chemical and bio-reaction in a microscopic space. Nanomaterials include inter/multi-disciplinary areas between nanotechnology and biotechnology, such as "Detection of negative ions by chemical methods (ID 94)". More RAs related to nanobiology will be found if a similar analysis is performed a year or two years later.

Figure 39: Sections of the map of correlation of RAs which are related to *Life science* and *healthcare*



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

The *C14-social sciences* is placed at the left center of the map in Figure 37. This study mostly targets natural science areas, but as a result of analysis, some RAs were found to be related to social sciences, such as "Research on venture capital (ID 59). Core papers in *C14* are mainly in the field of social sciences. One can see from the correlation map that there exists a group of RAs between *C14*-social sciences and *Life science*-related categories, such as "Brain function imaging of cognitive psychological phenomena (ID 47)" and "Visual stimulation and oscillatory brain activities (ID 50) " (within the dotted line at the left hand side of Figure 39). It is expected that an integrated category of social sciences and *Life science*s will emerge in the future.

Thus, 14 categories can be divided into the following two groups:

- The categories strongly influenced by a single field (Single type)
  C1-chemical synthesis, C2-superconducing/quantum computing, C5-particle physics/cosmology, C9-plant science research, C10-cancer research, C13-research on heart and blood vessels, C14-social sciences
- The category influenced by several fields with inter/multi-disciplinary character (Multiple type)

C3-nanomaterials/devices, C4-environment, C6-brain research, C7-post-genomics, C8-regenerative medicine, C11-research on infectious diseases and immunology, C12-study on obesity

(3) Portfolio analysis of 14 categories

Benchmarking Research & Development Capacity in Japan (NISTEP REPORT No.90) gives details of field-specific portfolio structures identified by the international comparison analysis of the balance among fields for producing papers. According to the report, Japan's portfolio is structured with high shares of papers in chemistry, materials science and physics and low shares in computer science, mathematics, *environment*/ecology, geosciences, and clinical science. In the U.S. and U.K. the weight of basic biology and clinical medicine is high and China and Korea have similar portfolio structures to Japan.

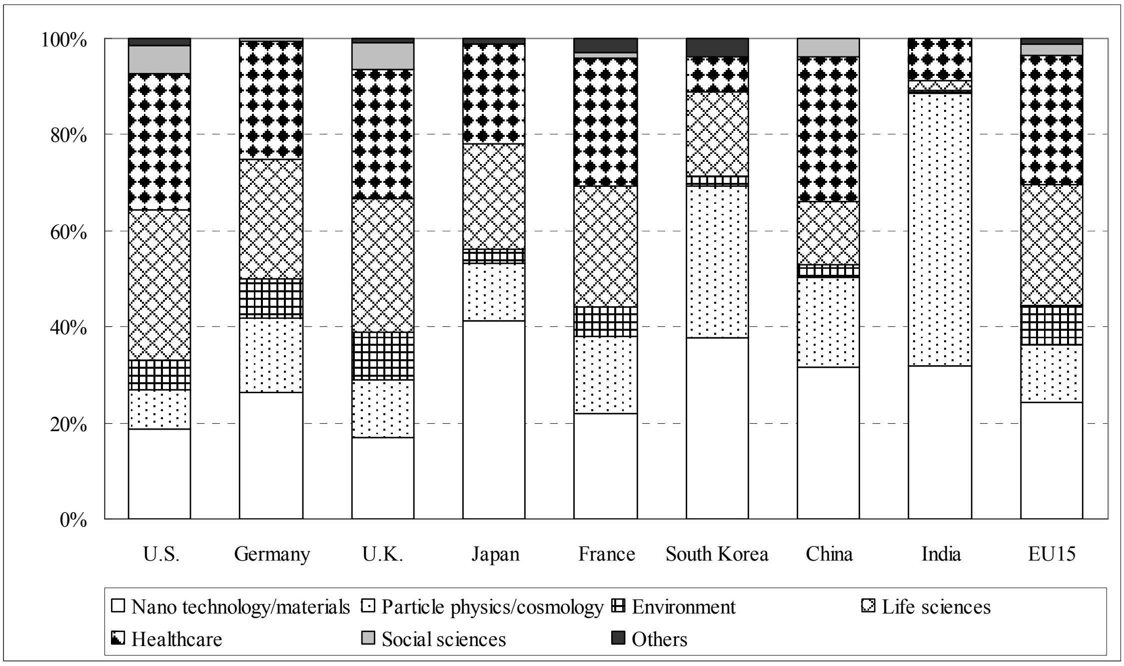
Here a study was conducted to find in what RAs different countries, including Japan, the U.S., Germany and the U.K., have high shares of core papers and citing papers. We counted the relevant number of papers in *Nanotechnology/materials*, *particle physics/cosmology*, *environment*, *Life science*, and *healthcare*, and analyzed the percentages. Figure 40 shows the result of core papers and Figure 41 that of citing papers.

Core papers are those within the threshold of the top 1% based on total citations and they constitute RAs, and it is believed that the situations of top-level researchers of different countries in 133 RAs are reflected in the portfolio of core papers. The share of each country of about 10,000 core papers is 61% for the U.S., 13% for Germany, 12% for the U.K., 9% for Japan, 7% for France, 3% for China, 2% for Korea, and 1% for India. About 40% of Japanese core papers are on *Nanotechnology/materials*, followed by *Life science* and *healthcare* with approximately 20% each. The share of the sum of *particle physics/cosmology*, *environment* and *others* accounts for the rest (about 20%). In comparison with other countries, the share of Japanese papers on *Nanotechnology/materials* is high, representing the strength of Japan.

About 50% of core papers of the U.S., Germany, the U.K. and France are on *Life science* and *healthcare*, suggesting an abundance of top-level researchers in these countries. It is also found that *environment* maintains a certain level of share when compared to Japan. Furthermore, *social sciences* have a certain presence in the U.S. and U.K.

In Korea, *Nanotechnology/materials* and *particle physics/cosmology* are the main categories. In China, the share of *healthcare* is high, and its domestic share is similar to that in the U.S. Unlike other countries, India is characterized by its dominance in *particle physics/cosmology*.

Figure 40: Distribution of shares in categories of RAs in each country (core papers)



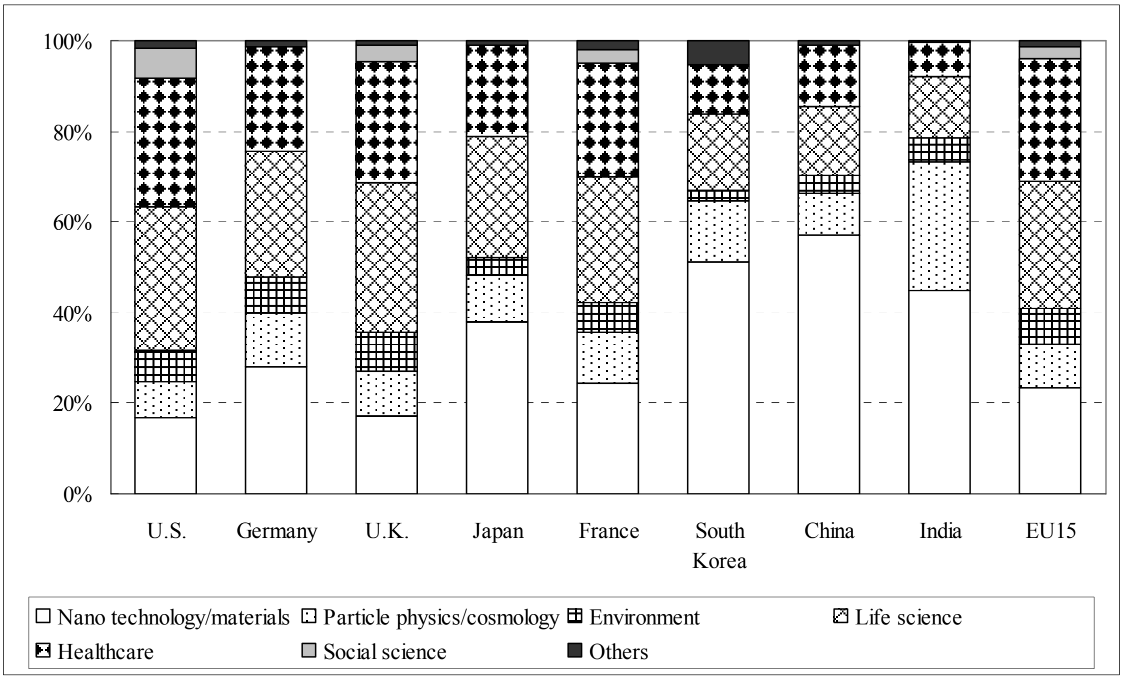
Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Science Citation Index CD-ROM(1999-2004)” of Thomson Scientific.

Citing papers are those citing core papers, and their portfolios are thought to represent the breadth of researchers of different countries in 133 RAs, not just world-class researchers. Therefore, when portfolios of core papers and citing papers are compared, one can see the relationship between top-level researchers and the breadth of researchers of each country. The share by country of about 330,000 citing papers is 39% for the U.S., 9% for Germany, 9% for the U.K., 8% for Japan, 5% for France, 4% for China, 2% for Korea and 1% for India.

There is no notable difference in the portfolios between core papers and citing papers in Japan, the U.S., Germany, the U.K., and France. This suggests that each country has a certain amount of researchers, and out of these produces a certain proportion of top-notch researchers.

On the other hand, there is a difference in the portfolios between core papers and citing papers in Korea, China and India, and citing papers on *Nanotechnology/materials* account for about 50%. Korea, China and India seem to have a wide breadth of researchers in the area of *Nanotechnology/materials*, in which Japan has strength, and it is necessary to pay particular attention to the developments in the future. India maintains a certain share of *environment* and *Life science* with some breadth of researchers, but has yet to produce top-notch researchers.

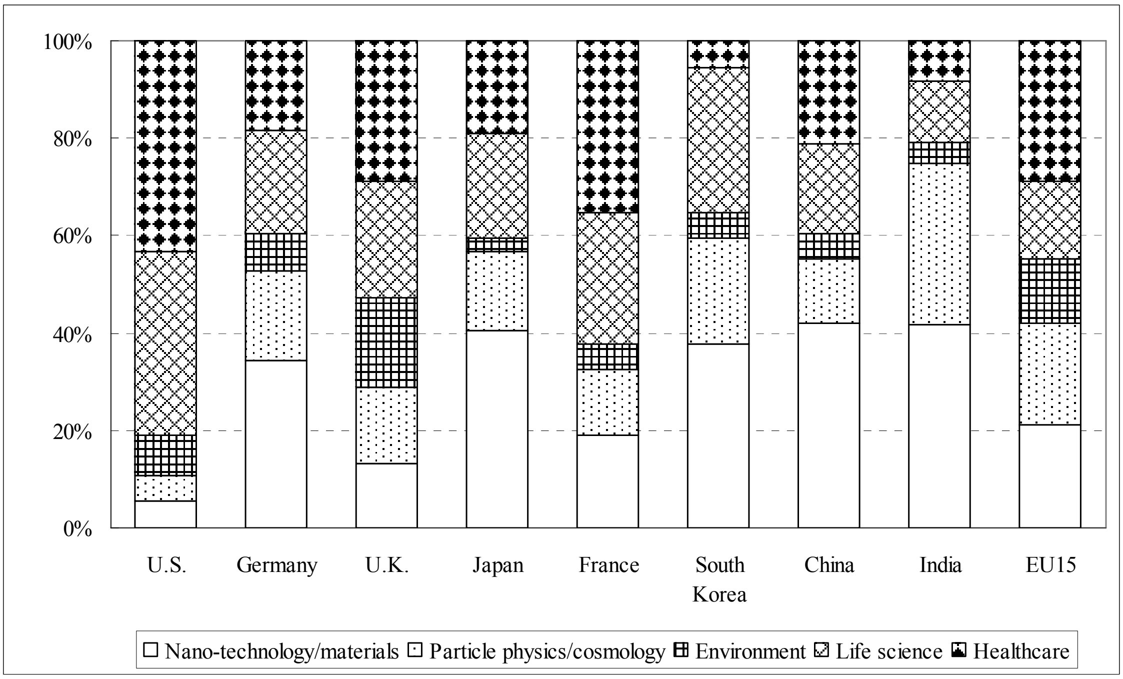
Figure 41: Distribution of shares in categories of RAs in each country (citing papers)



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Science Citation Index CD-ROM(1999-2004)" of Thomson Scientific.

Next, we drew out the top 30% of RAs (38 RAs) of core papers and citing papers of those countries such as Japan, the U.S., Germany and the U.K. We then counted the number of RAs corresponding to *Nanotechnology/materials*, *particle physics/cosmology*, *environment*, *Life science*, and *healthcare*, and analyzed the percentages. Figure 42 shows the result of core papers and Figure 43 that of citing papers.

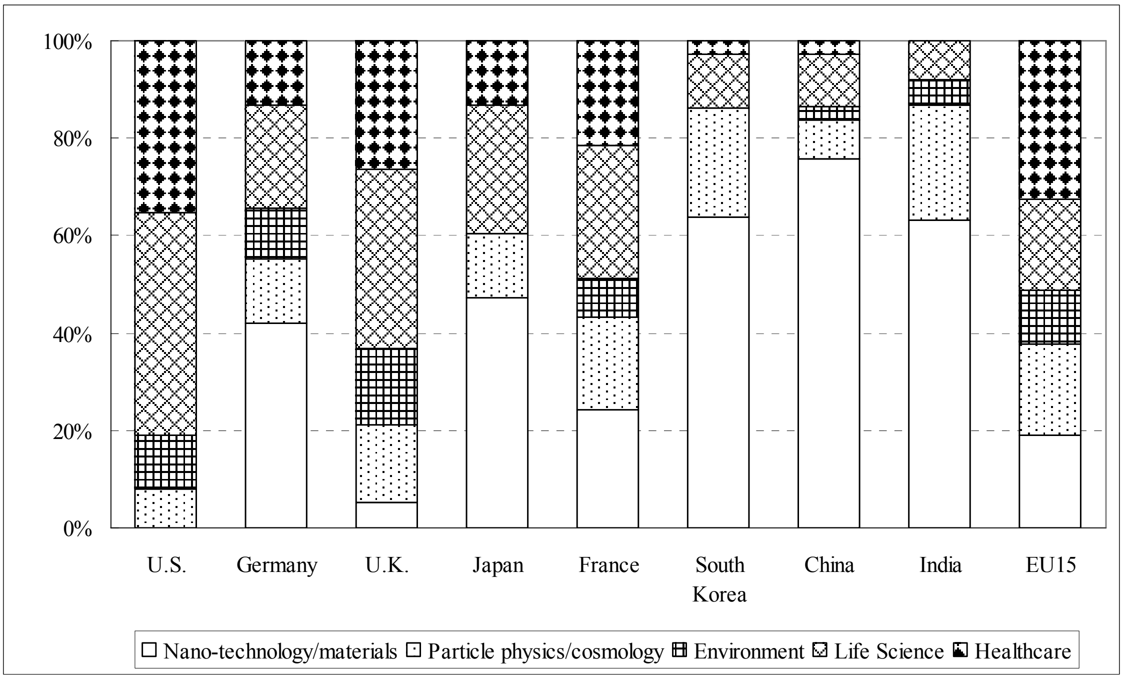
Figure 42: Distribution of shares in categories of RAs in which each country has a strong presence (core papers)



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Science Citation Index CD-ROM(1999-2004)" of Thomson Scientific.

As shown in Figure 42, the percentage of *Life science*-related areas, such as *Life science* and *healthcare*, and that of physics/chemistry-related areas, such as *Nanotechnology/materials*, *particle physics/cosmology*, are clearly different in each country. Specifically, the U.S., U.K. and France have a higher relative ratio of *Life science*-related areas. Japan exhibits a similar distribution to Germany. A similar tendency can be found in citing papers (Figure 43).

Figure 43: Distribution of shares in categories of RAs in which each country has a strong presence (citing papers)



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Science Citation Index CD-ROM(1999-2004)" of Thomson Scientific.

(4) Strengths and weaknesses of individual countries identified from Correlation map

Figure 44 – 51 show the shares of core papers and citing papers colored on the correlation maps of RAs (except for social sciences) by country, namely Japan, Germany, France, China, Korea and the US (two). The size of a circle is the same in each RA, and inside the circle indicates core papers and outside citing papers. This can enable us to picture the degree of involvement of researchers of each country. Since we use a correlation map of RAs here, it is also possible to understand the balance of strengths and weaknesses of research activities within a country. In the case of Japan (Figure 44), the presence of both core papers and citing papers is prominent in areas such as *chemical synthesis, superconductivity/quantum computing, nanomaterials/devices* and *particle physics/cosmology*. A particularly notable presence is found in superconductivity/quantum computing. *Life science*-related categories (*C10-13*) and *healthcare* (*C6-9*) exhibit a mixture of RAs, ranging from high presence RAs to low presence RAs. The overall presence of *environment* is low.

In the case of the U.K. (Figure 45), strength is found in *Life science*-related RAs, *healthcare*- related RAs, *environment*, and *particle physics/cosmology*.

In the case of Germany (Figure 46), a notable presence is found in superconductivity/quantum computing, *particle physics/cosmology* and *environment*. Chemical synthesis, *Life science-related* RAs and *healthcare-related* RAs exhibit a mixture of high presence RAs and low presence RAs.

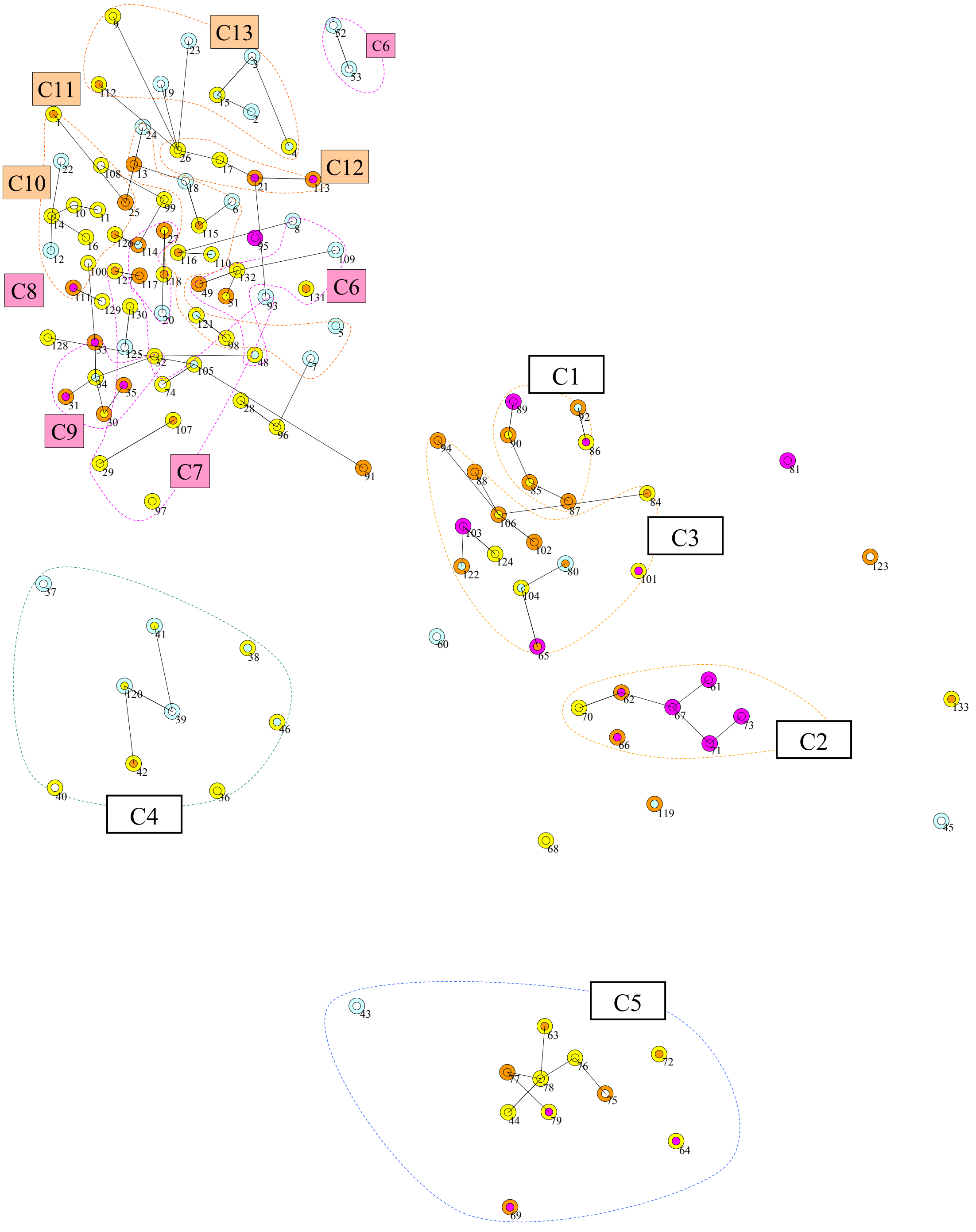
In the case of France (Figure 47) a notable presence is found in *particle physics/cosmology* and *Life science* related RAs.

In China (Figure 48), there is a presence of core papers and citing papers in the areas of *chemical synthesis, superconductivity/quantum computing, and nanomaterials/devices*. There is a presence of core papers in some *particle physics/cosmology*, *Life science* related areas and *healthcare* related RAs.

In Korea (Figure 49), the presence is relatively high in *chemical synthesis, superconductivity/quantum* *computing, and nanomaterials/devices*, and this pattern of strength is similar to that of China although the shares are somewhat behind China.

The U.S. (Figure 50) maintains more than 15% of the shares in almost all RAs. Thus, targeting the U.S., the correlation map of RAs was developed by revising the coloring criteria (Figure 51). With respect to core papers, the share is high in the *Life science*-related areas and *healthcare*-related RAs. With respect to citing papers, the share varies by category. When compared to core papers, the presence in such areas as *superconductivity/quantum computing, nanomaterials/devices,* and *particle physics/cosmology* is particularly low.

Figure 44: Correlation map (Japan)



- Each circle (fixed size): research area
- Area inside the circle: share of core papers
- Area outside the circle: share of citing papers

<Color coding by share>

- 15%-
- 9-15%
- 4-9%
- 0-4%
- 0%

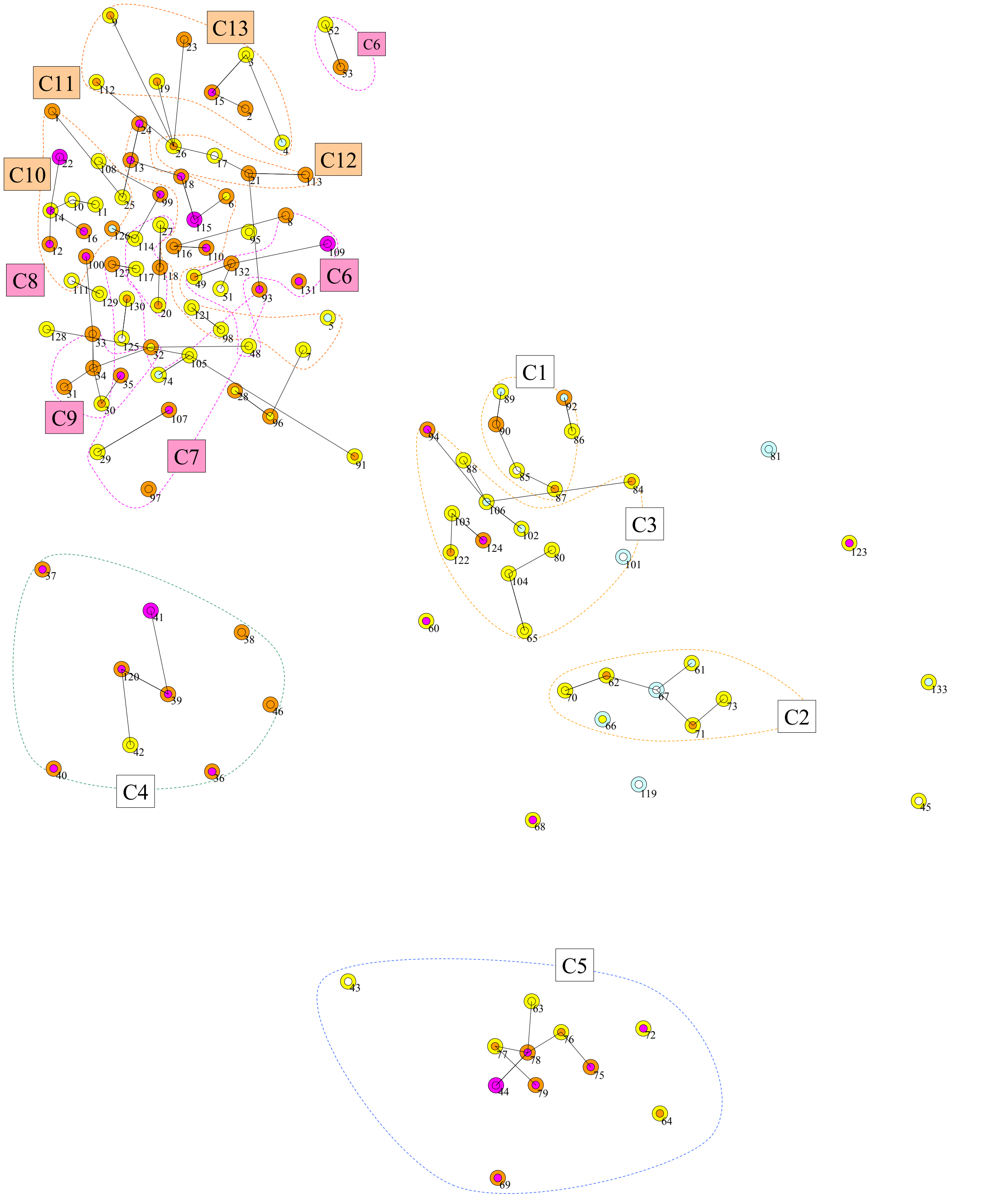
<Categories>

C1: Chemical synthesis
C2: Superconductivity/quantum computing
C3: Nano materials/devices
C4: Environment
C5: Particle physics/cosmology
C6: Brain research
C7: Post-genomics
C8: Regenerative medicine
C9: Plant science research
C10: Cancer research
C11: Research on infectious diseases/immunology
C12: Study of obesity
C13: Research on heart and blood vessels

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: This map was developed excluding ID47, 50, 54-59, and 83 from the Correlation map.

Figure 45: Correlation map (U.K.)



- Each circle (fixed size): research area
- Area inside the circle: share of core papers
- Area outside the circle: share of citing papers

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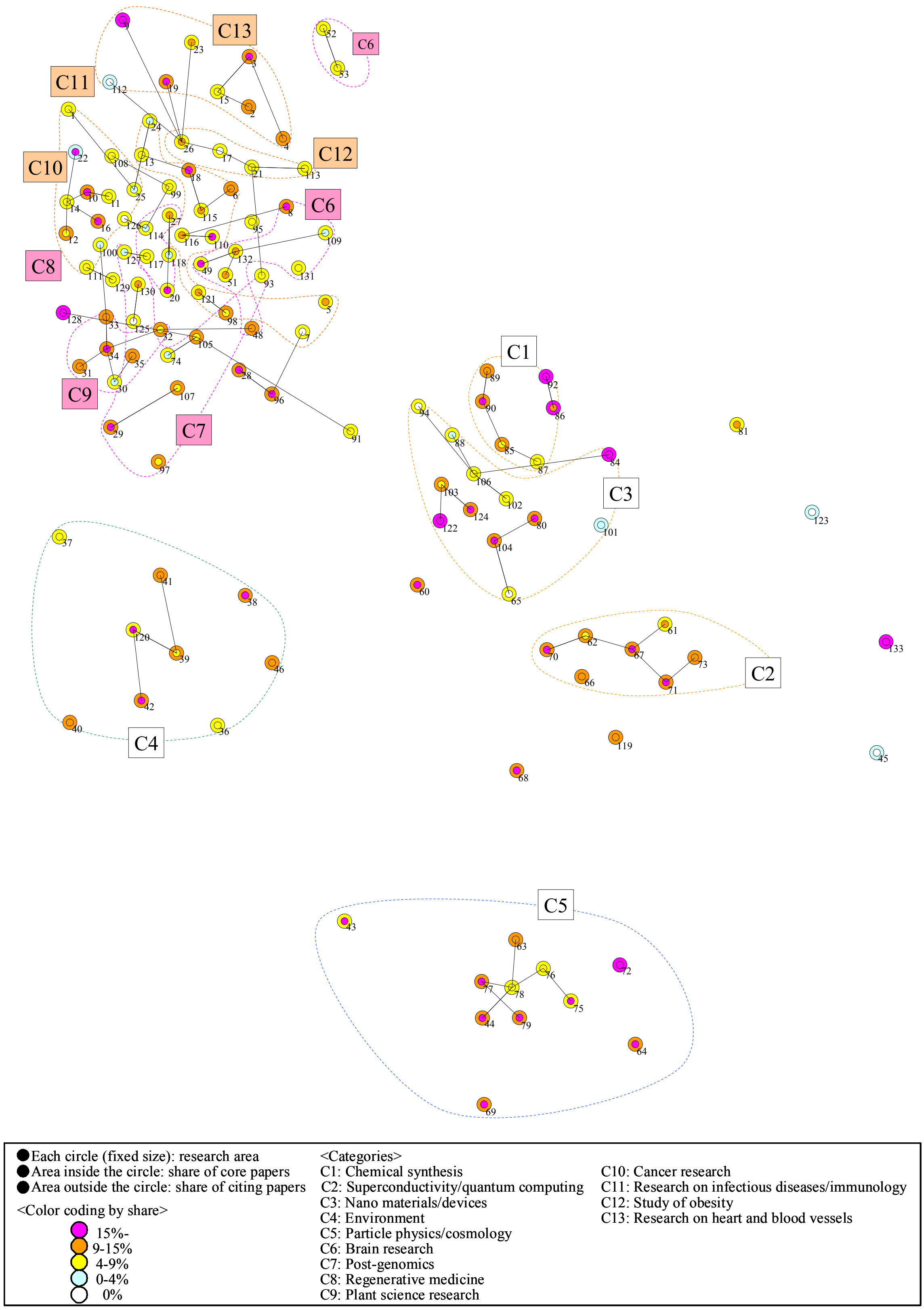
Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: This map was developed excluding ID47, 50, 54-59, and 83 from the Correlation map.

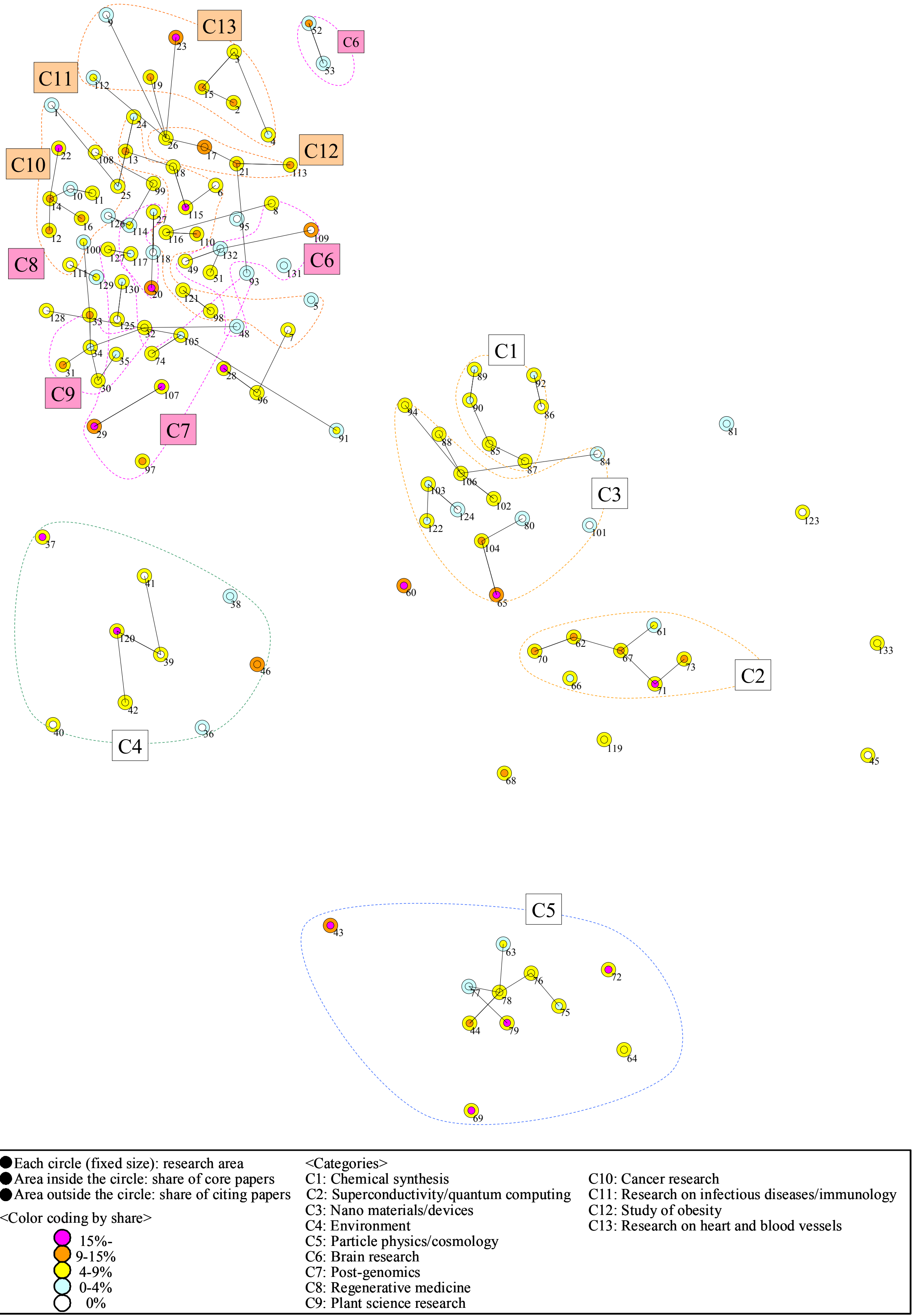
Figure 46: Correlation map (Germany)



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: This map was developed excluding ID47, 50, 54-59, and 83 from the Correlation map.

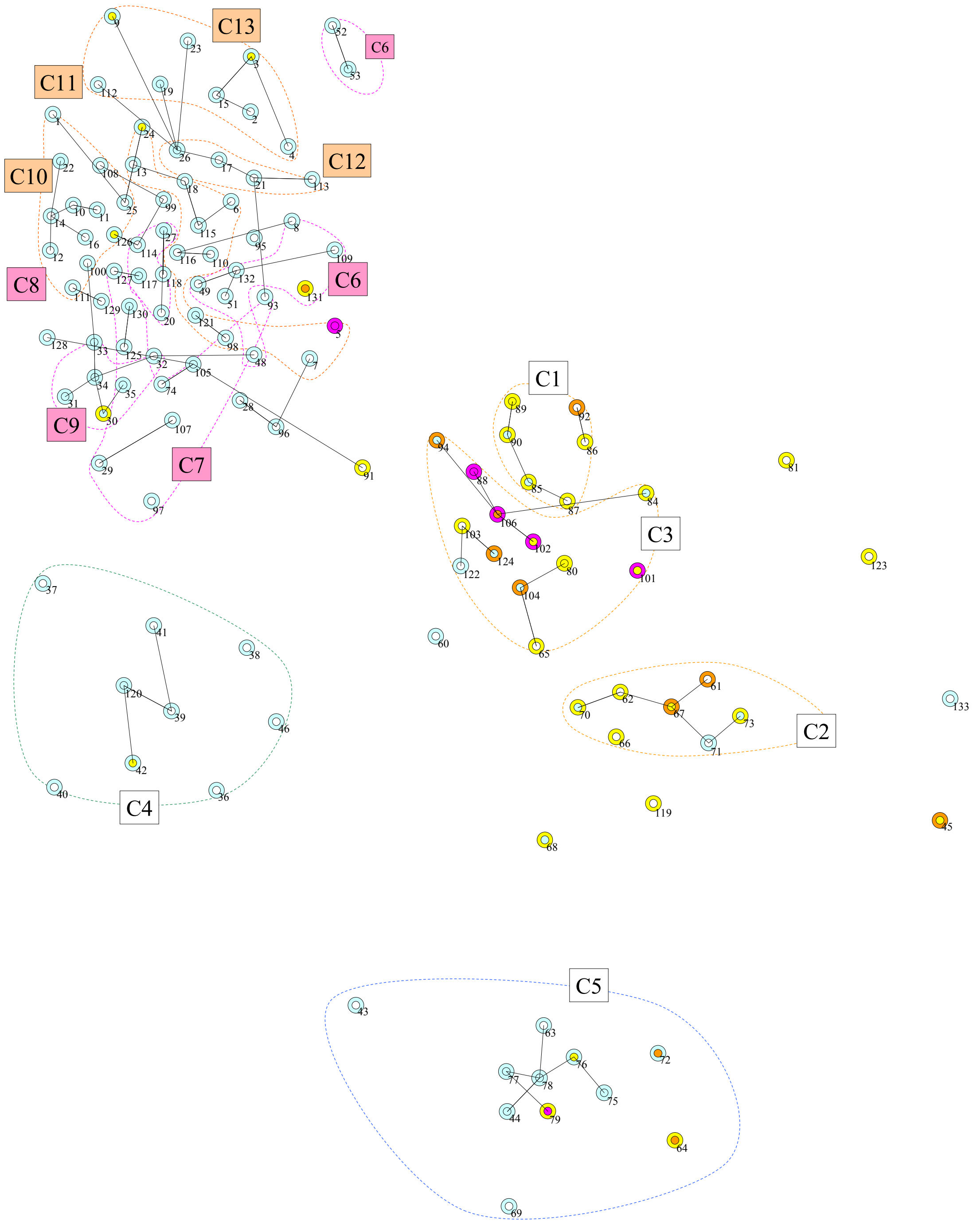
Figure 47: Correlation map (France)



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: This map was developed excluding ID47, 50, 54-59, and 83 from the Correlation map.

Figure 48: Correlation map (China)



- Each circle (fixed size): research area
- Area inside the circle: share of core papers
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<Color coding by share>

- 15%-
- 9-15%
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- 0-4%
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<Categories>

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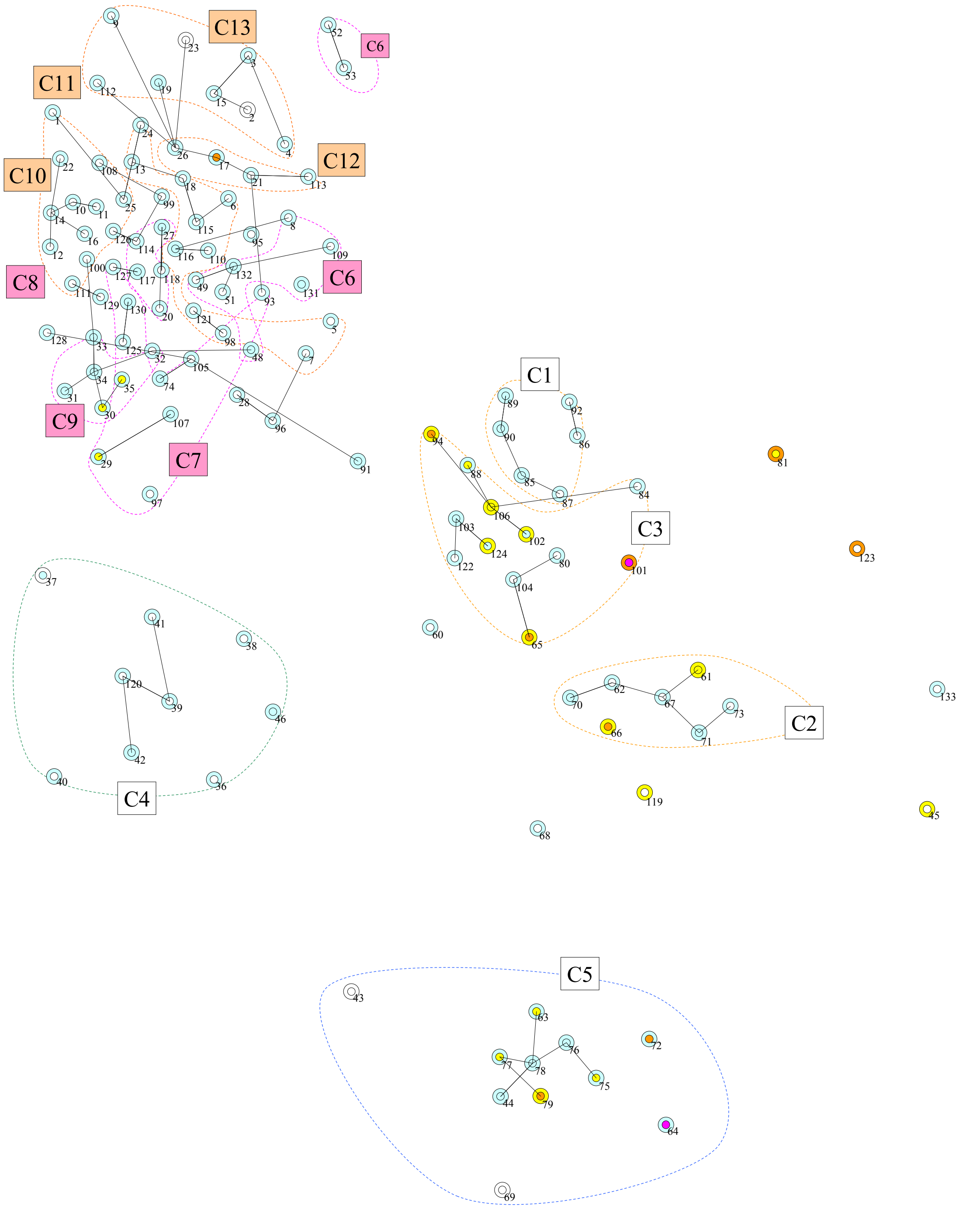
C9: Plant science research
C10: Cancer research
C11: Research on infectious diseases/immunology
C12: Study of obesity
C13: Research on heart and blood vessels

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

Note: This map was developed excluding ID47, 50, 54-59, and 83 from the Correlation map.

Figure 49: Correlation map (South Korea)



- Each circle (fixed size): research area
- Area inside the circle: share of core papers
- Area outside the circle: share of citing papers

<Color coding by share>

- 15%-
- 9-15%
- 4-9%
- 0-4%
- 0%

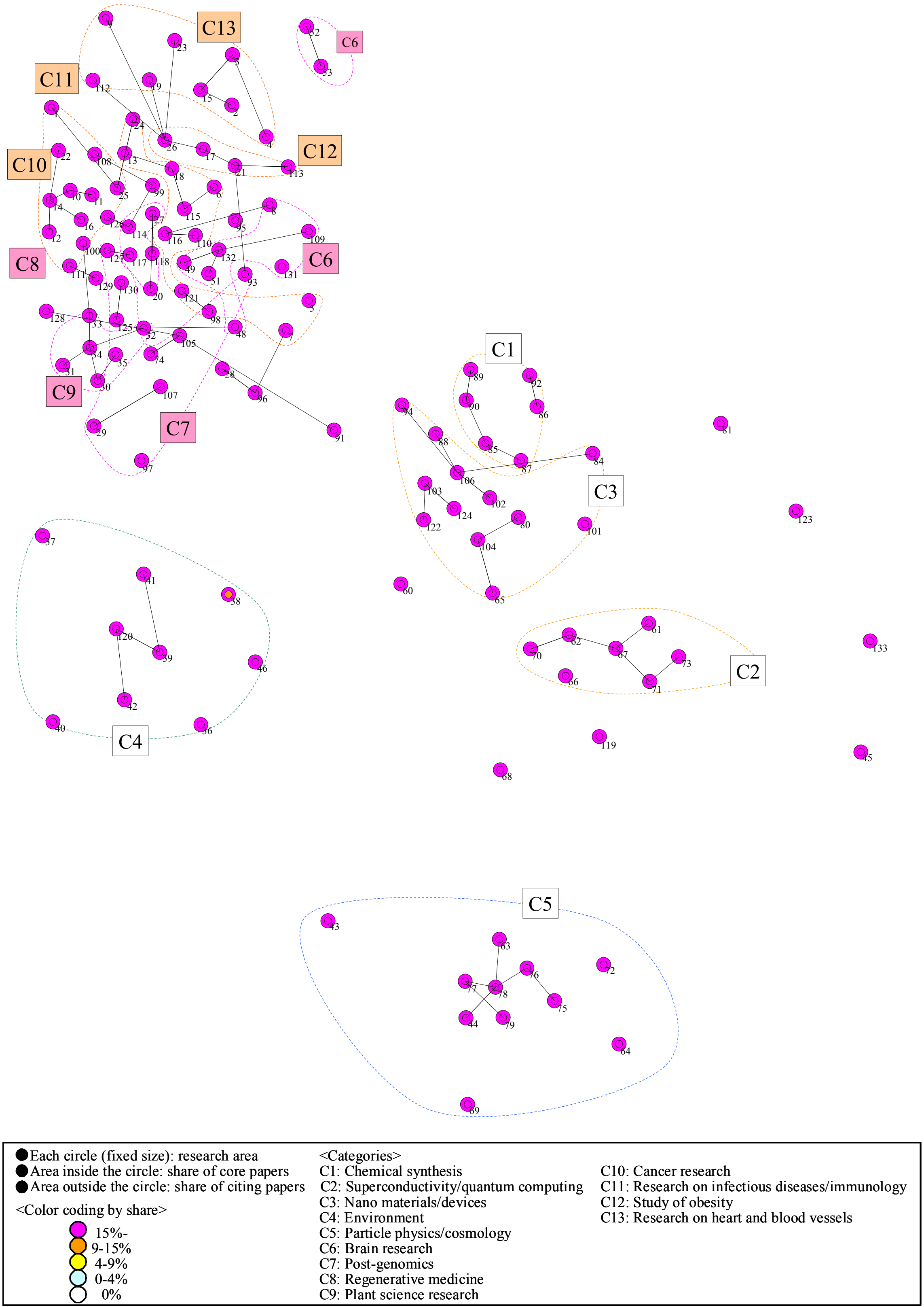
<Categories>

C1: Chemical synthesis
C2: Superconductivity/quantum computing
C3: Nano materials/devices
C4: Environment
C5: Particle physics/cosmology
C6: Brain research
C7: Post-genomics
C8: Regenerative medicine
C9: Plant science research
C10: Cancer research
C11: Research on infectious diseases/immunology
C12: Study of obesity
C13: Research on heart and blood vessels

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

Note: This map was developed excluding ID47, 50, 54-59, and 83 from the Correlation map.

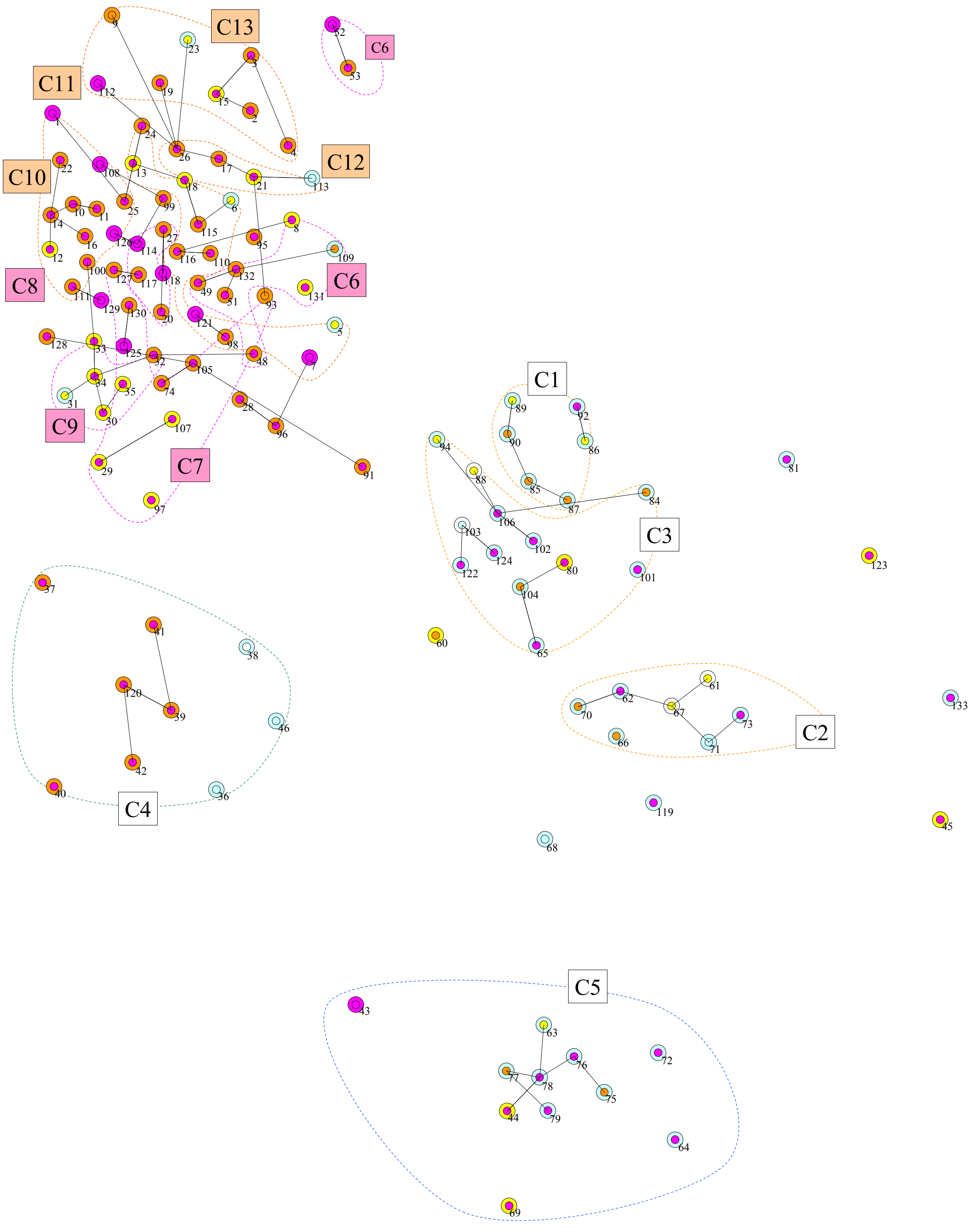
Figure 50: Correlation map (U.S.)



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: This map was developed excluding ID47, 50, 54-59, and 83 from the Correlation map.

Figure 51: Correlation map (U.S.: alternative version)



●Each circle (fixed size): research area
●Area inside the circle: share of core papers
●Area outside the circle: share of citing papers

<Color coding by share>
15%-
9-15%
4-9%
0-4%
0%

<Categories>
C1: Chemical synthesis
C2: Superconductivity/quantum computing
C3: Nano materials/devices
C4: Environment
C5: Particle physics/cosmology
C6: Brain research
C7: Post-genomics
C8: Regenerative medicine
C9: Plant science research
C10: Cancer research
C11: Research on infectious diseases/immunology
C12: Study of obesity
C13: Research on heart and blood vessels

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: This map was developed excluding ID47, 50, 54-59, and 83 from the Correlation map.

(5) Portfolio analysis using Correlation map

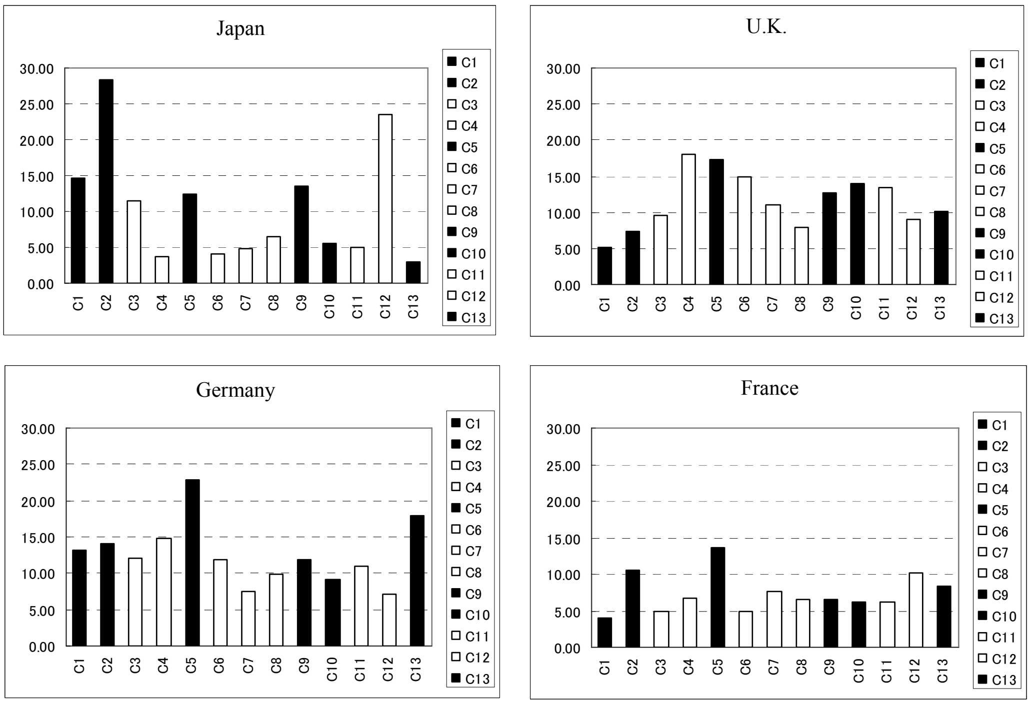
Figure 52 shows the average of share of core papers of different countries in each category. Figure 53 contains the graphs of Japan, the U.K., Germany and France. It is found that there is a variation in the share of core papers in Japan. When taking into consideration the categorical characteristics described in 3-3(1), it is clear that there is a mixture of strengths and weaknesses in the categories strongly influenced by a single field (in black) and in the categories influenced by multiple fields with an inter/multi-disciplinary character (in white). It was mentioned, as Figure 25 showed, that Japan was performing well in inter/multi-disciplinary areas. However, looking at the performance by category, there is a difference in the share of core papers within the inter-disciplinary categories. On the other hand, there is a characteristic that the variation in the share of core papers among categories is small in the U.K., Germany and France.

Table 52: Average share of core papers in each category for each country

Category number	Category name		Japan	U.K.	Germany	France	China	South Korea	U.S.
C1	Nano technology/materials	Chemical synthesis	14.63	5.24	13.12	4.07	1.76	0.88	44.76
C2	Nano technology/materials	Superconductivity/quantum computing	28.42	7.45	14.03	10.54	1.47	3.29	48.96
C3	Nano technology/materials	Nano materials	11.53	9.50	12.03	5.00	4.56	4.49	49.72
C4	Environment		3.77	18.07	14.79	6.65	0.81	0.47	58.25
C5	Particle physics/cosmology		12.36	17.35	22.87	13.56	4.47	6.67	62.42
C6	Life sciences	Brain research	4.05	14.85	11.95	4.82	1.69	0.46	71.32
C7	Life sciences	Post-genomics	4.90	11.06	7.57	7.70	0.28	1.51	69.03
C8	Life sciences	Regenerative medicine	6.39	7.83	9.83	6.47	0.28	0.19	71.55
C9	Life sciences	Plant science research	13.45	12.63	11.84	6.50	1.97	3.44	57.62
C10	Healthcare	Cancer research	5.60	14.03	9.16	6.10	0.78	0.00	76.83
C11	Healthcare	Research on infectious diseases/immunology	4.97	13.52	10.96	6.23	5.24	0.03	68.70
C12	Healthcare	Study of obesity	23.59	9.09	7.08	10.10	0.06	3.13	60.14
C13	Healthcare	Research on heart and blood vessels	2.91	10.15	17.87	8.41	1.49	0.50	61.49

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

Figure 53: Average share of core papers in each category (Japan, U.K., Germany, France)



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.
Note: Colored bars indicate the categories strongly influenced by single-type fields and white bars indicate the categories influenced by multiple-type fields with inter-/multi-disciplinary character.

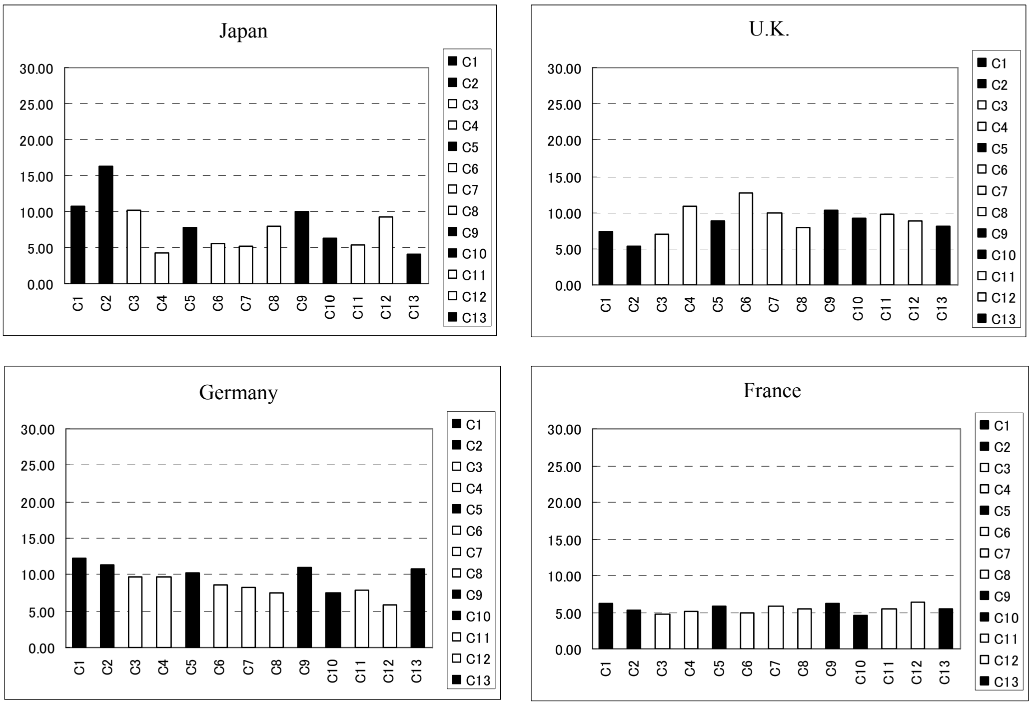
Next, Figure 54 shows the average share of citing papers of different countries in each area. With respect to citing papers, the share of the U.S. is not as outstanding as that shown by the data in Figure 42. On the other hand, as is clear from the comparison with Figure 52, China has a growing share of citing papers. Figure 55 shows graphs of Japan, the U.K., Germany and France. There is a characteristic that Japan has a wide variation in the share of citing papers among categories. Such variation is not found in the U.K., Germany or France. It is observed that there is a mixture of strengths and weaknesses in the categories strongly influenced by a single field (in black) and in the categories influenced by multiple fields with an inter/multi-disciplinary nature (in white). In other words, we have found that in the RAs, which are the subject of this analysis, Japan has a variation in the number of researchers involved, whereas other countries, such as the U.K., have a certain size of research units in each RA.

Table 54: Average share of citing papers in each category for each country

Category number	Category name		Japan	U.K.	Germany	France	China	South Korea	U.S.
C1	Nano technology/materials	Chemical synthesis	10.77	7.29	12.18	6.17	7.66	2.27	26.25
C2	Nano technology/materials	Superconductivity/quantum computing	16.38	5.28	11.41	5.21	6.75	3.42	23.76
C3	Nano technology/materials	Nano materials	10.18	6.96	9.67	4.81	11.33	4.36	27.25
C4	Environment		4.19	10.86	9.74	5.14	1.98	0.62	37.42
C5	Particle physics/cosmology		7.79	8.79	10.26	5.87	2.99	2.22	31.83
C6	Life sciences	Brain research	5.54	12.62	8.54	4.89	1.70	0.63	42.92
C7	Life sciences	Post-genomics	5.27	9.94	8.22	5.90	1.93	1.01	44.58
C8	Life sciences	Regenerative medicine	7.94	7.91	7.45	5.39	1.35	1.37	48.59
C9	Life sciences	Plant science research	9.95	10.71	10.92	6.20	3.01	1.59	37.51
C10	Healthcare	Cancer research	6.26	9.18	7.47	4.56	0.93	1.04	47.97
C11	Healthcare	Research on infectious diseases/immunology	5.30	9.79	7.86	5.40	3.78	0.55	42.04
C12	Healthcare	Study of obesity	9.33	8.83	5.91	6.29	1.09	0.94	38.80
C13	Healthcare	Research on heart and blood vessels	4.04	8.10	10.82	5.42	0.84	0.59	42.82

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Figure 55: Average share of citing papers in each category for each country (Japan, U.K., Germany, France)



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.
Note: Colored bars indicate the categories strongly influenced by single-type fields and white bars indicate the categories influenced by multiple-type fields with inter-/multi-disciplinary character.

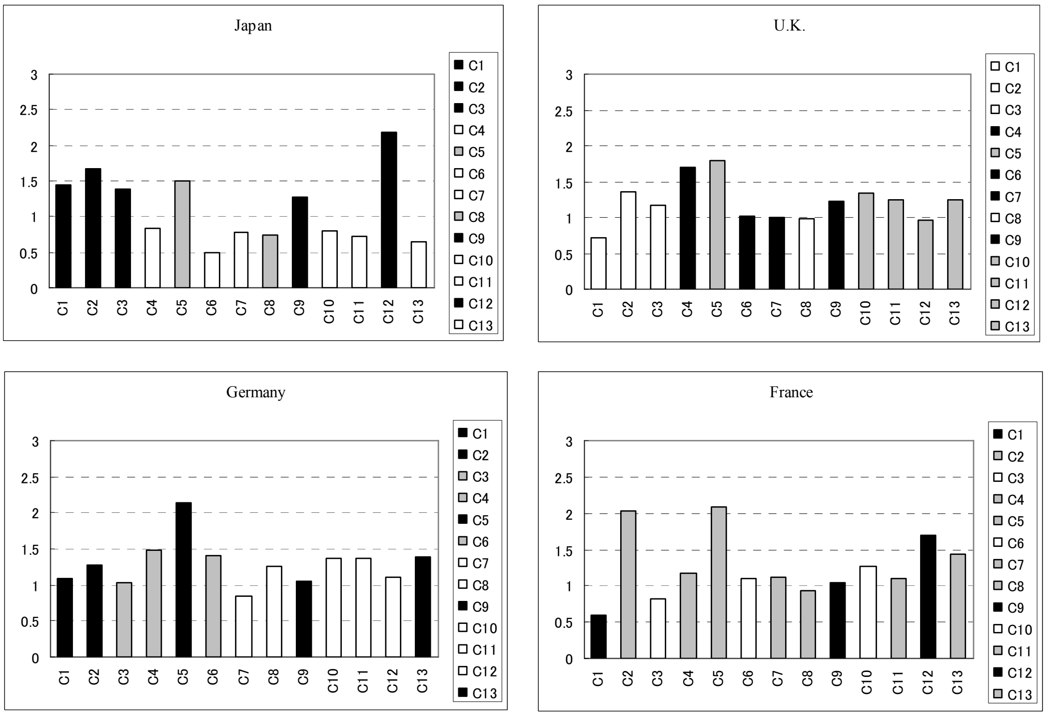
In Figure 56, we calculated the ratio of the average of core papers to that of citing papers in each category for different countries. Table 57 shows the graphs of Japan, the U.K., Germany and France. Most of the categories in the U.K., Germany and France exceed 1, whereas in Japan there is a wide variety with about half of the categories not exceeding 1. In order to examine the relationship between the number of researchers associated with a given category and that of core papers and top notch researchers, black is used where the number of researchers is relatively large in each country, white where it is relatively small, and gray where it is within an average range. In Japan, there is a correlation that if the number of top notch researchers is large, the number of researchers around them is also large. No such characteristic is found in the U.K., Germany or France.

Table 56: Ratio of the average of core papers to that of citing papers in each category for each country

Category number	Category name		Japan	U.K.	Germany	France	China	South Korea	U.S.
C1	Nano technology/materials	Chemical synthesis	1.45	0.72	1.08	0.60	0.24	0.37	1.71
C2	Nano technology/materials	Superconductivity/quantum computing	1.67	1.35	1.28	2.03	0.19	0.58	2.06
C3	Nano technology/materials	Nano materials	1.38	1.16	1.04	0.83	0.33	0.84	1.81
C4	Environment		0.83	1.70	1.48	1.18	0.29	-	1.47
C5	Particle physics/cosmology		1.49	1.79	2.14	2.09	1.12	-	2.04
C6	Life sciences	Brain research	0.49	1.02	1.40	1.09	0.56	0.34	1.67
C7	Life sciences	Post-genomics	0.77	1.00	0.84	1.12	0.14	1.14	1.58
C8	Life sciences	Regenerative medicine	0.74	0.98	1.25	0.93	0.16	0.12	1.49
C9	Life sciences	Plant science research	1.28	1.23	1.04	1.03	0.63	1.93	1.54
C10	Healthcare	Cancer research	0.80	1.34	1.37	1.27	1.29	0.00	1.60
C11	Healthcare	Research on infectious diseases/immunology	0.73	1.24	1.37	1.10	1.24	0.03	1.63
C12	Healthcare	Study of obesity	2.18	0.96	1.11	1.70	0.09	1.98	1.50
C13	Healthcare	Research on heart and blood vessels	0.65	1.24	1.38	1.43	2.13	-	1.44

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.
Note: The average value, by category, is calculated based on the numeric value obtained by dividing the share of core papers by the share of citing papers. The "hyphen" in the Table denotes that calculation was not possible due to a 0% share of citing papers.

Figure 57: Ratio of the average of core papers to that of citing papers in each category in each country (Japan, U.K., Germany, France)



Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.
Note: If the share of citing papers in each category in each country is larger by more than 10% of the average share of citing papers, it is expressed in black, and if it is smaller by more than 10%, it is expressed in white. When it is within ±10% of the average, it is expressed in gray.

4. Time-series analysis of Research Areas

As seen in the previous sections, with categorization of papers through co-citation analysis, it is possible to have a holistic view of RAs beyond traditional disciplines and understand scientific activities in RAs of different countries. The results introduced thus far are those at one point of time based on the 2004 database (six years from 1999 to 2004). This method allows the predicting of what sort of valuable RAs will emerge by integration of traditional disciplines (see 3-3).

This study shared information with OECD to comprehensively understand science focusing on basic research in addition to rapidly-developing RAs extracted in the previous study and re-designed methodology to use the information as science and technology indicators for international research trends.

With these situations in mind, the result of the pilot time-series study of the databases of 2002 and 2004 on comparable RAs is introduced here for reference purposes. It will be possible to perform this time-series analysis from the next study onwards.

4-1 Analysis database

In the time-series analysis, 133 RAs obtained from the 2004 database of this study were compared to 153 RAs, including two rapidly-developing RFs, obtained from the 2002 database of the previous study (Figure 58).

Please refer to the Study on Rapidly-Developing Research Areas (NISTEP REPORT No.95) for the 2002 database.

Table 58: Outline of database

(2004 dataset: this study)

Version of the database	Updated data of March 1, 2005
Publication date of papers used for the establishment of RAs	January 1999 – December 2004
Total number of RFs	5350 fronts
Number of core papers which constitute RFs	21411 papers

(2002 dataset: present study)

Version of the database	Updated data of March 1, 2003
Publication date of papers used for the establishment of RAs	January 1997 – December 2002
Total number of RFs	5221 fronts
Number of core papers which constitute RFs	21183 papers

4-2 Patterns of change in Research Areas

A time-series analysis is made on two separate aspects: (1) change in the overall RAs and (2) change in individual RAs.

(1) Changes in the overall Research Areas

In order to understand the change in the overall 133 RAs of this study by making comparisons with the database of the previous study (2002), examination was made using the databases of 2002 and 2004 to see if there were any RAs with common core papers. Among the 153 RAs obtained from the 2002 database, 61 RAs had no common papers with the 2004 database and 92 had common papers. Four items (average number of core papers, average number of RFs, average number of rapidly increasing fronts, and average rate of increase in citations) are listed in Figure 59, showing that the RAs with common papers with the 2004 database have a higher average number of core papers, a higher average number of RFs, and a higher average number of rapidly increasing fronts. From this, it is suggested that the RAs with a certain size containing high-profile RFs with a rapidly increasing number of citations achieve sustainable development.

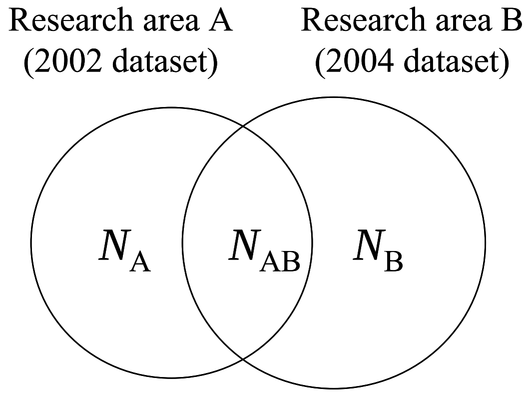
Table 59: Details of 153 RAs extracted from the 2002 database

		Number of research areas	Average number of core papers	Average number of research fronts	Average number of rapidly increasing fronts	Average rate of rapidly increasing fronts
153 research areas extracted in 2002 dataset	All research areas	153	66.7	14.3	3.7	38%
	Research areas with no common papers with the 2004 database	61	20.8	6.0	2.4	53%
	Research areas with common papers with the 2004 database	92	97.1	19.8	4.6	28%

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on “Essential Science Indicators” of Thomson Scientific.

Next, commonality analysis of core papers was conducted in order to clarify the relations between 92 RAs (2002 dataset) having common papers with the 2004 database and 133 RAs obtained from the 2004 database. Figure 60 is a graphic image of a comparison of N_{A}, N_{B}, N_{AB} between two RAs (A and B).

Figure 60: Comparison of RAs



Commonality was assessed by the following formula denoting the number of core papers in RA A by N_A, the number of core papers in RA B by N_B, and the number of core papers appearing in both RAs A and B by N_{AB}. For the purpose of analysis in this study, the threshold of commonality between RAs A and B was experimentally set at 0.2.

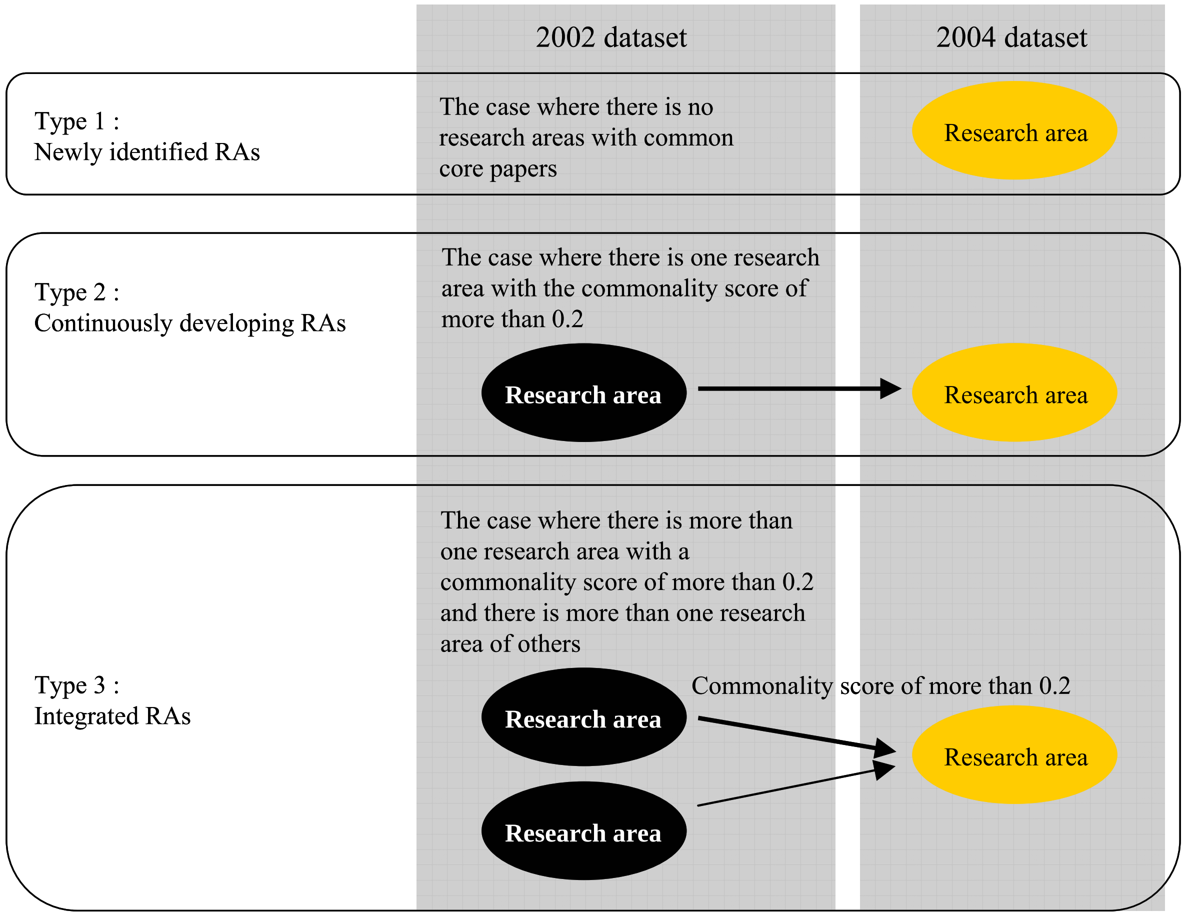
$$N_{common} = N_{AB} / \left(\sqrt{N_A}\sqrt{N_B}\right)$$

Commonality in 63 RAs of the 2004 database was identified, exceeding the threshold value (0.2). This commonality has two patterns (see Figure 61).

When one RA of the 2002 database shares a commonality of over 0.2 with a RA of the 2004 database, it is categorized under Type 2 (Continuously developing RAs). There are 45 RAs categorized under Type 2. When more than one RA of the 2002 database shares the commonality (0.2 or over) with a RA of the 2004 database and when there is more than one RA with the commonality value of less than 0.2, it is categorized under Type 3: an integrated RA. There are 18 RAs in Type 3.

Thirty-two RAs obtained from the 2004 database do not overlap with those of 2002 (Type 1: newly identified RAs) (see Figure 61). Analysis was not conducted on the 38 RAs which do not belong to any types (Types 1-3).

Figure 61: Patterns of RAs



Four items (average number of core papers, average number of RFs, average number of rapidly increasing fronts, and average rate of increase in citations) for Types 1-3 are listed in Figure 62, showing that the RAs in Type 1 have the lowest average number of core papers, whereas the RAs identified as Type 3 have the highest average number of core papers. This indicates that the scale of RAs changes depending of the situation regarding the RAs. Details of Types 1-3 are described below.

Table 62: Details of 133 RAs extracted from the 2004 database

		Number of research areas	Average number of core papers	Average number of research fronts	Average number of rapidly increasing fronts	Average rate of rapidly increasing fronts
133 research areas extracted in 2004 dataset	All research areas	133	79.0	16.5	3.8	22%
	Research areas newly extracted in 2004 dataset (Type 1)	32	40.6	8.6	2.2	24%
	Research areas continuing from a single area of the 2002 database (Type 2)	45	65.8	14.0	3.0	20%
	Research areas as integration of several research areas of the 2002 database (Type 3)	18	203.3	41.0	9.0	21%

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

- **Type 1: Newly integrated RAs**

RAs that had not been established as a RA in the 2002 database but newly extracted in the 2004 database were named "Newly identified RAs". Among the 133 RAs obtained from the 2004 database, more than 20%, *i.e.* 32 RAs were newly identified. These areas are listed in Table 63. RA ID5 targets the occurrence of SARS or avian influenza which shook the world in 2003. That fact that this has grown to form a RA in the 2004 database indicates its rapid development. Thus, by using this method, it is possible to understand high profile RAs established in the past year or two. Among these RAs, 16 RAs have the average core paper share of 9% or over in Japan.

When compared with the map of relations with traditional disciplines, more than 30% of the 32 newly identified RAs have an inter/multi-disciplinary character.

Table 63: List of 32 newly identified RAs

Research area ID	Name of research areas	Research area ID	Name of research areas
1	Research on medical examination of colorectal cancer	80	Formation of nanostructures based on block copolymers
2	Clinical treatment of severe sepsis and septic shock	81	Research on plastic deformation in nano-crystals
5	Research on SARS and avian influenza	82	Application of cryptographic technologies to digital information distribution
6	Research on allergy therapy	84	Catalytic activity of gold clusters
13	Research on osteoclastic mechanism	89	Catalytic asymmetric synthesis
18	Autoimmune disease	95	Signal conduction of the lysophospholipids receptors
19	Prevention of post-coronary angioplasty restenosis with drug-eluting stents	100	Hypoxia-inducible factor and tumorigenesis
41	Research on paleoclimate	103	High-efficiency dye-sensitised solar cell
47	Brain function imaging of cognitive psychological phenomena	112	Intake of soy- and plant-derived estrogen/isoflavone and its effects on age-associated diseases
50	Visual stimulation and oscillatory brain activities	113	Ghrelin; its mechanism of action
59	Research on venture capital	115	Genetic diagnosis and therapy of Crohn's disease
60	Stability and vitrification of supercooled liquid	119	Development and application of proton-exchange membrane fuel cells
64	Baryon consisting of five quarks	125	Development of statistics method for microarray data analysis
65	Photonic crystal and devices	128	Nucleocytoplasmic traffic and cell function
69	Relativistic astronomy and gravity waves	129	Mechanism of control of life-span
75	Super string theory and spatiotemporal physics	133	Research on nitride compound semiconductor

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: RA IDs are colored according to the Japanese core papers as described below.

15%～ 9%～15% 4%～9% 0%～4% 0%

- **Type 2: Continuously developing RAs**

Forty-five RAs of the 2004 database have continued their research activities from 2002 and have a commonality value of 0.2 or over (Table 64). For example, it is shown that "Cardiac resynchronization therapy for intractable heart failure (ID 3)" in 2004 database is a continuation of "Research on the prevention of sudden death from fatal arrhythmia (ID 7)" in 2002 database. Among these RAs, 14 RAs have the average core paper share of 9% or over in Japan.

When compared with the map of relations with traditional disciplines, more than 10% of the 45 RAs with continuing development have an inter/multi-disciplinary character.

Table 64: List of 45 continuously developing RAs

ID	Name of research area	ID (2002 dataset)	Name of research area
3	Cardiac resynchronization therapy for intractable heart failure	7	Study on lethal arrhythmia and the prevention of sudden death caused by it
4	Diversity of arrhythmia-related genes	7	Study on lethal arrhythmia and the prevention of sudden death caused by it
7	Research on countermeasures to bioterrorism	6	Bioterrorism research on smallpox & anthrax
8	Therapy of multiple sclerosis	140	Development of multiple sclerosis diagnosis/treatment methods
9	Development of imaging techniques for cardiovascular system	15	Development of diagnostic imaging technique for circulatory disease & its clinical use
12	Research on diseases for which Rituxan is effective	11	Antibody treatment of lymphoma
14	Research on cancer therapy	5	Study on molecular-targeted cancer drugs
21	Molecular mechanism of adipocytokines and the onset of metabolic syndrome	117	Adipocyte hormones
23	Research on venous thromboembolism therapy	24	Anticoagulant medications in surgery
24	Clinical research on COX-2 inhibitor as anti-inflammatory drug	2	Study on Cyclooxygenase-2 inhibitors
28	Structures and functions of G-protein-coupled receptor	102	Study on G-protein-coupled receptor structure and function
30	Plant genome research	53	Plant genome research
31	Functional analysis on abscisic acid, a plant hormone	50	Functional analysis on the plant hormone, abscisic acid
32	Dynamics and regulation of cytoskeleton	48	Plant cell function control
33	Analysis of mechanism of regulation of plant growth	52	Functional analysis on the plant hormone, auxin
35	Study of biological clock	47	Biological clock research
36	Environment pollution and risk of persistent organic halide pollutants	58	Environmental pollution and risks caused by persistent organic halides
37	Study on biodiversity in plants	61	Plant diversity mechanism and function
38	Aquatic pollution by toxic chemical compounds	59	Environmental pollution and biological effects caused by new chemicals
39	Carbon cycle in south Pacific Ocean	62	Limitation to biological activity from biogeochemical factors of elements in the ocean
40	North Atlantic Oscillation and climate change	63	Research on global climate change
42	Effects of aerosol and air pollutant on climate and atmospheric circulation model	64	Climate change and atmospheric aerosols
44	Large-scale structure of the universe	99	The mechanism and evolution of the universe
46	Research on spectroanalysis	77	Trace element analysis of environmental and biological materials
48	Glutamate receptors in plasticity brain	115	(1) glutamine receptor, (2) inhibition of cancer growth
51	Mechanism of molecules involved in formation of brain	68	Molecules associated with cerebral neocortex development and neurodegeneration
54	Law and behavioral science	73	Behavioral analysis in law and economics
57	Study on local economy and regional integration	74	Regional economic development and networks
58	Research on corporate governance	73	Behavioral analysis in law and economics
61	Physical attributes and material process of MgB2	94	Metallic superconductors and heavy fermion superconductors
68	Basic and applied research on ultra-short-pulse laser	96	Study on specific optical phenomena
72	Quantum chromodynamics	88	Exploration of high-temperature, high-density substances by heavy ion collisions
83	Research on modulation schemes for ultra-wideband communications	76	Wireless communications technology
85	Dendrimer research	36	Dendrimers
86	High performance catalysis for olefin polymerization	29	Enzyme/complex catalysis
87	Research on living free-radical polymerization	32	Living radical polymerization
91	Chemical-/bio-system with microchips	35	Devices for Bioanalysis
93	Drug discovery research	110	Influenza research
94	Detection of negative ions by chemical methods	39	Molecular devices/molecular machines
101	Nanocomposites consisting of inorganic nano materials and organic polymers	109	Clay mineral nanocomposites
102	Basic and applied research on carbon nanotubes	144	Carbon nanotubes
104	Synthesis of nano-structures form microstructure with microparticles and polymers	132	Mesoporous materials and nanowires
107	Genome analyses of Helicobacter pylori and Mycobacterium tuberculosis	136	Genome analysis of pathogenic microbes
123	High-dielectric gate insulating technology for semiconductor integrated circuits	146	High-dielectric constant gate insulators
124	Research on high efficiency organic LED	148	Study on polymeric light-emitting devices

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: RA IDs of the 2004 database are colored according to the Japanese core papers in the same way as Table 63.

- **Type 3: Integrated RAs**

The areas established by integration of some of the 133 RAs obtained from 2004 and some of the 153 developing RAs extracted from the 2002 database are identified as integrated RAs. In the 18 RAs shown in Table 65, RAs are formed by integration of more than two developing areas. For example, the RA ID 15 of the 2004 database is an integration of ID 4 and ID 18(*) of the 2002 database. When a RA ID of the 2002 database is marked with (*), it shows that the commonality value with the corresponding the 2004 database is 0.2 or over. In this case, the commonality value between the RA ID15 of the 2004 database and the RA ID 18(*) of the 2002 database is over 0.2. Among these RAs, 7 RAs have the average core paper share of 9% or over in Japan.

When compared with the map of relations with traditional disciplines, more than 30% of the 18 integrated RAs have an inter/multi-disciplinary character.

Table 65: List of 18 integrated RAs

ID	Name of research area	ID (2002 dataset)	2002 dataset: Name of research area
15	Clinical trial of therapeutic agent for cardiovascular disease	4	Study on Hypertension disease
		18 (*)	Relation between renal disorders and cardiac disease
25	Effects of COX-2 inhibitor against cancer	2	Study on Cyclooxygenase-2 inhibitors
		13 (*)	Study on the treatment of functional gastrointestinal disorders and gastro-esophageal reflux disease
26	Signal transducing molecules associated with lifestyle-related diseases	1	Study on acute coronary syndromes
		14	Hormone therapy
		114 (*)	Study on peroxisome proliferactor activated receptor
27	Stem cell therapy on nervous, hematopoietic, and cardiovascular system	14	Hormone therapy
		118 (*)	Study on regeneration from stem calls
34	Stress response in plants	48	Plant cell function control
		50	Functional Analysis on the plant hormone, abscisic acid
		51 (*)	Research in molecular plant biology using Arabidopsis thaliana
		52	Functional Analysis on the plant hormone, auxin
63	Noncommutative field theory and super string theory	92 (*)	Non-commutative space/structural string theory
		97	Non-commutative field theory/branes with background fields
70	Quantum electronics and its application to quantum information processing	93 (*)	Quantum computing
		96	Study on specific optical phenomena
73	Bi-based high-temperature superconductors	90 (*)	High-temperature superconducting oxides
		91	Study on the physical properties of perovskite manganites
77	Neutrino oscillation and creation of material universe	87 (*)	Neutrino research
		89	Particle cosmology based on string theory
78	Cosmic microwave background fluctuation and inflationary cosmology	89 (*)	Particle cosmology based on string theory
		99	The mechanism and evolution of the universe
88	Metal-organic hybrid porous materials	28	Self-organization
		30 (*)	Inorganic/organic hybrid materials
90	Organic synthesis and its application to a sustainable society	31 (*)	Ionic liquids
		33 (*)	Synthetic organic reaction based on high-efficiency carbon-carbon bond formation reaction
		38	Microwave-assisted organic synthesis
96	Water and iron transport mechanism in organism	103 (*)	Cell membrane channels
		152	Carbon fixation by forest and other terrestrial ecosystems
105	Research on proteome	35	Devices for Bioanalysis
		108 (*)	Proteomics
		150	Study on the isoprenoid biosynthesis pathway in Plasmodium
117	Research on molecular mechanism in apoptosis	46 (*)	DNA methylation
		100	Function of the nerve terminal protein regulating neurotransmitter release
		116 (*)	Molecular mechanism of apoptosis
130	Research on epigenetic transcriptional regulation	46	DNA methylation
		119	Gene expression analysis based on DNA microarrays
		138 (*)	RNAi (RNA interference)
131	TRP channel and cellular senses	69	Neurotic desorders, stress-related disorders, and somatoform disorders
		141 (*)	Integration system for nociception and physiological function of the vanilloid receptor
132	Research on Alzheimer's disease and Parkinson's disease	68	Molecules associated with cerebral neocortex development and neurodegeneration
		139 (*)	Study on neurodegenerative disease

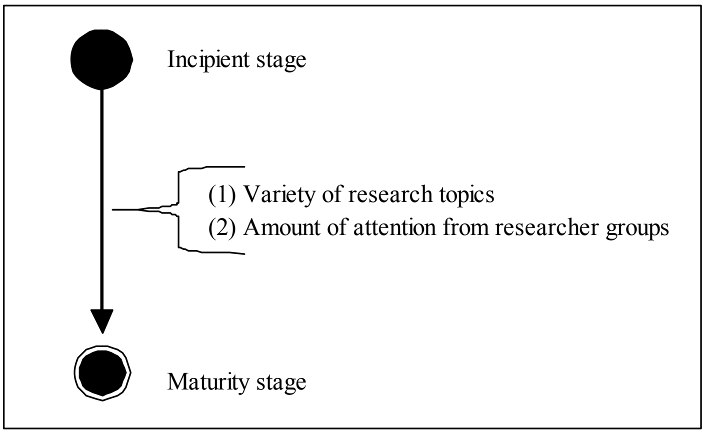
Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: When RAs of the 2002 database are marked with (*), this denotes that the commonality with the corresponding RAs of the 2004 database is more than 0.2. RA IDs of the 2004 database are colored according to the Japanese core papers in the same way as Table 63.

(2) Changes in individual Research Areas

Changes in individual RAs are illustrated in Figure 66. The change starts when a research paper with a possibility of forming a RA is published: “incipient stage”. The RA makes progress as time goes by and finally reaches its “maturity stage”.

Figure 66: Image of changes in individual RAs



Two factors describe the condition of a RA: 1) the variety of research topics and 2) the amount of attention from researcher groups.

1) The variety of research topics is an indicator for the size of activities within a RA. As Figure 67(a) shows, the number of research topics increases as time goes by when various research activities are conducted, such as construction of new models and development of methods, etc. And from a certain point in time, the number decreases as consensus is being built among researcher groups. In other words, the activities in a RA expand at first and then reach a certain conclusion. This study enables us to quantify the amount of topics by the number of RFs.

2) The amount of attention from researcher groups also increases and decreases along with the time line as shown in Figure 67(b). In other words, an increase in the amount of attention from researcher groups is activated at first until it reaches a certain equilibrium and becomes stabilized. This study enables us to quantify the amount of attention from researcher groups by the ratio of rapidly-increasing fronts (see p** for rapidly-increasing fronts).

It must be noted, however, that the magnitude of change and the time required for the change may vary in the RAs of Figure 67(a) and (b).

Figure 67: Two axes indicating the conditions of RAs (absolute value)

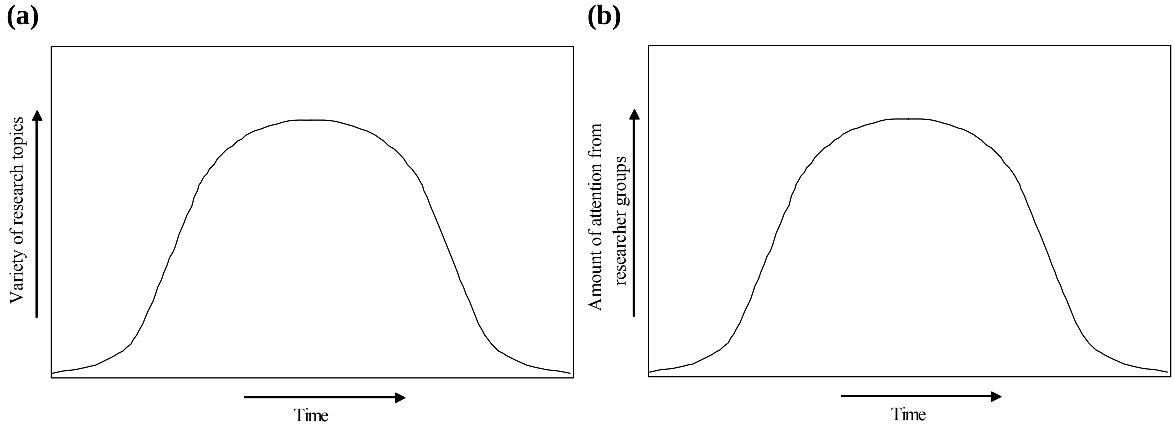


Figure 67 shows the absolute value for each axis, and a similar change curve is believed to be obtained in the rate of changes on each axis in Figure 68. It must be noted, however, that the magnitude of the rate of change and the time required for the rate change of Figure 68 (a) and (b) may also vary. Therefore, the conditions of the RAs illustrated by the combination of Figure 68 (a) and Figure 68 (b) become complex.

Figure 68: Two axes indicating the conditions of RAs (rate of change)

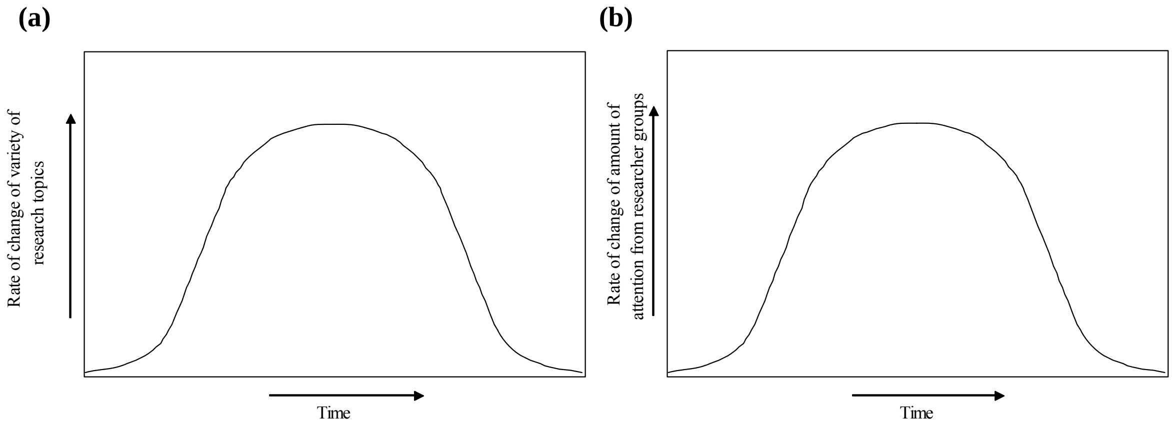


Figure 69 shows the result of categorization of 45 RAs (Type 2) by the change in the number of RFs and the ratio of rapidly increasing fronts in comparison with the 2002 database. The number of RAs with a decreasing number of RFs is notably larger than that of an increasing number of RFs. Also, with respect to the change in the ratio of rapidly increasing fronts, the number is decreasing in about two-thirds of the RAs. Therefore, when a RA is showing a continuous development, a variety of research topics tends to converge and the attention of researcher groups tends to be stabilized.

Figure 70 shows the result of categorization of 18 integrated RAs (Type 3) by the change in the number of RFs and the rate of rapidly increasing fronts in comparison with the 2002 database. The number of RAs with an increasing number of RFs is notably larger than those with a decreasing number of RFs. The change in the ratio of rapidly increasing fronts does not show a great deal of difference. Therefore, when RAs are integrated, the variety of research topics tends to expand, while an increase in the amount of attention from researcher groups is activated in some cases and stabilized in others.

When the characteristics of RAs with continuing development RAs (Type 2) and integrated RAs (Type 3) are incorporated in Figure 68, we obtain Figure 71.

Table 69: Conditions of 45 continuously developing RAs (Type 2)

		(1) Variety of research topics (Number of research fronts)			
		Decline (tailing off)	No change	Increase (expansion)	Total
(2) Amount of attention from researcher groups (Rate of rapidly increasing fronts)	Increase (activated)	9	0	4	13
	No change	4	0	1	5
	Decline (stabilized)	17	2	8	27
	Total	30	2	13	45

Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: For categorization of research topics (item 1) above), the rate of change was obtained from the number of RFs in 2002. When the rate is smaller than -10%, it is categorized as a "decline". When the rate is within+/-10%, it is categorized as "no change". When the rate is larger than 10%, it is categorized as an "increase". For categorization of the amount of attention from researcher groups (item 2) above), the rate of change was calculated from the ratio of rapidly increasing fronts in 2002, When the rate is smaller than -10%, it is categorized as a "decline". When the rate is within+/-10%, it is categorized as an "no change". When the rate is larger than 10%, it is categorized as an "increase".

Table 70: Conditions of 18 integrated RAs (Type 3)

		(1) Variety of research topics (Number of research fronts)			
		Decline (tailing off)	No change	Increase (expansion)	Total
(2) Amount of attention from researcher groups (Rate of rapidly increasing fronts)	Increase (activated)	3	0	3	6
	No change	0	0	3	3
	Decline (stabilized)	2	0	7	9
	Total	5	0	13	18

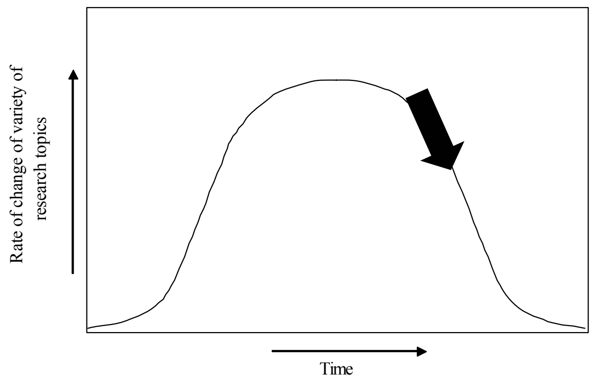
Data: Obtained by the National Institute of Science and Technology Policy (NISTEP) based on "Essential Science Indicators" of Thomson Scientific.

Note: For categorization of research topics (item 1) above), the rate of change was obtained from the number of RFs in 2002. When the rate is smaller than -10%, it is categorized as a "decline". When the rate is within+/-10%, it is categorized as "no change". When the rate is larger than 10%, it is categorized as an "increase". For categorization of the amount of attention from researcher groups (item 2) above), the rate of change was calculated from the ratio of rapidly increasing fronts in 2002, When the rate is smaller than -10%, it is categorized as a "decline". When the rate is within+/-10%, it is categorized as an "no change". When the rate is larger than 10%, it is categorized as an "increase".

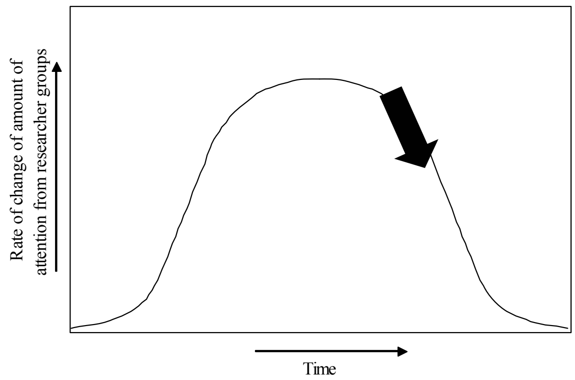
Figure 71: Conditions of RAs

[Type 2: Continuously developing RAs]

(a)

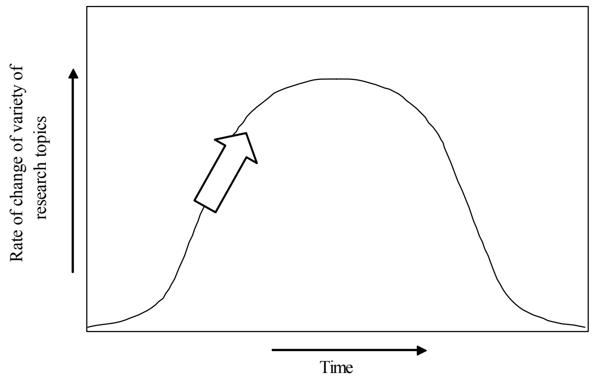


(b)



[Type 3: Integrated RAs]

(a)



(b)

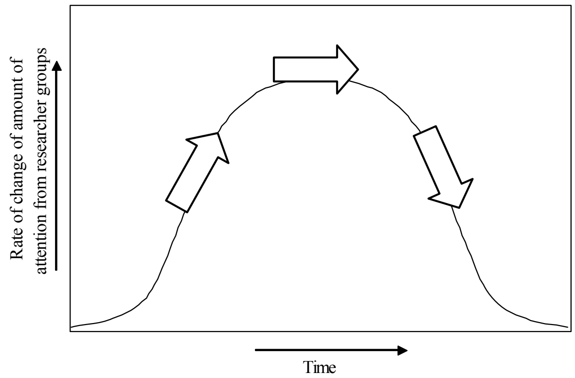


Figure 72: Changes in RAs

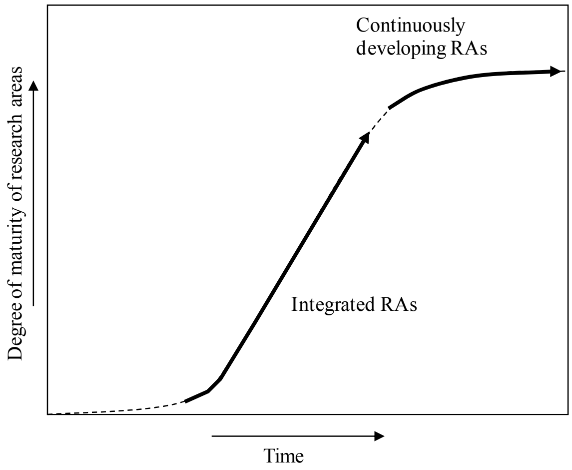


Figure 72 is the model illustration of RAs expressed by the synthesis of arrows of Figure 71. It is fair to say that the RAs with continuous development are stabilized in the process from “incipient stage” to “maturity stage” illustrated in Figure 66 (in short, it is expressed by the degree of maturity of a RA). In the integrated RAs (although it depends of the amount of attention from researcher groups), changes may be in place even at the maturity stage, due to the increasing variety of research topics. When these two situations are considered, it is suggested that RAs go through changes, which produces the S-shaped curve.

In the future, it will be possible to depict the changes in RAs in detail by quantitatively evaluating the situations regarding RAs and by combining time-series analysis.

5 Summary

In this study, we examined the trends of science focusing on basic science at the level of RAs (RAs) by bibliometric analysis. We developed Science Maps (Individual RA map, Map of relations with traditional disciplines, and Correlation map). In addition, we attempted to understand the current science activities in Japan through the analysis of Japan's presence in RAs.

Understanding of RAs requires not only advanced and specialized knowledge, but also a bird's eye view of the overall RAs, beyond the boundaries of traditional disciplines. Therefore, we re-examined the method of bibliometric analysis to take a holistic and objective view of the RAs. This study found that the characteristics of this method can be summarized into the following three points:

- **A holistic analysis of the overall RAs, without being confined to traditional disciplines**
  Since the RAs are constructed using only co-citation relations, this enables an understanding of RAs from a holistic perspective, without being confined to traditional disciplines. We can also explore inter/multi-disciplinary areas.
- **An objective analysis of RAs based on statistical data**
  Analysis of the change in citation frequencies of core papers, which constitute RAs, enables an objective understanding of the evolution of RAs. Analysis of the percentage share of Japanese core papers and citing papers enables the analysis of the presence of Japan in RAs.
- **Continuous analysis using the same method is effective**
  The RAs obtained in this study are transformed over time. It is possible to continue to understand newly emerging and ever developing scientific areas through continuation of this study.

5-1 Summary of results

(One hundred and thirty-three RAs obtained by bibliometric analysis)

The bibliometric analysis yielded 133 RAs. The distribution of 22 fields relating to the 133 RAs shows that 42 RAs are in *Life science*-related areas, such as clinical medicine and plant and animal science, among which about half, *i.e.* 27 RAs, are in clinical medicine. There are 37 RAs in physics, chemistry, engineering and materials science (physics/chemistry-related areas), 7 RAs are in *environment*/ecology and geosciences. Although small in number, some areas are in cosmology, social sciences and general.

About 30% of the 133 RAs, *i.e.* 39 RAs are found in the inter/multi-disciplinary areas. From this, it is found that a considerable number of RAs have an inter/multi-disciplinary character. It is also observed that the more rapidly a RA has been developing in recent years, the stronger the inter/multi-disciplinary character is.

Using co-citation relations among the 133 RAs obtained, we also developed a Correlation map, which shows the correlation among RAs, to provide a holistic understanding of current scientific activities. As a result of the mapping, it was found that the 133 RAs can be classified into 14 categories.

(Characteristics of research activities in Japan in each RA)

The percentage share of Japan's core papers, which constitute RAs, shows there are many areas with a more than 9%[1] share, such as physics, chemistry, plant/animal science and materials science, indicating the strong presence of Japan in these areas. On the other hand, only a small number of RAs in engineering, *environment*/ecology, and cosmology have shares exceeding 9%, indicating the limited presence of Japan.

[1] The share percentage of Japanese core papers of all the core papers that constitute 133 research areas is approximately 9%.

Furthermore, no presence of Japan was found in psychiatric medicine/psychology, social sciences/general and economics. More than 20% of the areas have no shares for Japan, a much greater percentage than the around 10% for the U.K. or Germany.

It was found in the Study on Rapidly-Developing RAs (NISTEP REPORT No.95) that Japan is not necessarily poor in the inter/multi-disciplinary areas and this is re-confirmed in this study. There are a number of RAs with 9% of core papers: for example, "Nanocomposites consisting of inorganic nanomaterials and organic polymers (ID101)", "High-efficiency organic thin-film solar cells (ID103)", "Signal conduction of lysophospholipid receptors (ID95)", "Cancer therapy with histone deacetylase (HDAC) inhibitors(ID111)", and "Ghrelin: its mechanism of action(ID113)".

(Characteristics of research activities of different countries in each RA)

In order to understand the characteristics of research activities among the high profile 133 RAs in Japan, the U.S., the U.K., Germany, France, China, Korea and India, we analyzed the relative balance of the portfolio of categories (*Nanotechnology/materials, particle physics/cosmology, environment, Life science, healthcare and Social sciences*) in each country.

Core papers are the papers ranked in the top 1% of highly cited papers and the components of RAs. Thus, the portfolio of core papers must reflect the situations of top notch researchers of different countries in the 133 RAs. The share of about 10000 core papers which constitute RAs is led by the U.S. at 61%, followed by 13% for Germany, 12% for the U.K., 9% for Japan, 7% for France, 3% for China, 2% for Korea, and 1% for India. *Nanotechnology/materials* accounts for about 40% of Japan's share, indicating its strong presence in Japan. *Life science* and *healthcare* make up about 20% each, and the sum of the shares of *particle physics/cosmology*, *environment* and *others* is about 20%. The share of *Life science* and *healthcare* in the U.S., Germany, U.K., and France is about 50%, suggesting an abundance of top-notch researchers in these countries. It is also evidenced that these countries maintain a certain level of share, compared to Japan. *Social sciences* occupy a certain presence in the U.S. and U.K. In Korea, *Nanotechnology/materials* and *particle physics/cosmology* are the main categories. The share of *healthcare* is large in China, exhibiting a similar domestic share to the U.S. In India, unlike other countries, the characteristic is that *particle physics/cosmology* is the major category.

Citing papers are those citing core papers, and their portfolios are thought to represent the breadth of researchers of different countries in 133 RAs, not just world-class researchers. Therefore, when portfolios of core papers and citing papers are compared, one can see the relationship between top-level researchers and the breadth of researchers of each country. The share by country of about 330,000 citing papers is 39% for the U.S., 9% for Germany, 9% for the U.K., 8% for Japan, 5% for France, 4% for China, 2% for Korea and 1% for India. There is no notable difference in the portfolios between core papers and citing papers in Japan, the U.S., Germany, the U.K., and France. This suggests that each country has a certain amount of researchers, and out of these produces a certain proportion of top-notch researchers.

On the other hand, there is a difference in the portfolios between core papers and citing papers in Korea, China and India, and citing papers on *Nanotechnology/materials* accounts for about 50%.

(Chronological change in RAs)

Since this study has redesigned the analysis method, a strict comparison with the previous study may not be possible. Still, time-series analysis was performed on the RAs. The overall 133 RAs extracted for this study were compared to the previous study (2002 database). As a result, 32 RAs (Type 1) were newly identified in this study, 45 RAs (Type 2) were identified as a continuation from the previous study, and 18 RAs (Type 3) were created as a result of integration. From this, it is found that frontline scientific research is not static in nature, but dynamically changing even within a short time period. In the newly identified RAs (Type 1), there are RAs involved in the occurrence of avian influenza and Severe Acute Respiratory Syndrome (SARS), which shook the world in 2003. It is found that this method enables the understanding of RAs which attract much attention and have rapidly developed in the past year or two.

RAs with continuing development (Type 2) and integrated RAs (Type 3) are compared with those of 2002 database, and categorized by the rate of change in the number of RFs and the ratio of rapidly increasing fronts. The following were found as a result. In 45 RAs (Type 2) the RFs number of decreasing RAs are prominently larger than those of increasing RAs. With respect to the ratio of rapidly increasing fronts, the ratio is decreasing in about two-thirds of RAs. As a conclusion, in RAs (Type 2), the variety of research topics that constitute the corresponding RAs tends to tail off and the amount of attention on research elements from researcher groups tends to be stabilized. On the other hand, in 18 RAs (Type 3), the number of increasing RFs is notably larger than that of decreasing RFs. With respect to the ratio of rapidly increasing fronts, some are increasing and some areas decreasing. In other words, in RAs (Type 3), the variety of research topics tends to expand, while the amount of attention on research elements from researcher groups tends to vary: for some an increase is activated and for some the amount is stabilized.

Furthermore, it is found to be possible to visualize the chronological change in individual RAs by comparing the maps of RAs. For example, in the “Research on countermeasures to bioterrorism (ID 7)”, the research has developed from that on bacteria to the research encompassing social aspects, such as practical emergency response measures.

In addition, from the time-series analysis of citing papers in each RA, we are able to describe the change in impacts of a given RA on other fields. For example, in the RA of the “Development of statistics methods for microarray data processing (ID 125)”, the majority of core papers are in the field of mathematics, but citing papers are found in 19 different fields, indicating this area is attracting a great deal of attention and used in many fields.

5-2 Political implications obtained from this study

The strategic implications obtained from this study are provided below.

In order to understand the evolution of science focusing on basic research, “hot RAs” were established in this study by bibliometric analysis. We then tried to understand the changes over time in these RAs. “Science Map” was developed to provide a bird’s eye view of current science. Using these data, we also tried to understand the relations between inter/multi-disciplinary areas and traditional disciplines.

The strategic implications obtained from this study are provided below.

(Significance of inter/multi-disciplinary areas)

As is evident from the fact that about 30% (39 RAs) of the 133 RAs are inter/multi-disciplinary areas, a considerable number of active RAs in recent years have an inter/multi-disciplinary character. The same result was found in the previous study (NISTEP REPORT No.95), though the method is different, and this tendency seems to continue. Since the traditional disciplines are effective and understandable for analysis, this classification is used in many analyses. The result of this study indicates that the RAs where more than 90% of the core papers belong to specific traditional disciplines are less than one third of all RAs. Furthermore, the more rapidly RAs are developing, the stronger the inter/multi-disciplinary character is. Therefore, it is required to be aware of the significance of inter/multi-disciplinary areas and to develop a system to encourage researchers to take part in these RAs. As an example of promoting the trying of new areas by researchers, various grant schemes for newcomers (the National Institutes of Health (NIH) K awards of NIH or the National Science Foundation (NSF) CAREER grant) are implemented in the United States.

Japan is often said to be weak in inter/multi-disciplinary areas. However, this study discovered that many inter/multi-disciplinary areas have a more than 9% share. The same result was found in the previous study, though the method is different, and this tendency seems to continue. Therefore, the policy to promote integration of fields is considered appropriate. It is assumed the outcomes of inter/multi-disciplinary RAs can raise the level of science as a whole.

(Significance of public research and development and public support in accordance with the development of RAs)

An overview of the RAs shows that there are three kinds of RAs: newly identified RAs (Type 1), continuously developing RAs (Type 2) and integrated RAs (Type 3), and some changes occur within a short period of time. It is also found that the situations within RAs are different between Type 2 and Type 3. Attention must be paid to these changing RAs, while giving consideration to the possible direction of developments in the future.

In the "Research on countermeasures to bioterrorism (ID 7)" the direction has been shifted from the research on bacteria to those incorporating clinical and social perspectives as to how to respond to real emergencies. The RA of the "Development of statistics methods for microarray data processing (ID 125)" has grown and had impacts on 19 fields. Particularly, it is observed that the changes in RAs occur extremely fast when *Life science-related* RAs are involved. Japan currently has little presence in these RAs. A program director, for example, of NSF of the United States has discretionary access to funds to support research programs, whereas the grant system is not sufficiently developed in Japan to swiftly respond to the changes made in RAs. Thus, discussions are warranted concerning the creation of such a system.

(Effectiveness of periodic monitoring of RAs using Science Map)

In this study, three types of Science Maps (Individual RA map, Relation map with traditional disciplines, and Correlation map) concerning RAs mainly in natural sciences were developed by bibliometric analysis and a new methodology was introduced to give a holistic understanding of these RAs. At the RA level, the activity trend of different countries exhibits different strengths.

The 3rd Science and Technology Basic Plan stipulates that a certain amount of resources shall be allocated to steadily promote basic research that would bring about diverse wisdom and innovation. Basic research includes the areas based on free ideas and the areas aiming for future applications in line with the policies. In terms of basic research promotion, the former is excluded from the principle of issue selection and resource concentration; however, the government needs to confirm steady progress in science through the monitoring of the research balance and the situations of inter/multi-disciplinary science. In other words, periodic observations by this method that describes the conditions of basic science in the recent past, targeting scientific papers, will be an effective benchmark for long-term policy for basic science, and in some cases, will be a good reference for reviewing the science policies. Nonetheless, it is necessary to pay special attention to the fact that there is a difference in scientific paper production activities of researchers even in basic science and this method alone does not necessarily enable a holistic capturing on scientific activities.

Results of content analysis of 133 Research Areas

The section starting from page 94 indicates the results of the content analysis of 133 research areas established through database analysis. Content analysis of research areas covers the following matters.

1) Names of research areas (Name of RA)

Names that accurately describe the contents of research areas are given.

2) Statistical information on research area

The numerical data of the following items are indicated:

- the number of research fronts which constitute a research area (# of RFs)
- the number of such research fronts where the number of citations is rapidly increasing (# of Hot RFs)
- the number of core papers which constitute a research front (# of core papers)
- the number of citations of core papers (# of unique citations)
- the gross number of core papers in each research area (# of citations)
- the average year of publication of core papers (Mean publication year)

3) Explanation of research areas

As the explanation of a research area, an “Outline of research areas and Contents of each research front” shall be given. This item shall be linked with 4) Interpretation of a map of individual areas, as closely as possible.

(Outline of the research areas)

A general explanation is given on research areas and research contents of research fronts that constitute a research. The contents of research fronts are described in accordance with either the following (1) or (2):

(1) When a group of research fronts with similar contents can be presented, the contents shall be itemized.

(2) When it is difficult to present groups, the contents of research fronts considered important (those linked with many research fronts, or those with a rapidly increasing number of citations, etc.) in the research area shall be itemized.

4) Map of individual research areas

A map of individual research areas was developed in order to visualize the relationships among research fronts which constitute a research area. The following is an explanation of the map of individual research areas.

- A circle drawn on the map of individual areas corresponds to one research front.
- The number next to a circle indicates the ID number of the corresponding research front.
- The area of a circle is proportional to the number of citations of core papers that constitute a research front.
- Dark color indicates the research fronts that have prominent increase in citations of core papers (Hot research fronts).
- Diagonal lines in the circle indicate the research fronts newly identified in 2004.
- The circles representing research fronts are closely placed when the co-citation relation is strong and placed far apart when the relation is weak.
- Research fronts having the strongest co-citation relations are connected with lines.

Also, contents of research fronts are described in accordance with either the following (1) or (2) in the map of individual research areas.

(1) When a group of research fronts with similar contents in the map of individual research areas can be presented, the relevant group of research fronts shall be parenthesized and its contents shall be described in the map of individual research areas.

(2) When it is difficult to present a group of research fronts in the map of individual research areas, research fronts that are considered important (those linked with many research fronts or those with a rapidly increasing number of citations, etc.) shall be illustrated and their contents shall be described in the map of individual research areas.

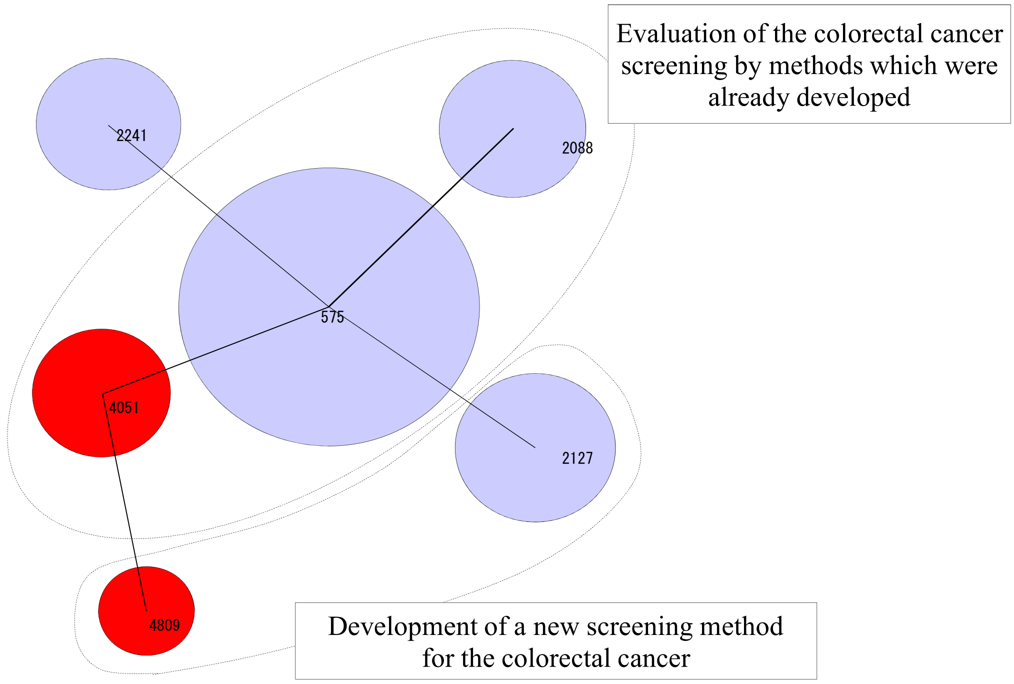
5) Keywords of research fronts

Keywords of respective research fronts which constitute a map of individual research areas are indicated. These keywords are obtained from frequency analysis of titles and abstracts of core papers.

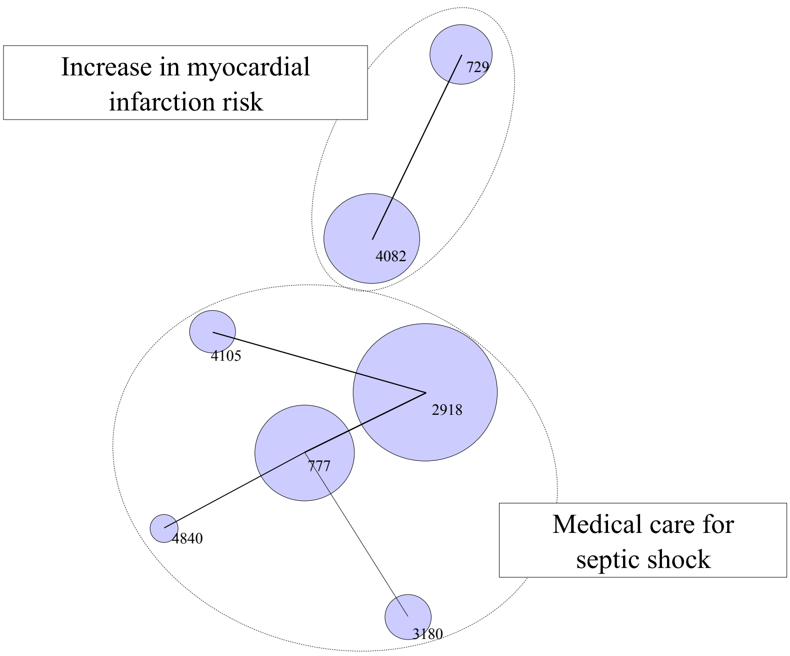
Content analysis of 133 research areas

Contents

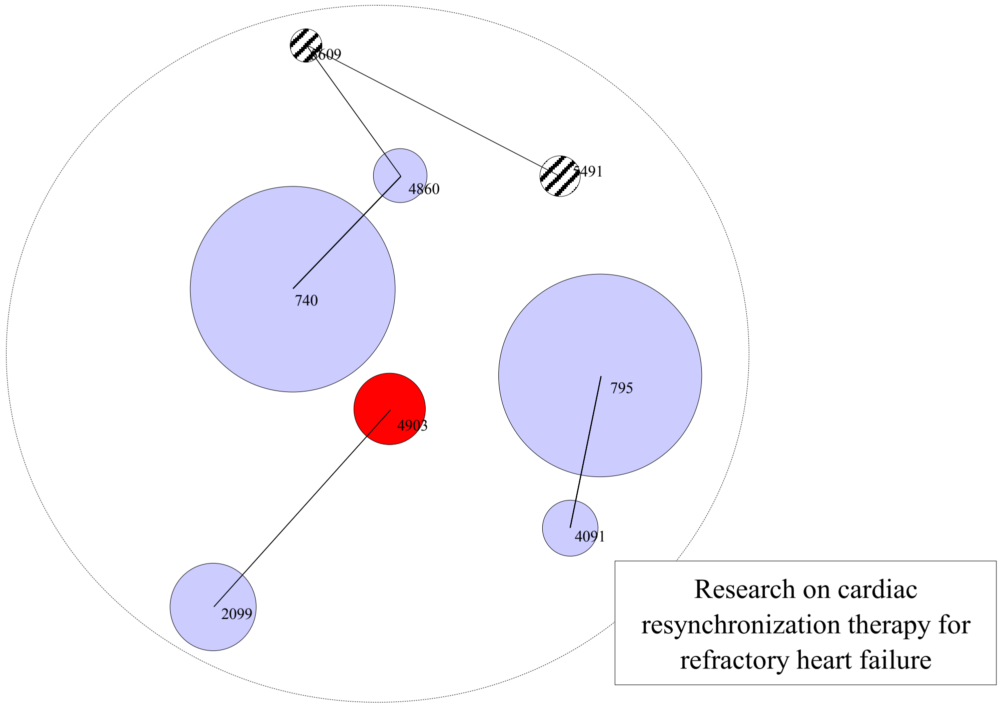
Name of RA	Research on medical examination of colorectal cancer		RA ID	1
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (2)	21	1116	2429	2001.0



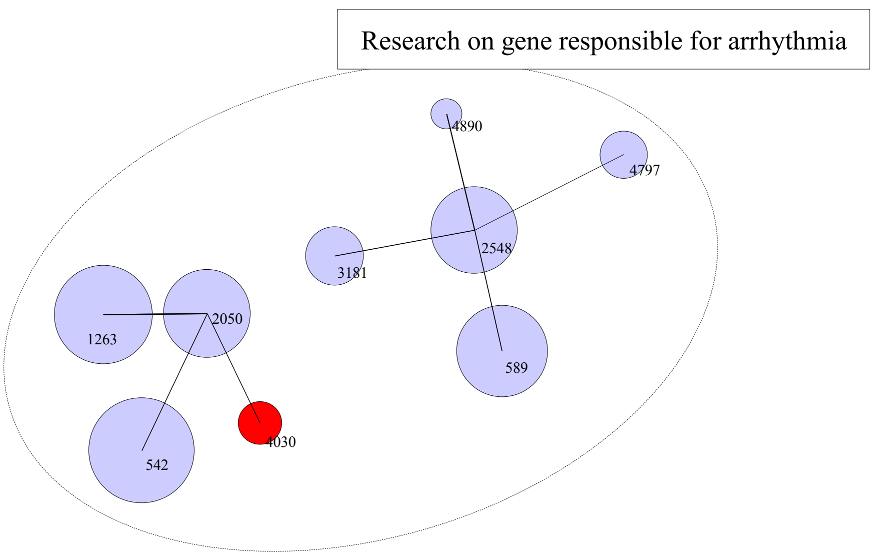
Name of RA	Clinical treatment of severe sepsis and septic shock		RA ID	2
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (0)	27	2308	4182	2001.8



Name of RA	Cardiac resynchronization therapy for intractable heart failure		RA ID	3
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (1)	37	1523	4059	2001.6

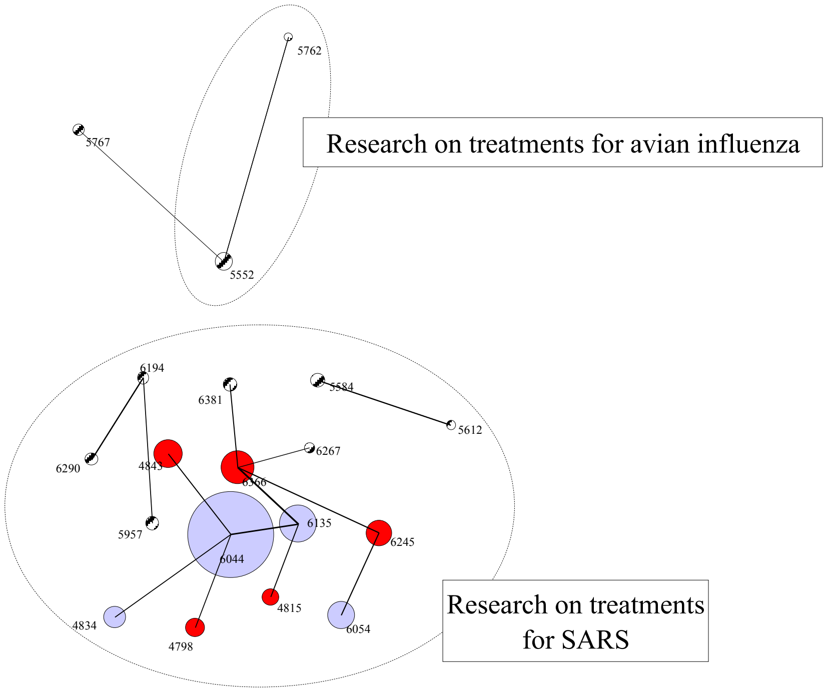


Name of RA	Diversity of arrhythmia-related genes		RA ID	4
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9 (1)	39	1946	3801	2001.1



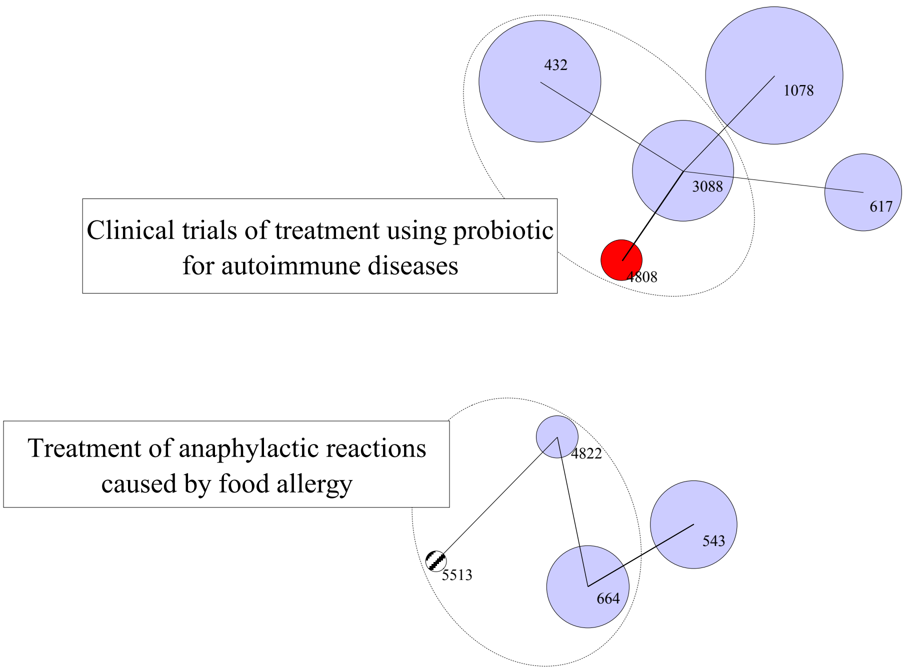
Name of RA	Research on SARS and avian influenza	RA ID	5

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
19 (5)	83	1143	5112	2003.6

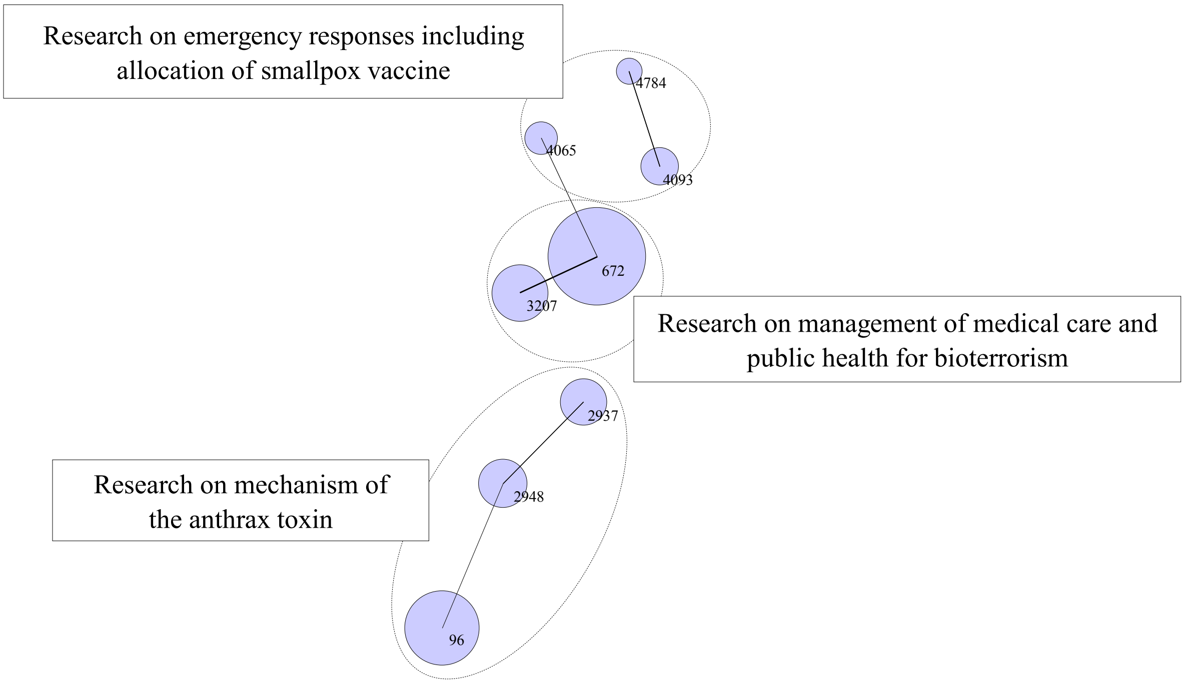


Name of RA	Research on allergy therapy	RA ID	6

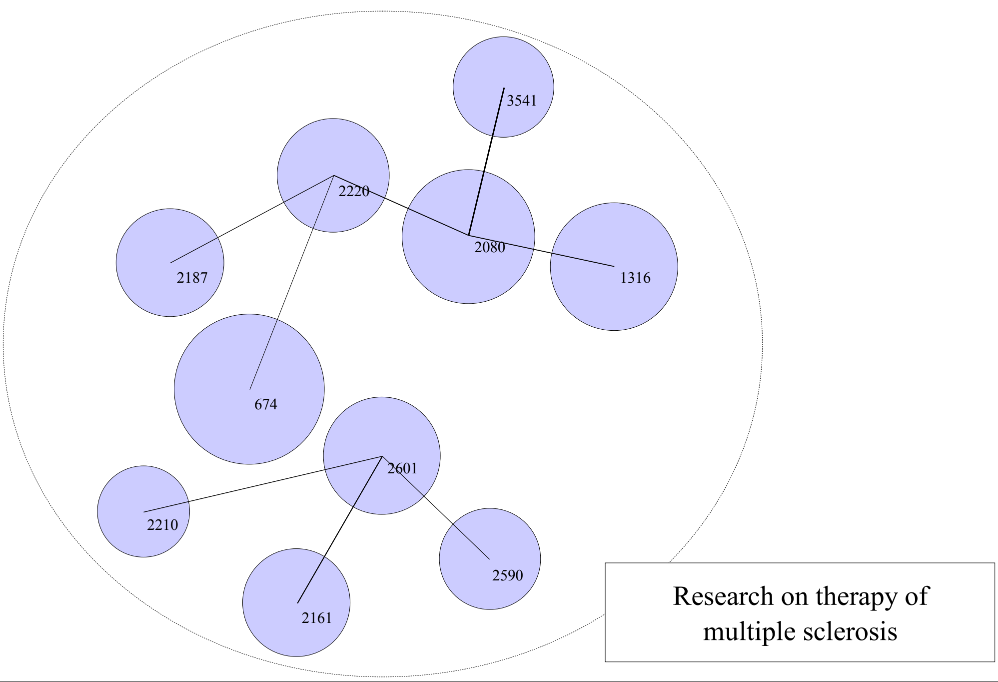
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9 (1)	32	1854	3548	2001.0



Name of RA	Research on countermeasures to bioterrorism		RA ID	7
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (0)	22	1567	2750	2000.9

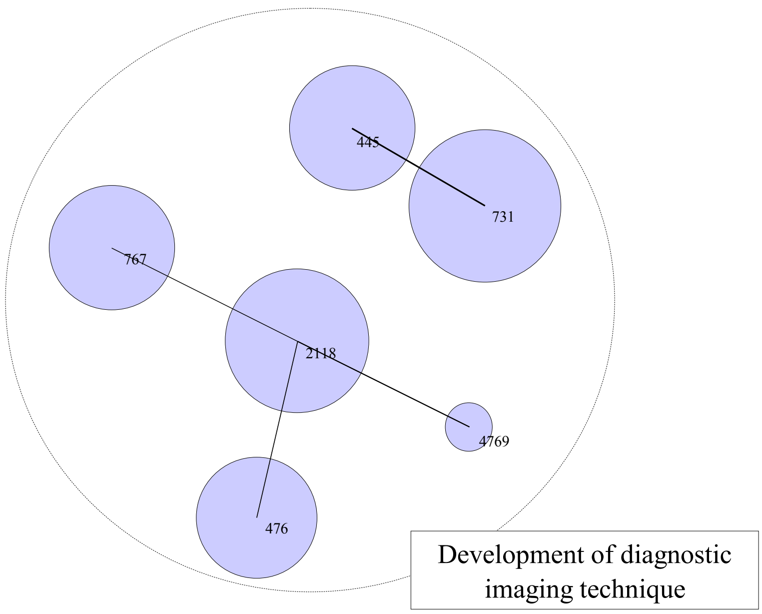


Name of RA	Therapy of multiple sclerosis		RA ID	8
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
10 (0)	22	1550	2734	2000.3



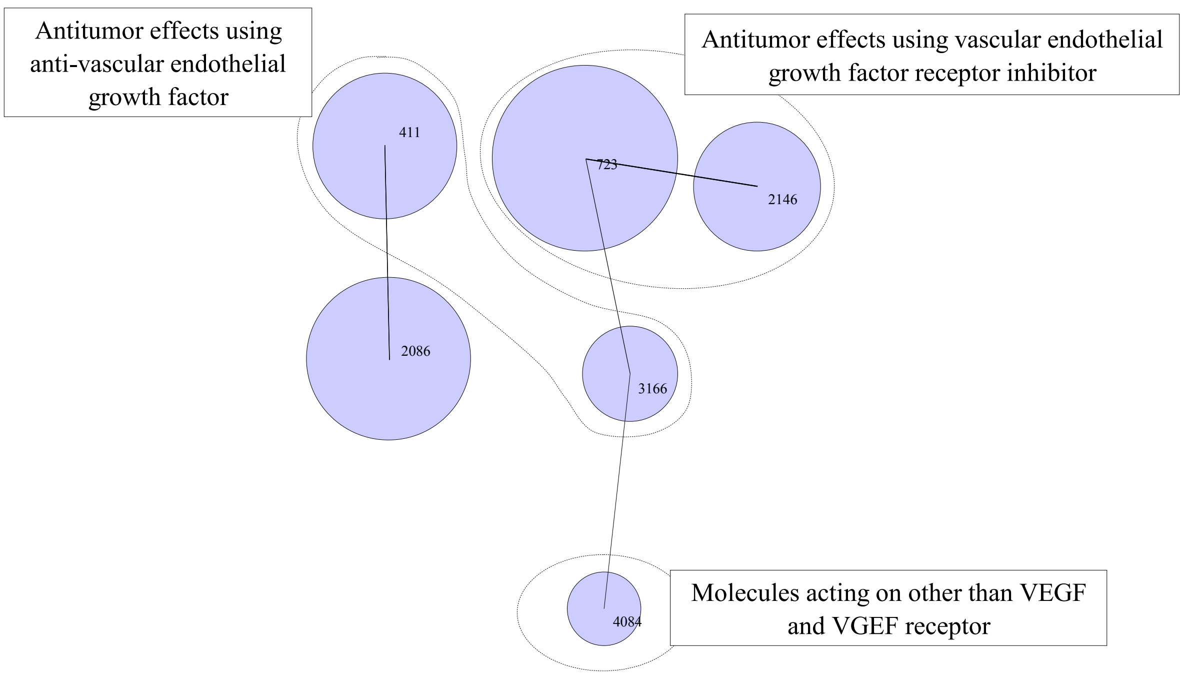
Name of RA	Development of imaging techniques for cardiovascular system	RA ID	9

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (0)	22	1213	2496	2000.6

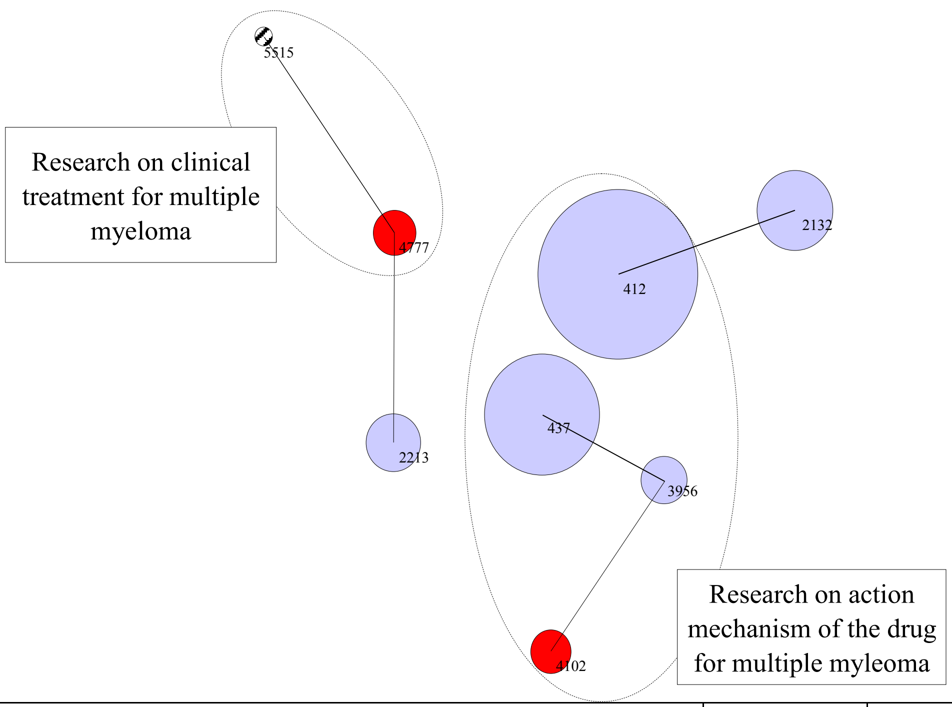


Name of RA	Cancer therapy with angiogenesis inhibitor	RA ID	10

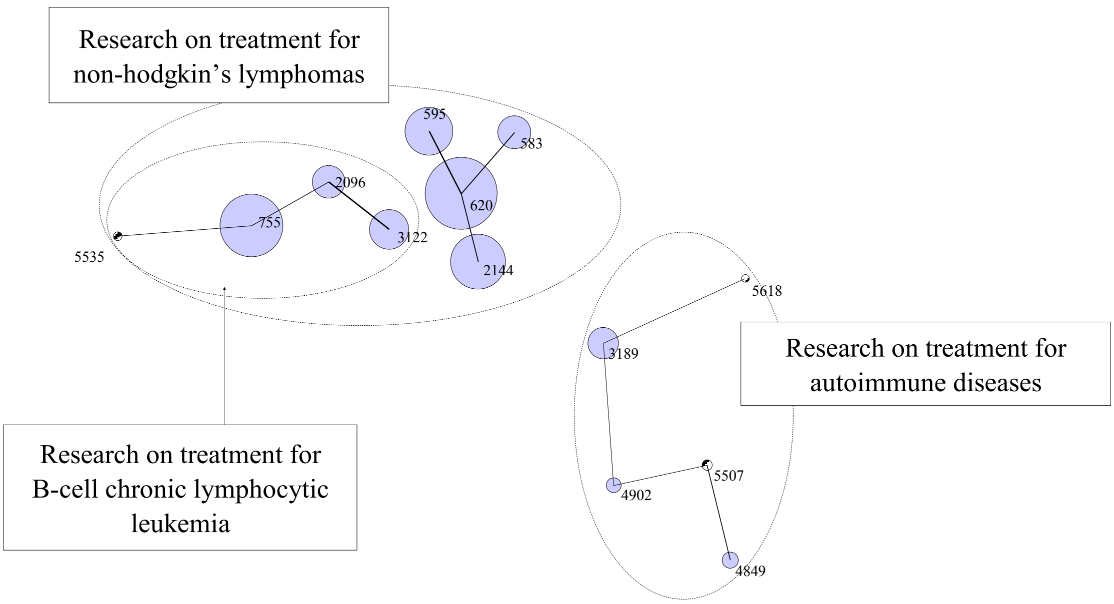
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (0)	15	1295	2094	2000.6



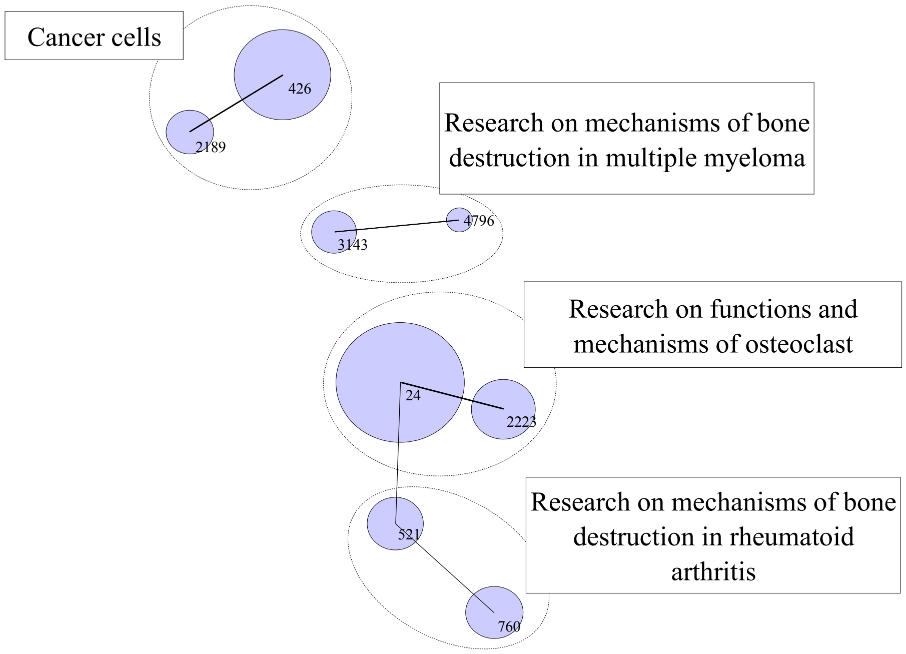
Name of RA	Research on multiple myeloma therapy		RA ID	11
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (2)	56	2318	5724	2001.2



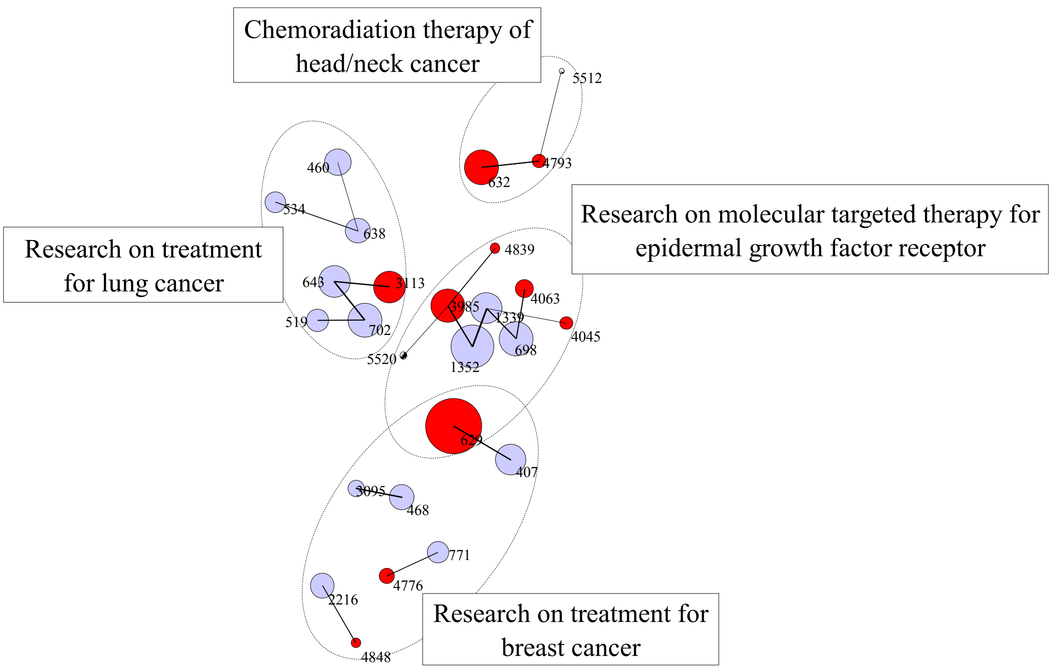
Name of RA	Research on diseases for which Rituxan is effective		RA ID	12
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13 (0)	62	2366	5809	2001.6



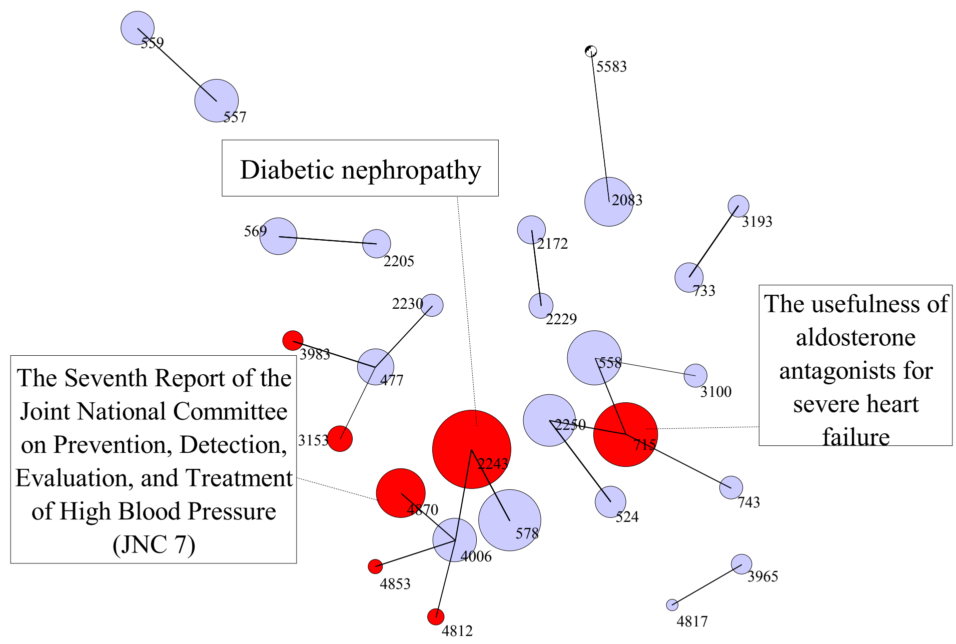
Name of RA	Research on osteoclastic mechanism	RA ID	13	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (0)	39	2283	4570	2000.9



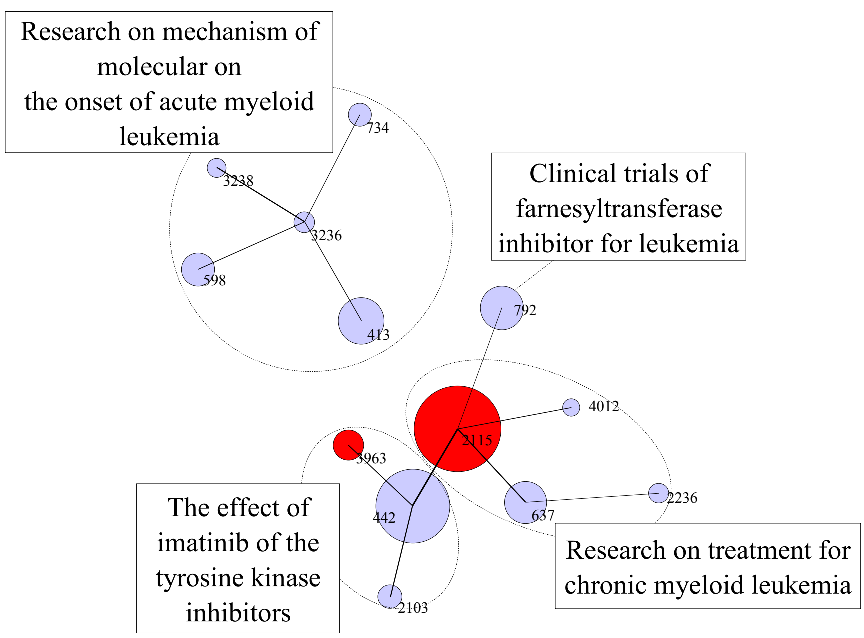
Name of RA	Research on cancer therapy	RA ID	14	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
26 (10)	95	5040	11598	2001.2



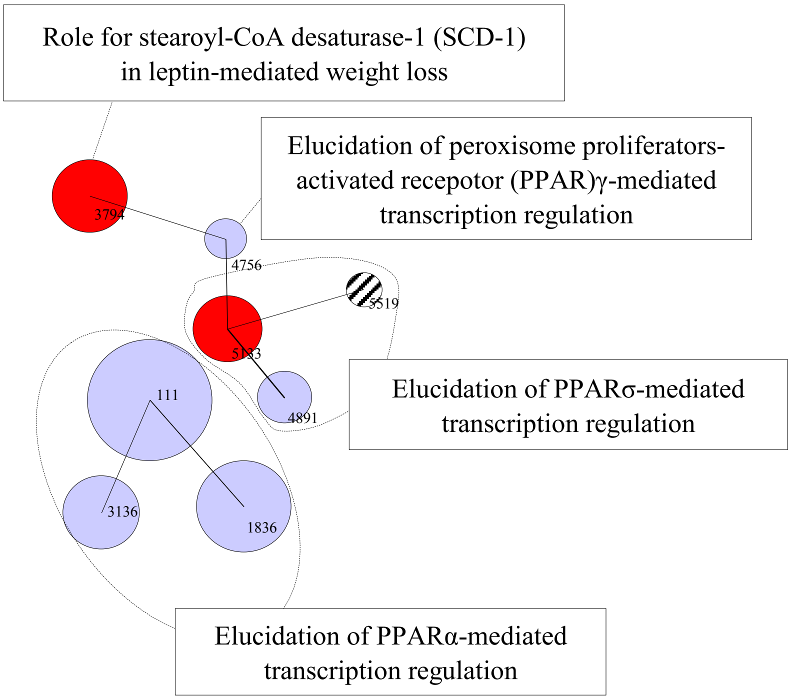
Name of RA	Clinical trial of therapeutic agent for cardiovascular disease		RA ID	15
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
28 (7)	119	8206	19278	2001.5



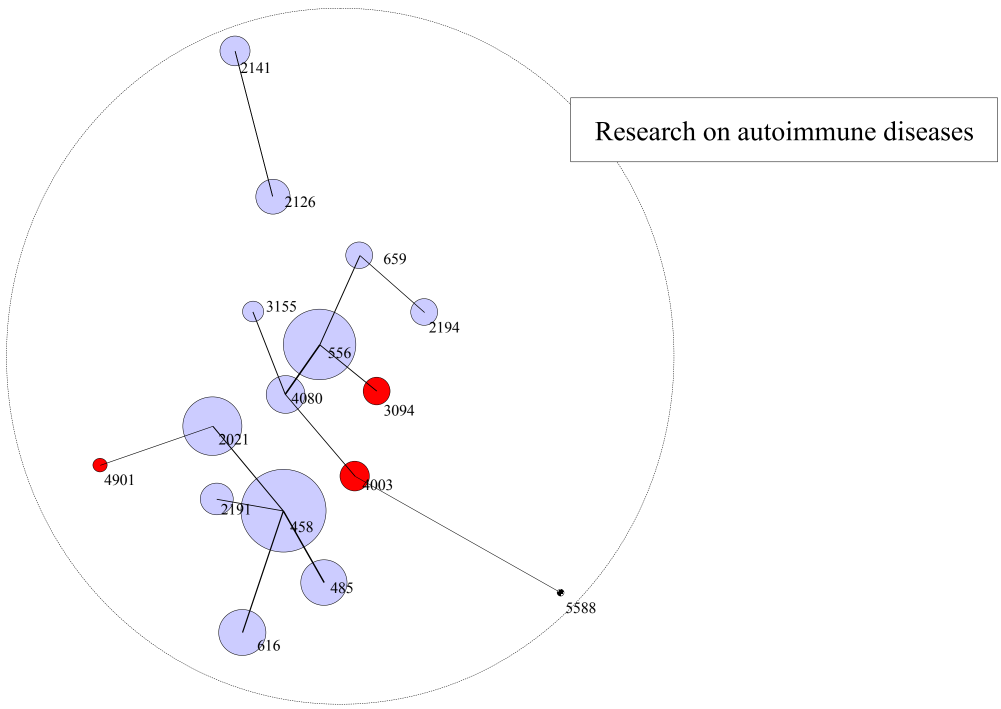
Name of RA	Research on molecular pathogenesis and leukemia therapy		RA ID	16
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13 (2)	125	4529	15727	2001.4



Name of RA	Functional nalysis of peroxisome proliferator-activated receptor		RA ID	17
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (2)	16	692	1084	2001.9

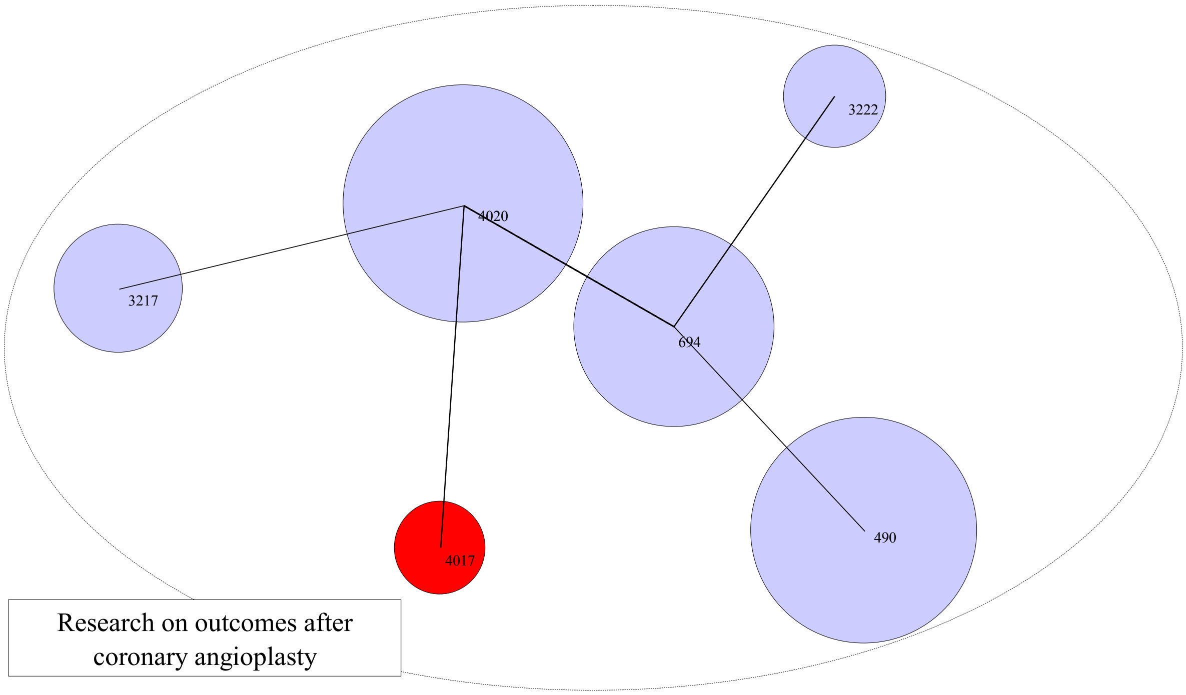


Name of RA	Autoimmune disease		RA ID	18
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
16 (3)	79	3908	10304	2001.3



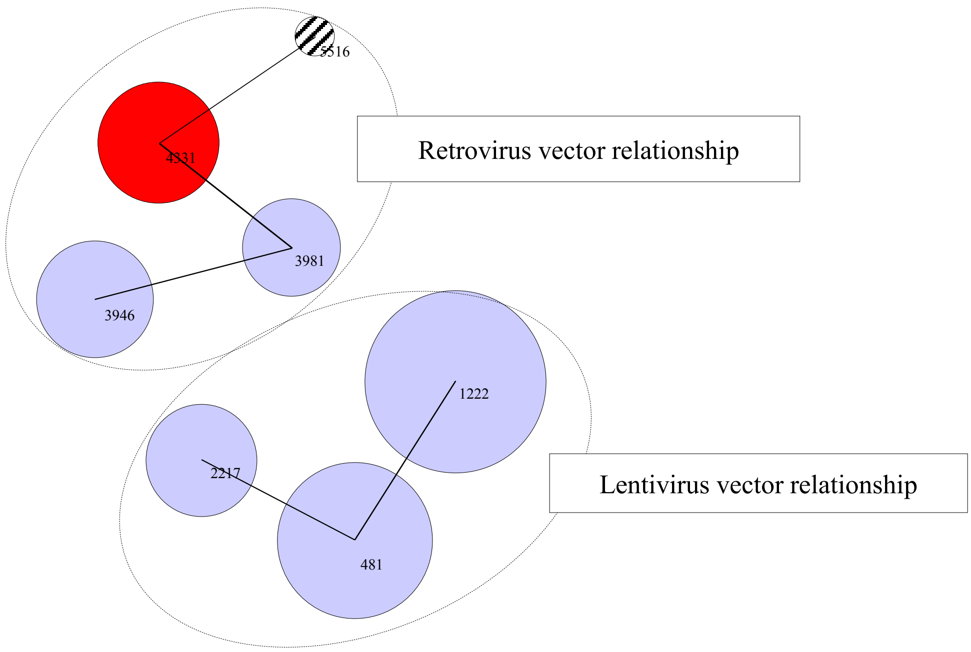
Name of RA	Prevention of post-coronary angioplasty restenosis with drug-eluting stents	RA ID	19

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (1)	50	1470	4289	2002.3



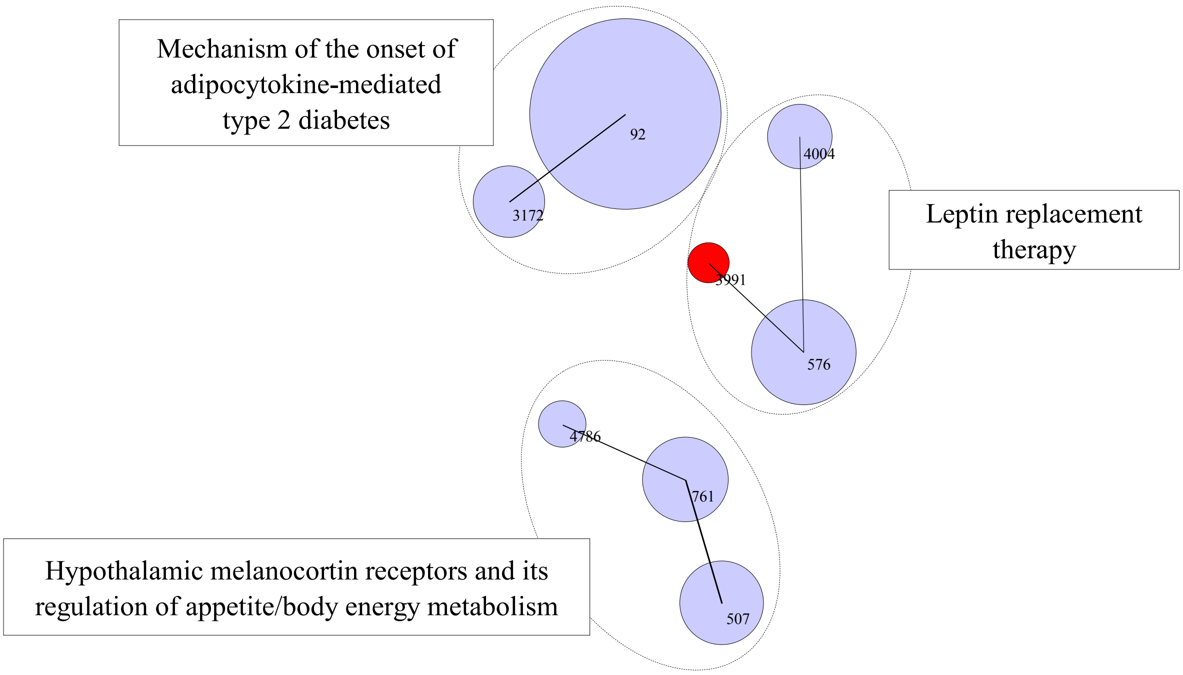
Name of RA	Gene therapy targeting hematopoietic stem cells and its side effects	RA ID	20

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (1)	18	1282	2331	2001.7



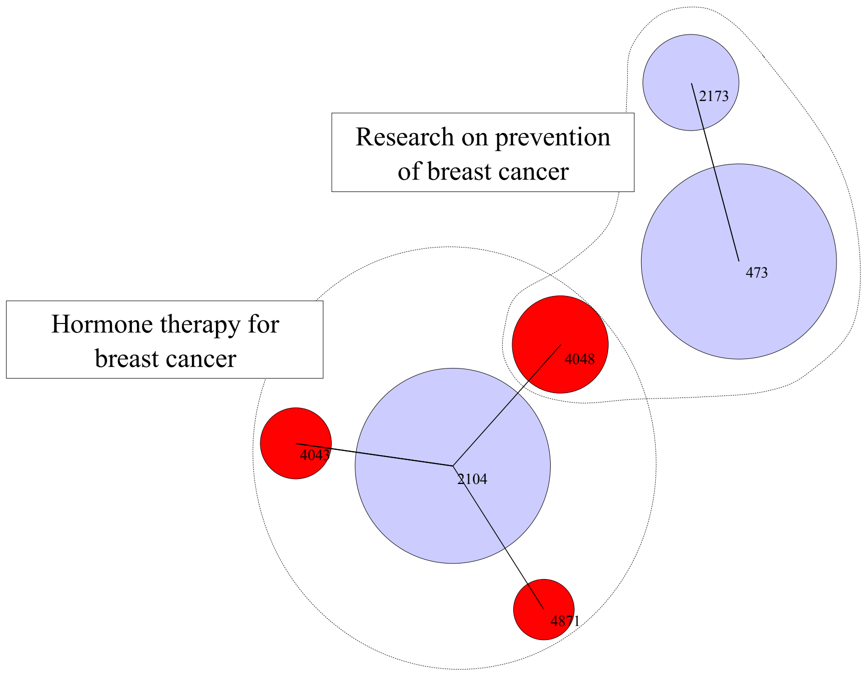
Name of RA	Molecular mechanism of adipocytokines and the onset of metabolic syndrome	RA ID	21

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year



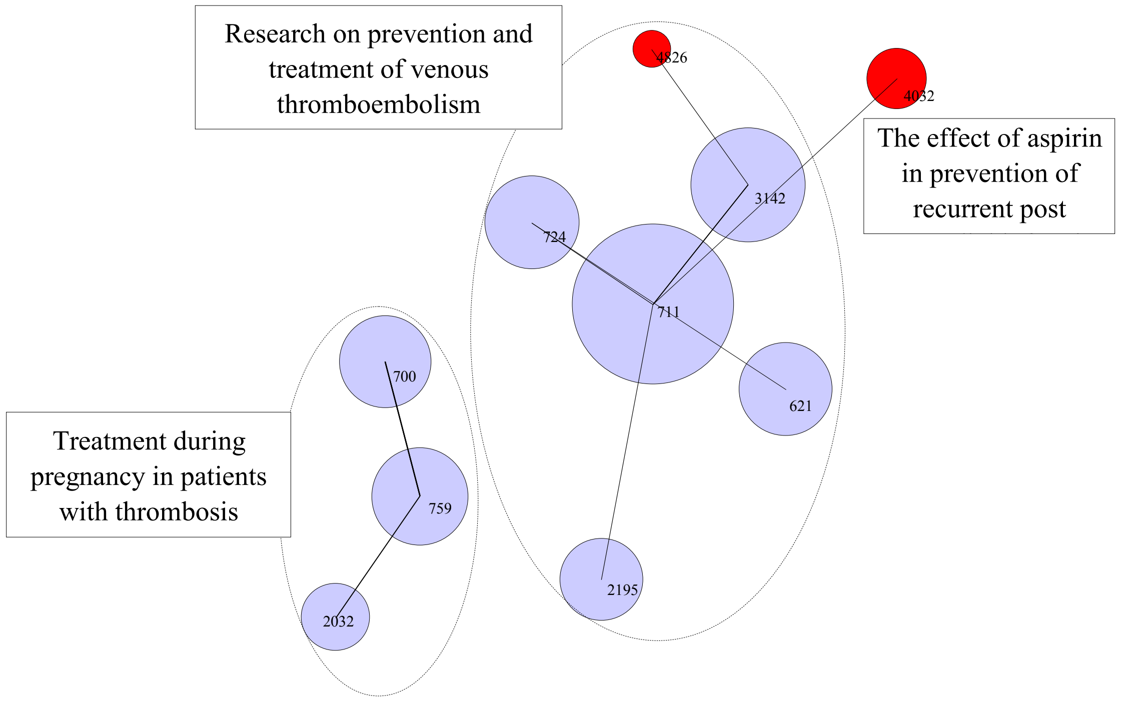
Name of RA	Research on breast cancer therapy	RA ID	22

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year



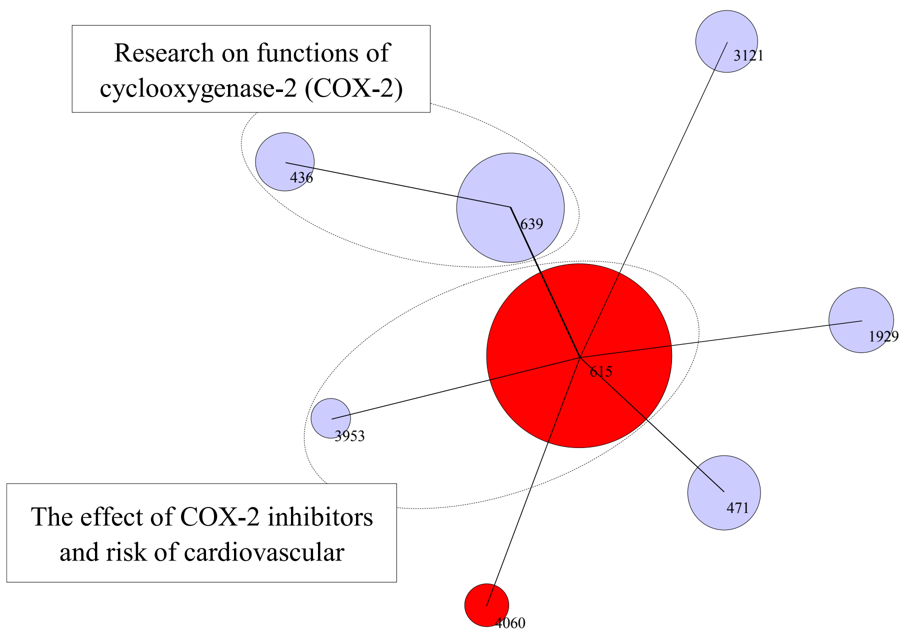
Name of RA	Research on venous thromboembolism therapy	RA ID	23

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year



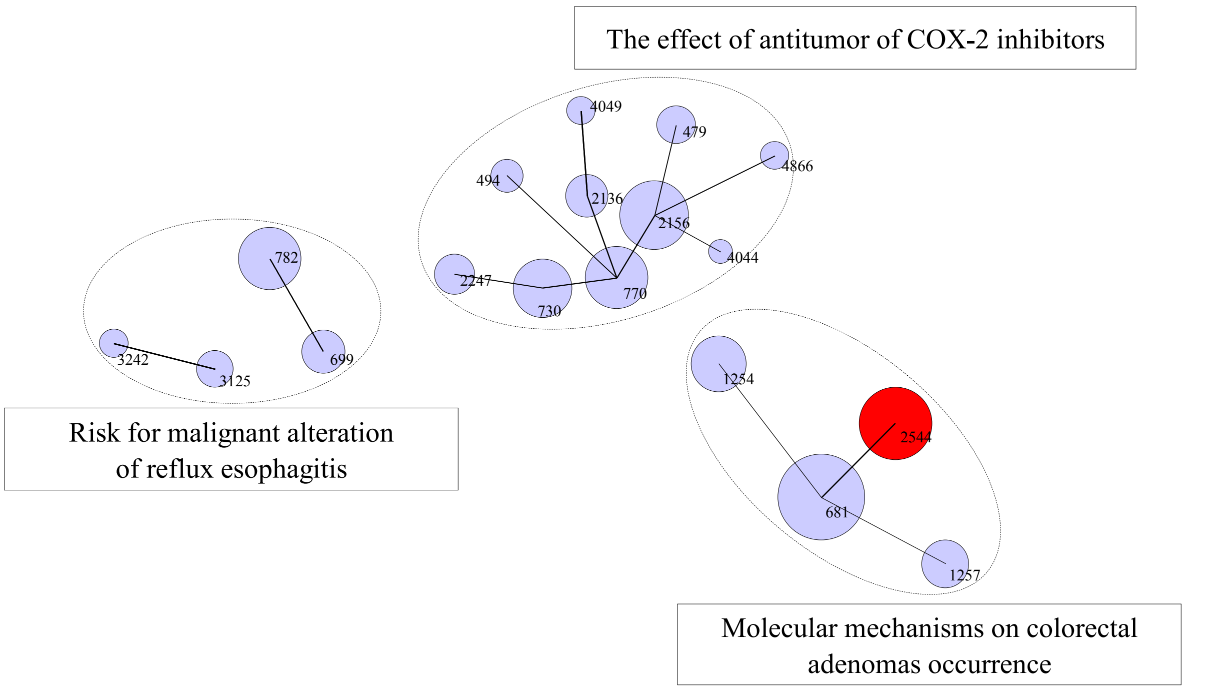
Name of RA	Clinical research on COX-2 inhibitor as anti-inflammatory drug	RA ID	24

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year



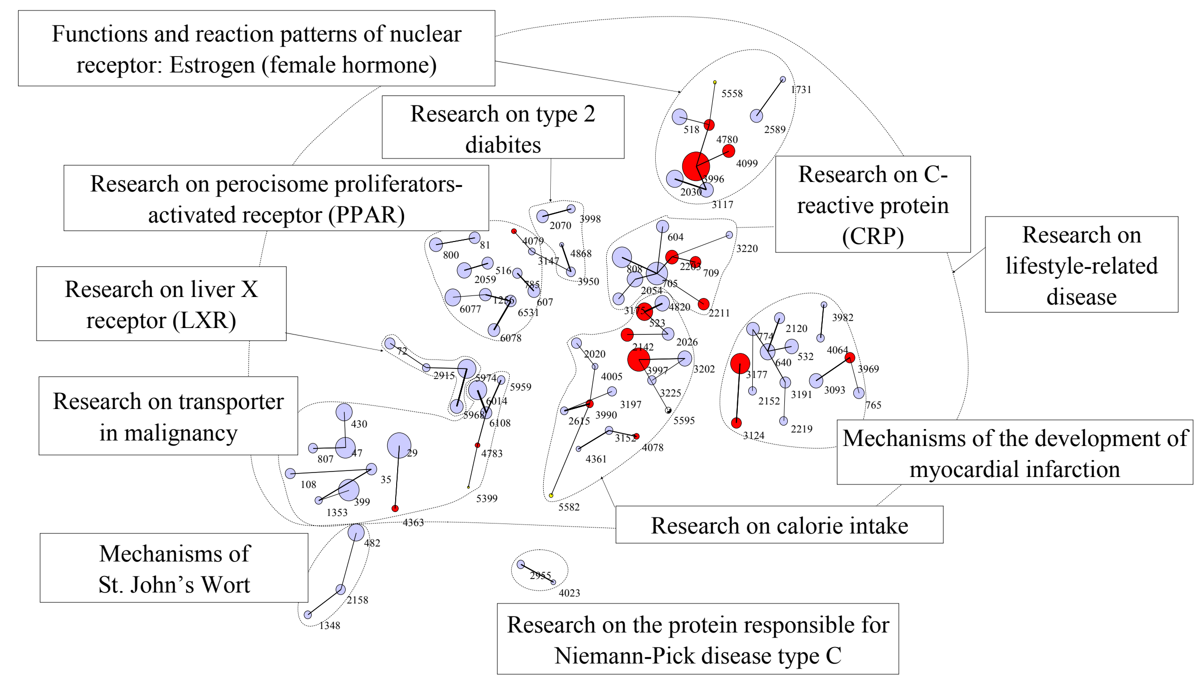
Name of RA	Effects of COX-2 inhibitor against cancer	RA ID	25

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year

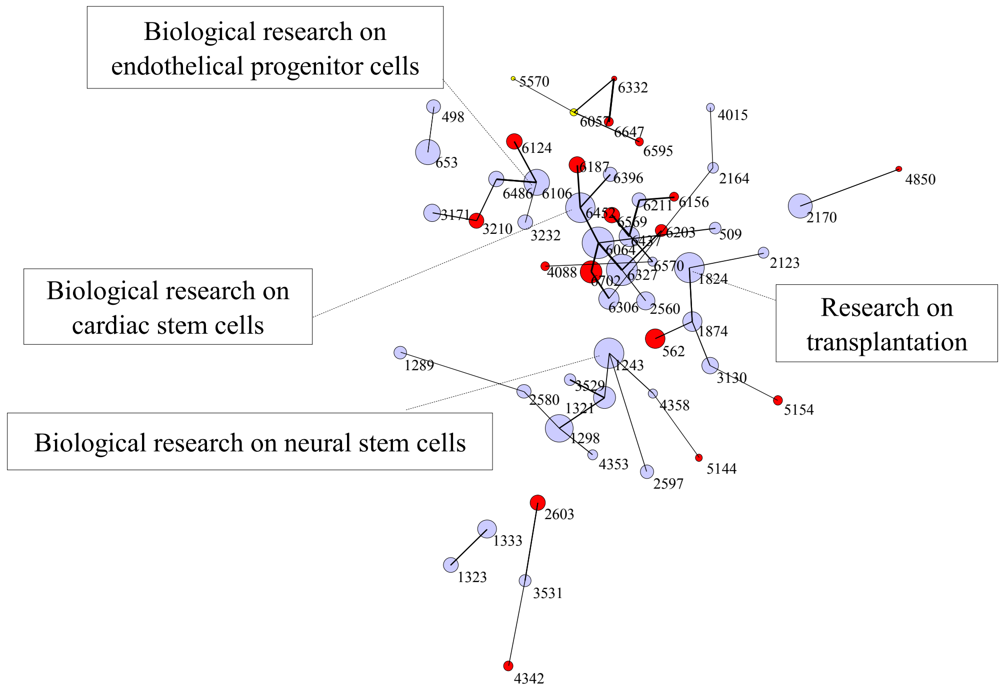


Name of RA	Signal transducing molecules associated with lifestyle-related diseases	RA ID	26

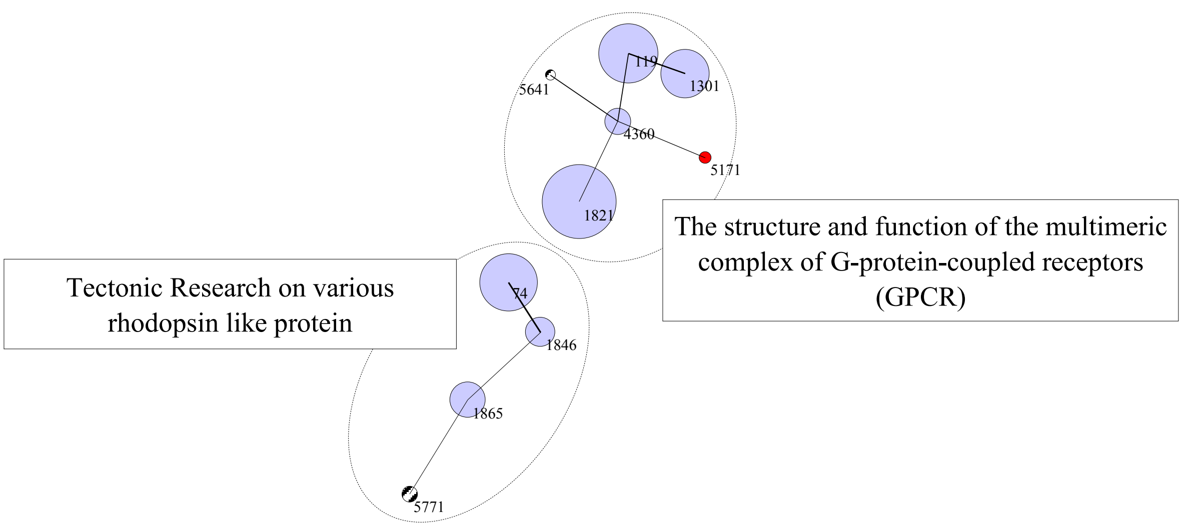
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year



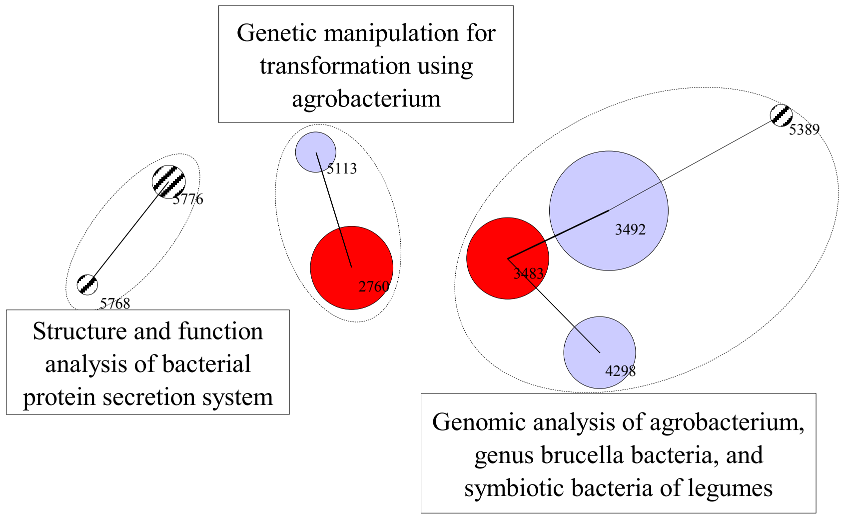
Name of RA	Stem cell therapy on nervous, hematopoietic, and cardiovascular system		RA ID	27
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year



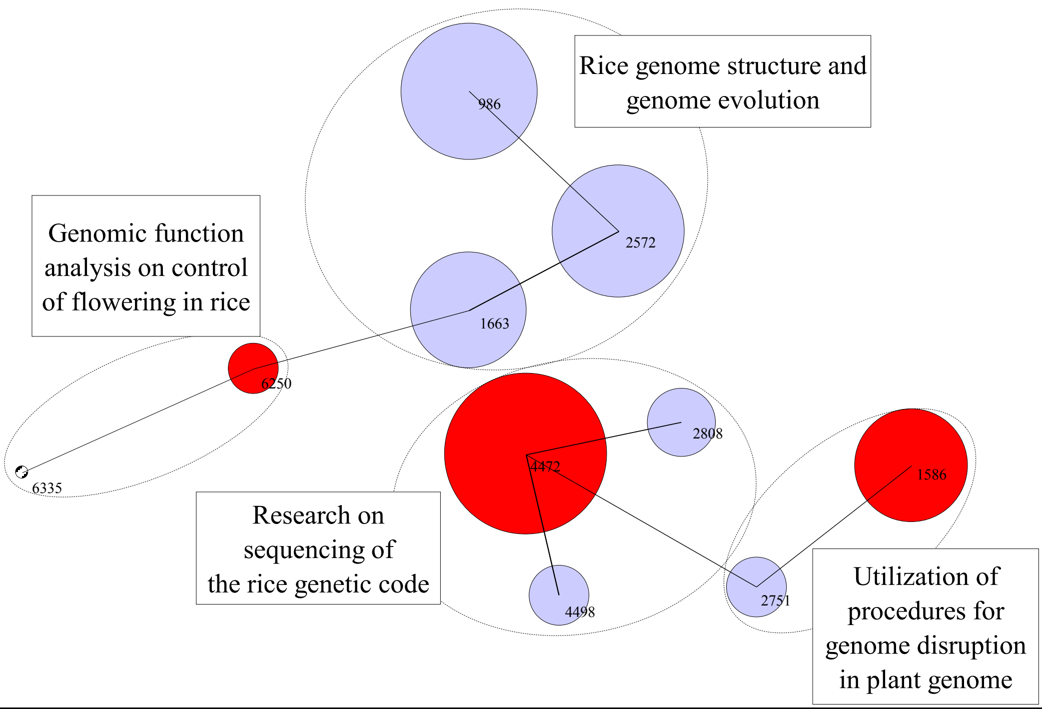
Name of RA	Structures and functions of G-protein-coupled receptor		RA ID	28
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year



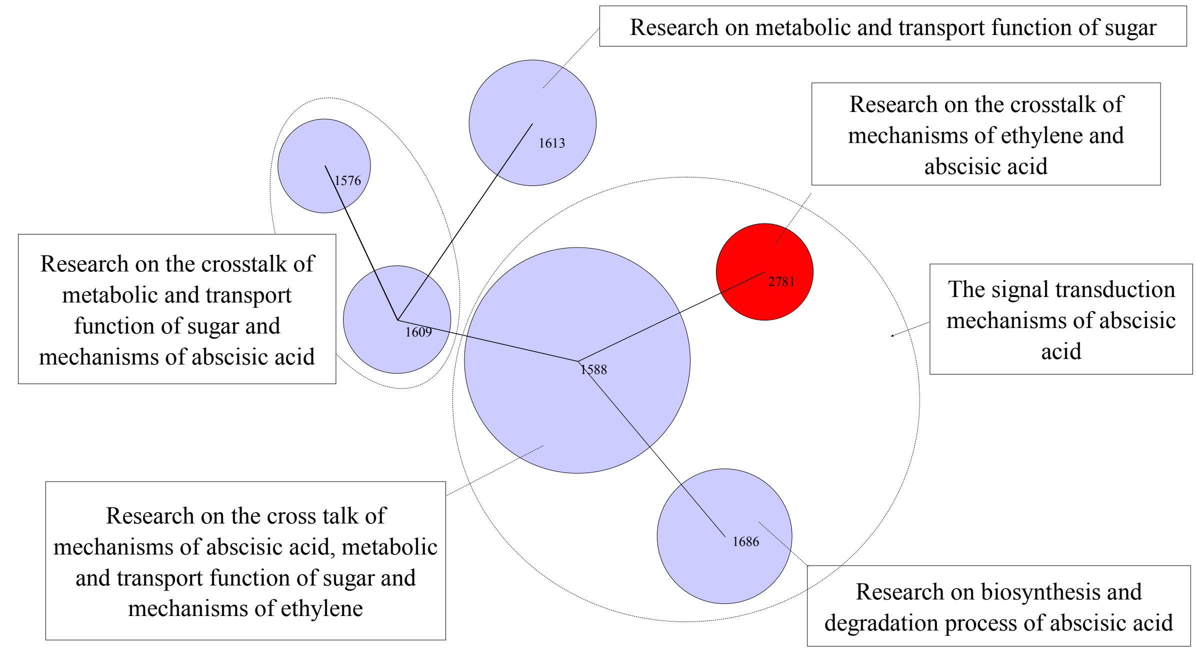
Name of RA	Utility of agrobacterium-mediated genetic engineering and the genomic character		RA ID	29
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year



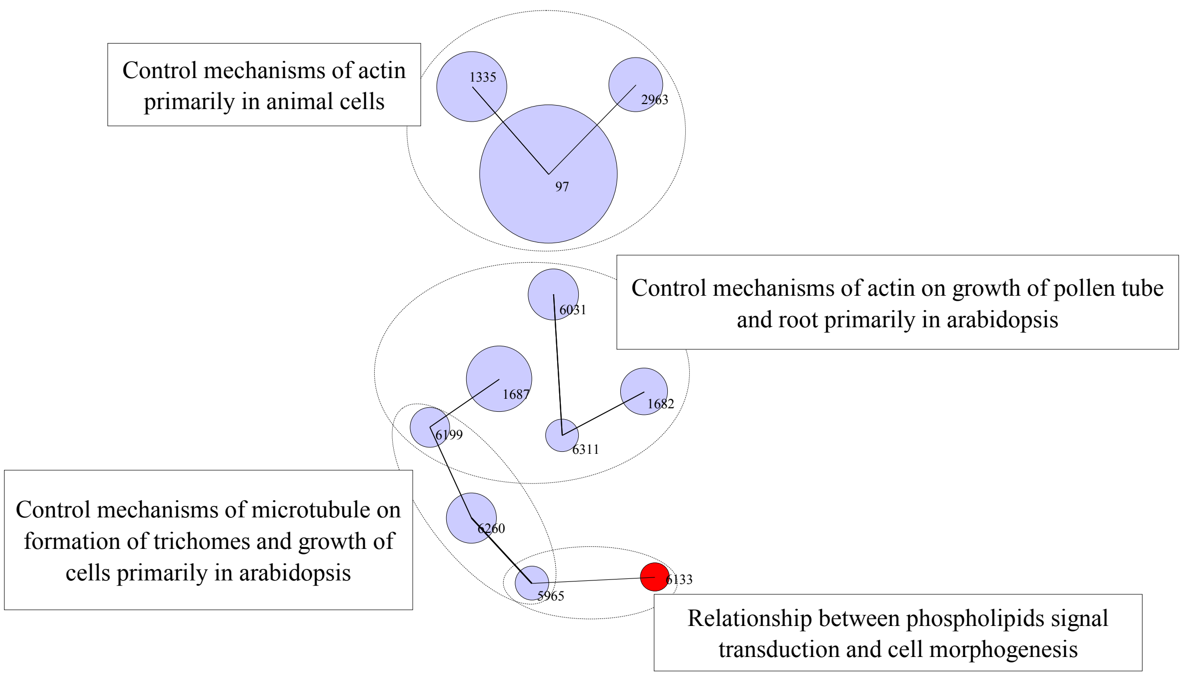
Name of RA	Plant genome research		RA ID	30
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year



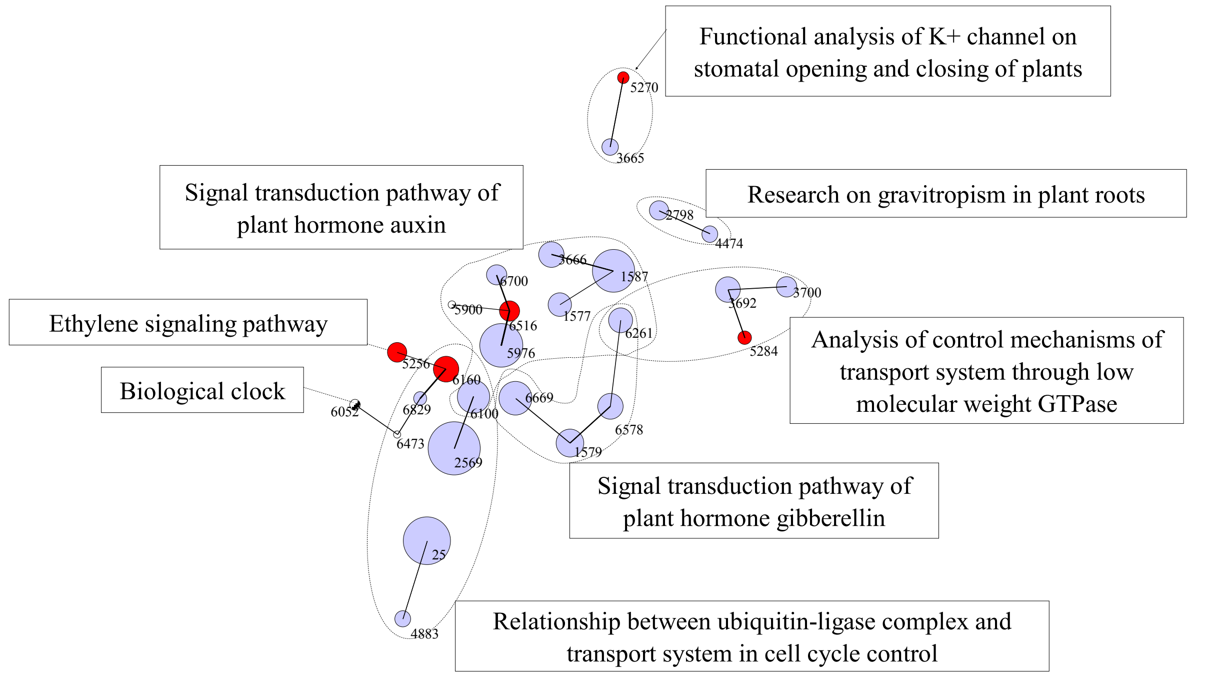
Name of RA	Functional analysis on abscisic acid, a plant hormone		RA ID	31
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (1)	33	1008	2160	2000.3



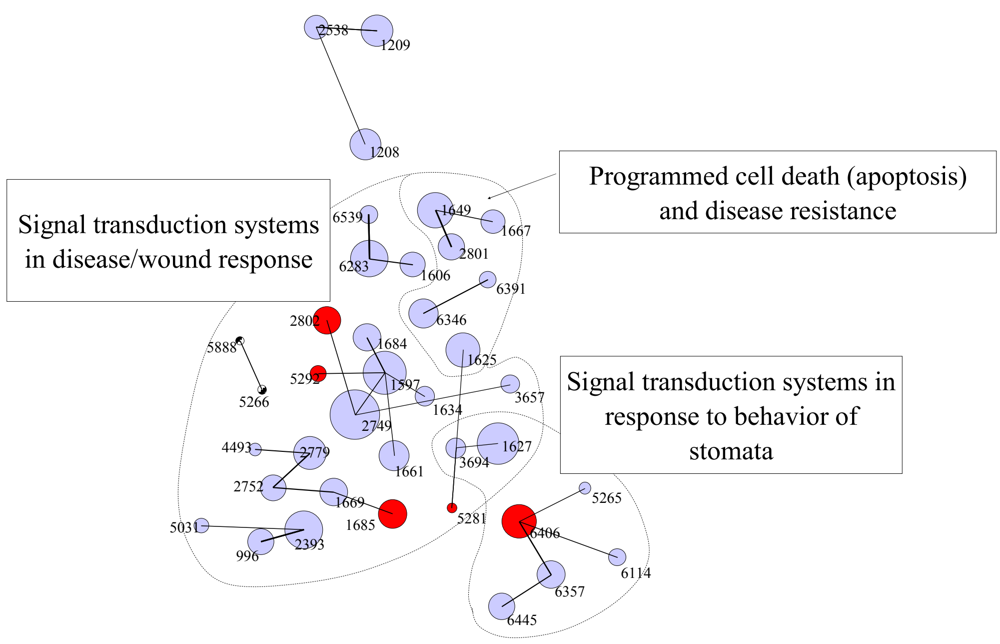
Name of RA	Dynamics and regulation of cytoskeleton		RA ID	32
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
11 (1)	46	1781	3807	2001.3



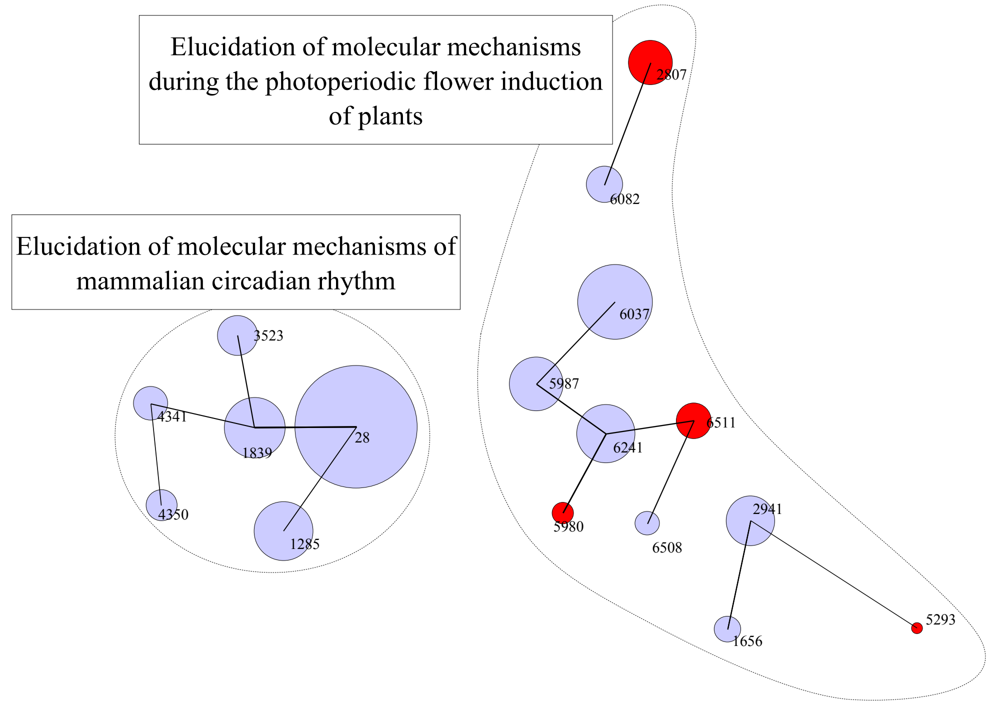
Name of RA	Analysis of mechanism of regulation of plant growth	RA ID	33	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
27 (5)	109	2426	5771	2001.7



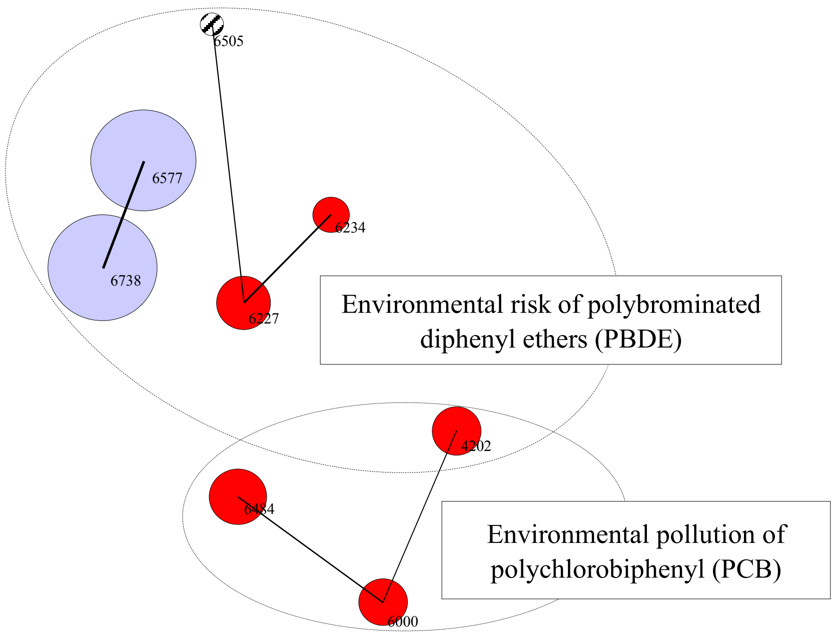
Name of RA	Stress response in plants	RA ID	34	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
38 (5)	183	3920	10347	2001.3



Name of RA	Study of biological clock		RA ID	35
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
17 (4)	122	3389	11071	2001.2

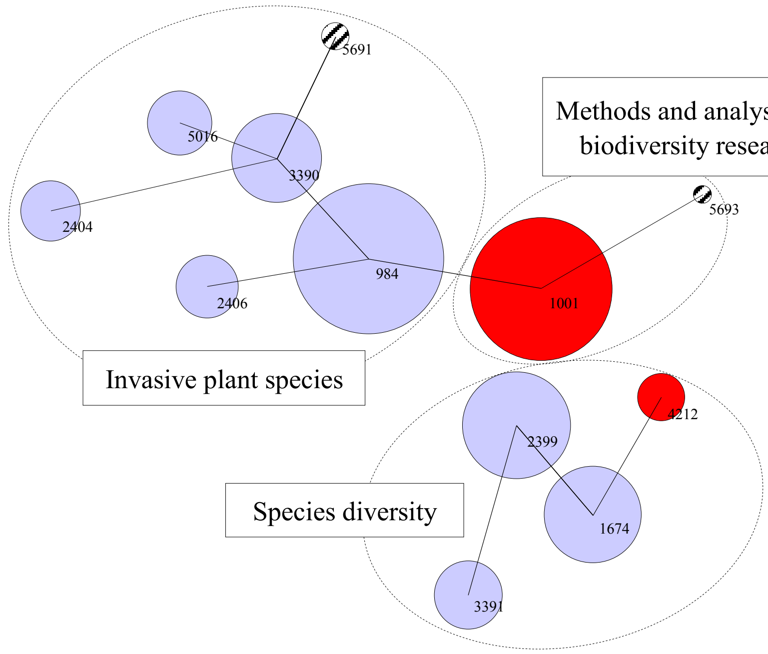


Name of RA	Environment pollution and risk of persistent organic halide pollutants		RA ID	36
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (5)	28	336	847	2002.6



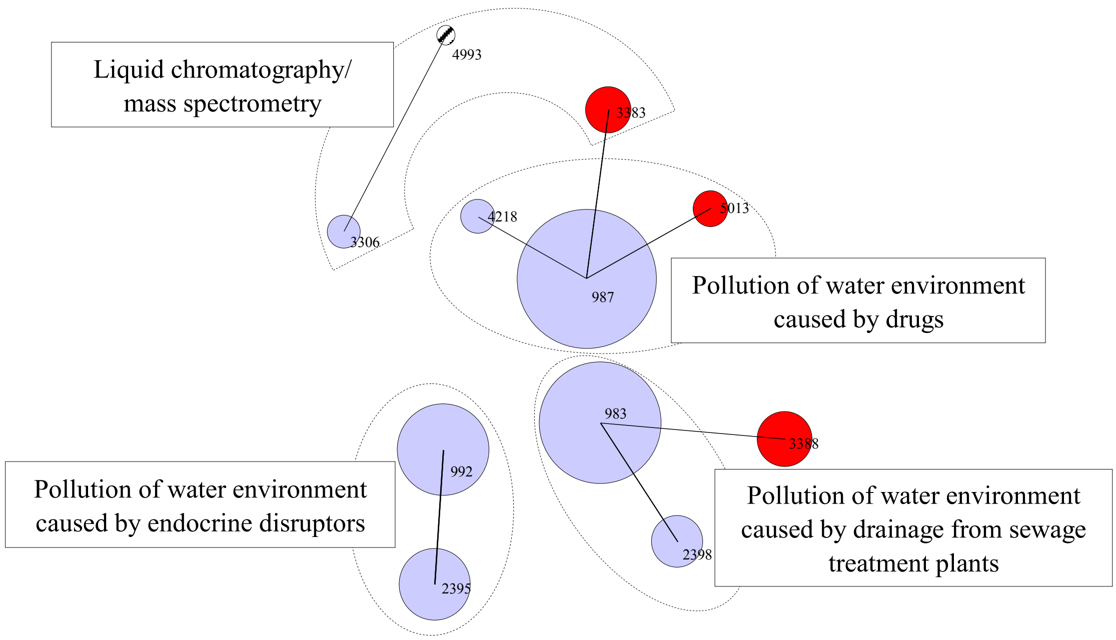
Name of RA	Study on biodiversity in plants	RA ID	37

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
12 (2)	62	1633	3277	2001.7

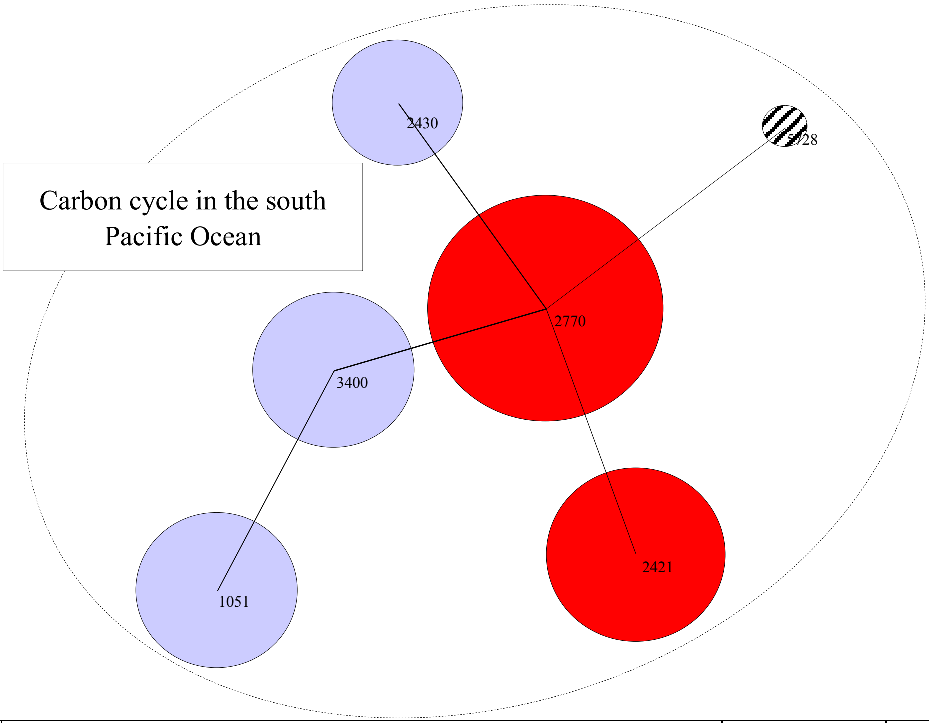


Name of RA	Aquatic pollution by toxic chemical compounds	RA ID	38

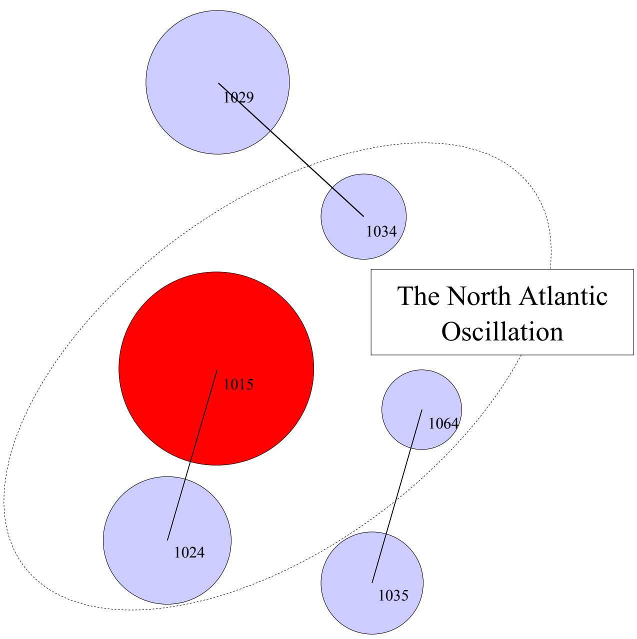
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
11 (3)	57	1225	3199	2000.9



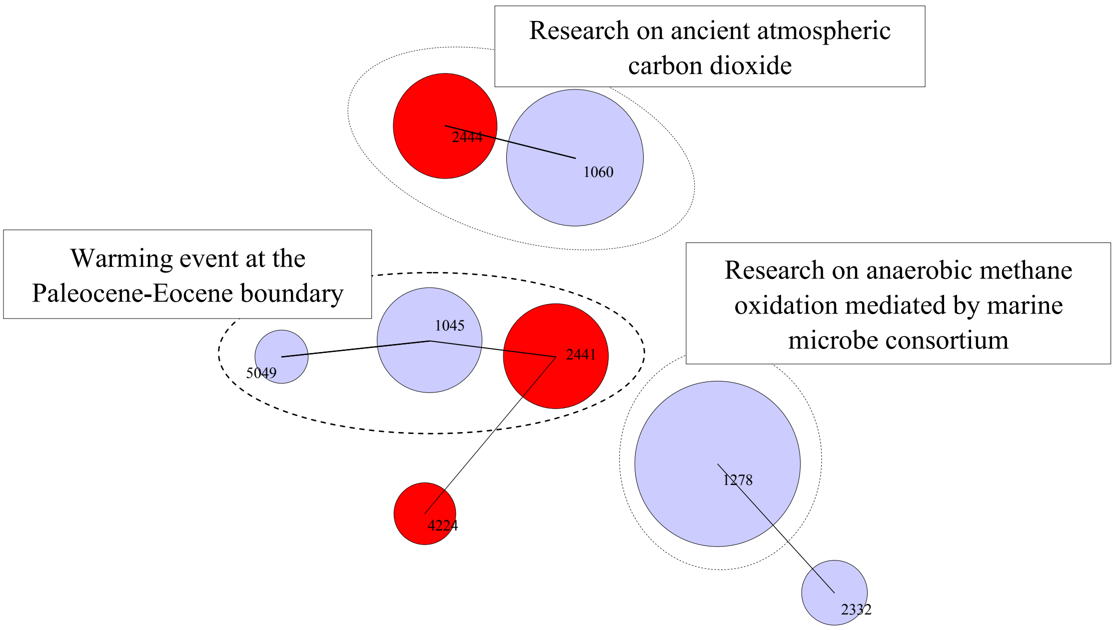
Name of RA	Carbon cycle in south Pacific Ocean		RA ID	39
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (2)	19	631	1085	2000.6



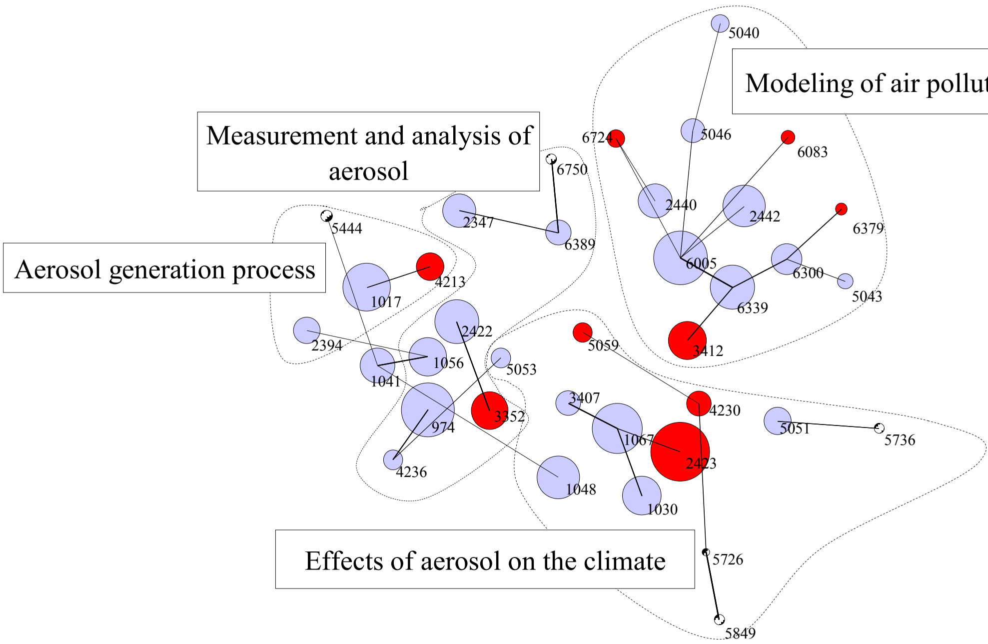
Name of RA	North Atlantic Oscillation and climate change		RA ID	40
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (1)	28	1321	2719	1999.8



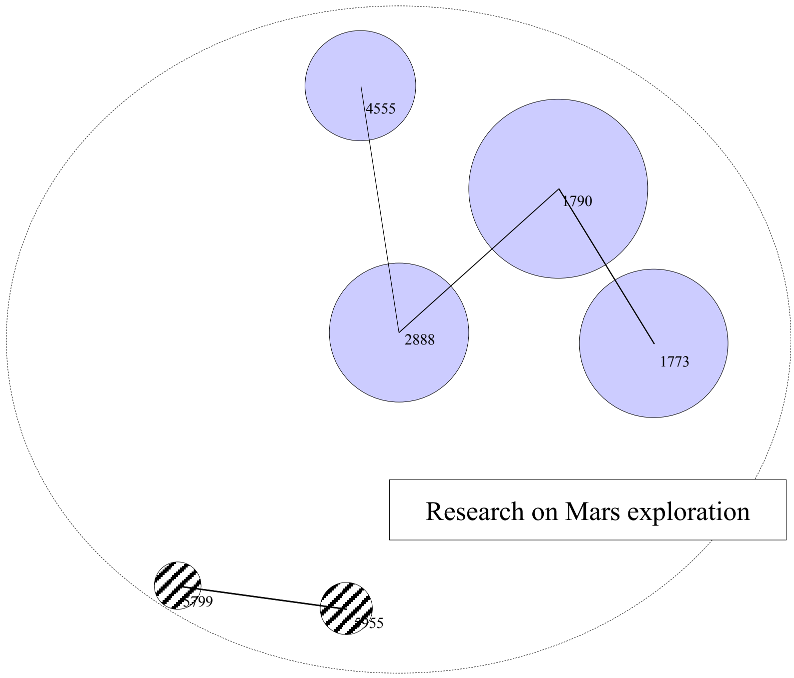
Name of RA	Research on paleoclimate		RA ID	41
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (3)	23	858	1505	2000.6



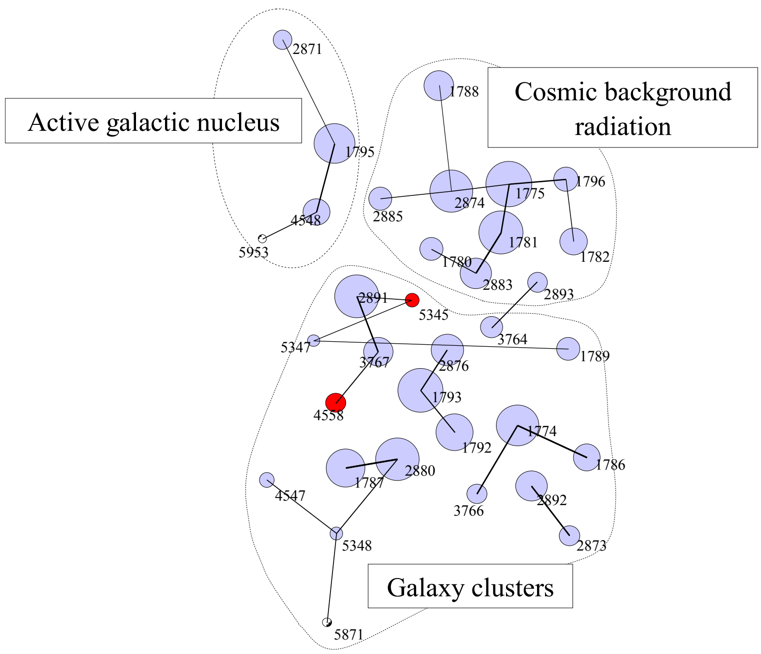
Name of RA	Effects of aerosol and air pollutant on climate and atmospheric circulation model		RA ID	42
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
37 (9)	143	2474	5466	2001.9



Name of RA	Mars exploration		RA ID	43
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (0)	14	659	1130	2001.5

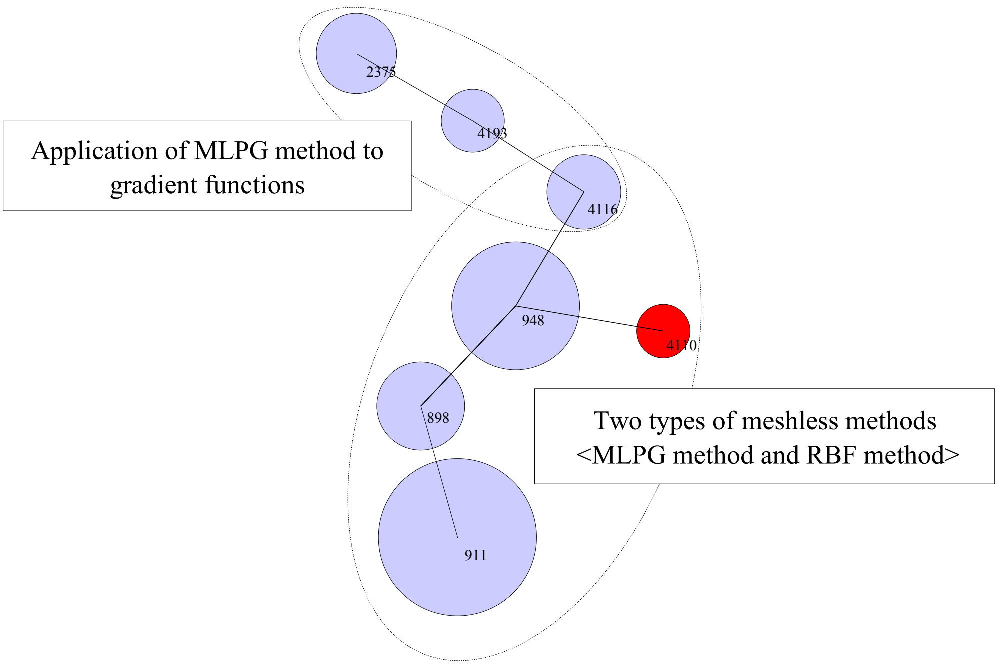


Name of RA	Large-scale structure of the universe		RA ID	44
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
34 (2)	191	6183	19690	2001.3



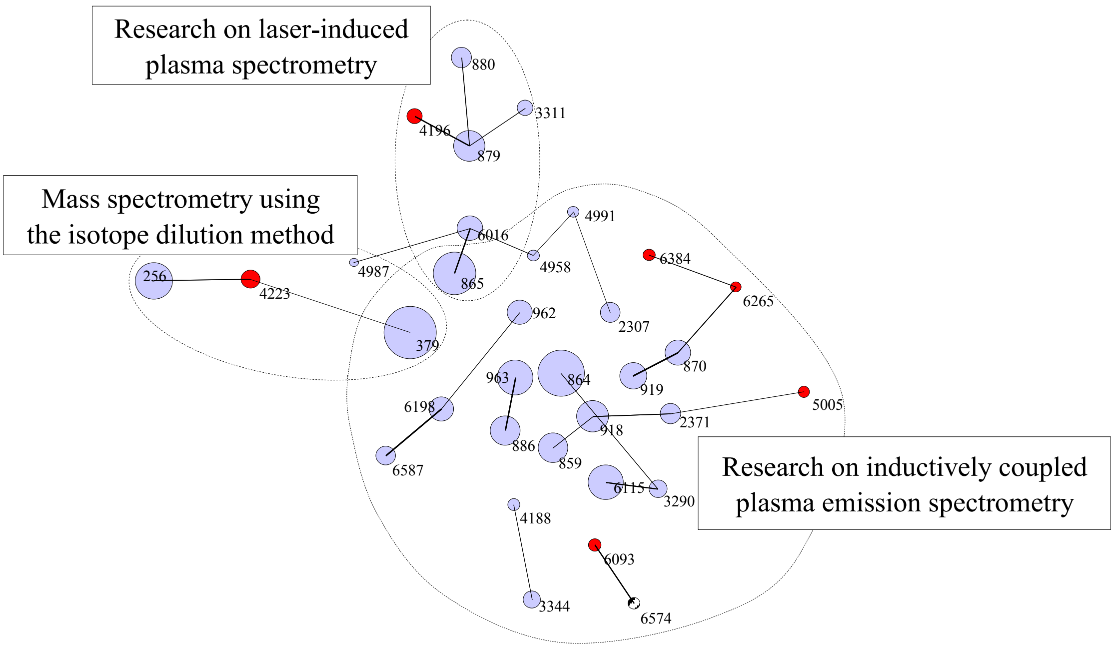
Name of RA	Research on meshless finite element method	RA ID	45

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (1)	37	483	1111	2001.2

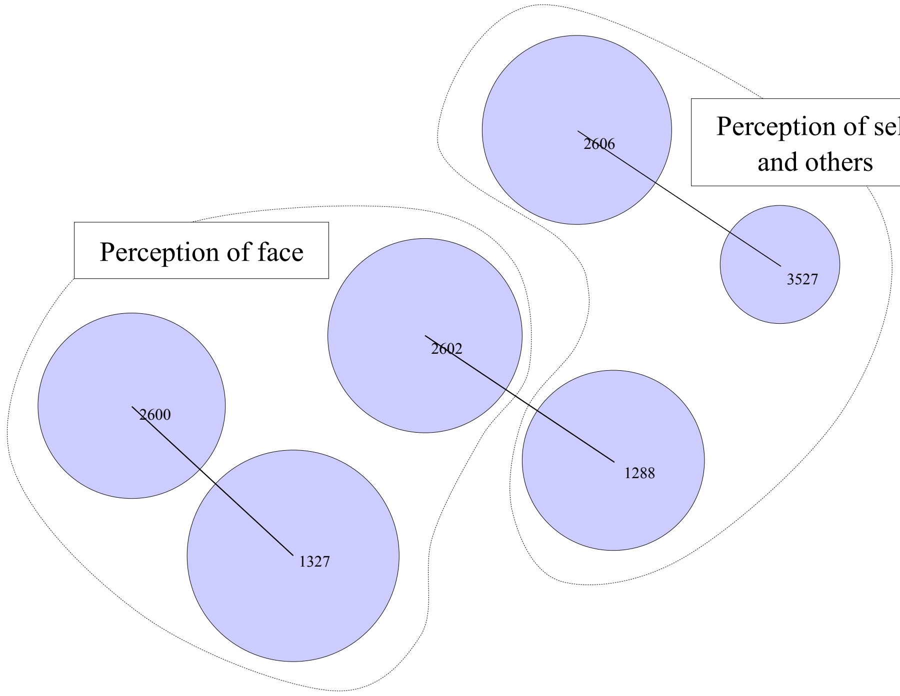


Name of RA	Research on spectroanalysis	RA ID	46

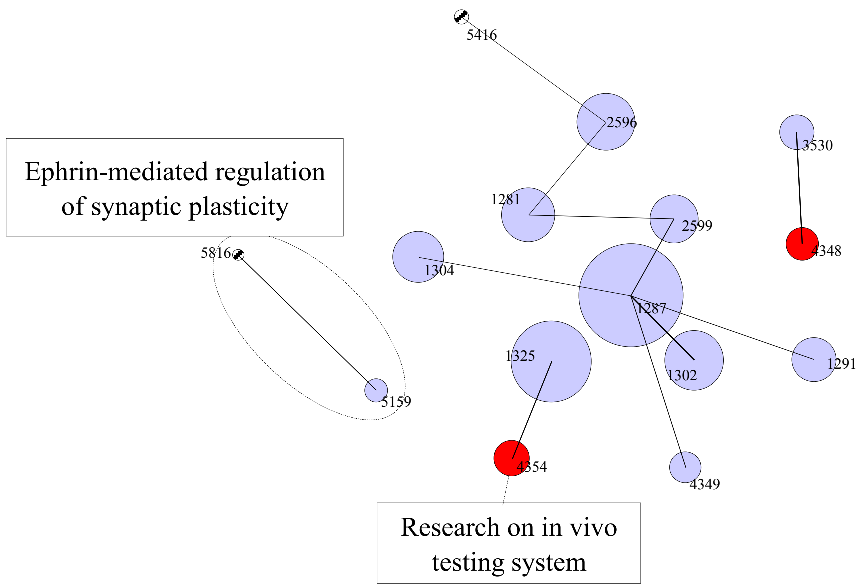
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
33 (6)	192	2052	5276	2001.4



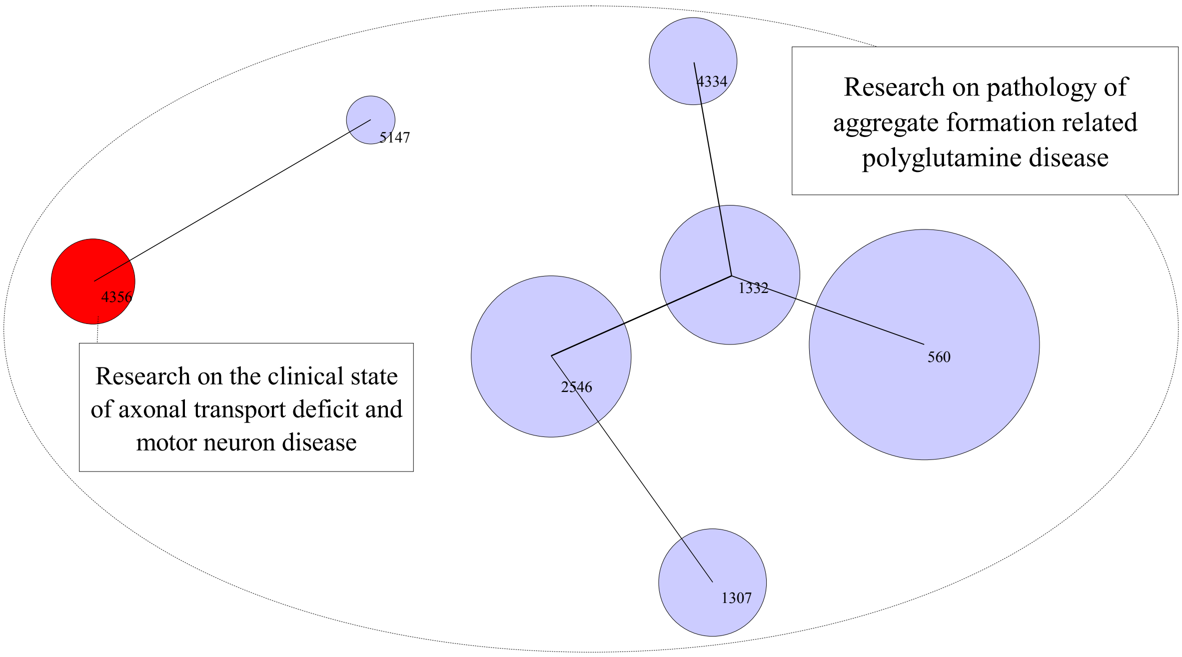
Name of RA	Brain function imaging of cognitive psychological phenomena	RA ID	47	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (0)	14	1114	1719	2000.1



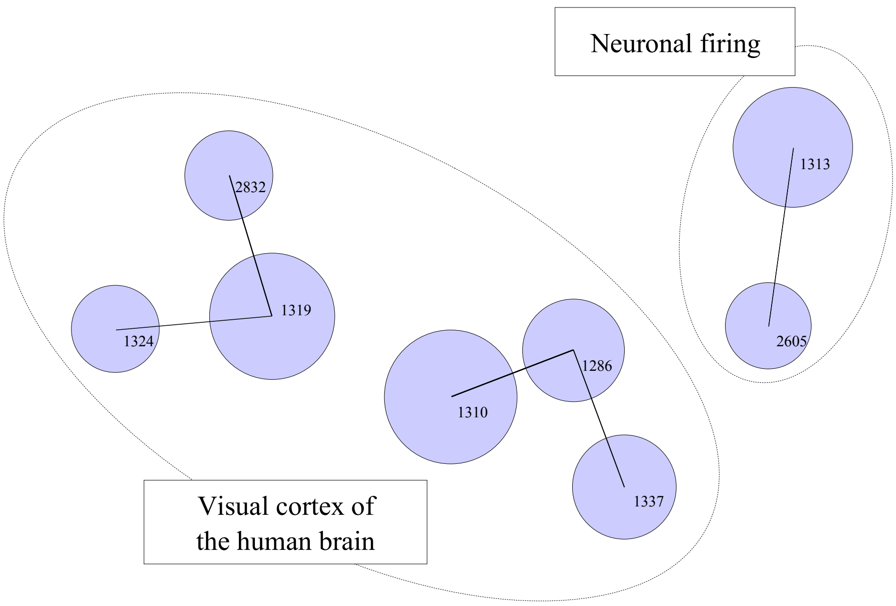
Name of RA	Glutamate receptors in plasticity brain	RA ID	48	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
15 (2)	51	2899	6911	2000.7



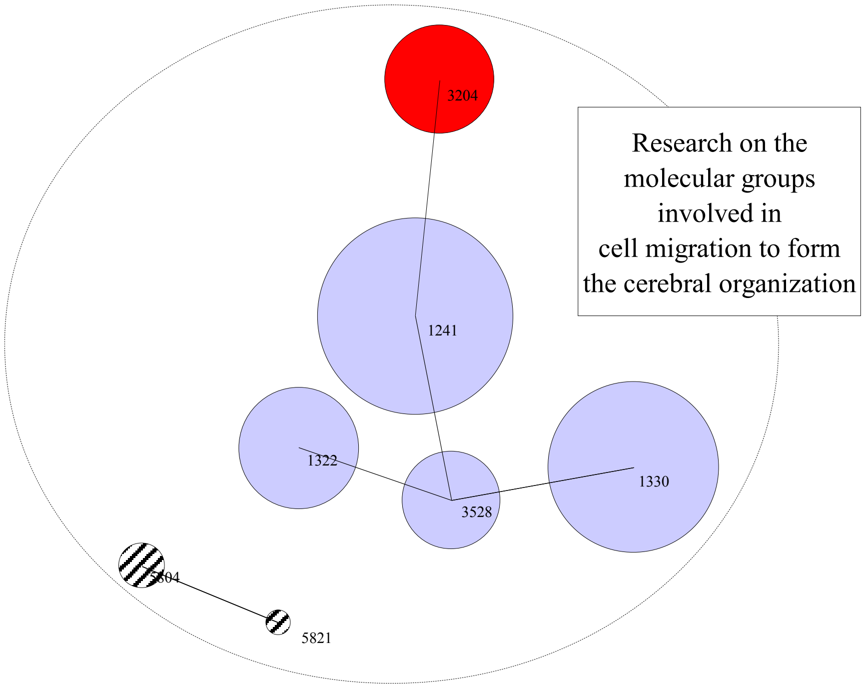
Name of RA	Research on neurodegenerative mechanism in Huntington's disease based on transgenic mice	RA ID	49	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (1)	28	1666	3305	2001.3



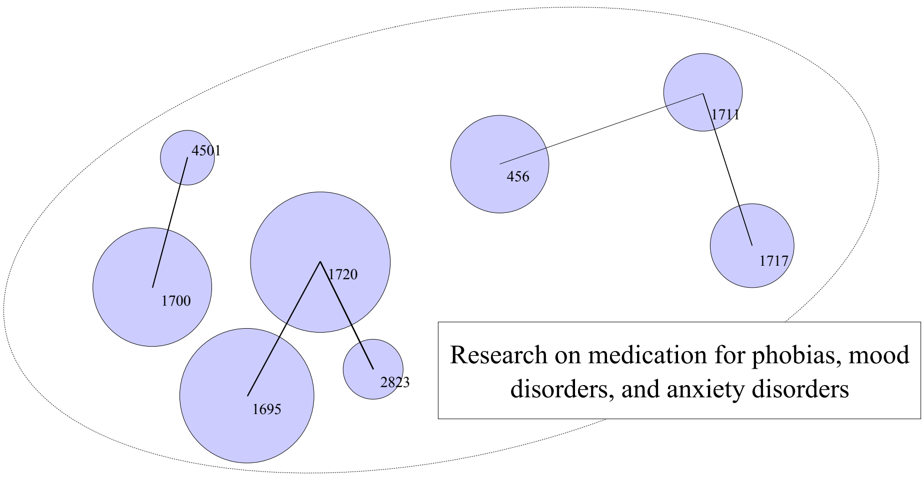
Name of RA	Visual stimulation and oscillatory brain activities	RA ID	50	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (0)	26	2224	3925	1999.8



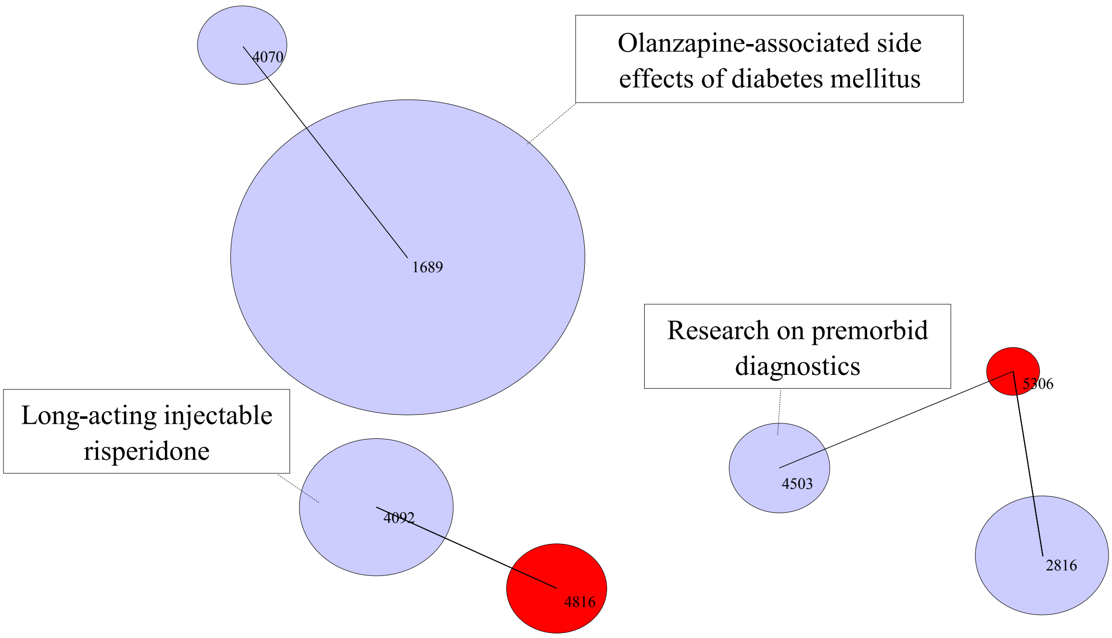
Name of RA	Mechanism of molecules involved in formation of brain	RA ID	51	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (1)	24	1320	2635	2001.3



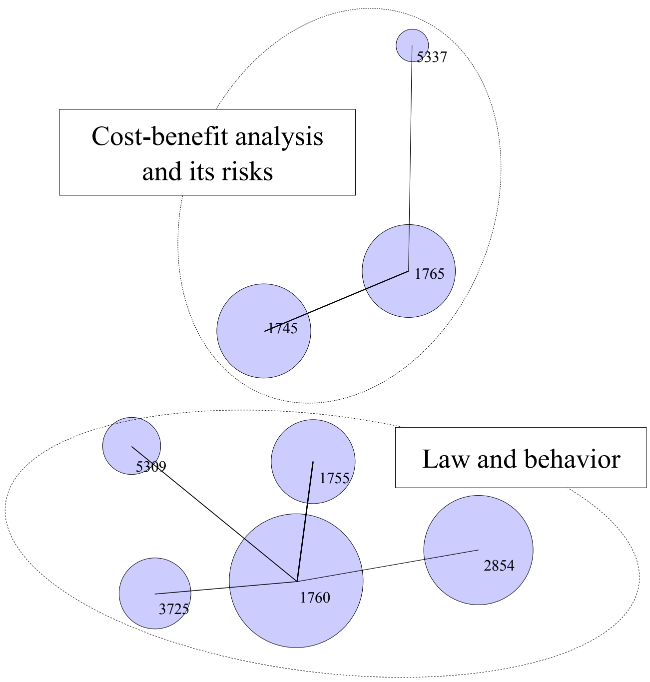
Name of RA	Clinical trials for phobias, mood disorders and anxiety disorders	RA ID	52	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (0)	52	1419	3395	2001.1



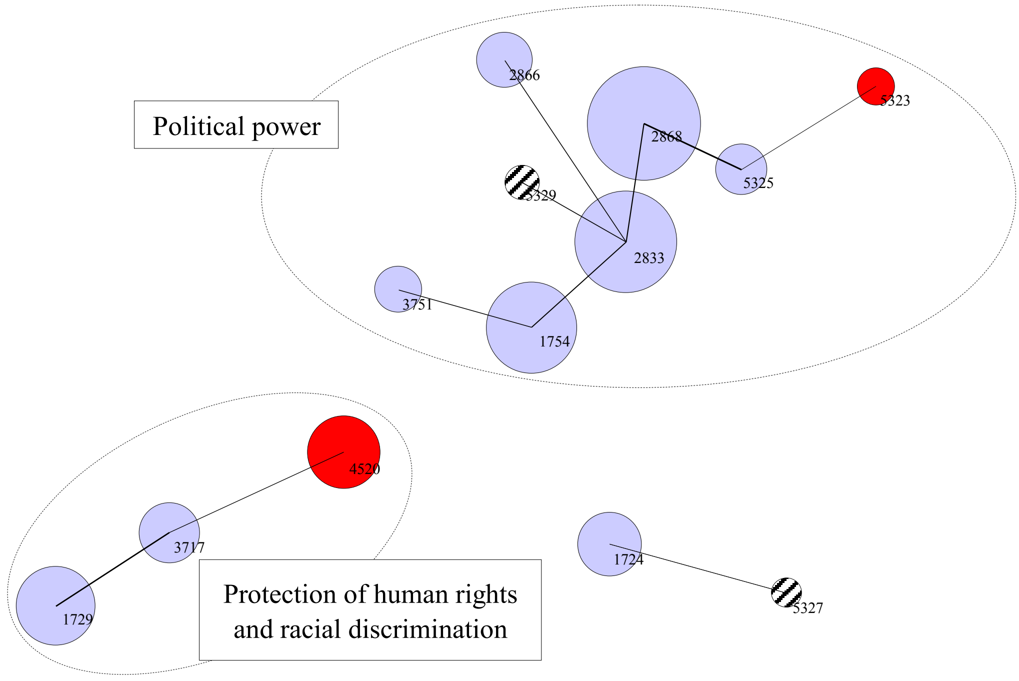
Name of RA	Early diagnostics and therapy of schizophrenia	RA ID	53	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (2)	51	1195	2957	2001.7



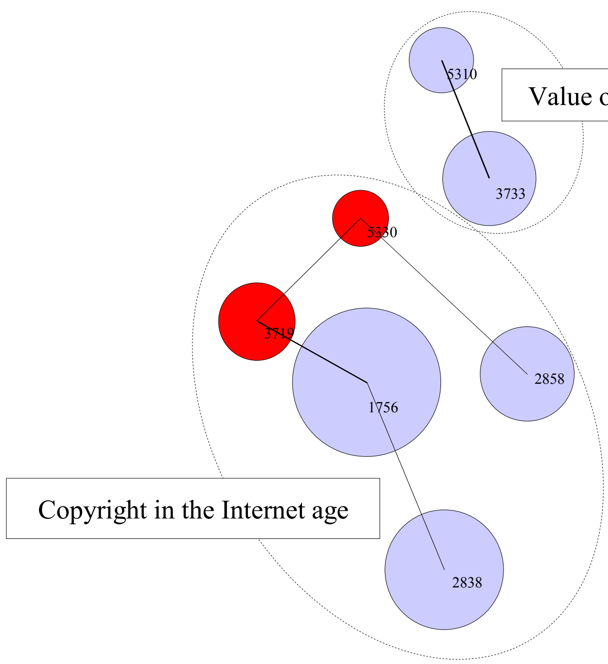
Name of RA	Law and behavioral science	RA ID	54	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (0)	31	503	922	2000.9



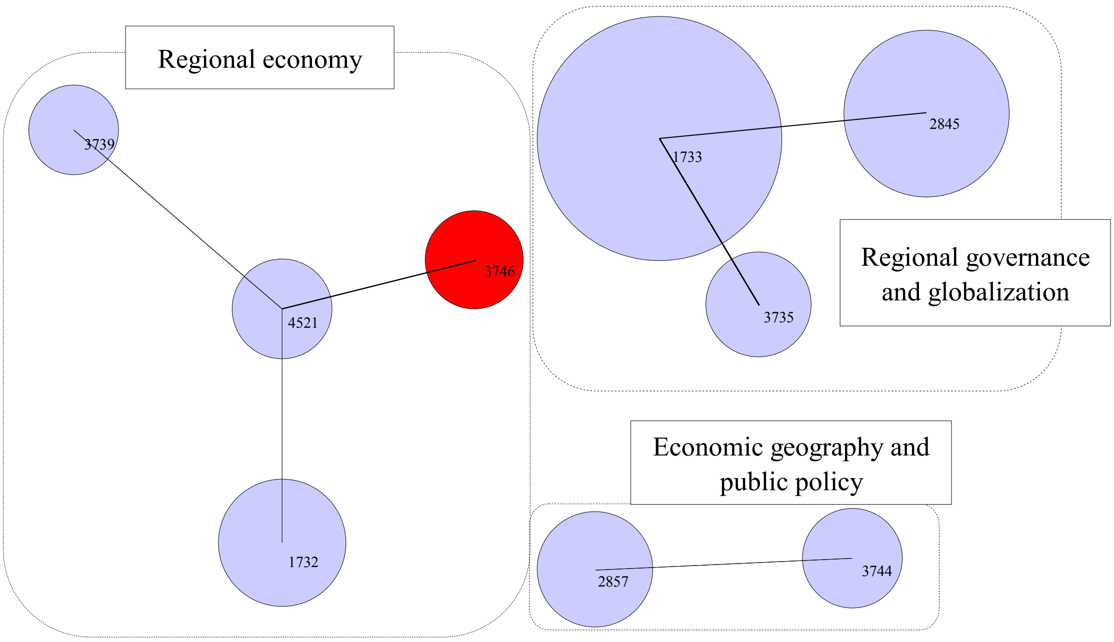
Name of RA	Political power and human rights		RA ID	55
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13 (2)	60	616	1329	2001.7



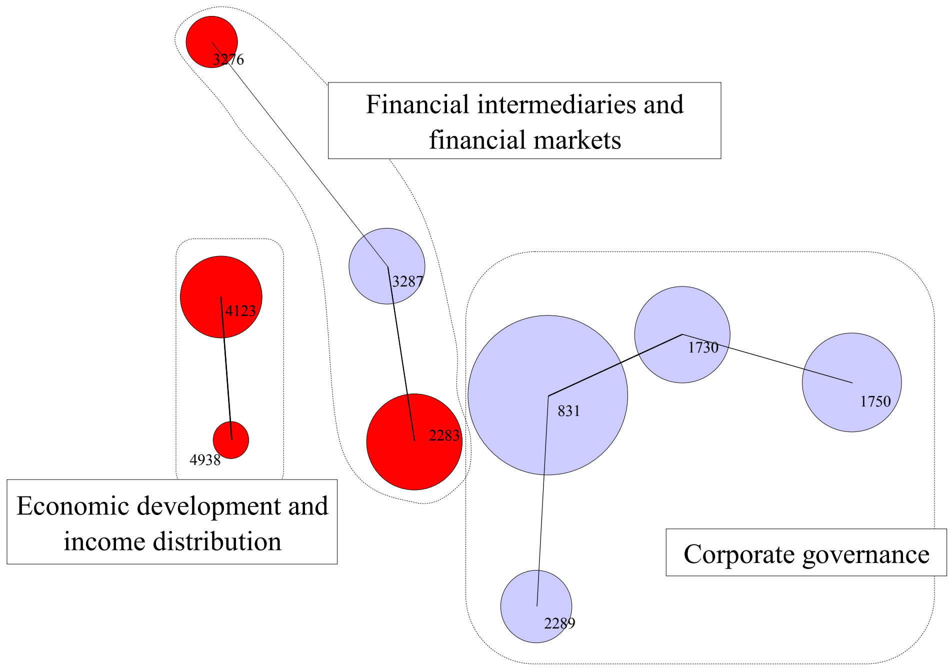
Name of RA	Research on intellectual property right problems		RA ID	56
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (2)	20	286	480	2001.2



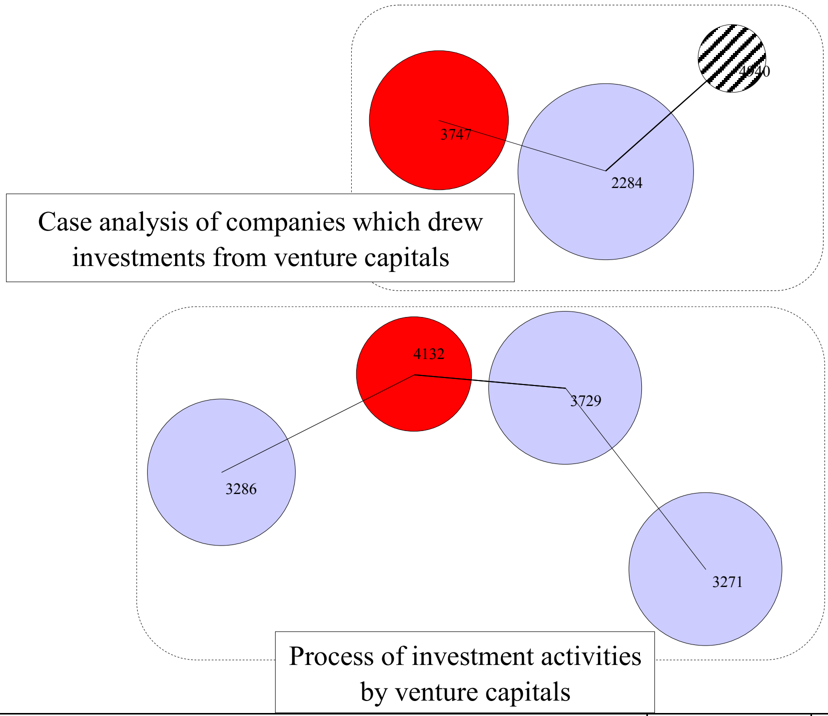
Name of RA	Study on local economy and regional integration		RA ID	57
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9 (1)	25	602	1133	2000.3



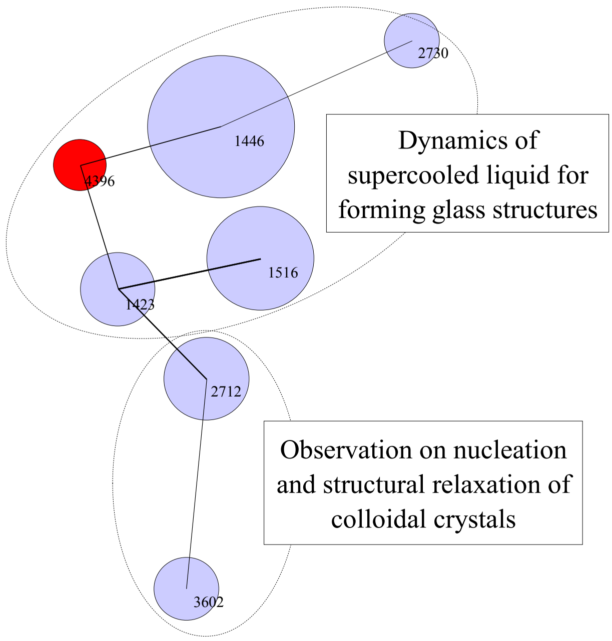
Name of RA	Research on corporate governance		RA ID	58
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9 (4)	68	729	1626	2001.8



Name of RA	Research on venture capital		RA ID	59
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (2)	17	203	309	2001.6

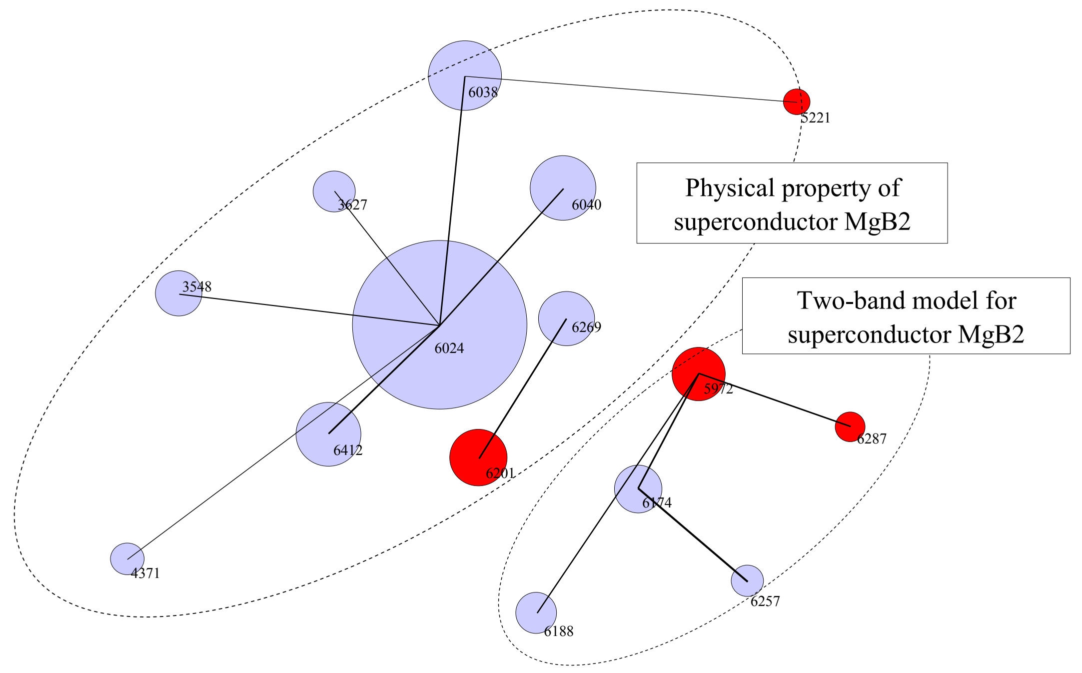


Name of RA	Stability and vitrification of supercooled liquid		RA ID	60
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (1)	31	1243	2617	2001.0



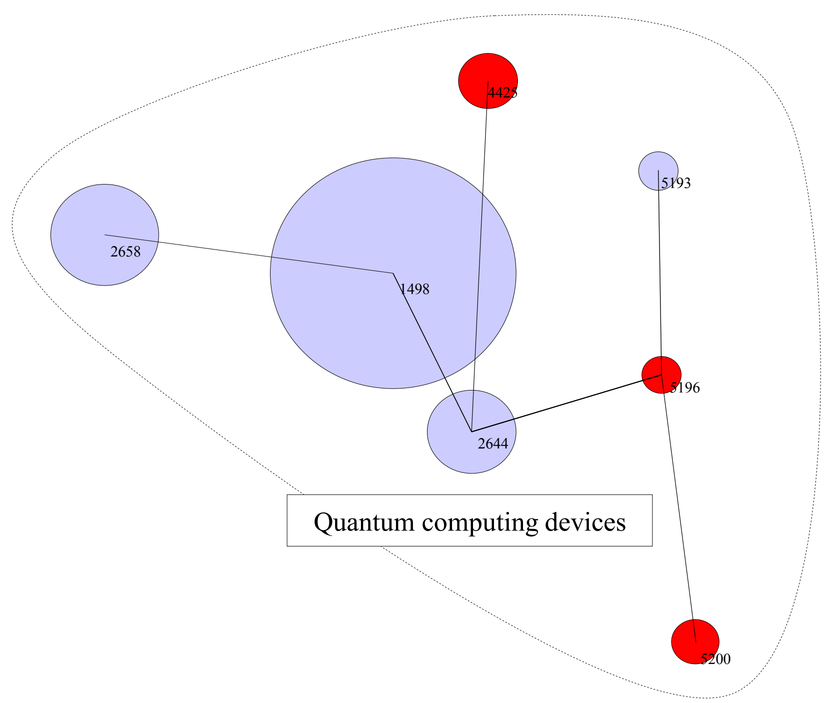
Name of RA	Physical attributes and material process of MgB2	RA ID	61

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
15 (4)	61	1796	7710	2001.4

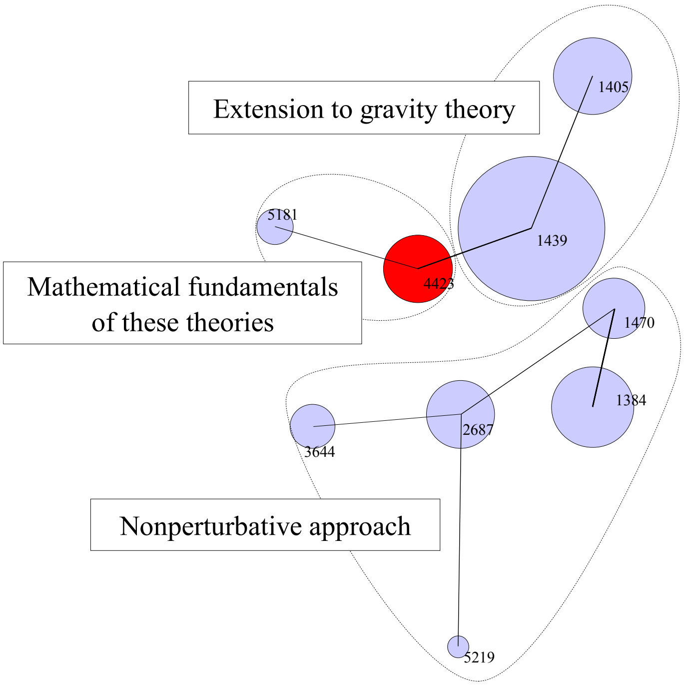


Name of RA	Quantum computing devices	RA ID	62

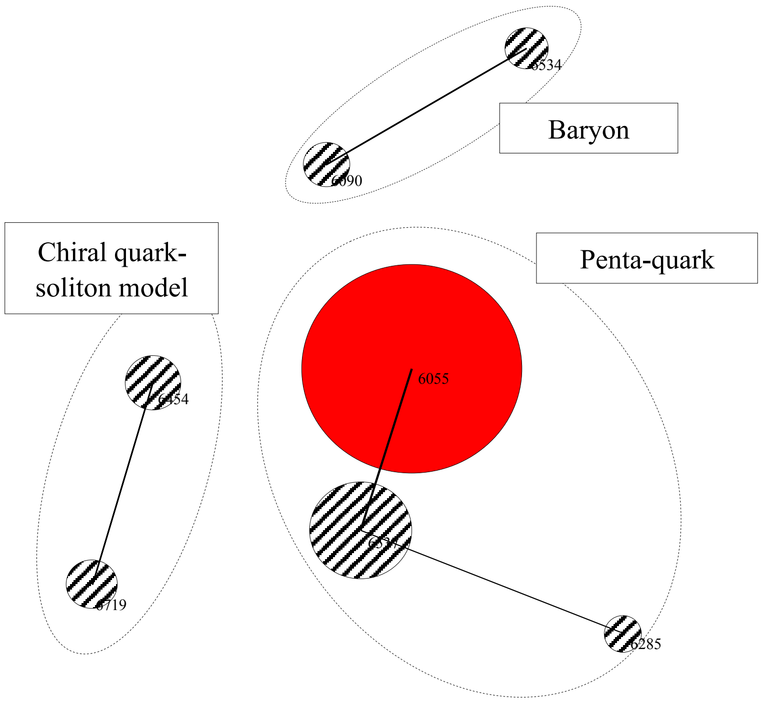
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (3)	31	1163	3246	2001.5



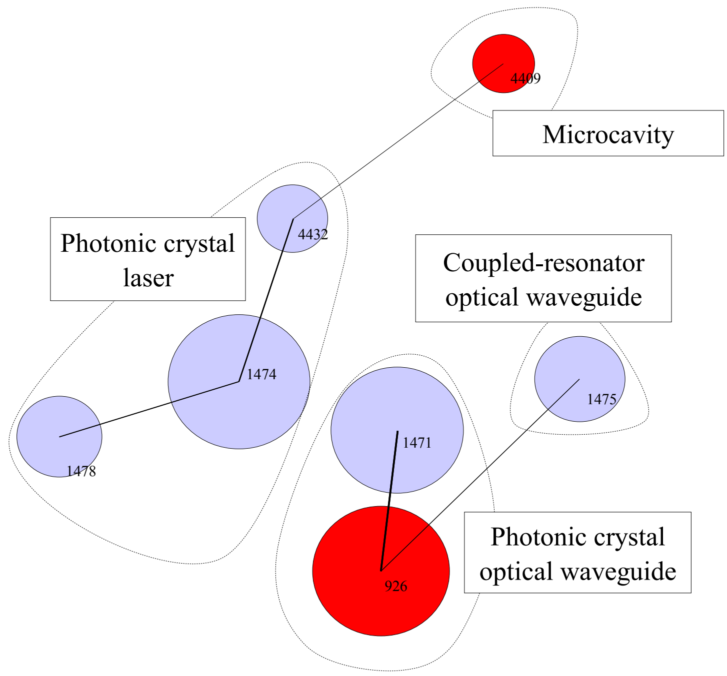
Name of RA	Noncommutative field theory and super string theory		RA ID	63
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9 (1)	77	1535	4268	2001.7



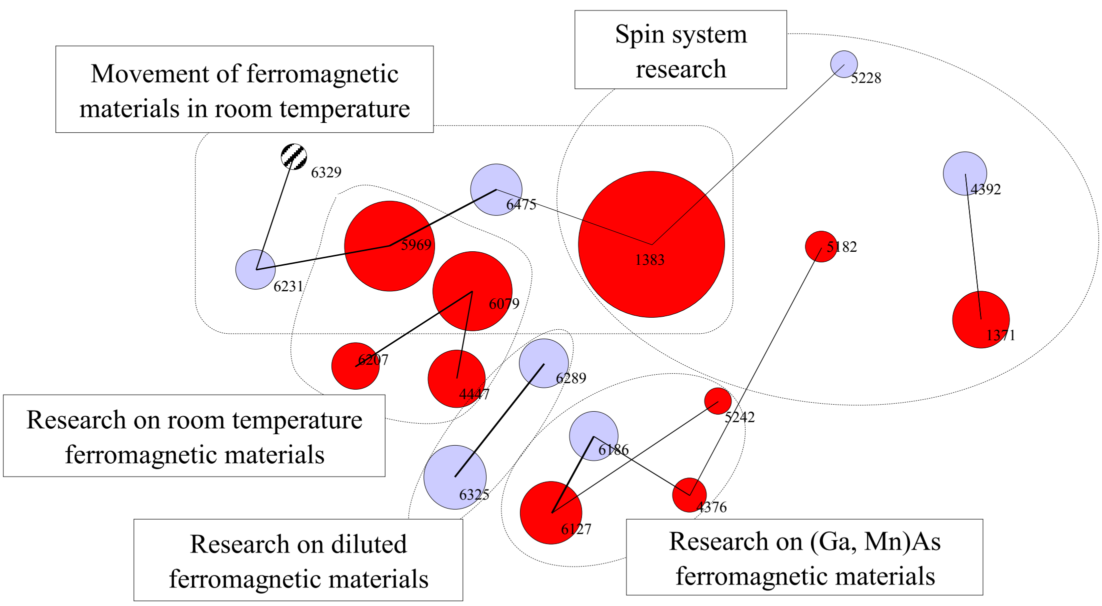
Name of RA	Baryon consisting of five quarks		RA ID	64
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (1)	39	200	1224	2003.7



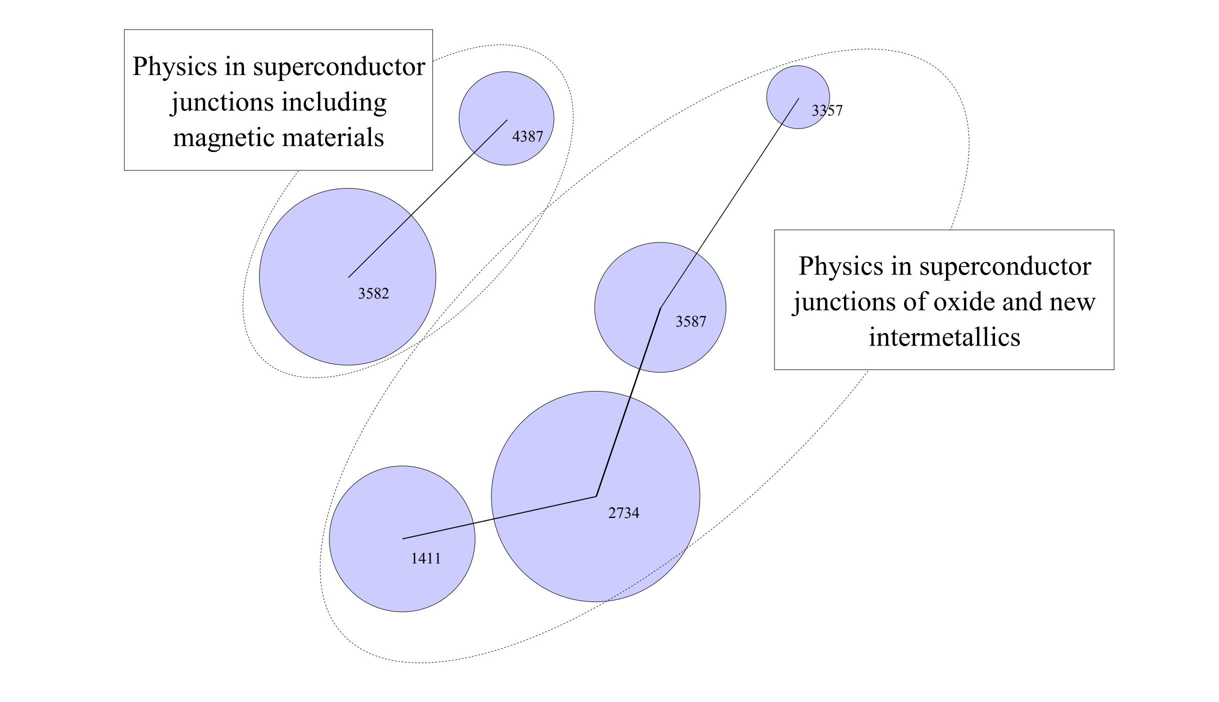
Name of RA	Photonic crystal and devices		RA ID	65
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (2)	24	1015	2073	2000.4



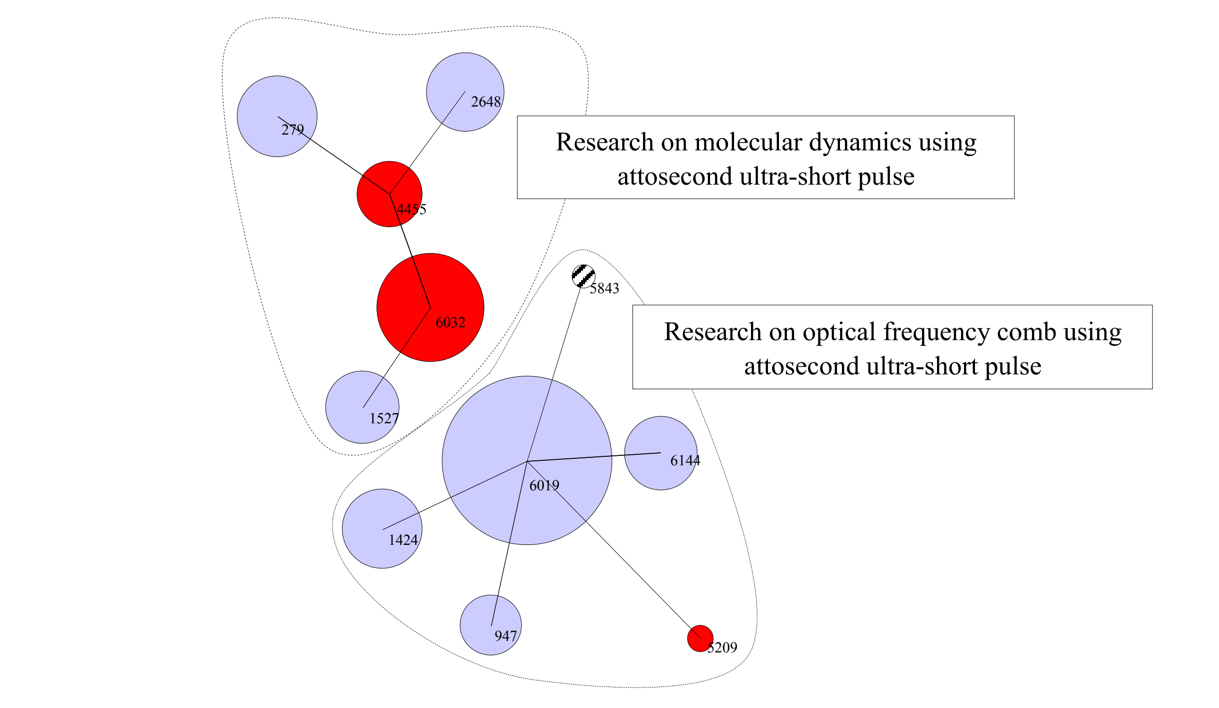
Name of RA	Spintronics		RA ID	66
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
18 (10)	79	2111	6244	2001.7



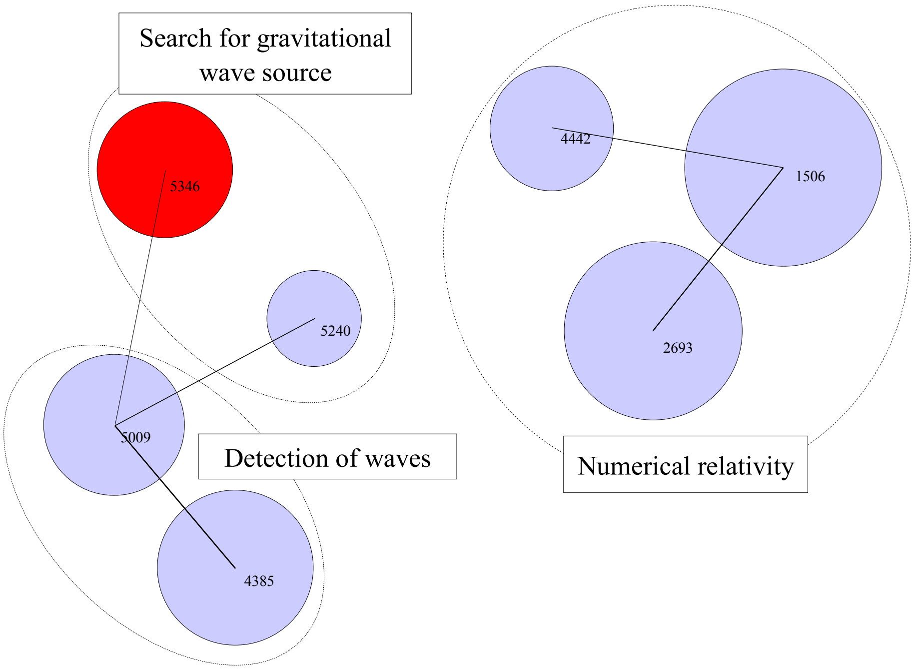
Name of RA	Physics in high-temperature superconductor junctions		RA ID	67
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (0)	18	538	946	2001.7



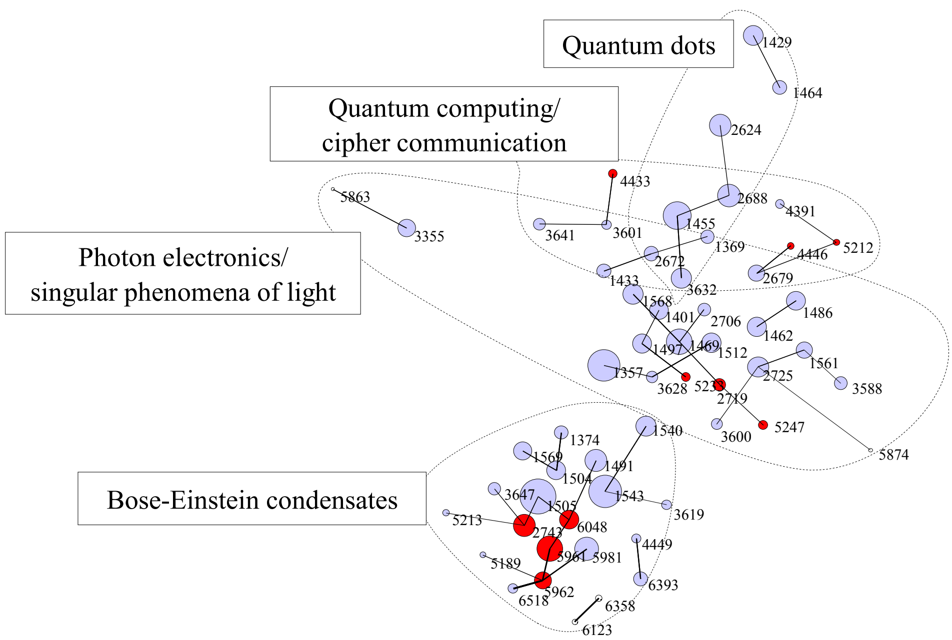
Name of RA	Basic and applied research on ultra-short-pulse laser		RA ID	68
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
11 (3)	54	1917	4764	2000.8



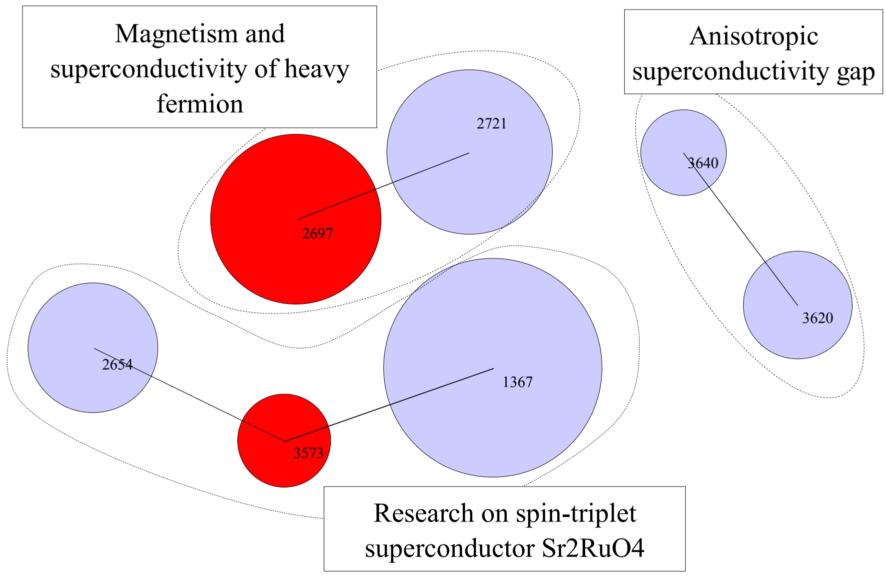
Name of RA	Relativistic astronomy and gravity waves		RA ID	69
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (1)	29	393	676	2003.0



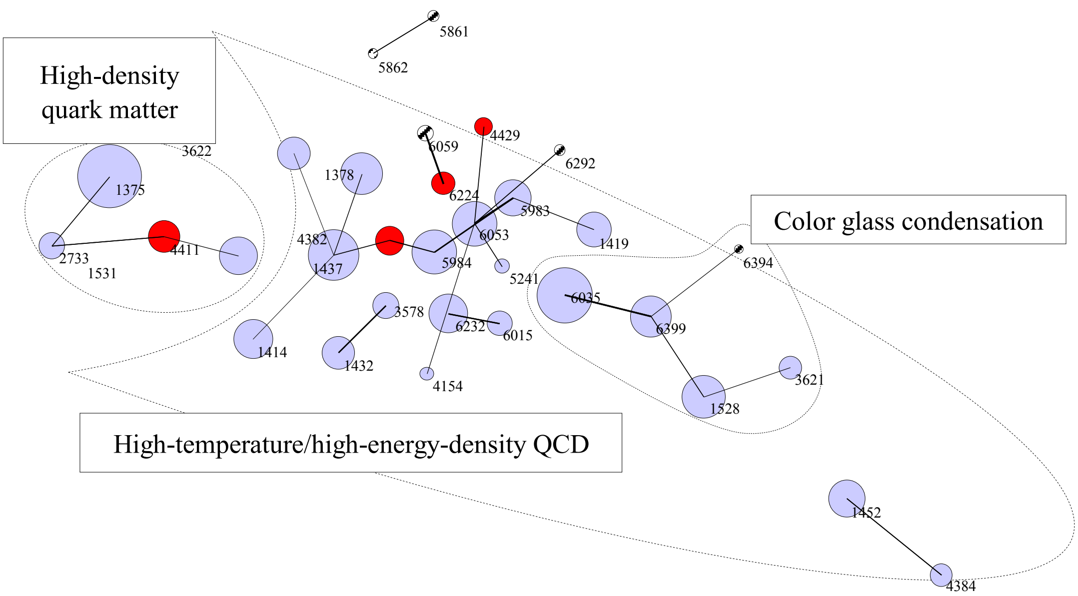
Name of RA	Quantum electronics and its application to quantum information processing		RA ID	70
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
57 (10)	332	8610	26819	2001.5



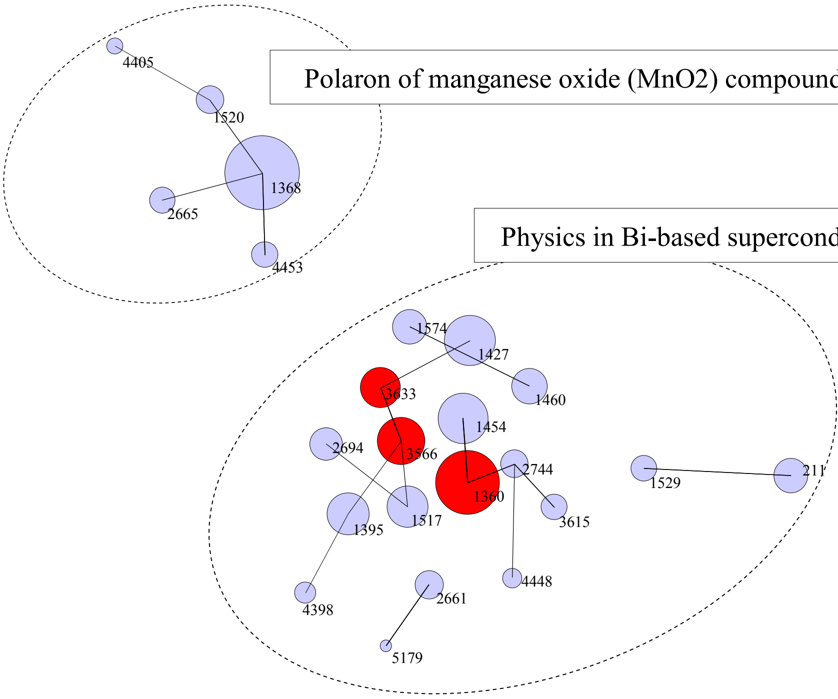
Name of RA	Superconductors with anisotropic gaps		RA ID	71
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (2)	44	1495	3604	2001.0



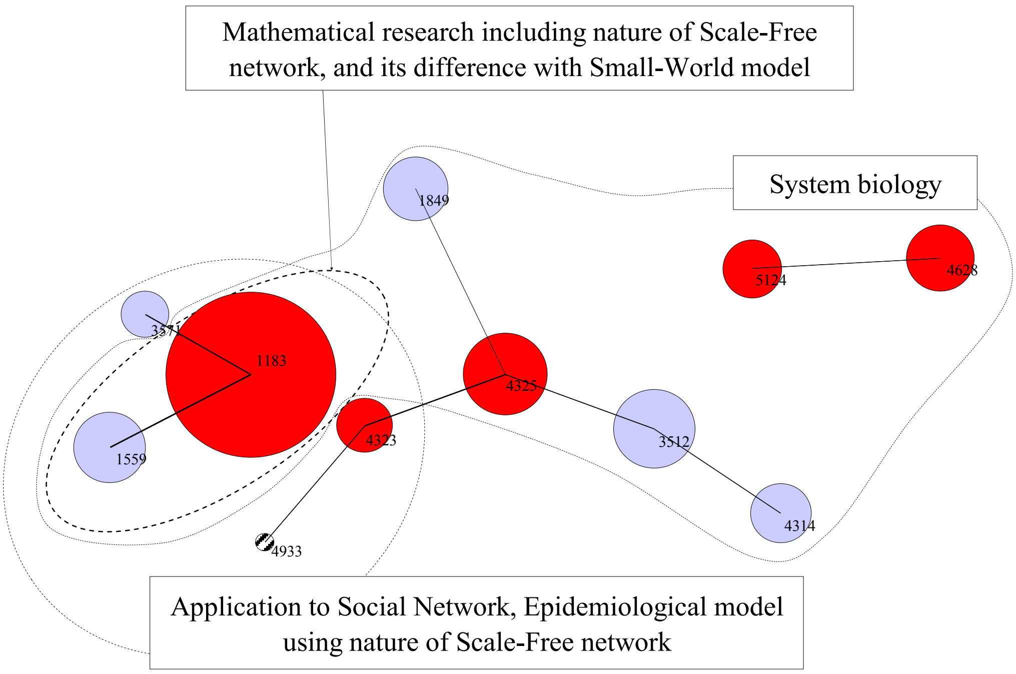
Name of RA	Quantum chromodynamics		RA ID	72
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
32 (4)	181	3372	11945	2001.5



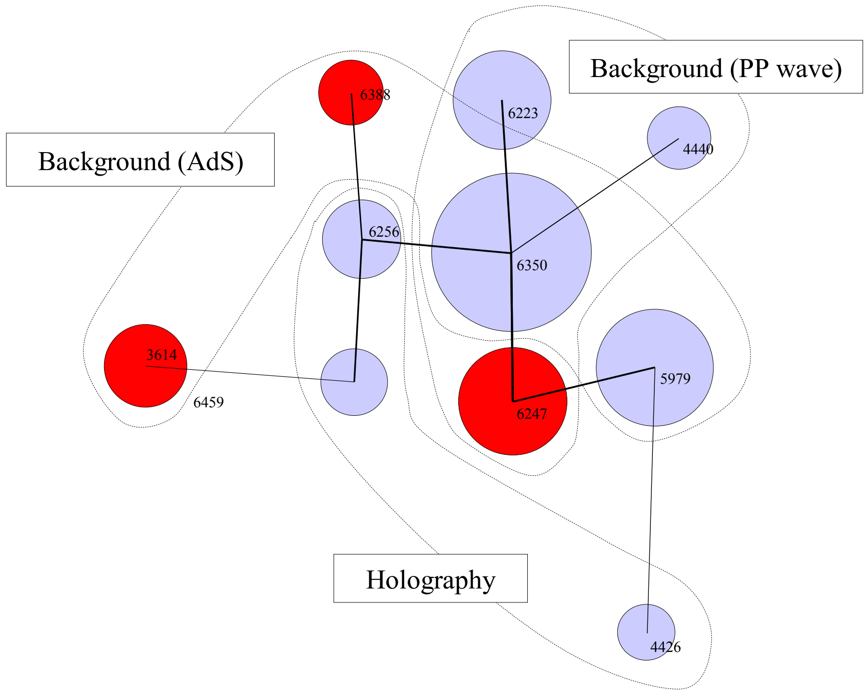
Name of RA	Bi-based high-temperature superconductors		RA ID	73
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
23 (3)	85	3525	7662	2000.9



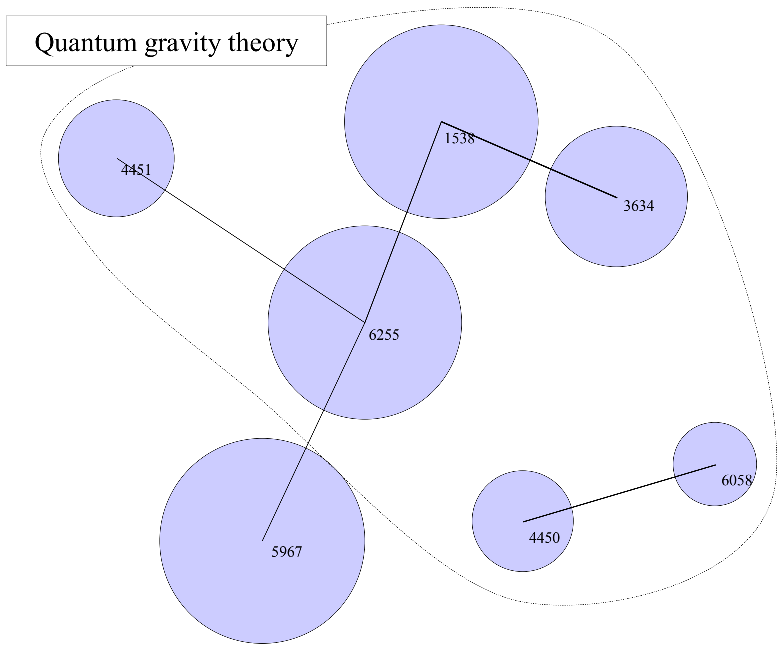
Name of RA	Network analysis and its application to genome, social-network, and infection transmission		RA ID	74
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
11 (5)	68	3131	9290	2001.2



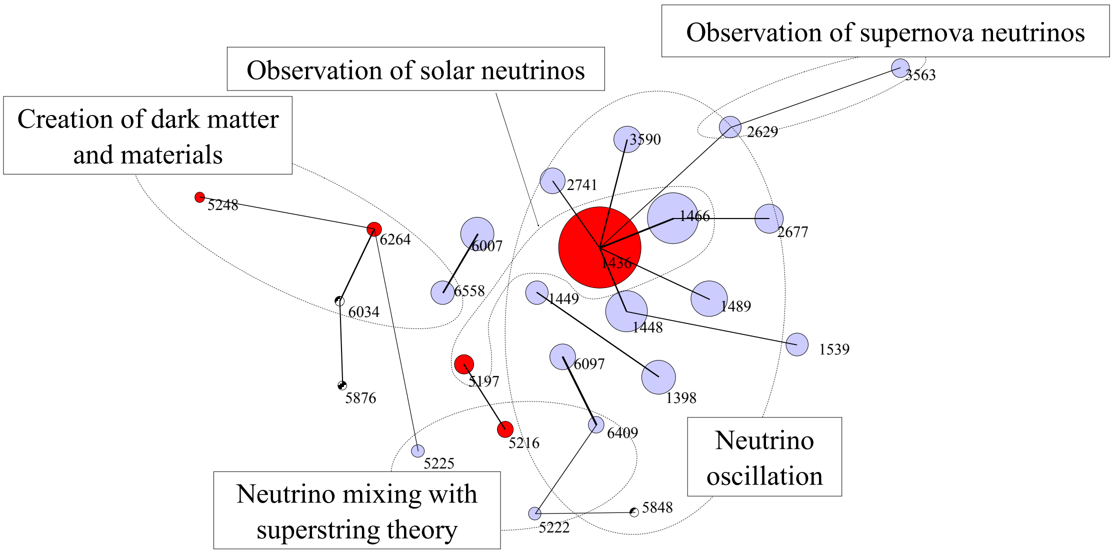
Name of RA	Super string theory and spatiotemporal physics		RA ID	75
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
10 (3)	71	638	3301	2002.6



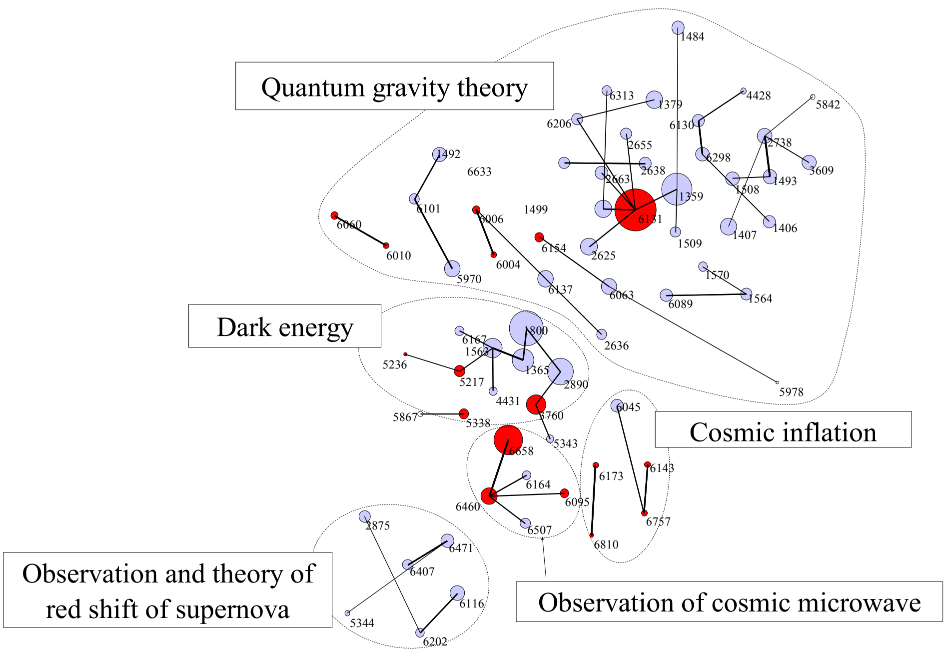
Name of RA	Quantum gravity		RA ID	76
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (0)	41	598	1724	2002.0



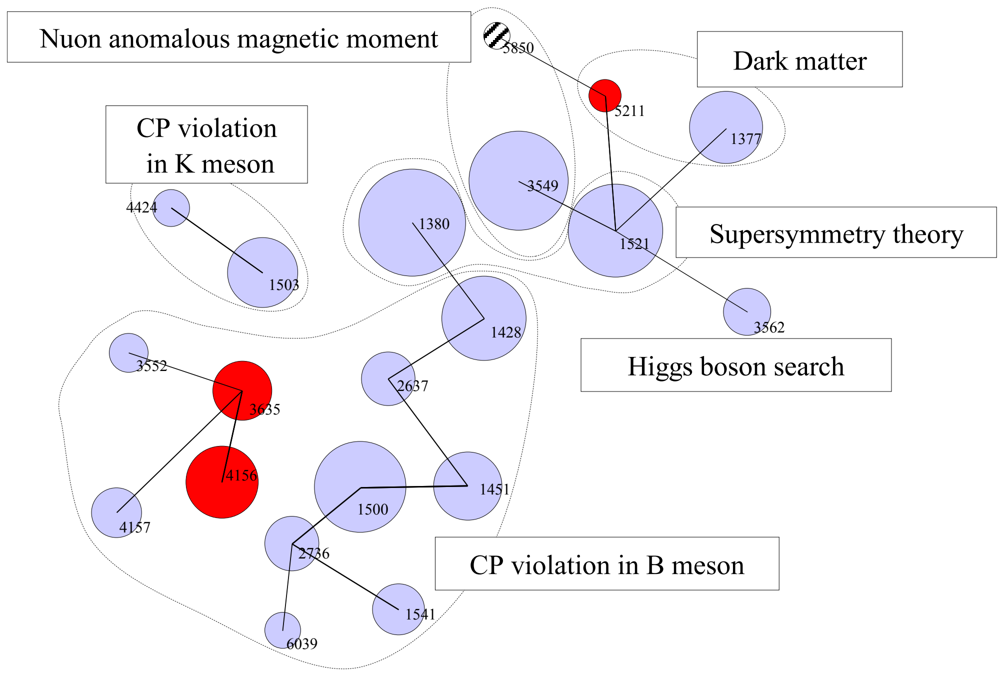
Name of RA	Neutrino oscillation and creation of material universe		RA ID	77
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
25 (5)	135	2712	11693	2001.6



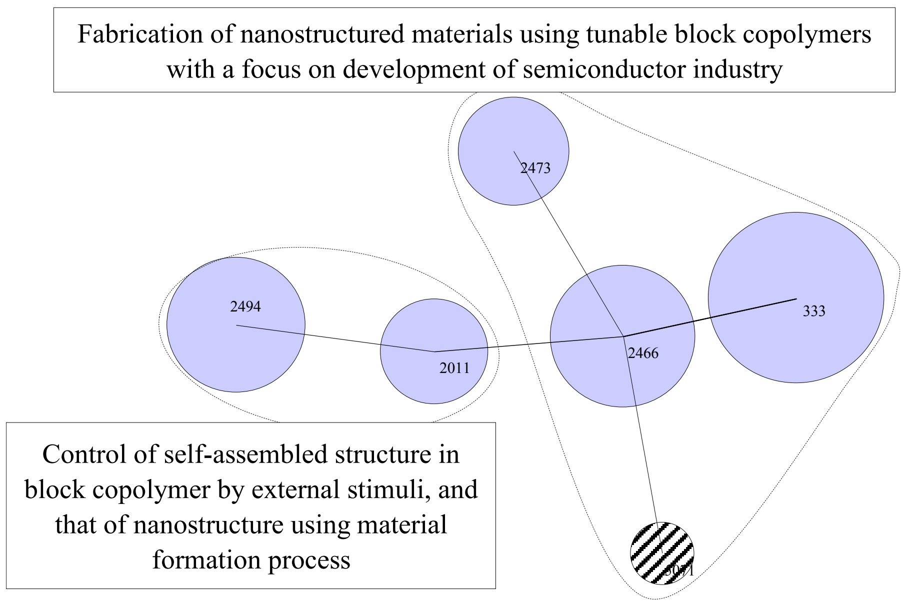
Name of RA	Cosmic microwave background fluctuation and inflationary cosmology		RA ID	78
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
66 (17)	542	9457	41763	2001.9



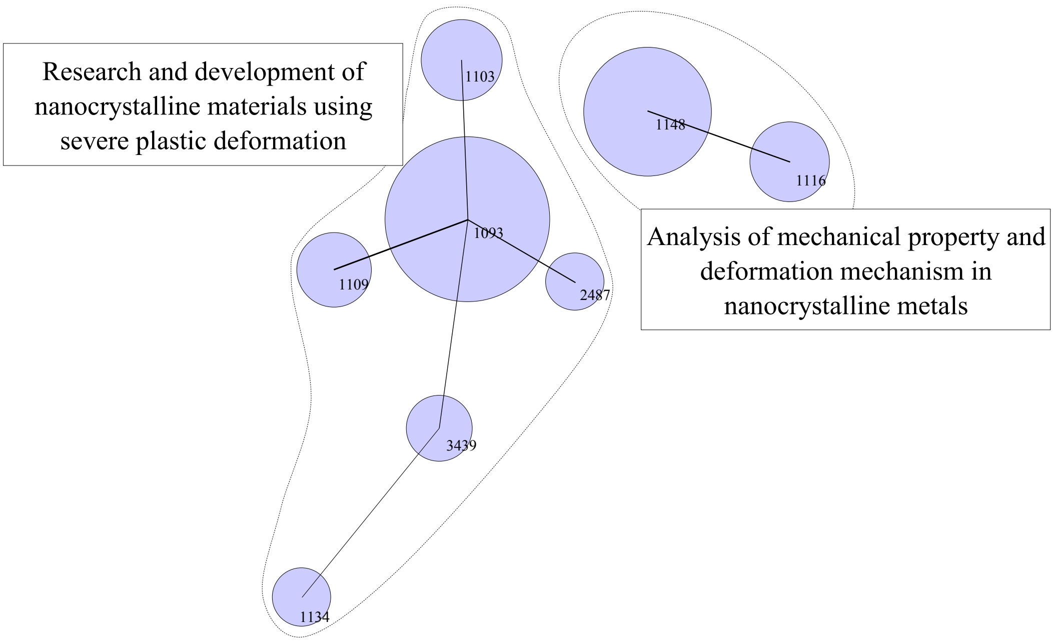
Name of RA	Supersymmetry and CP violation	RA ID	79	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
20 (3)	154	3078	10626	2001.5



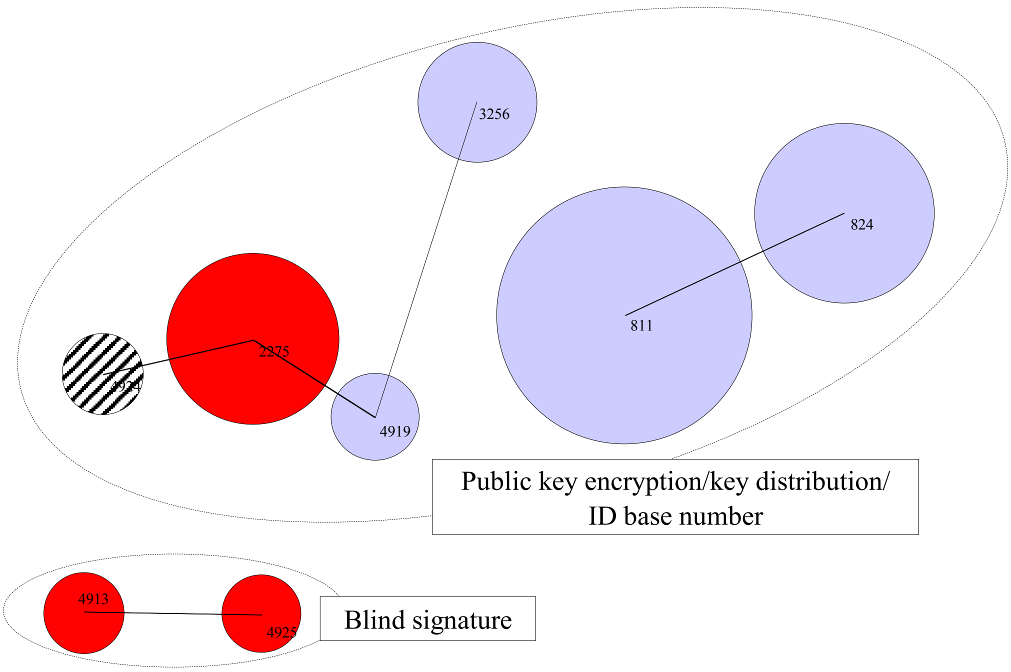
Name of RA	Formation of nanostructures based on block copolymers	RA ID	80	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (0)	20	553	952	2000.9



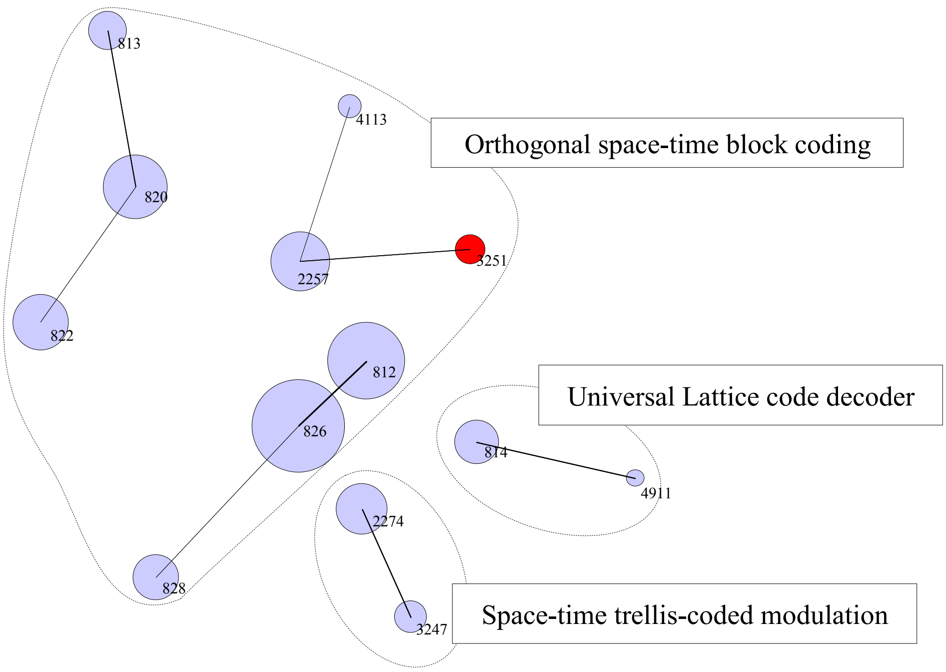
Name of RA	Research on plastic deformation in nano-crystals		RA ID	81
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (0)	58	1130	2554	2001.6



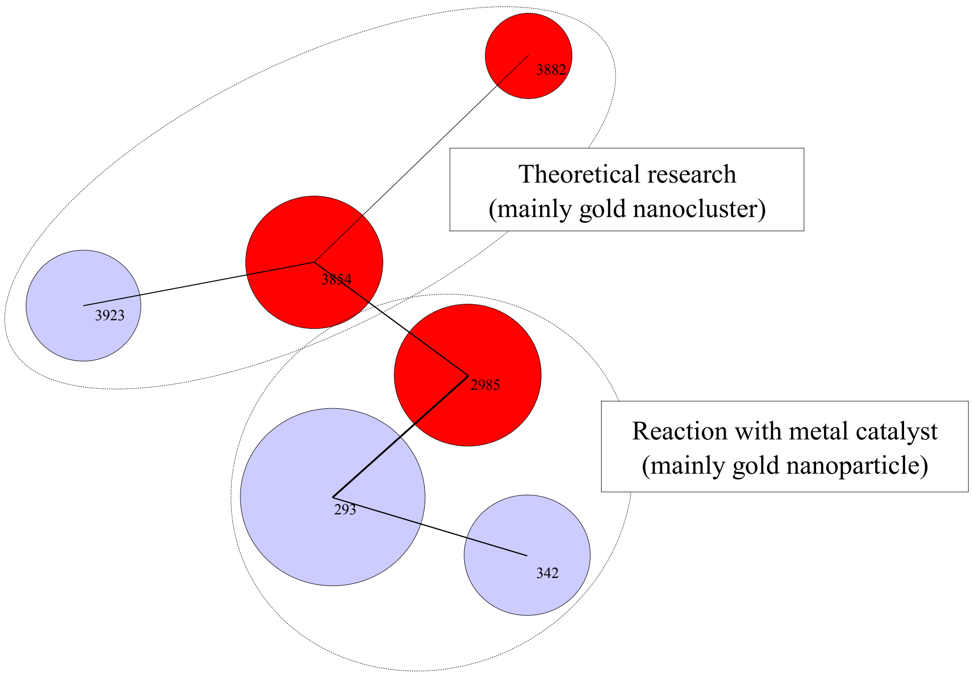
Name of RA	Application of cryptographic technologies to digital information distribution		RA ID	82
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (3)	23	359	667	2000.9



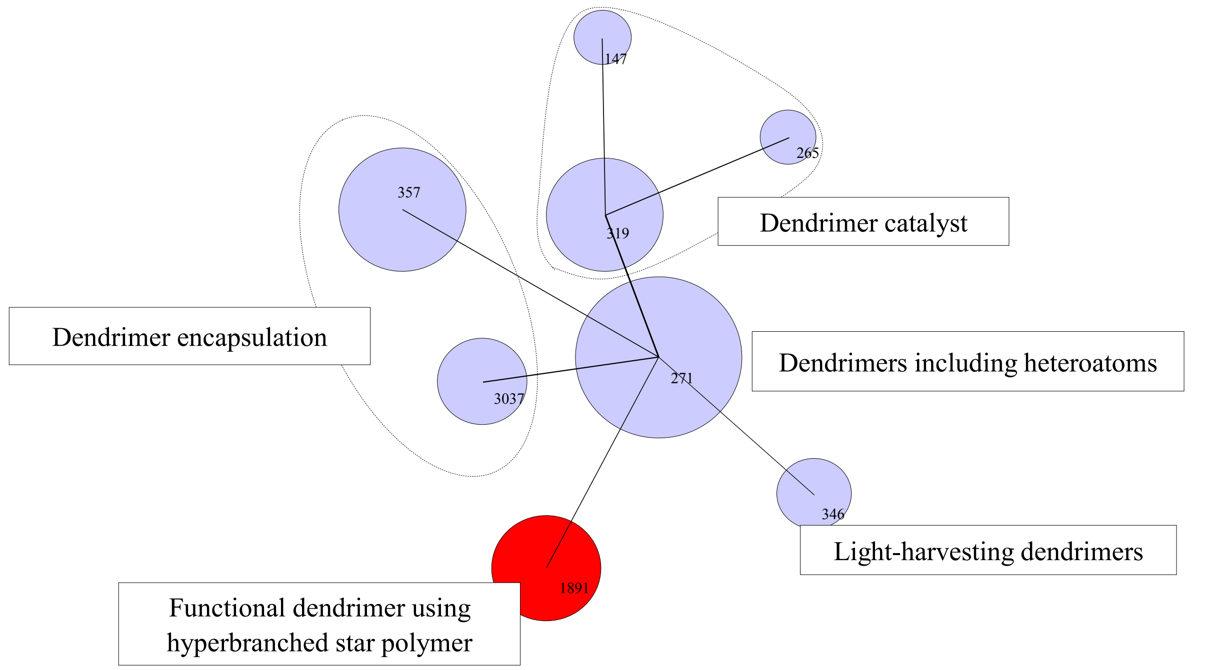
Name of RA	Research on modulation schemes for ultra-wideband communications		RA ID	83
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13 (1)	45	1082	2453	2000.5



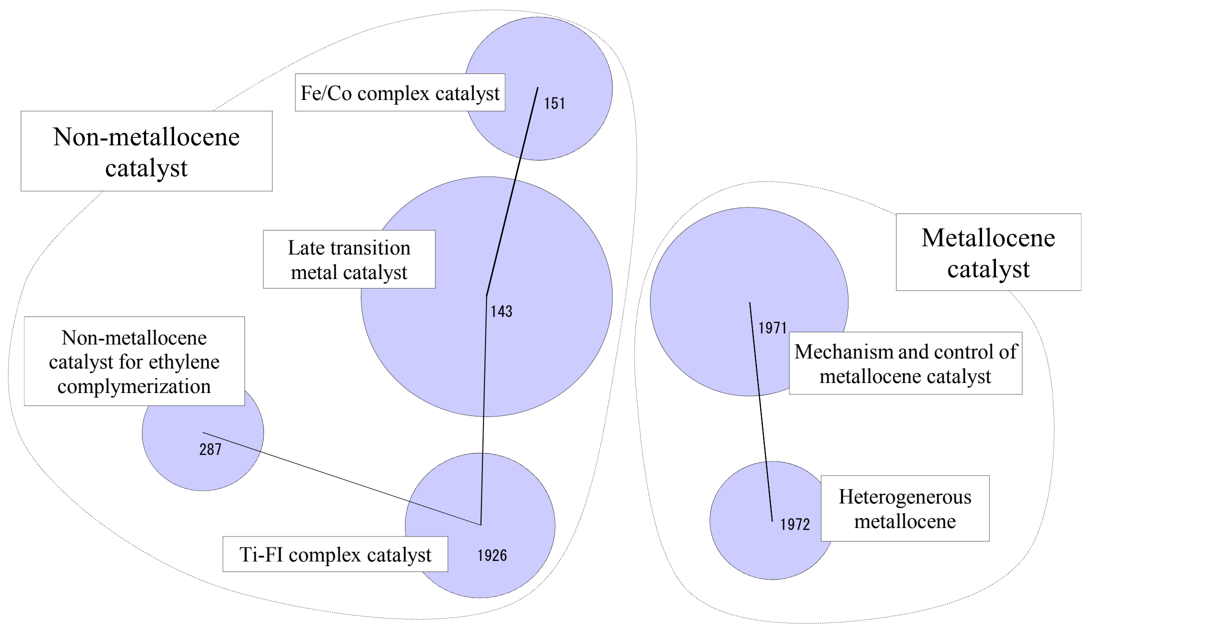
Name of RA	Catalytic activity of gold clusters		RA ID	84
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (3)	32	698	1474	2002.1



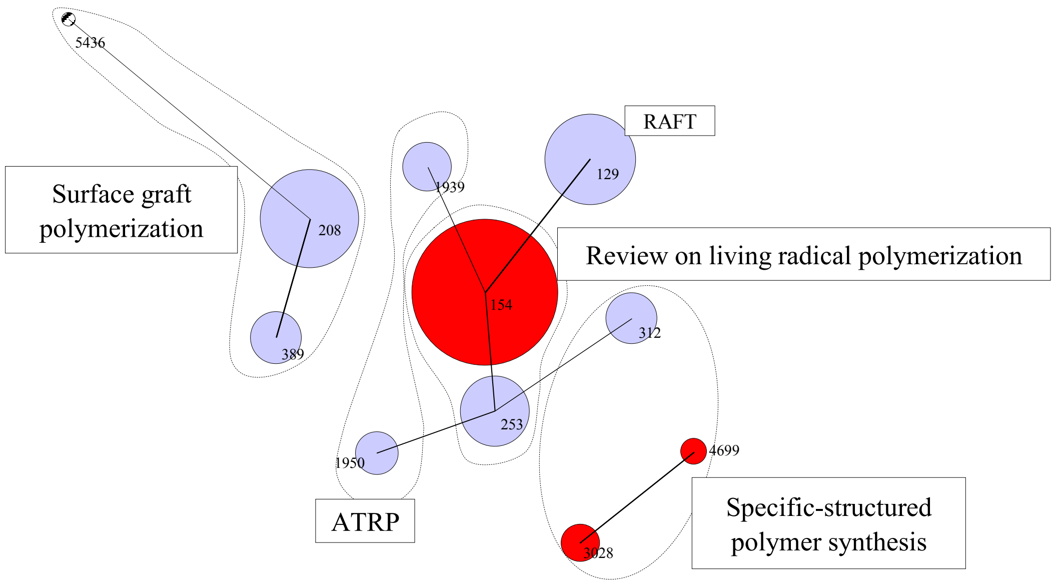
Name of RA	Dendrimer research		RA ID	85
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (1)	38	2155	4626	2000.2



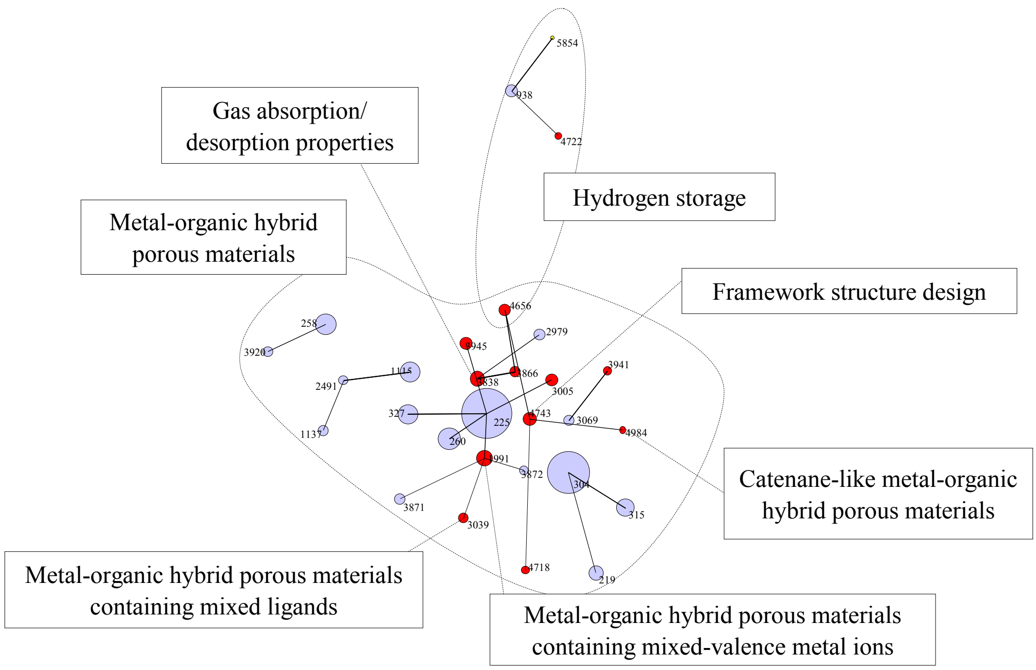
Name of RA	High performance catalysis for olefin polymerization		RA ID	86
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (0)	43	1738	4160	2000.8



Name of RA	Research on living free-radical polymerization		RA ID	87
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
11 (3)	71	1898	5625	2001.1

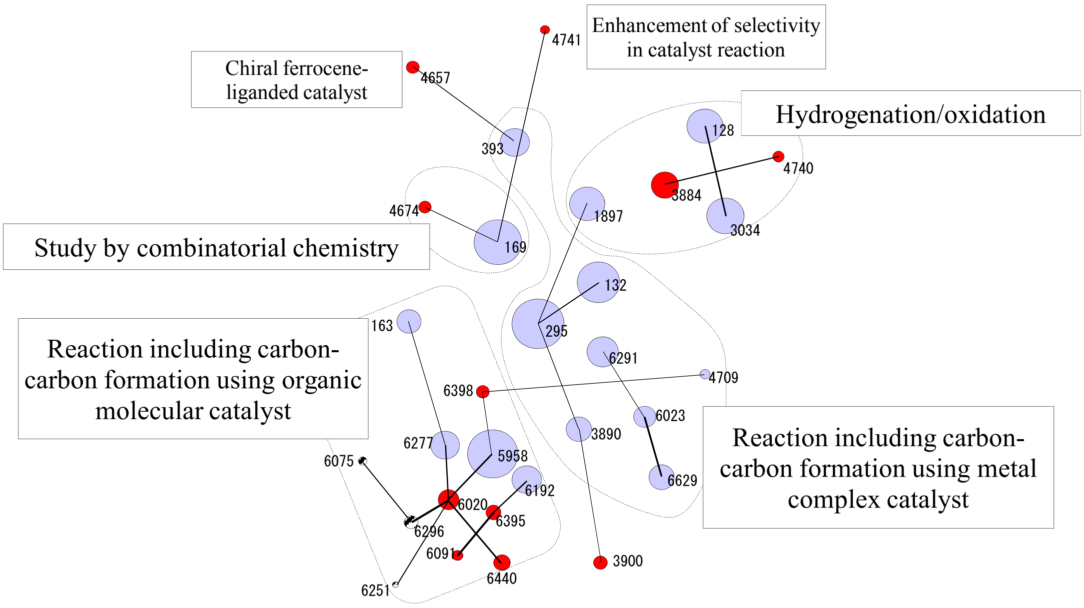


Name of RA	Metal: Organic hybrid porous materials		RA ID	88
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
29 (12)	103	3734	9288	2001.4



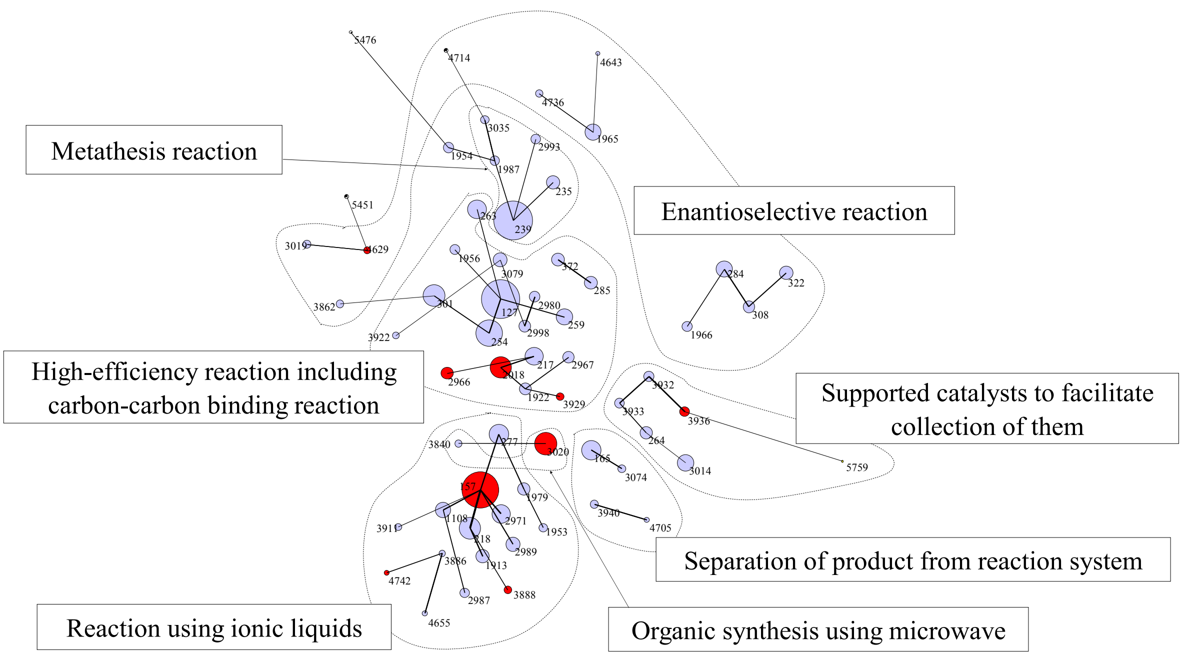
Name of RA	Catalytic asymmetric synthesis	RA ID	89

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
30 (11)	170	3288	9794	2001.8

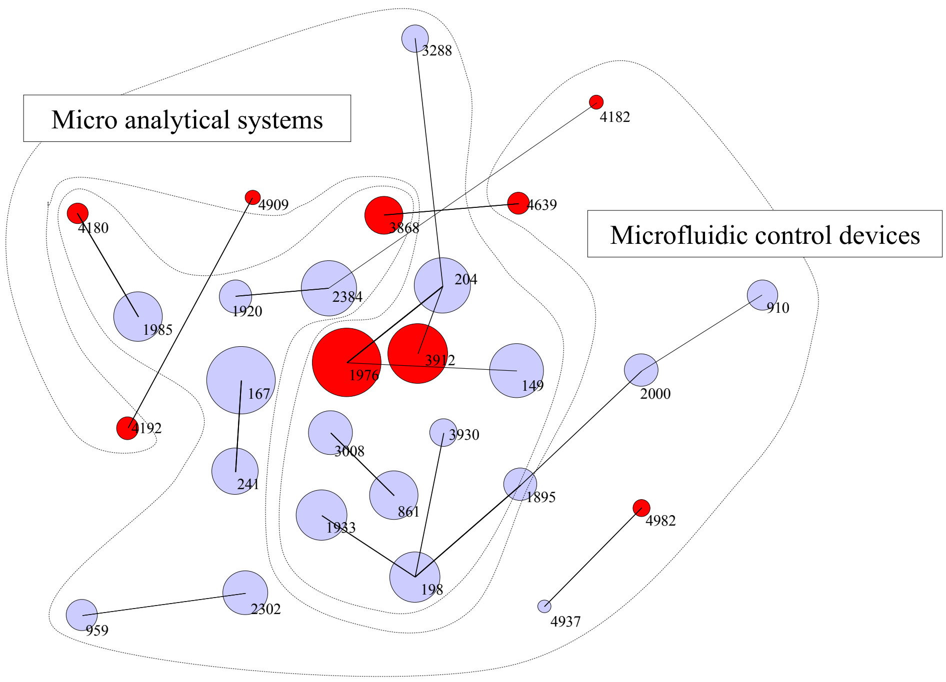


Name of RA	Organic synthesis and its application to a sustainable society	RA ID	90

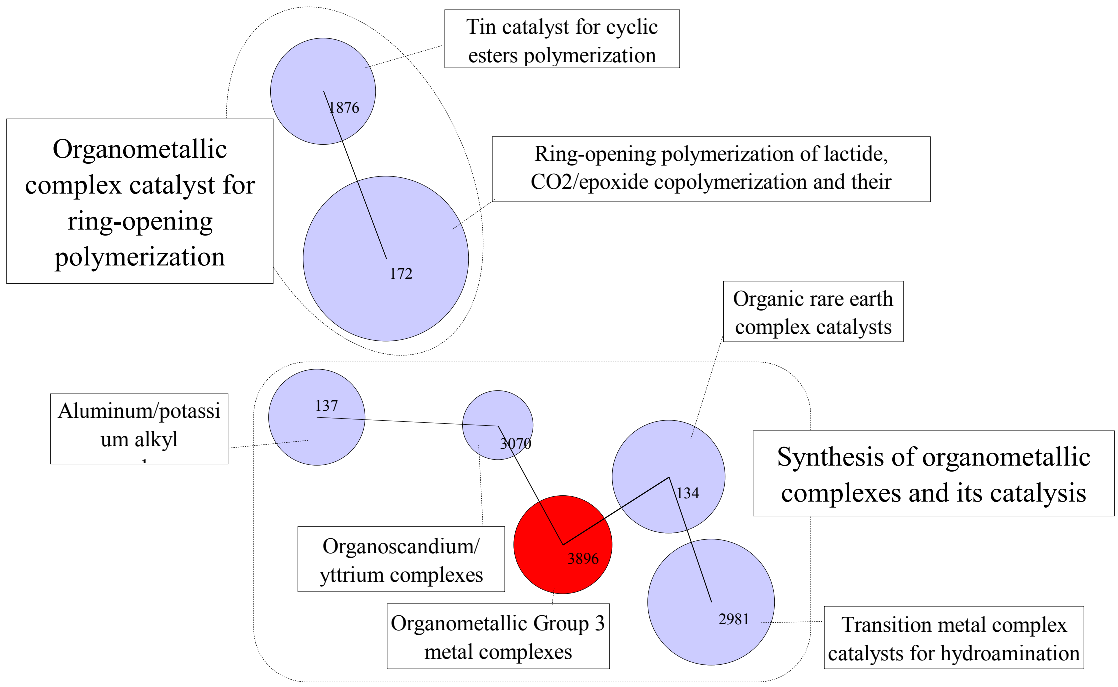
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
64 (9)	344	8919	27167	2001.4



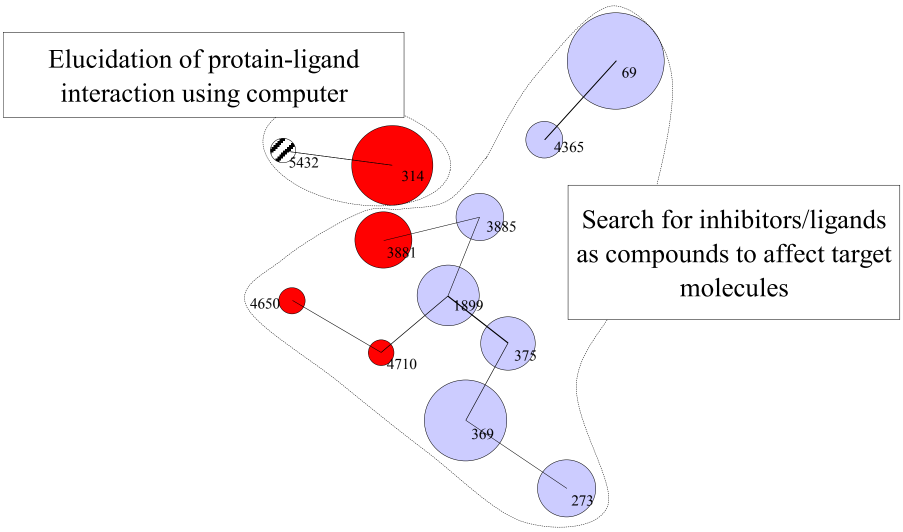
Name of RA	Chemical-/bio-system with microchips		RA ID	91
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
28 (9)	97	2413	5850	2001.0



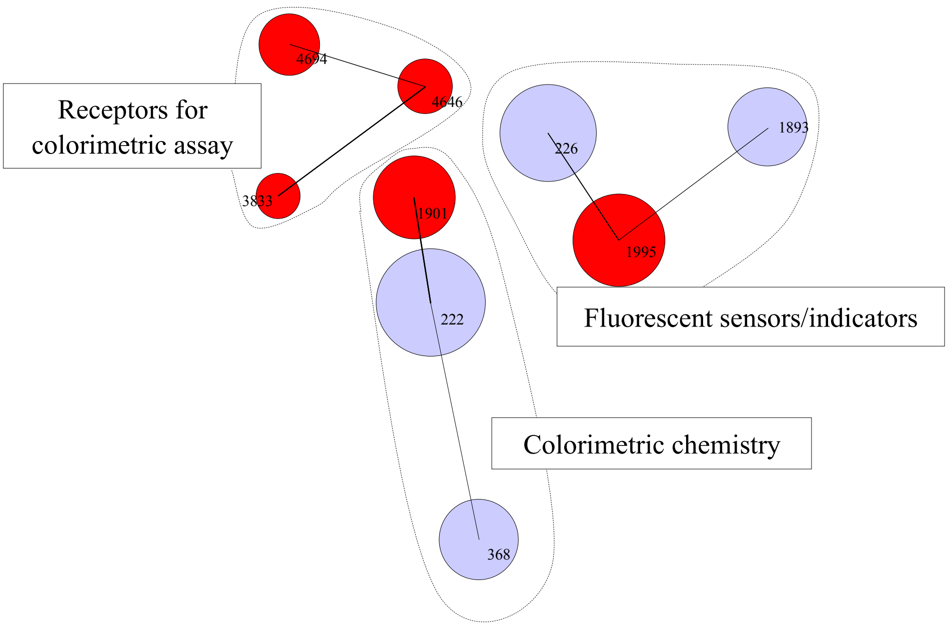
Name of RA	Metal-organic complex and its catalytic activity		RA ID	92
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (1)	62	1099	2734	2001.6



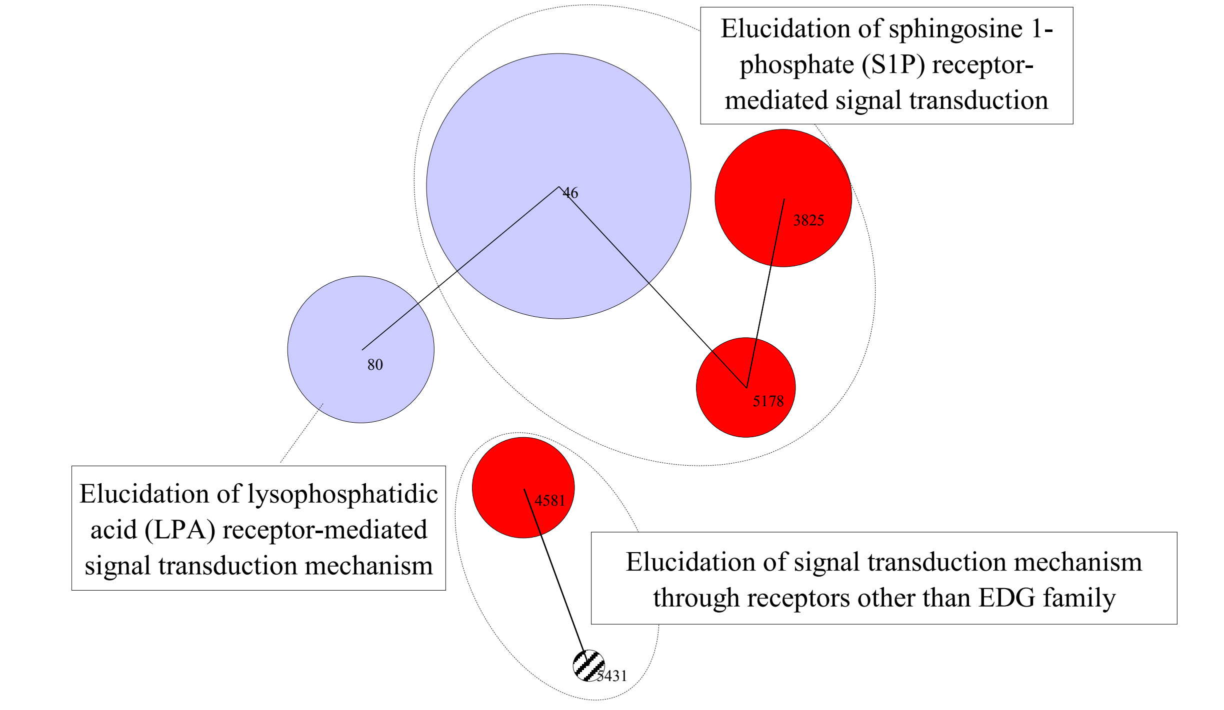
Name of RA	Drug discovery research	RA ID	93	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
12 (4)	45	1597	2770	2001.7



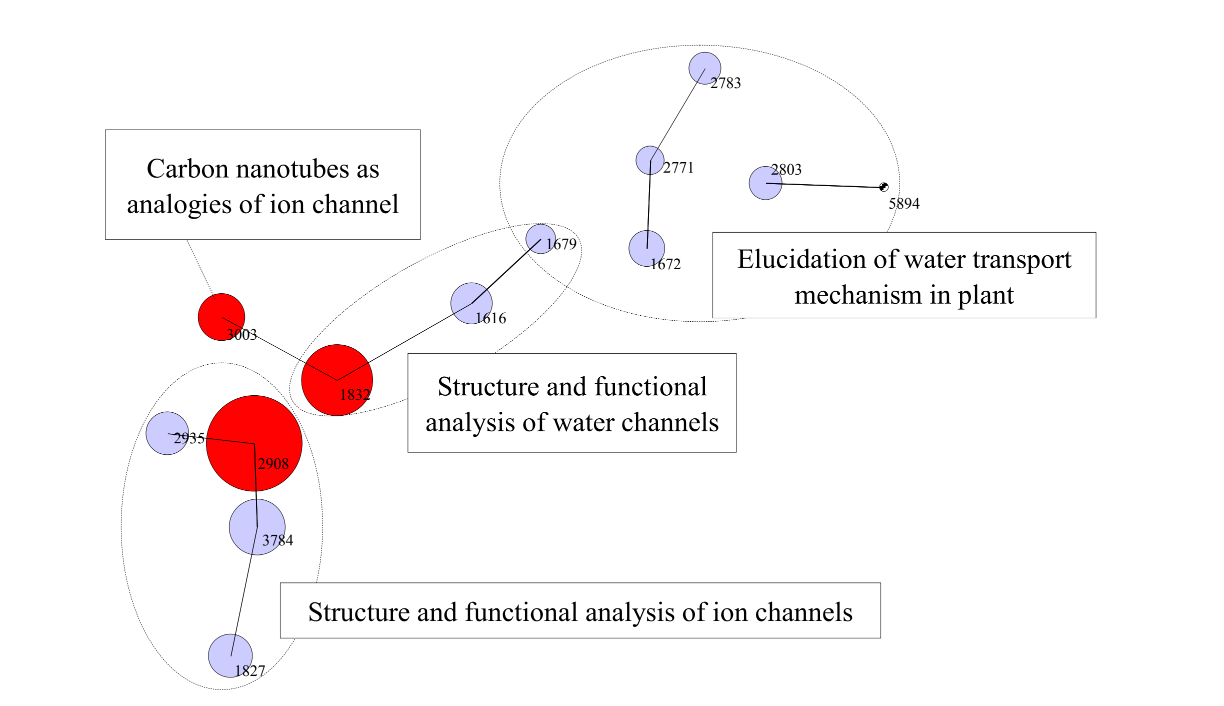
Name of RA	Detection of negative ions by chemical methods	RA ID	94	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9 (5)	44	1092	2295	2001.5



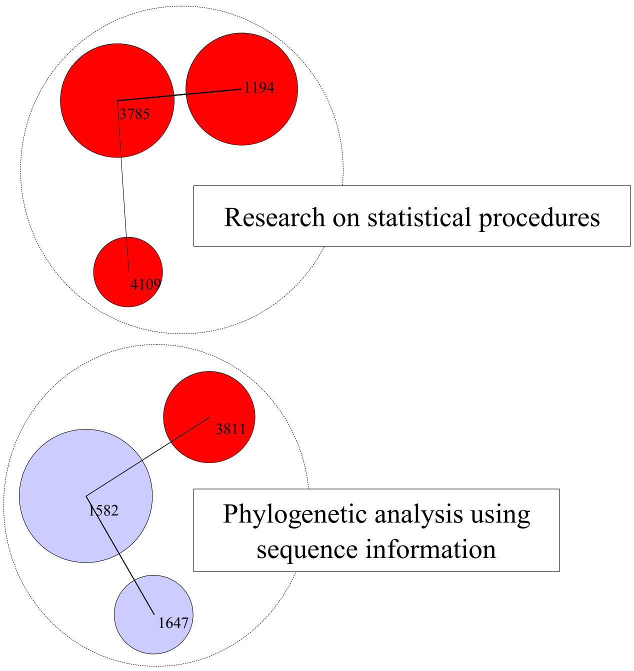
Name of RA	Signal conduction of the lysophospholipids receptors		RA ID	95
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (3)	24	982	2072	2001.8



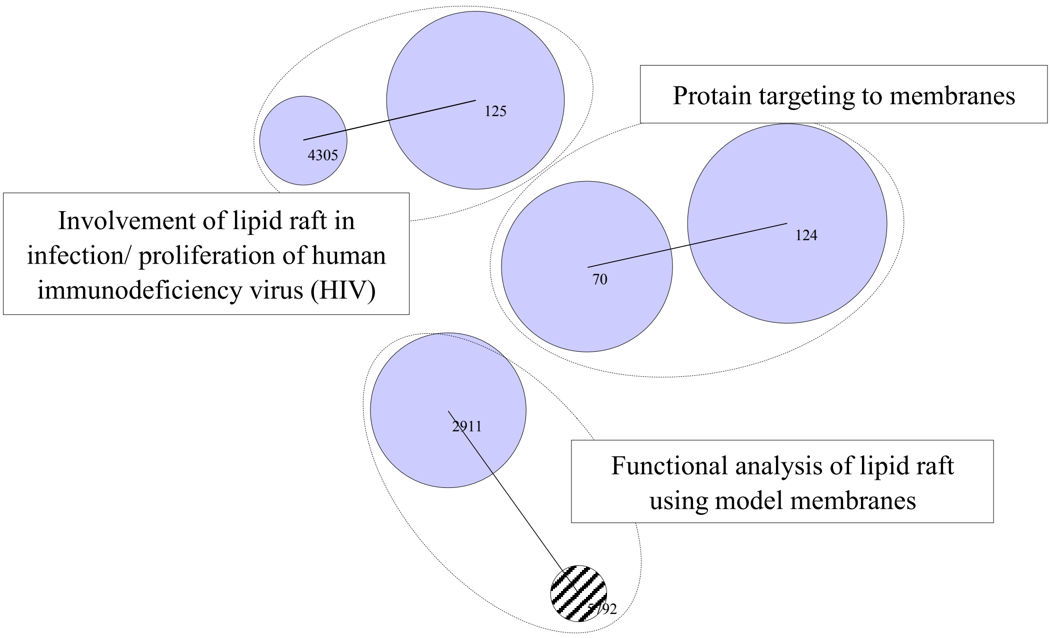
Name of RA	Water and iron transport mechanism in organism		RA ID	96
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
13 (3)	53	2184	4526	2001.5



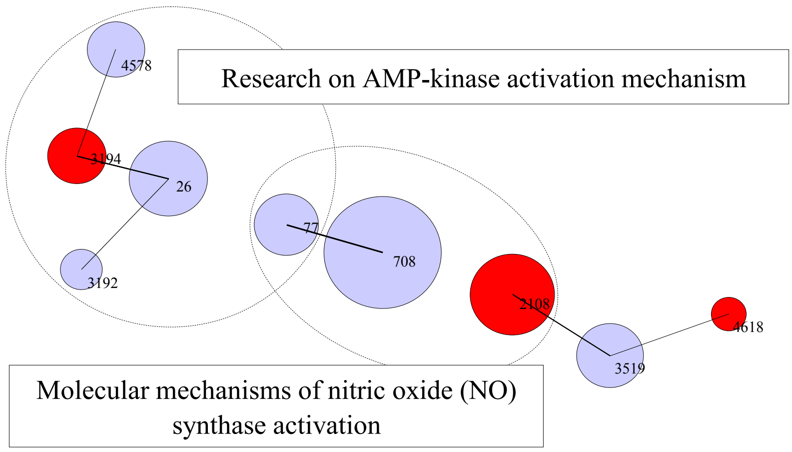
Name of RA	Molecular phylogenetic analysis	RA ID	97	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (4)	24	984	1762	2001.1



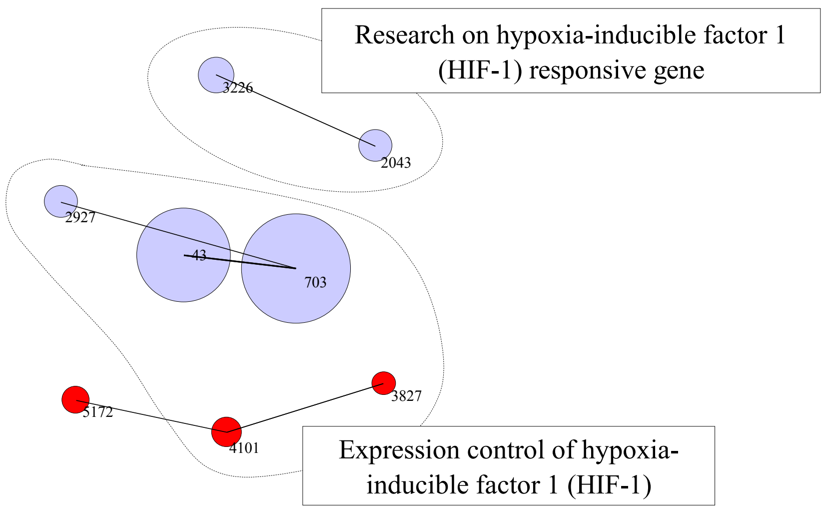
Name of RA	Research on infection mechanism of HIV	RA ID	98	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (0)	15	1228	1854	2000.9



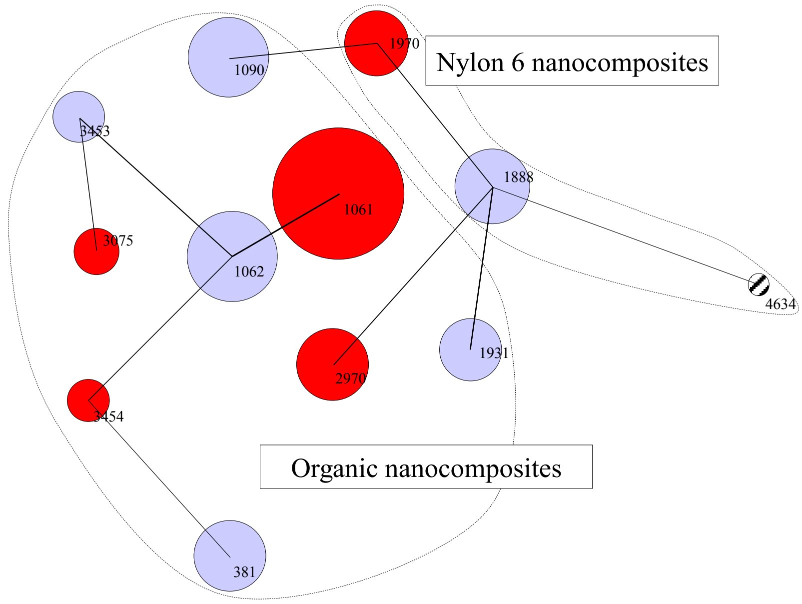
Name of RA	Signal transduction in metabolic pathway		RA ID	99
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9 (3)	36	2214	4076	2001.7



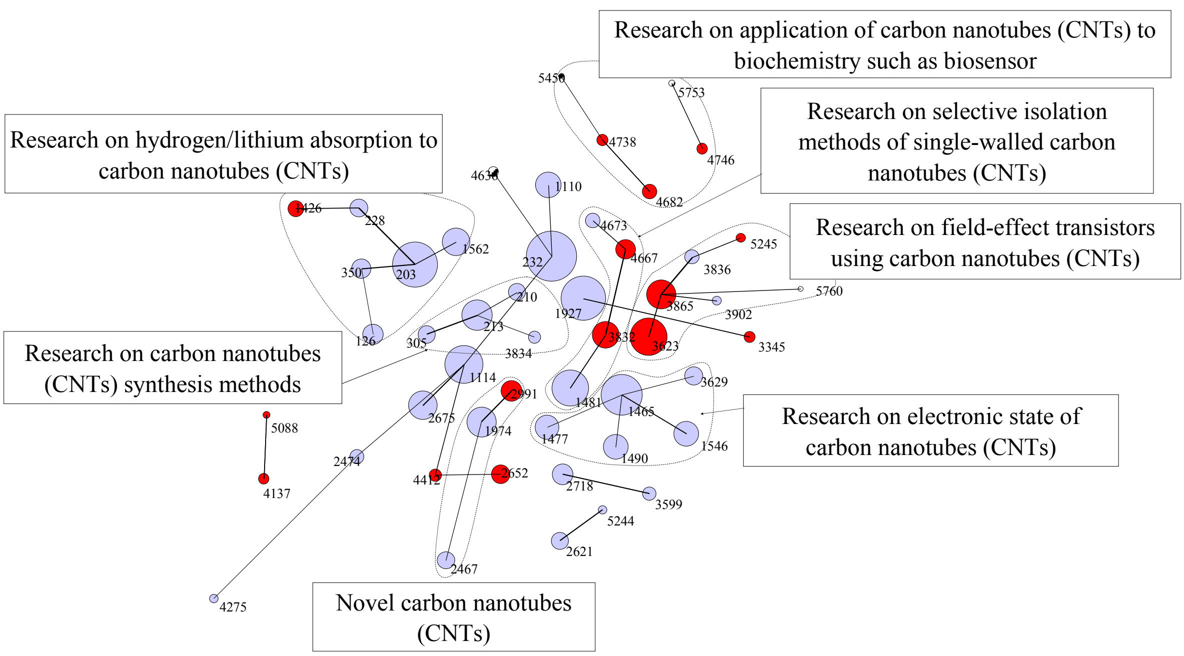
Name of RA	Hypoxia-inducible factor and tumorigenesis		RA ID	100
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (3)	52	2583	8688	2001.0



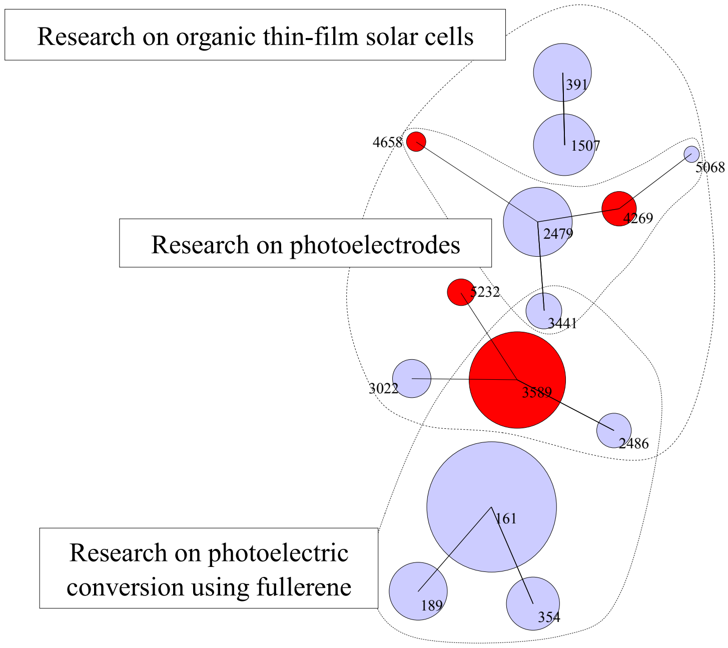
Name of RA	Nanocomposites consisting of inorganic nano materials and organic polymers	RA ID	101	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
12 (5)	43	1373	3158	2001.0



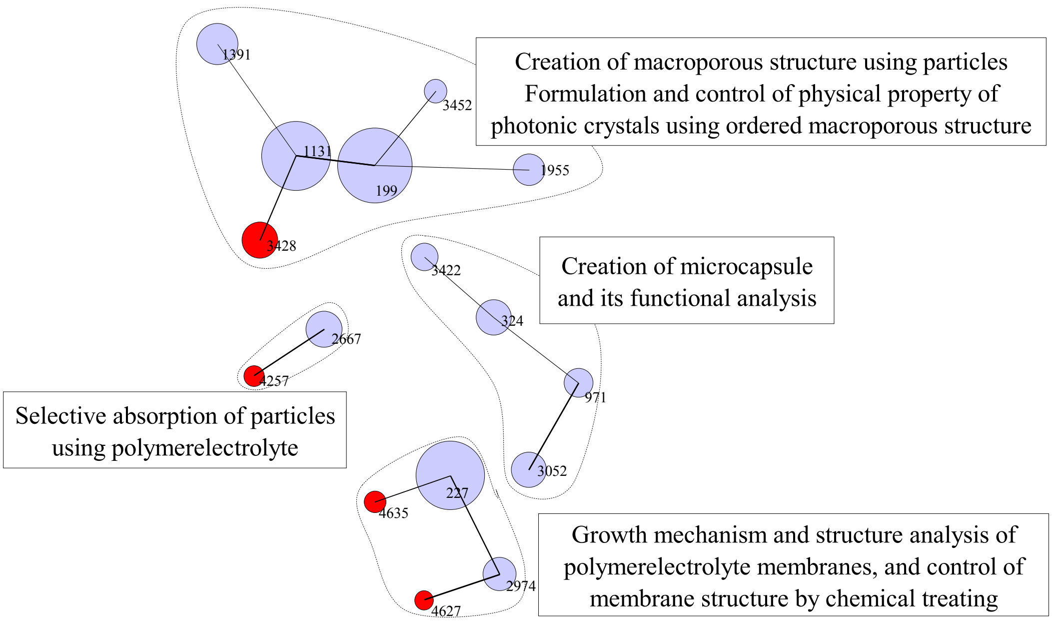
Name of RA	Basic and applied research on carbon nanotubes	RA ID	102	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
50 (15)	245	6014	17077	2001.5



Name of RA	High-efficiency dye-sensitised solar cell		RA ID	103
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
14 (4)	79	2186	4706	2001.4

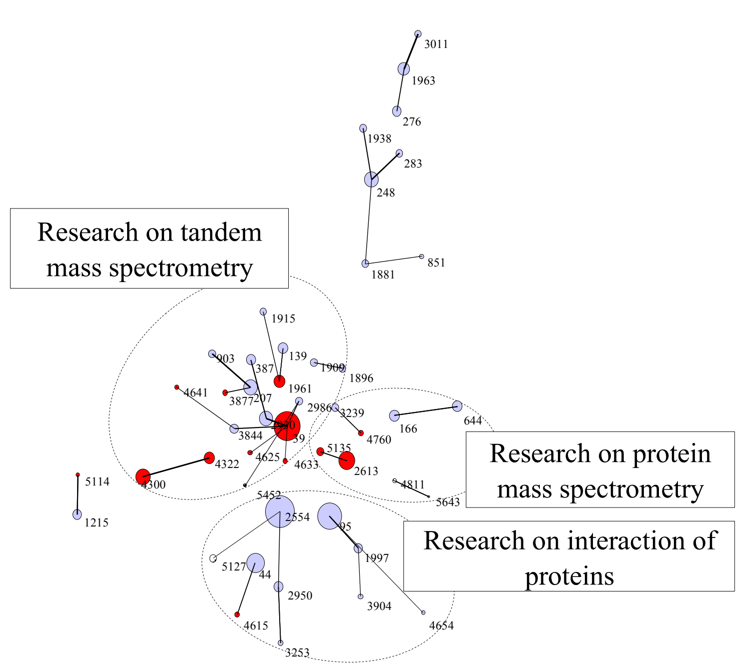


Name of RA	Synthesis of nano-structures form microstructure with microparticles and polymers		RA ID	104
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
16 (4)	82	2314	5566	2001.0



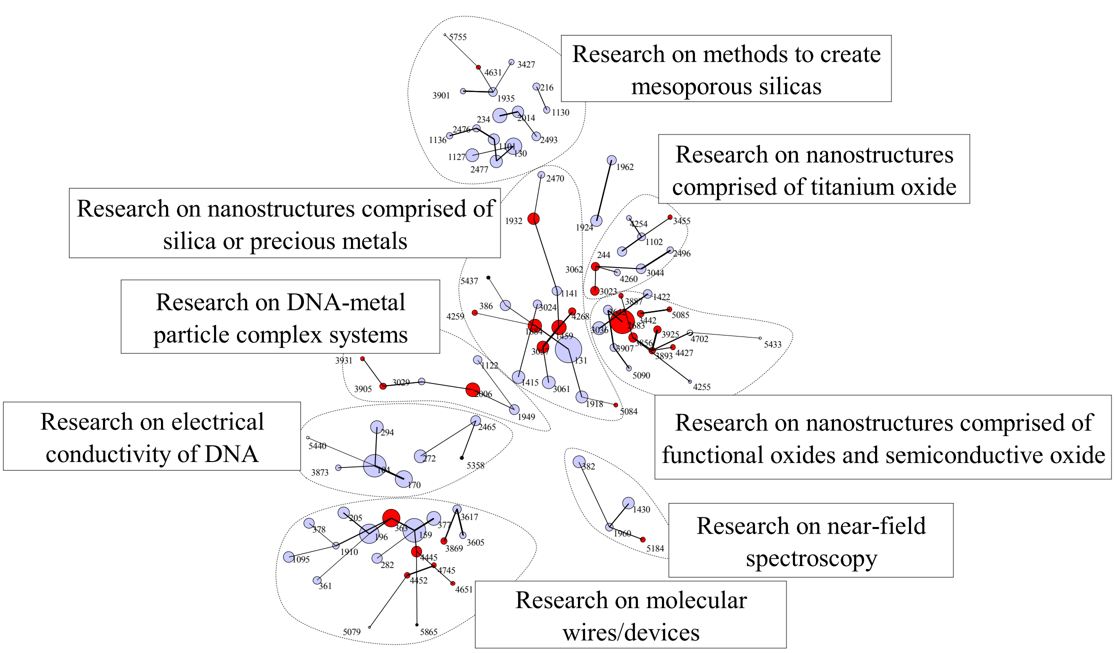
Name of RA	Research on proteome	RA ID	105

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
47 (13)	223	8453	21745	2001.2

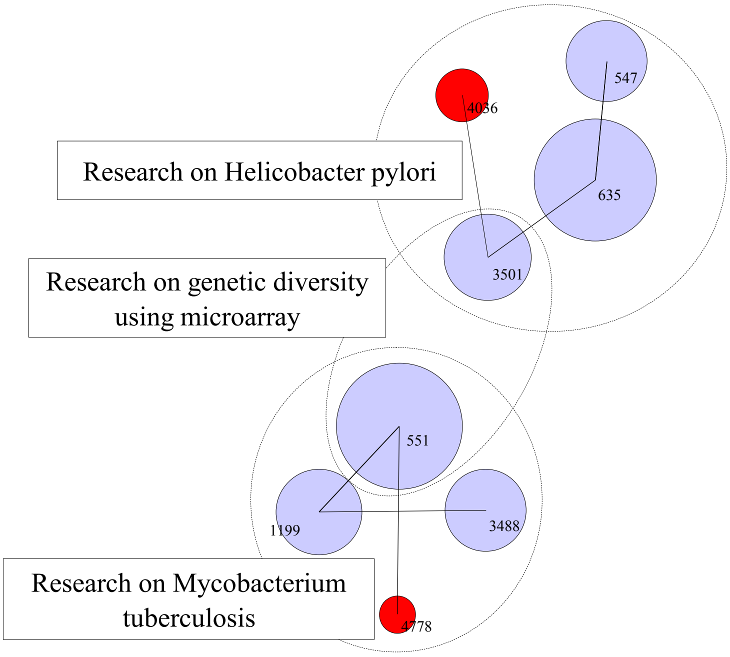


Name of RA	Development of nanostructure and its application to molecular devices	RA ID	106

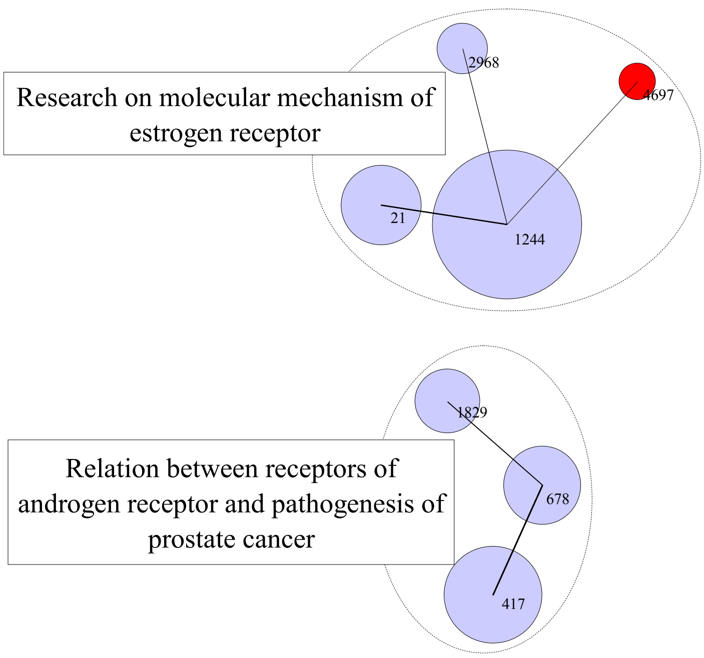
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
96 (29)	482	12078	33911	2001.5



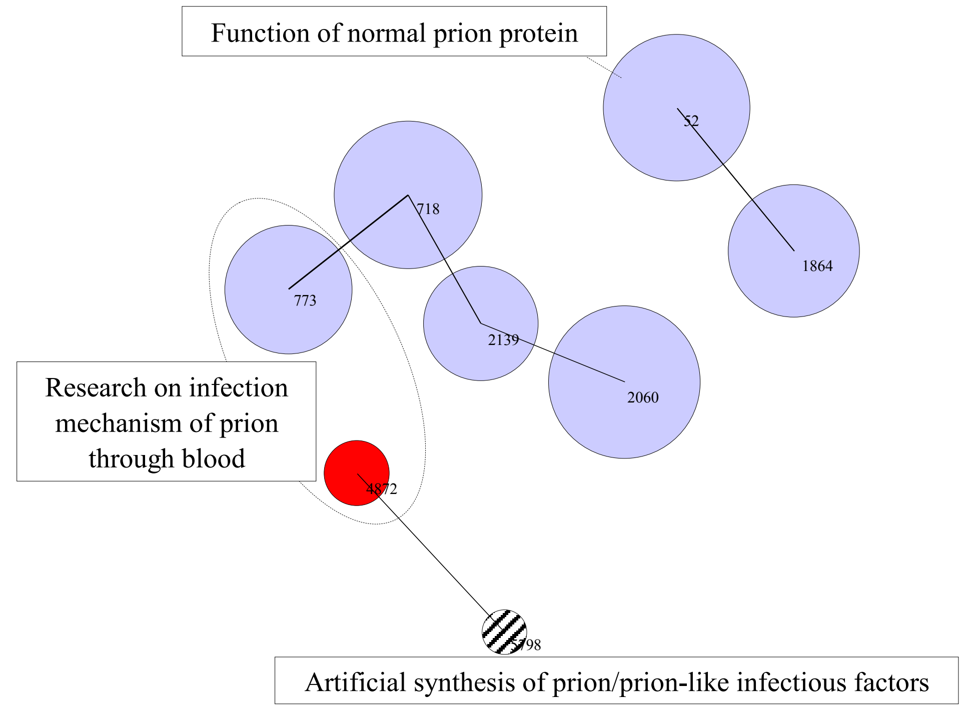
Name of RA	Genome analyses of Helicobacter pylori and Mycobacterium tuberculosis	RA ID	107	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (2)	25	1538	2891	2001.0



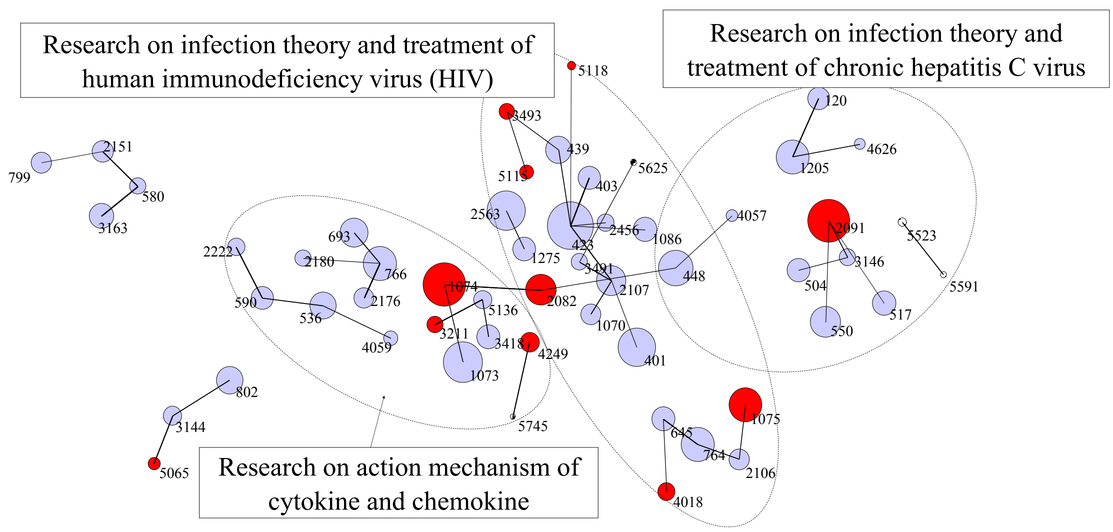
Name of RA	Research on molecular mechanism of sex hormone receptors against cancer	RA ID	108	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (1)	16	1697	2707	2000.1



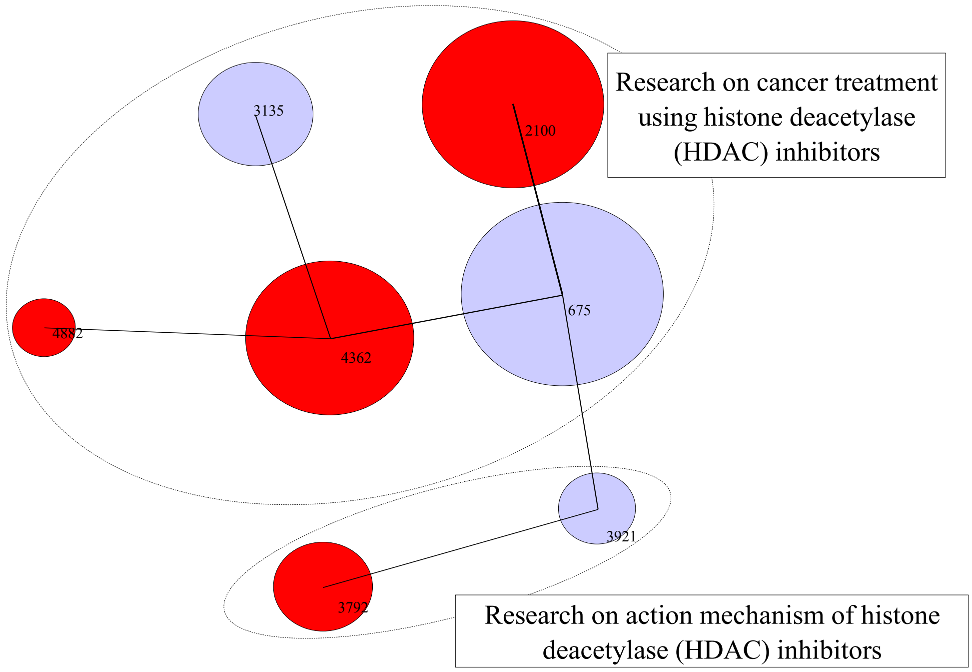
Name of RA	Research on prion diseases	RA ID	109	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (1)	32	1498	2875	2001.5



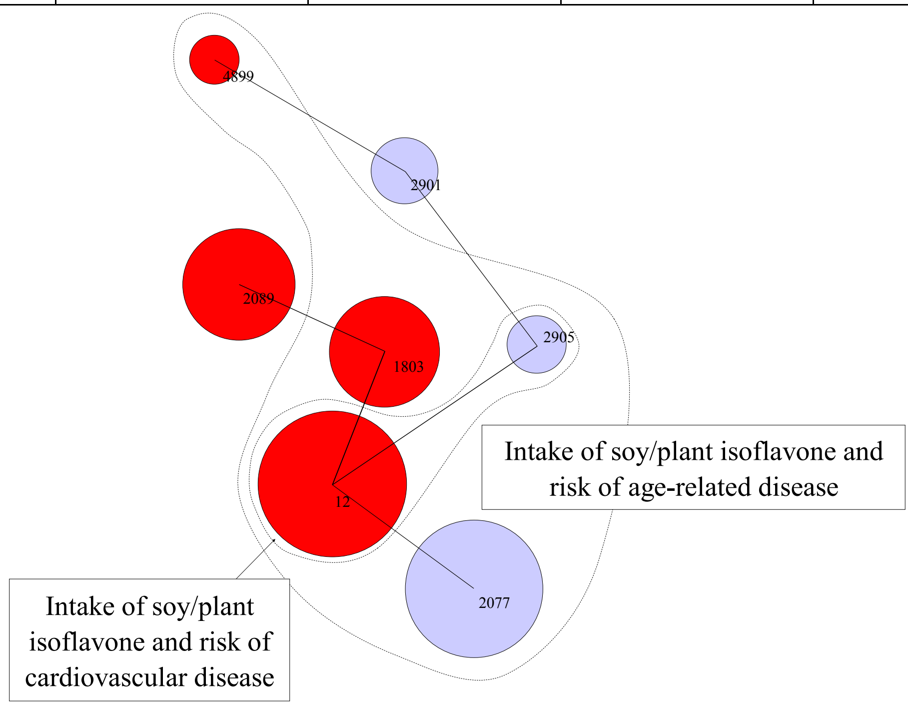
Name of RA	Research on infection mechanism and therapy of HCV and HIV	RA ID	110	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
55 (11)	253	13908	34642	2001.1



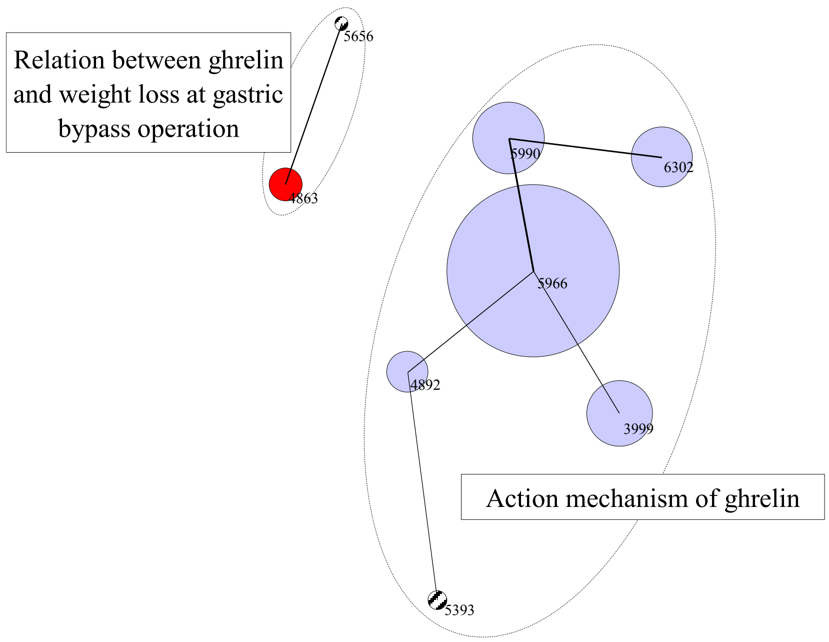
Name of RA	Cancer therapy with histone deacetylase inhibitor		RA ID	111
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (4)	15	832	1536	2001.2



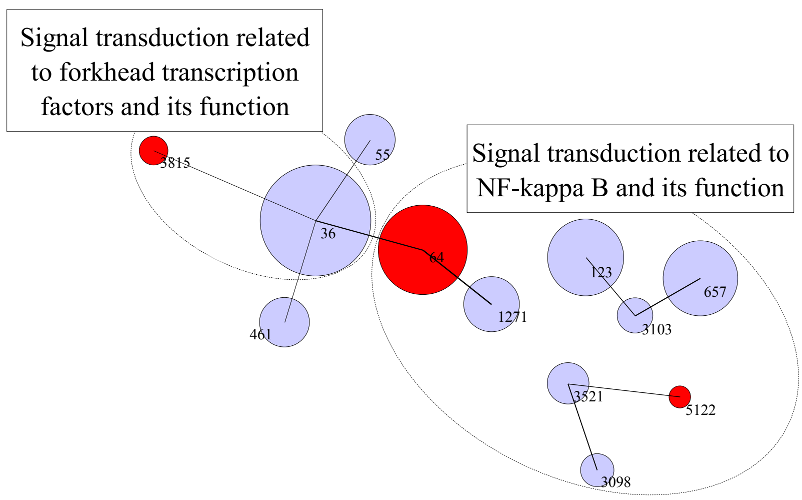
Name of RA	Intake of soy- and plant-derived estrogen/isoflavone and its effects on age-associated diseases		RA ID	112
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (4)	22	683	1171	2001.3



Name of RA	Ghrelin; its mechanism of action		RA ID	113
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (1)	51	1429	7284	2001.5

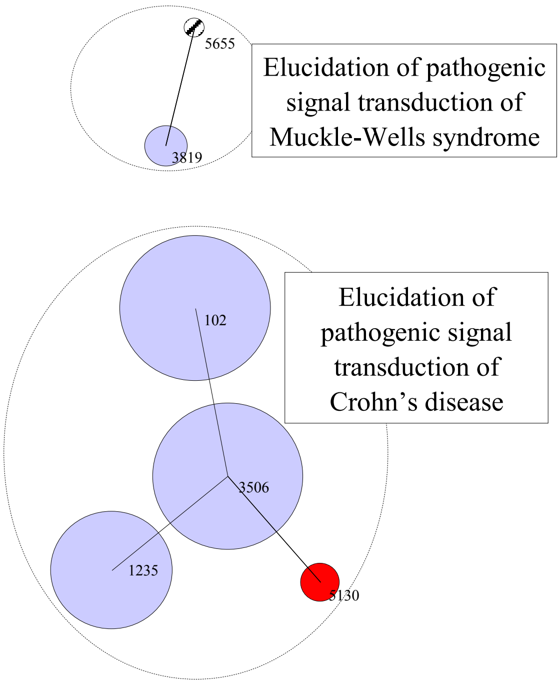


Name of RA	Molecular mechanism of PI3/Akt signal transduction pathway		RA ID	114
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
12 (3)	61	4361	10642	2000.8



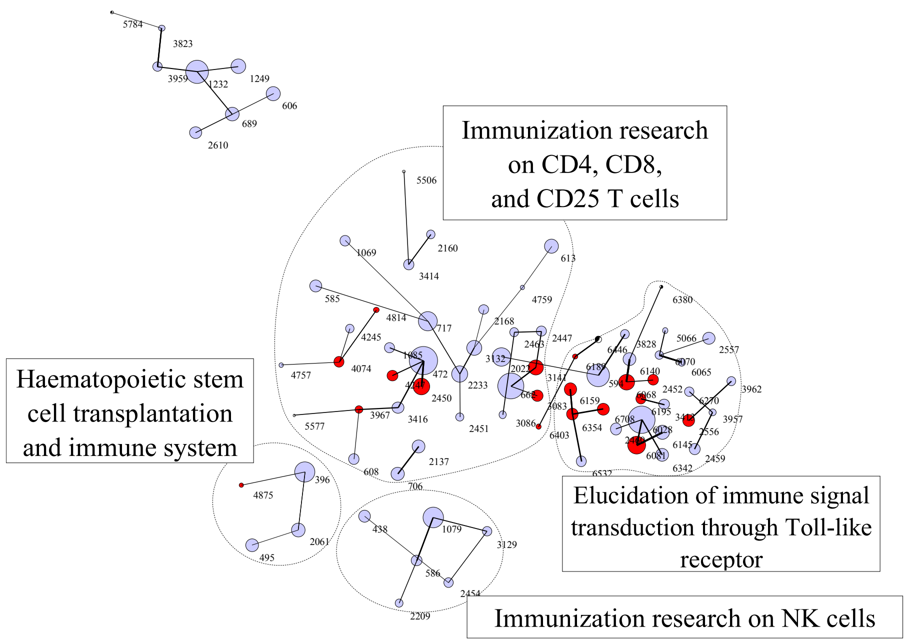
Name of RA	Genetic diagnosis and therapy of Crohn's disease	RA ID	115

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (1)	44	3034	7407	2002.0

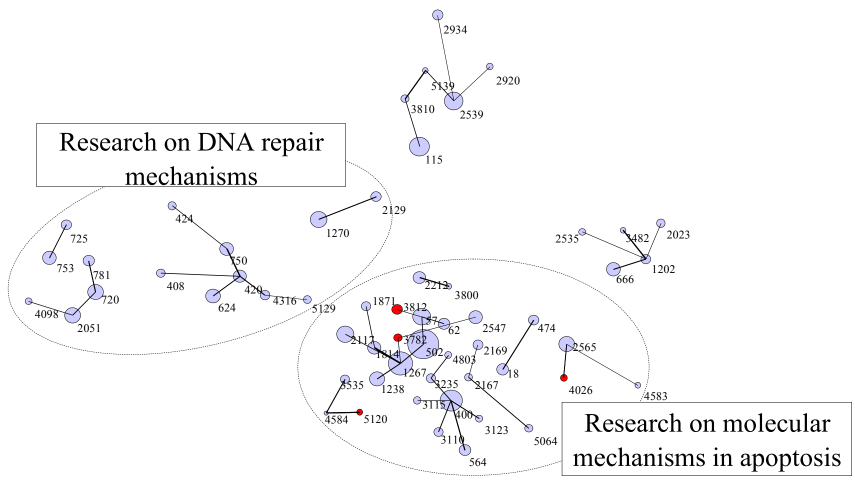


Name of RA	Research on immune system	RA ID	116

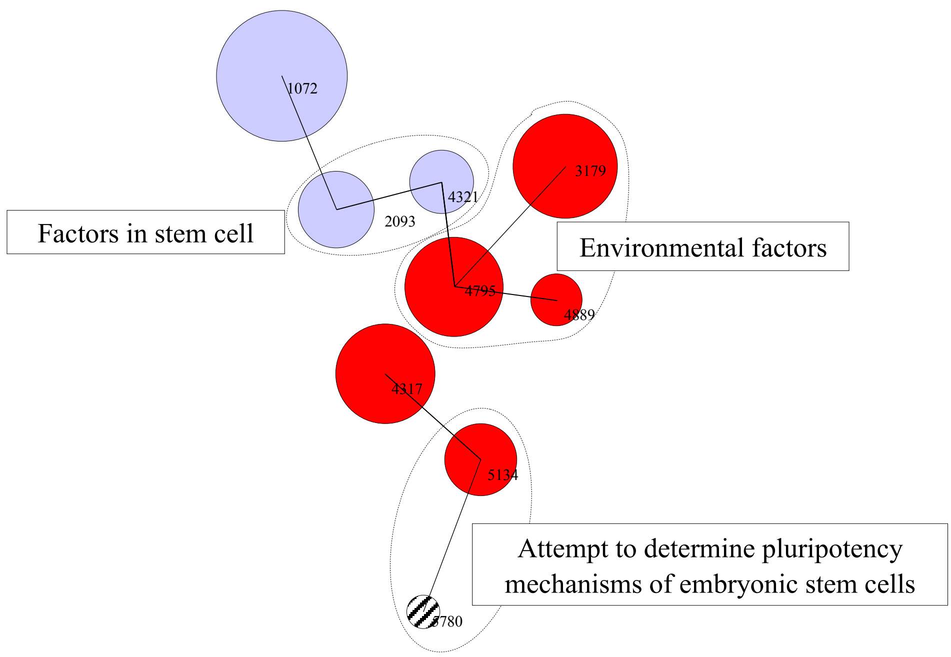
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
80 (18)	329	17601	49188	2001.3



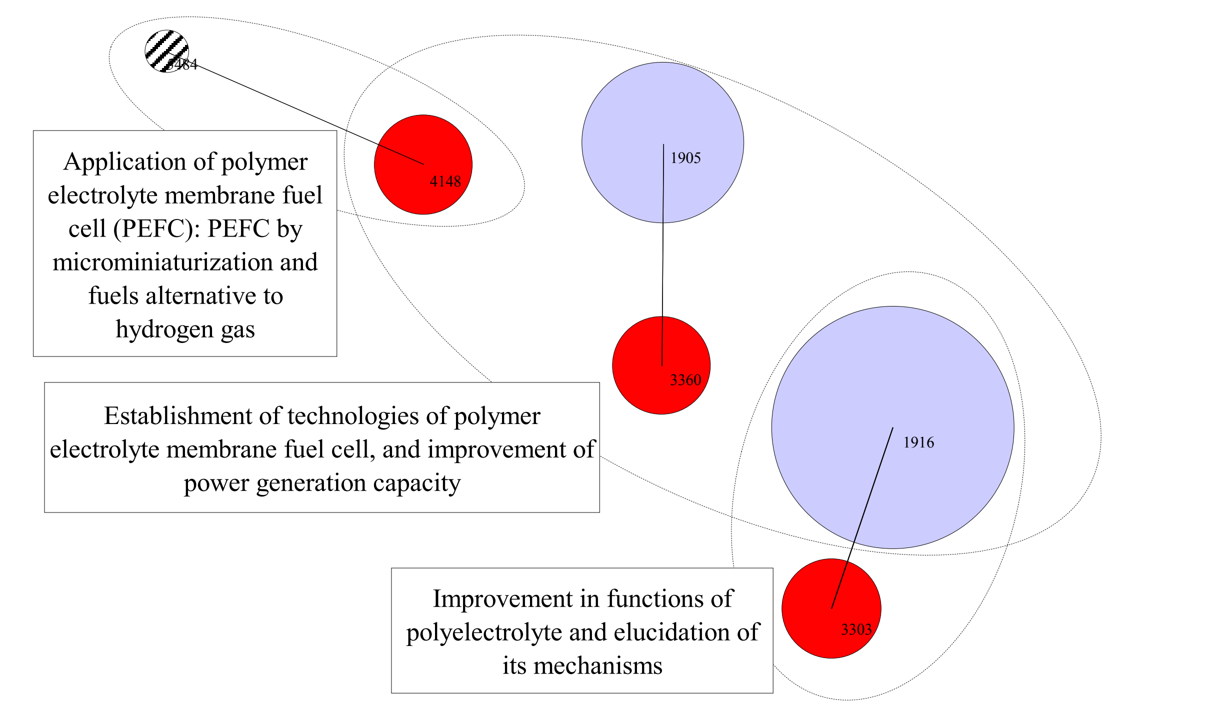
Name of RA	Research on molecular mechanism in apoptosis	RA ID	117	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
57 (4)	219	13723	34609	2000.7



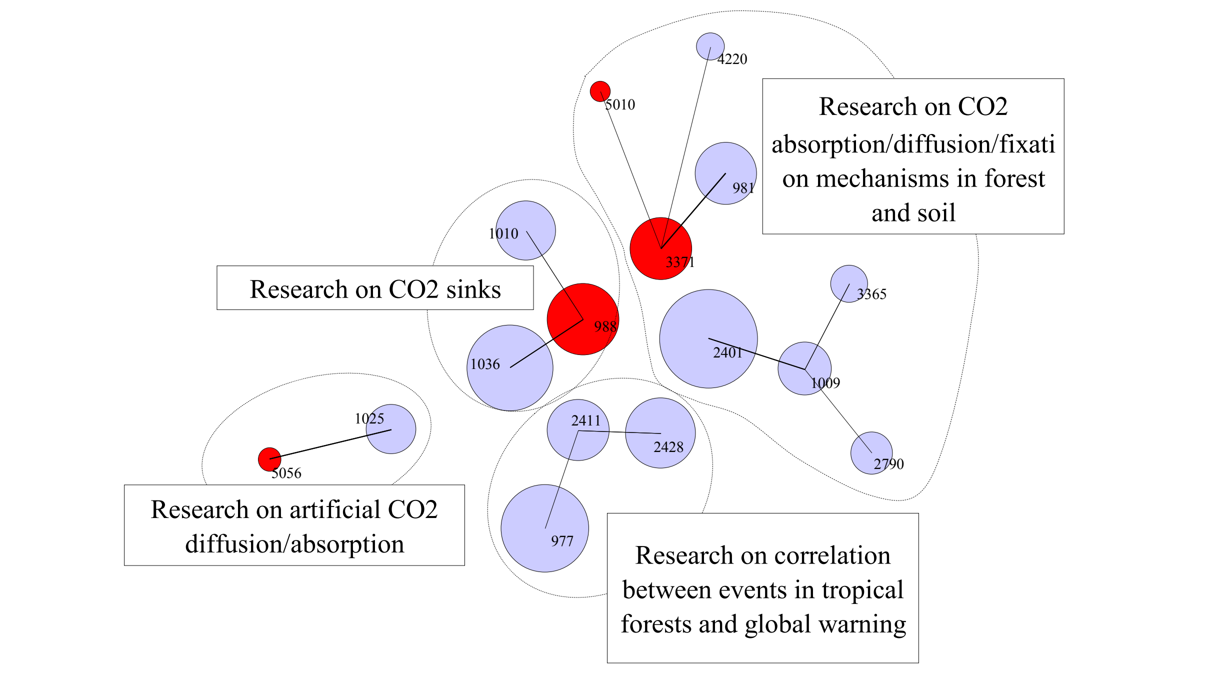
Name of RA	Research on multipotency and differentiation mechanism of stem cells in cardiovascular system, cancer, and embryos	RA ID	118	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
9 (5)	29	1376	2798	2002.1



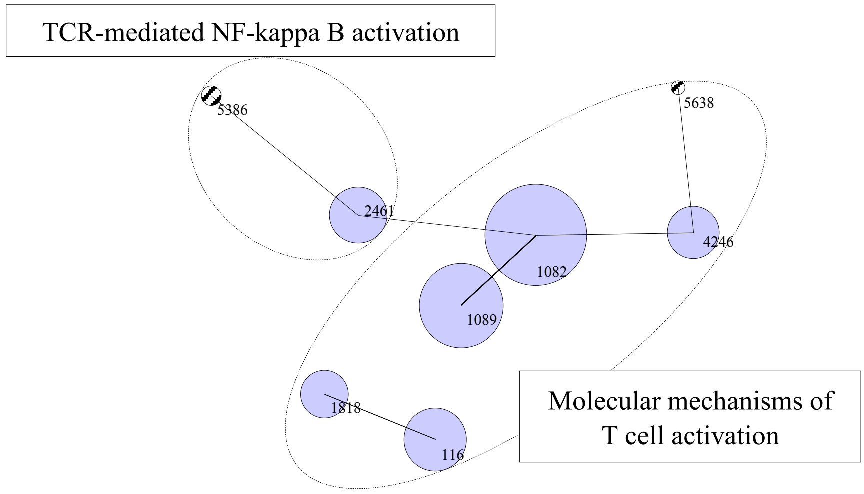
Name of RA	Development and application of proton-exchange membrane fuel cells	RA ID	119	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (3)	29	540	1095	2001.6



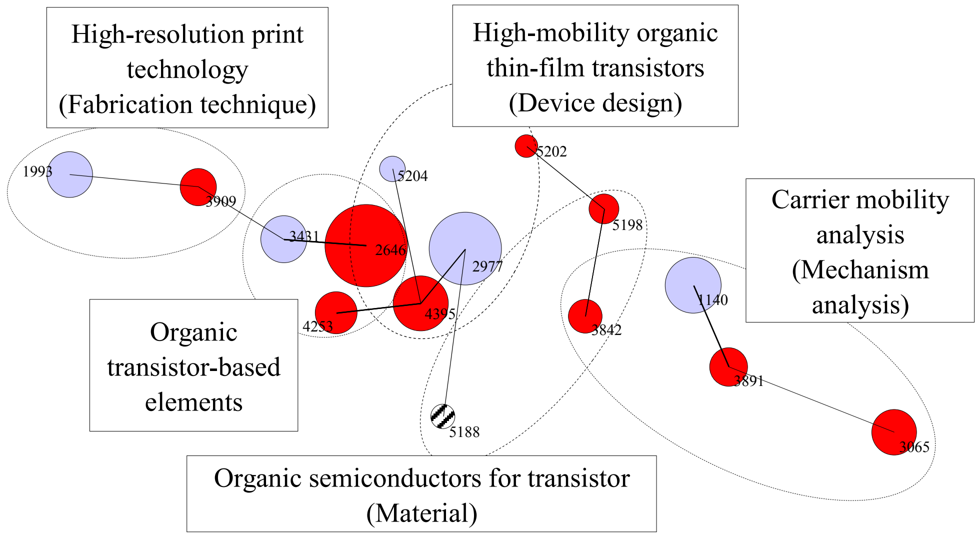
Name of RA	Research on global carbon cycle	RA ID	120	
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
16 (4)	60	1871	3447	2001.4



Name of RA	Signal transduction in immune system		RA ID	121
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
8 (0)	30	1978	3195	2002.2

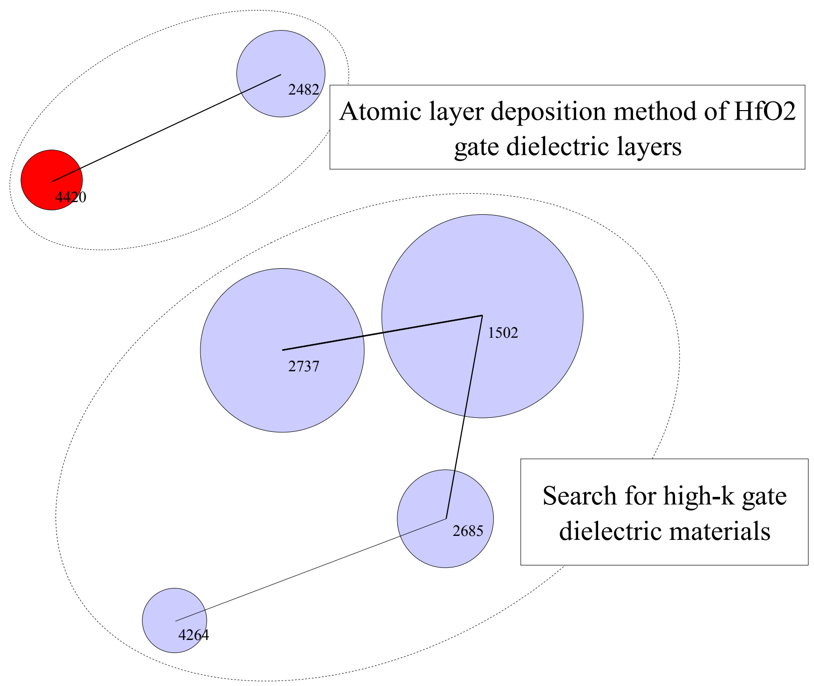


Name of RA	Research on high performance organic thin film transistor		RA ID	122
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
15 (9)	59	1015	1949	2002.5



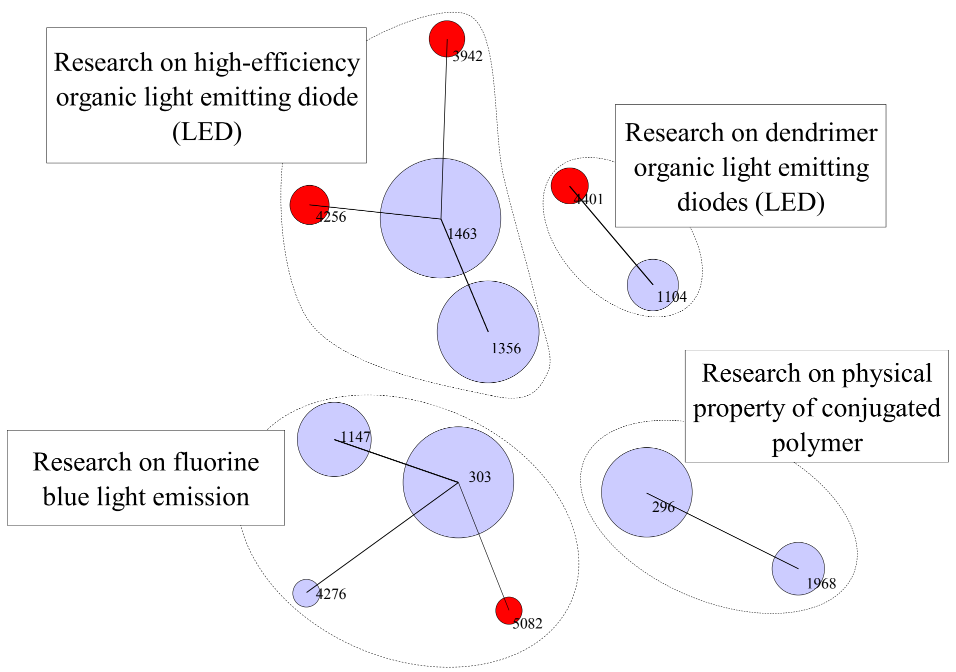
Name of RA	High-dielectric gate insulating technology for semiconductor integrated circuits	RA ID	123

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (1)	17	734	1271	2001.2



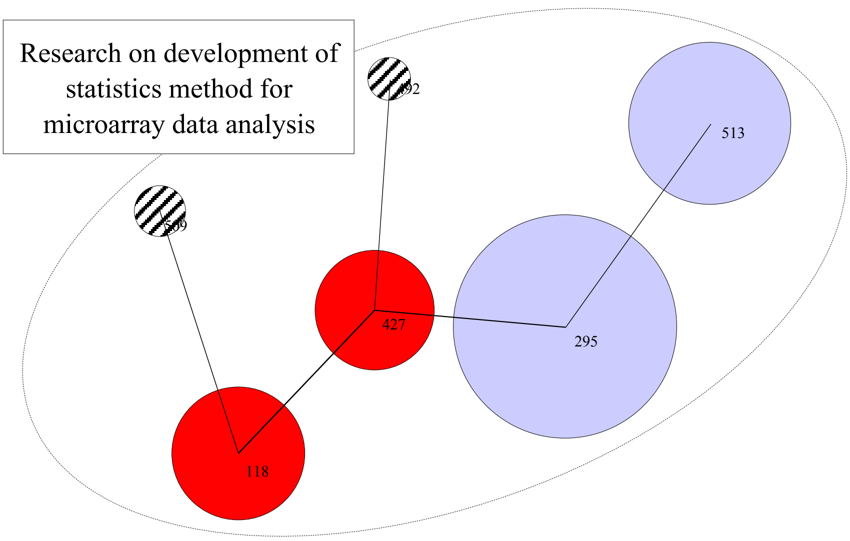
Name of RA	Research on high efficiency organic LED	RA ID	124

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
12 (4)	68	1915	4801	2001.1



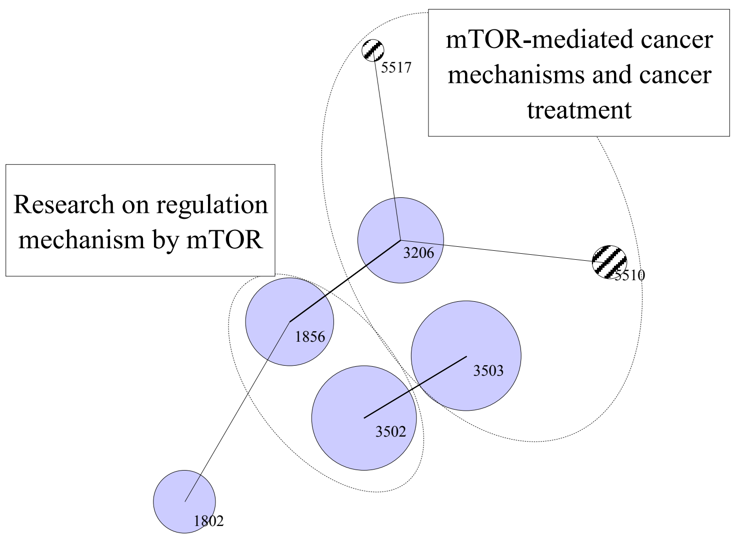
Name of RA	Development of statistics method for microarray data analysis	RA ID	125

# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (2)	16	662	1070	2001.6

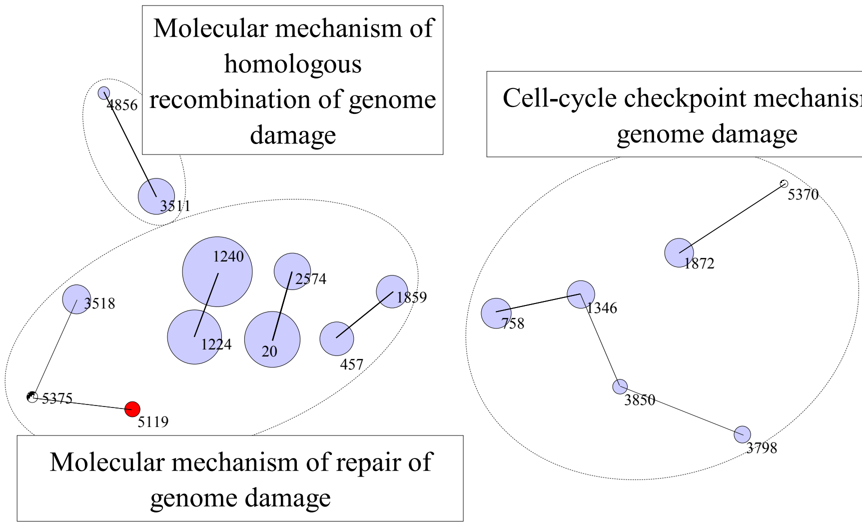


Name of RA	Function study of mammalian TOR	RA ID	126

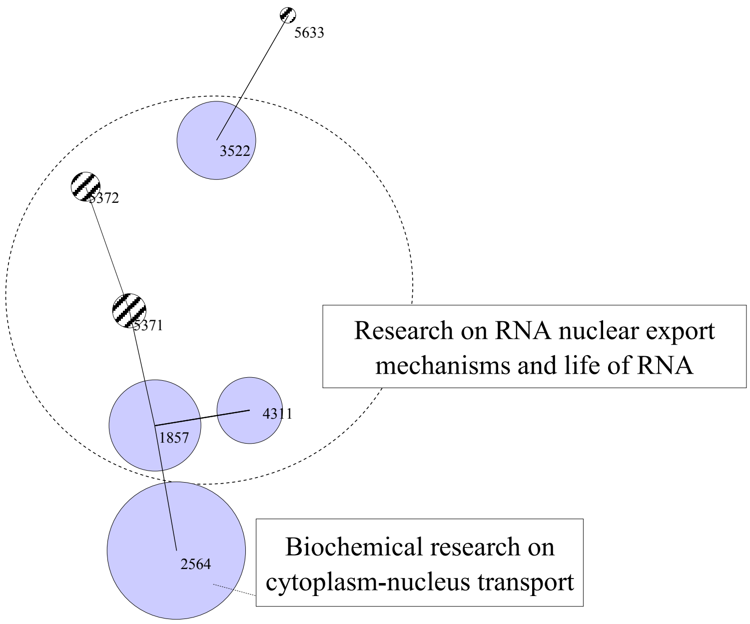
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (0)	33	1076	2609	2002.2



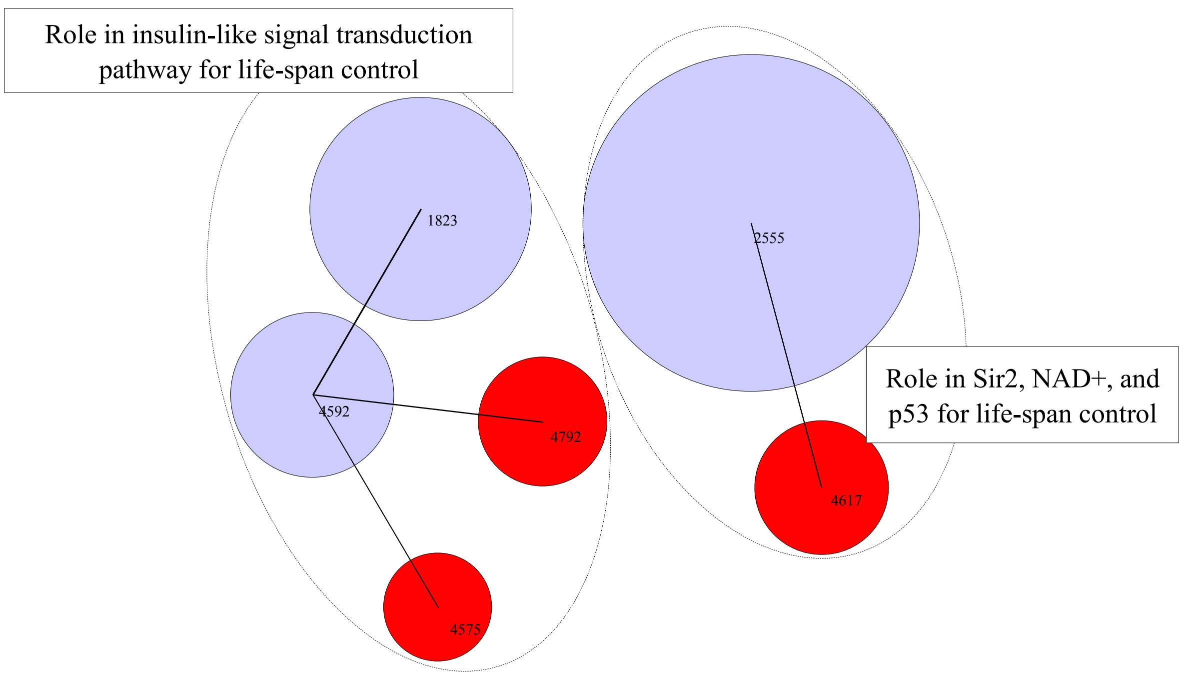
Name of RA	Molecular mechanism of DNA damage and repair		RA ID	127
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
17 (1)	76	3933	9746	2001.4



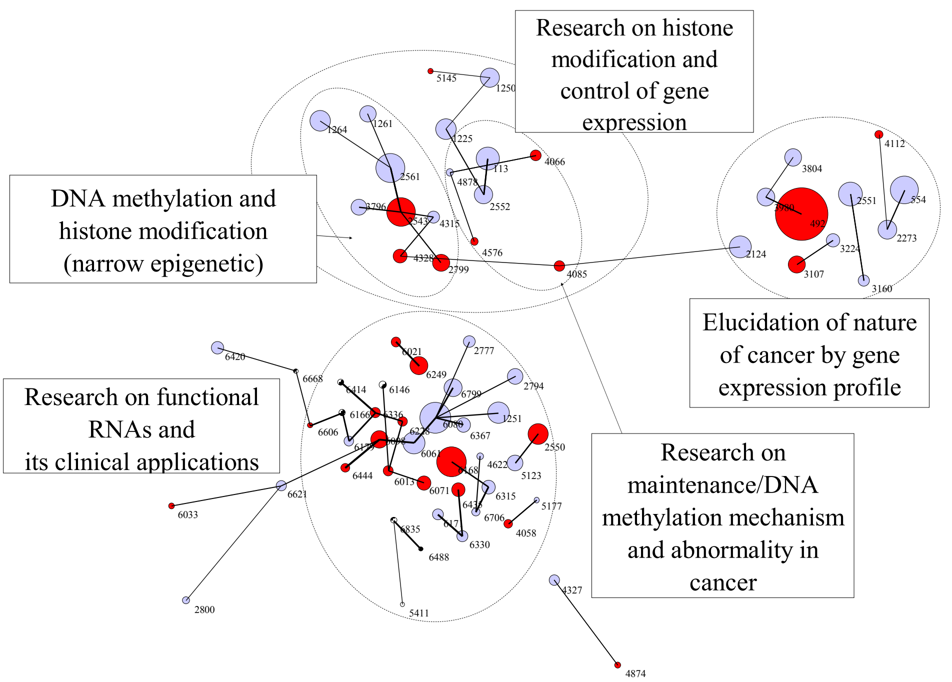
Name of RA	Nucleocytoplasmic traffic and cell function		RA ID	128
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
7 (0)	19	1454	2146	2002.1



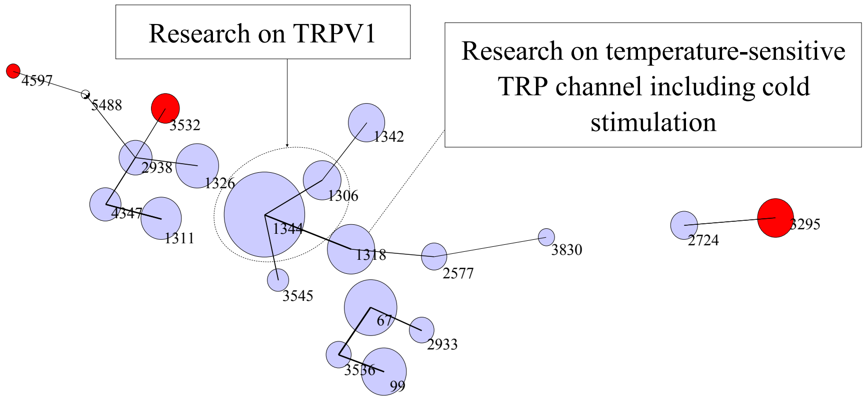
Name of RA	Mechanism of control of life-span		RA ID	129
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (3)	24	1187	2754	2001.9



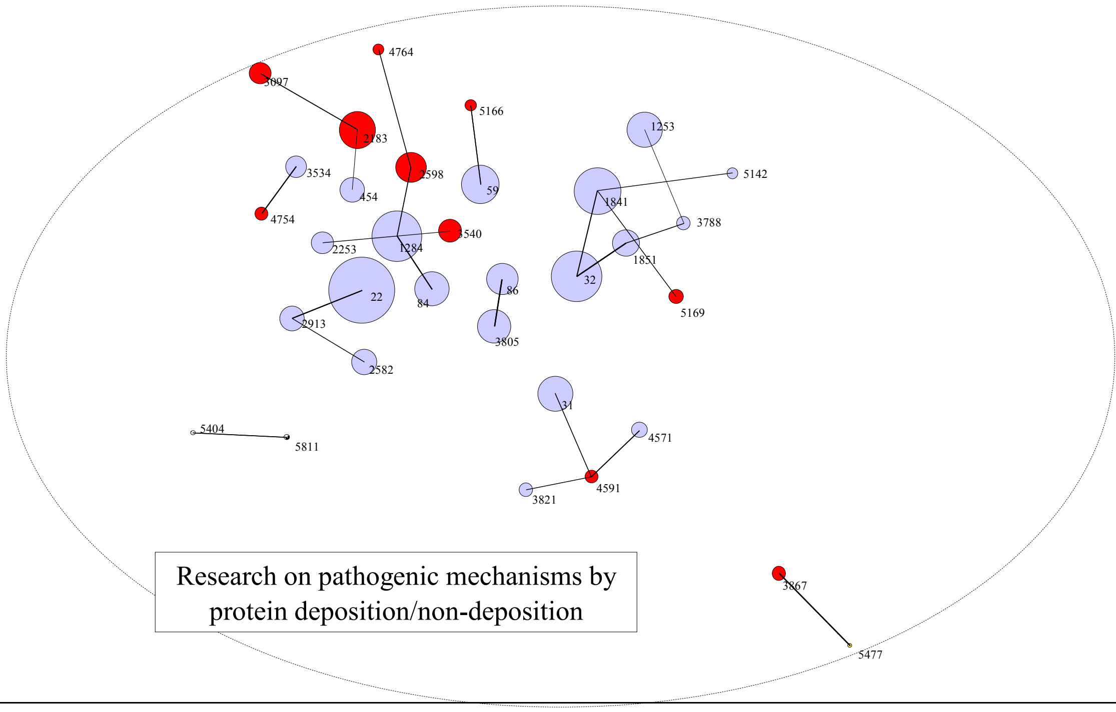
Name of RA	Research on epigenetic transcriptional regulation		RA ID	130
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
69 (25)	268	14149	42032	2002.0



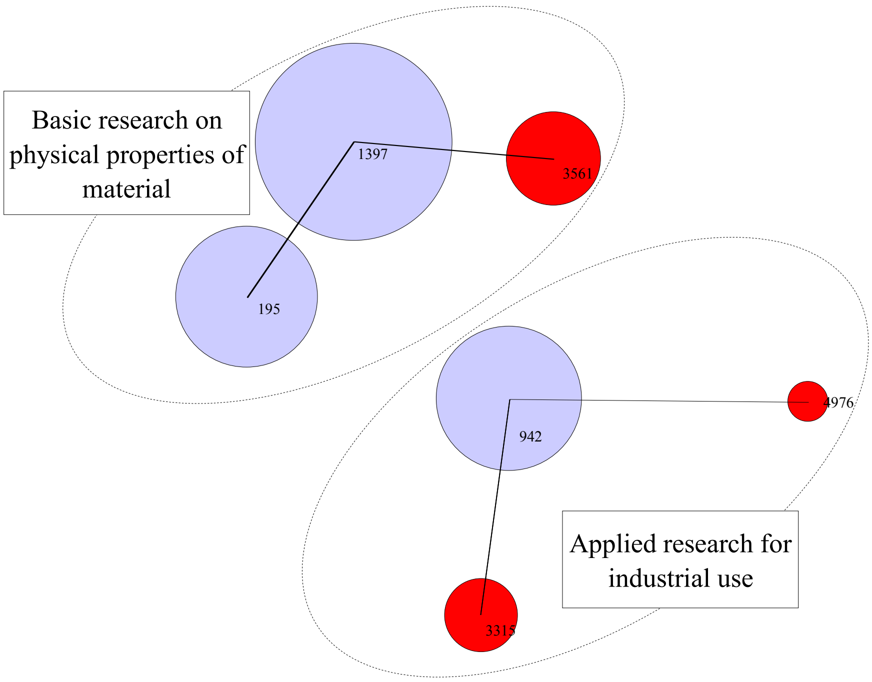
Name of RA	TRP channel and cellular senses		RA ID	131
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
20 (3)	116	4024	10525	2001.6



Name of RA	Research on Alzheimer's disease and Parkinson's disease		RA ID	132
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
33 (10)	215	8536	28410	2001.4



Name of RA	Research on nitride compound semiconductor		RA ID	133
# of RFs (# of Hot RFs)	# of core papers	Unique citations	Citations	Mean publication year
6 (3)	30	917	2359	2000.5



List of Research Members Concerning This Analysis

In this study, NISTEP exchanged information and data with OECD. The participant in this analysis is as follows.

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(Coordinator)

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(Researcher who analyzed contents of each research area)

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IMADA Jun	Research Unit for Science and Technology Analysis and Indicators Visiting Researcher	
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OHIRA Tatsuya	Science and Technology Foresight Center	Visiting Researcher [up to March 31, 2006]
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SAKA Ayaka	Science and Technology Foresight Center	Research Fellow (already mentioned)
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TADA Kuniyuki	Science and Technology Foresight Center	Affiliated Fellow
TATSUNO Kimio	Science and Technology Foresight Center	Affiliated Fellow
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- Study on Hot Research Areas (1999-2004) by bibliometric method -

MAR, 2007
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Ministry of Education, Culture, Sports, Science and Technology (MEXT)
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