2018
RESEARCH FRONTS

Institutes of Science and Development,
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Clarivate Analytics

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1. METHODOLOGY

1. BACKGROUND

The world of scientific research presents a sprawling, ever-changing landscape. The ability to identify where the action is and, in particular, to track emerging specialty areas, provides a distinct advantage for administrators, policy makers, and others who need to monitor, support, and advance the conduct of research in the face of finite resources.

To that end, Clarivate Analytics generates data and reports on "Research Fronts." These specialties are defined when scientists undertake the fundamental scholarly act of citing one another's work, reflecting a specific commonality in their research – sometimes experimental data, sometimes a method, or perhaps a concept or hypothesis.

By tracking the world's most significant scientific and scholarly literature and the patterns and groupings of how papers are cited—in particular, clusters of papers that are frequently cited together, "Research Fronts" can be discovered. When such a group of highly cited papers attains a certain level of activity and coherence (detected by quantitative analysis), a Research Front is formed, with these highly cited papers serving as the front's foundational "core." Research Front data reveal links among researchers working on related threads of scientific inquiry, even if the researchers' backgrounds might not suggest that they belong to the same "invisible college."

In all, Research Fronts afford a unique vantage point from which to watch science unfold—not relying on the possibly subjective judgments of an indexer or cataloguer, but hinging instead on the cognitive and social connections that scientists themselves forge when citing one another's work. The Research Fronts data provide an ongoing chronicle of how discrete fields of activity emerge, coalesce, grow (or, possibly, shrink and dissipate), and branch off from one another as they self-organize into even newer nodes of activity. Throughout this evolution, the foundations of each core – the main papers, authors, and institutions in each area—can be ascertained and monitored. Meanwhile, analysis of the associated citing papers (those papers that cite the core literature) provides a tool for unveiling the latest progress and the evolving direction of scientific fields.

In 2013, Clarivate Analytics published an inaugural report in which 100 hot Research Fronts were identified. In 2014 and 2015, *Research Fronts 2014* and *Research Fronts 2015* were undertaken as a collaborative project by the Joint Research Center of Emerging Technology Analysis established by Clarivate Analytics and the National Science Library, Chinese Academy of Sciences (CAS). In 2016 and 2017, Institutes of Science and Development, CAS, National Science Library, CAS and Clarivate Analytics jointly released the *Research Fronts 2016 and Research Fronts 2017*. These reports have gained widespread attention from around the world.

This year, the same methodology was employed. For the newest edition, *Research Fronts 2018*, 100 hot Research Fronts and 38 emerging Research Fronts were identified based on co-citation analysis that generated 10,143 Research Fronts in the Clarivate Analytics database Essential Science Indicators (ESI).

2. METHODOLOGY AND PRESENTATION OF DATA

The study was conducted in two parts. Clarivate Analytics selected Research Fronts and provided data on the core papers and citing papers of the selected Research Fronts. Final selection of key Research Fronts (i.e. hot Research Fronts and emerging Research Fronts), and the interpretation of these respective specialty areas, were completed by Institute of Strategic Information within Institutes of Science and Development, CAS. For the 2018 update, the Research Fronts drew on ESI data from 2012 to 2017, which were obtained in March 2018.

2.1 RESEARCH FRONTS SELECTION

Research Fronts 2018 presents a total of 138 Research Fronts, including 100 hot and 38 emerging ones. As in the previous reports, the Research Fronts are classified into 10 broad research areas in the sciences and social sciences. Starting from 10,143 Research Fronts in ESI, the objective was to discover which Research Fronts were most active or developing most rapidly.

The specific methodology used for identifying the 138 Research Fronts is described as follows.

2.1.1 SELECTING THE HOT RESEARCH FRONTS

First, 21 ESI fields were classified into 10 broad research areas. Research Fronts in each ESI field were ranked by total citations, and the Top 10 percent of the fronts in each ESI field were extracted. These Research Fronts were then merged into 10 areas and re-ranked according to the average (mean) year of their core papers to produce a Top 10 list in each broad area, resulting in a total of 100 hot Research Fronts. The 10 fronts selected for each of the 10 highly aggregated, main areas of science and social sciences represent the hottest of the largest fronts, not necessarily the hottest Research Fronts across the database (all disciplines). Due to the different characteristics and citation behaviors in various disciplines, some fronts are much smaller than others in terms of number of core and citing papers.

2.1.2 SELECTING THE EMERGING RESEARCH FRONTS

A Research Front with core papers of recent vintage indicates a specialty with a young foundation that is rapidly growing. To identify emerging specialties, the immediacy of the core papers is a priority, and that is why it is characterized as "emerging." To identify emerging specialties, extra preference, or weight, was given to the currency of the foundation literature: only Research Fronts whose core papers dated, on average, to the second half of 2016 or more recently were considered. Then these were sorted in descending order by their total citations in each ESI field. We selected the top 10% research fronts in each ESI field and ensured that at least one research front was selected in an ESI field even if there are only a limited number of research fronts in the field. The selected Research Fronts were delivered to Institute of Strategic Information where the analysts with domain knowledge made the final selection of emerging Research Fronts and grouped them into 10 broader fields. Because the selection was not limited to any research area, the 38 fronts are distributed unevenly in the 10 fields. For example, there are eight Research Fronts in chemistry and materials sciences but only one in ecology and environmental sciences, geosciences, and economics, psychology and other social sciences.

Based on the above two methods, the report presents the Top 10 hot fronts in 10 broad areas (100 fronts in total) and 38 emerging ones.

2.2 FINAL SELECTION AND INTERPRETATION OF KEY RESEARCH FRONTS

On the basis of 138 Research Fronts provided by Clarivate Analytics, analysts at the Institute of Strategic Information, conducted a detailed analysis and interpretation to highlight 31 key Research Fronts (Chapter 2 to Chapter 11) of particular interest, including both hot and emerging fronts.

As discussed above, a Research Front consists of a core of highly cited papers along with the citing papers that have frequently co-cited the core. In other words, core papers are all highly cited papers in ESI – papers that rank in top one percent in terms of citations in the same ESI field and in the same publication year. Since the authors, institutions and countries/territories listed on the core papers have made significant contributions in the particular specialty, a tabulation of these appears in the analysis of the Research Fronts. Meanwhile, by reading the full text of the citing articles, greater precision can be obtained in specifying the topic of the Research Front, especially in terms of its recent development or leading-edge findings. In this case, it is not necessary that the citing papers are themselves highly cited.

2.2.1 FINAL SELECTION OF KEY RESEARCH FRONTS

In *Research Fronts 2014*, an index known as CPT was designed to select key Research Fronts. From 2015 on, a scale indicator, the number of core papers (P), is also considered.

(1) The number of core papers (P)

ESI classifies Research Fronts according to the co-cited paper clusters and reveals their development trend based on the metadata of the paper clusters and statistical analysis. The number of core papers (P) indicates the size of a Research Front, and average (mean) publication year and the time distribution of the core papers demonstrate the progress of the area. The number of core papers (P) also illustrates the importance of the knowledge base in the Research Fronts. In a certain period of time, a higher P value usually represents a more active Research Front.

(2) CPT indicator

The CPT indicator was applied to identify the key Research Fronts. C represents the number of citing articles, i.e., the amount of articles citing the core papers; P is the number of core papers; T indicates the age of citing articles, which is the number of citing years, from the earliest year of a citing paper to the present. For example, if the most-recent citing paper was published in 2016 and the earliest citing paper was published in 2012, the age of citing articles T equals 4.

$$CPT = ((C/P)/T) = \frac{C}{P \cdot T}$$

CPT is the ratio of the average citation impact of a Research Front to the age/occurrence of its citing papers, meaning the higher the number, the hotter or the more impactful the topic. It measures how extensive and immediate a Research Front is and can be used to explore the emerging or developing aspects of Research Fronts and to forecast future possibilities. The degree of citation impact can also be seen from CPT, while it also takes the publication years of citing papers into account and demonstrates the trend and extent of attention on certain Research Fronts across years.

Given the condition that a particular Research Front was cited continuously,

1) When P as well as T is equal in two Research Fronts, the bigger C, the bigger CPT, indicating the broader citation influence of the Research Front with bigger C.

2) When C as well as P is equal in two Research Fronts, the smaller T, the bigger CPT, indicating the Research Front with smaller T attracts more intensive attention in a short period.

3) When C as well as T is equal in two Research Fronts, the smaller P, the bigger CPT, indicating the broader citation influence of the Research Front with smaller P.

In the *Research Fronts 2018*, for each of the 10 broad research areas, one key hot Research Front was selected based on the number of core papers (P) in combination with the professional judgment of analysts from the Institute of Strategic Information. Based on their knowledge, the analysts assessed the significance of the key hot Research Front in addressing major issues in the given area. The Top two Research Fronts with the largest numbers of core papers (P) were analyzed to compare their significance. For example, in a comparison of the

Research Fronts "Electronic cigarettes, user preferences, and smoking cessation" and "Measurements of economy-wide energy efficiency," it is obvious that the latter is of more practical significance or consequence. Another key hot Research Front was chosen by the indicator CPT. As the area of mathematics, computer science and engineering includes three ESI fields, we ensured that one key hot research fornt was selected from each of the ESI field for further interpreatation.

By taking advantage of the above two indicators as well as our domain experts' judgment, we selected 21 key hot Research Fronts from the 100 hot Research Fronts in the 10 broad research areas. Moreover, based on CPT and experts' judgement, 10 key emerging Research Fronts were selected from the 38 emerging Research Fronts. Thus, we interpret in detail the selected 31 key Research Fronts from the 138 Research Fronts.

2.2.2 PRESENTATION AND DISCUSSION OF KEY RESEARCH FRONTS

(1) Examination of key hot Research Fronts

The first table under each discipline section lists the 10 top-ranked Research Fronts for each of the 10 broad areas, as well as the number of core papers, total citations and the average publication year of the core papers of each Research Front. The selected key hot Research Fronts which are discussed below the tables are highlighted in green background in the table. Since the papers analyzed in this report were published between 2012 and 2017, their average publication year will also fall into this period.

A bubble diagram shows the age distribution of the citing articles in the 10 Research Fronts listed for each broad area. Key hot Research Fronts selected based on core papers (P) are marked in blue bubbles and those selected based on CPT are marked in red bubbles. The size of the bubble represents the amount of citing articles per year. Key hot Research Fronts can be easily identified, particularly when large amounts of citing papers appear in a very short publication window (i.e. the first two explanations for CPT's values, as discussed above). But other data must be considered when the number of core papers is small. Generally speaking, the amount of citing papers in most fronts will grow with time, so the bubble diagram can also help us understand the development of the Research Fronts.

The second table for each area analyze the affiliated countries, institutions of the core papers, which reveal the players making fundamental contributions in the key hot Research Fronts. Countries and institutions of the citing papers are analyzed in the third table to reveal their research strategy as they carry forward the work in these specialty areas.

(2) Interpretation of key emerging Research Fronts

Because the emerging Research Fronts identified were usually small in terms of number of core and citing papers, the figures did not generally lend themselves to detailed statistical analysis. Nevertheless, information professionals endeavored to examine and interpret the data to better understand the content, research efforts, and ongoing trends in the key emerging Research Fronts.

2. AGRICULTURAL, PLANT AND ANIMAL SCIENCES

1. HOT RESEARCH FRONT

1.1 TREND OF THE TOP 10 RESEARCH FRONTS IN AGRICULTURAL, PLANT AND ANIMAL SCIENCES

The Top 10 hot Research Fronts in agricultural, plant and animal sciences mainly cover research on plant-gene regulatory networks and genome editing; crop disease and pest control; food nutrition and safety; photosynthesis; plant rhizosphere microbial community; immunity of aquatic animals; and forest tree cultivation (Table 1). There are three hot fronts on plant-gene regulatory networks and genome editing, including "Dissection of the genetic networks underlying yield related traits in crop", "Gene regulation of biosynthesis of medicinal compounds in plants" and "Application of CRISPR/Cas9 gene editing technology in crop genome editing." Among those hot fronts, gene-editing technology and its application in agriculture was previously highlighted in the 2017 Top 10 hot Research Fronts.

Crop disease and pest control have always been concerns in agriculture, and related research has continued to be one of the Top 10 hot Research Fronts for five consecutive years. For example: "Biological control of invasive crop pest using predators" in 2014, "Insect resistance to *Bacillus thuringiensis* (Bt) transgenic crops" in 2015, "White-nose syndrome in bats, the predators of pests" in 2016, and "Invasion biological study of *Drosophila suzukii*" in 2017. In the 2018 selection, "Invasion biology and control strategy of *Drosophila suzukii*" appears in the Top 10 hot Research Fronts list again, and expands the research scope to include control strategy.

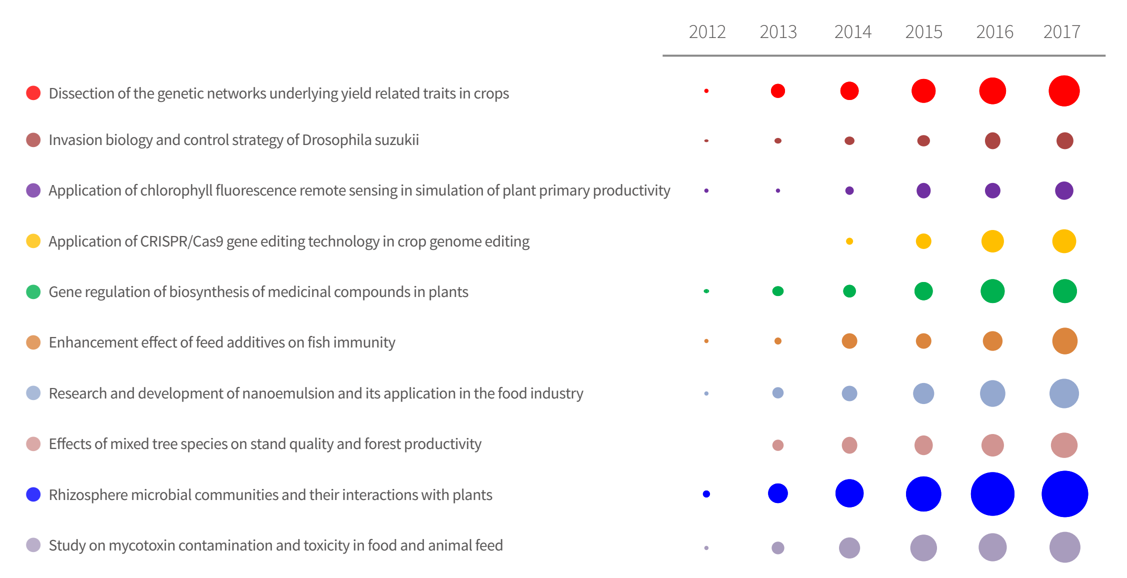
The topic of food nutrition and safety has also been receiving constant attention, and pertinent research has previously been included among the Top 10 hot Research Fronts. For example: "Statistics of foodborne disease in the USA and evaluation of economic loss" in 2014, "Hyperspectral imaging in food processing" in 2015, and, in 2016, "Hyperspectral imaging in quality evaluation of food," "Outbreak, prevention and control of microbial contamination of fresh produce" and "Nanoemulsion delivery systems used for nutrients absorption." This year two Top 10 hot Research Fronts are featured on the topic of food nutrition and safety: "Study on mycotoxin contamination and toxicity in food and animal feed" and "Research and development of nanoemulsion and its application in the food industry."Photosynthesis and microbial communities in the soil region known as the rhizosphere have also been the focus of research in the field of agriculture and botany. Past Top 10 hot Research Fronts related to photosynthesis include "C-4 photosynthesis evolution and the effect of CO_2 concentration on mesophyll conductance"(2014), "Structure and function of photosynthetic light-harvesting complex"(2016) and "Application of chlorophyll fluorescence remote sensing in simulation of plant primary productivity" (2018). There have been three Top 10 hot Research Fronts involving research on rhizosphere microbial communities in previous years, including "Analysis of rhizosphere fungal communities using DNA sequencing" in 2014, "Research on arbuscular mycorrhizal symbiosis and mechanisms of nutrition and signals" in 2017, and "Rhizosphere microbial communities and their interactions with plants" this year.

The other two 2018 Top 10 hot Research Fronts, "Enhancement effect of feed additives on fish immunity" and "Effects of mixed tree species on stand quality and forest productivity," belong respectively to aquatic animal immunity research and forest tree cultivation, which are emerging research topics in our annual series of Research Fronts.

Table 1: Top10 Research Fronts in agricultural, plant and animal sciences

Rank	Hot Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Dissection of the genetic networks underlying yield related traits in crops	18	1329	2014.8
2	Invasion biology and control strategy of *Drosophila suzukii*	19	972	2014.8
3	Application of chlorophyll fluorescence remote sensing in simulation of plant primary productivity	14	767	2014.8
4	Application of CRISPR/Cas9 gene editing technology in crop genome editing	14	1285	2014.6
5	Gene regulation of biosynthesis of medicinal compounds in plants	16	993	2014.6
6	Enhancement effect of feed additives on fish immunity	14	814	2014.6
7	Research and development of nanoemulsion and its application in the food industry	33	1561	2014.5
8	Effects of mixed tree species on stand quality and forest productivity	15	1092	2014.5
9	Rhizosphere microbial communities and their interactions with plants	44	4983	2014.4
10	Study on mycotoxin contamination and toxicity in food and animal feed	27	1803	2014.4

Figure 1: Citing papers for the Top 10 Research Fronts in agricultural, plant and animal sciences



1.2 KEY HOT RESEARCH FRONT – "Dissection of the genetic networks underlying yield related traits in crops"

Under the pressure of food-security demand, high yield has been an important goal of agricultural production. In recent breeding history, the techniques of dwarfing and cross breeding have led to two great crop-yield leaps. At present, with the breakthrough of life sciences, biological breeding has become a revolutionary new technology. Therefore, in order to achieve another leap in yield, it is necessary to dissect the genetic networks of yield-related traits, discover and utilize key genes, tap the genetic potential of crop yield, and propose new breeding pathways and methods. In the last decade, with the progress in crop-genome sequencing, the application of molecular markers based on PCR technology, the construction of various mutant libraries and databases, and the development of next-generation sequencing technology, the molecular mechanism and genetic regulatory networks of yield traits has become a hot Research Front.

Eighteen papers constitute the core of this hot Research Front. Most of them explore key genes and their genetic networks regulating rice yield related traits, such as grain size, width, shape and weight, as well as plant architecture. The main research outcomes include: In 2016, a quantitative trait locus GS2 controlling grain size and weight was identified in rice. It was further found that the transcription factor OsGRF4, encoded by GS2, is regulated by OsmiR396. In the same year, another quantitative trait locus, GLW7, which controls the grain size of rice, was also discovered, and the transcription factor OsPLS13, encoded by GLW7, was observed to play a positive regulation role on the rice grain size. In addition, other grain regulatory factors (e.g., GL2 and GW5) and IPI1 proteins regulating rice plant architecture were also found. A few core papers examine re-sequencing of rice genome and provide an important base for rice gene resources mining. Among the core papers, a review published in *Trends in Plant Science* in 2012 proposed that the genetic network analysis of plant growth and organ size was becoming a high priority in plant science.

In terms of countries and institutions (Table 2), China is the main contributor to this hot Research Front, with 12 core papers, accounting for 66.7% of the total. The USA and Japan contribute four and three core papers, respectively accounting for 22.2% and 16.7% of the total. Important contributing institutions include the Chinese Academy of Sciences, the Chinese Academy of Agricultural Sciences and the National Institute of Agrobiological Sciences in Japan, with respective totals of nine, eight, and three core papers.

Table 2: Top countries and institutions producing the 18 core papers in the Research Front "Dissection of the genetic networks underlying yield related traits in crops"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	China	12	66.7%	1	Chinese Academy of Sciences	China	9	50.0%
2	USA	4	22.2%	2	Chinese Academy of Agricultural Sciences	China	8	44.4%
3	Japan	3	16.7%	3	National Institute of Agrobiological Sciences - Japan	Japan	3	16.7%
4	Philippines	2	11.1%	4	Ghent University	Belgium	2	11.1%
4	Belgium	2	11.1%	4	International Rice Research Institute - Philippines	Philippines	2	11.1%

In terms of countries that cite the core papers of this hot Research Front (Table 3), China is also the main contributing country with 450 citing papers, accounting for 43.6% of the total. The USA ranks 2nd with 205 citing papers that account for 19.9% of the total, while Japan ranks 3rd with 130 citing papers, accounting for 12.6% of the total. In terms of citing institutions, the Chinese Academy of Agricultural Sciences ranks 1st with 125 citing papers, followed by the Chinese Academy of Sciences and Ghent University in Belgium with 111 and 51 citing papers, respectively.

Table 3: Top countries and institutions producing citing papers in the Research Front "Dissection of the genetic networks underlying yield related traits in crops"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	China	450	43.6%	1	Chinese Academy of Agricultural Sciences	China	125	12.1%
2	USA	205	19.9%	2	Chinese Academy of Sciences	China	111	10.8%
3	Japan	130	12.6%	3	Ghent University	Belgium	51	4.9%
4	India	68	6.6%	4	Nanjing Agricultural University	China	44	4.3%
5	Germany	64	6.2%	5	National Institute of Agrobiological Sciences - Japan	Japan	39	3.8%
6	Belgium	62	6.0%	6	Huazhong Agricultural University	China	35	3.4%
7	France	61	5.9%	7	United States Department of Agriculture (USDA)	USA	29	2.8%
8	Philippines	56	5.4%	8	Cornell University	USA	26	2.5%
9	South Korea	50	4.8%	9	French National Institute for Agricultural Research (INRA)	France	25	2.4%
10	UK	42	4.1%	10	China Agricultural University	China	24	2.3%

1.3 KEY HOT RESEARCH FRONT – "Rhizosphere microbial communities and their interactions with plants"

The rhizosphere is a narrow (several millimeters wide) soil mass surrounded by and extensively affected by plant roots. It contains countless microorganisms and invertebrates, and is one of nature's most active interfaces. In agricultural ecosystems, rhizosphere microorganisms have a profound impact on crop growth, nutrition and health. The rhizosphere has attracted much attention since it was first proposed by German microbiologist Lorenz Hiltner in 1904. Rhizosphere research has been in the ascendant for more than 100 years. Rhizosphere microbial ecological processes are not only affected by plant physiological processes, but also exert impact on plant growth. Rhizosphere microorganisms can inhibit soil pathogens and promote plant growth through nutrient competition, antagonism, and induced systemic resistance, and can also cause considerable plant death through accumulation of pathogens. Therefore, the interaction between rhizosphere microorganisms and plants has become a research hotspot.

There are 44 core papers in the hot Research Front. Most of them focus on the definition, structure, variation, assembly mechanism, diversity, heritability and functions of plant rhizosphere microbial communities. Many plant species are involved, such as *Arabidopsis thaliana*, rice, soybean, maize, barley, grape, *Populus trichocarpa*, and agave species. For example, metagenomic analysis and metaproteogenomic analysis are used to analyze microbial communities in rice rhizosphere in some papers, while other papers examine the diversity and heritability of microbial communities in corn rhizosphere, taxonomical and functional microbial community selection in soybean rhizosphere, and root microbiota-driven direct integration of phosphate stress and immunity, and etc. The most-cited paper reviews the relationship between the rhizosphere microbiome and plant health.

Analysis of the countries and institutions producing core papers (Table 4) shows that the USA is the important country contributing to this hot Research Front, with 16 core papers, accounting for 36.4% of the total. Germany ranks 2nd with 14 core papers (31.8% of the total), followed by the Netherlands with six core papers (13.6%). In terms of institutions, the Max Planck Society and the US Department of Energy are the main contributing institutions, with eight and seven core papers, respectively.

Table 4: Top countries and institutions producing the 44 core papers in the Research Front "Rhizosphere microbial communities and their interactions with plants"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	USA	16	36.4%	1	Max Planck Society	Germany	8	18.2%
2	Germany	14	31.8%	2	United States Department of Energy (DOE)	USA	7	15.9%
3	Netherlands	6	13.6%	3	University of North Carolina	USA	6	13.6%
4	Switzerland	5	11.4%	3	Howard Hughes Medical Institute	USA	6	13.6%
5	France	4	9.1%	5	Helmholtz Association	Germany	5	11.4%
5	Italy	4	9.1%	6	Heinrich Heine University Dusseldorf	Germany	4	9.1%
5	Brazil	4	9.1%	6	University of Bremen	Germany	4	9.1%
5	UK	4	9.1%	6	Cornell University	USA	4	9.1%
9	Australia	3	6.8%	6	University of California Davis	USA	4	9.1%
9	Spain	3	6.8%					

In terms of countries that cite the core papers of this hot Research Front (Table 5), the USA is also the top contributor with 606 citing papers, accounting for 24.9% of the total. China ranks 2nd with 364 citing papers (15.0% of the total), while Germany ranks 3rd with 291 citing papers (12.0%). In terms of citing institutions, the French National Institute for Agricultural Research (INRA) contributes the most citing papers of 105. The Chinese Academy of Sciences, the National Center for Scientific Research in France (CNRS) and the Spanish National Research Council (CSIC) rank 2nd or 3rd, and all have more than 90 citing papers.

Table 5: Top countries and institutions producing citing papers in the Research Front "Rhizosphere microbial communities and their interactions with plants"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	606	24.9%	1	French National Institute for Agricultural Research (INRA)	France	105	4.3%
2	China	364	15.0%	2	Chinese Academy of Sciences	China	93	3.8%
3	Germany	291	12.0%	2	CNRS	France	93	3.8%
4	France	201	8.3%	4	Consejo Superior De Investigaciones Cientificas (CSIC)	Spain	91	3.7%
5	Italy	199	8.2%	5	United States Department of Energy (DOE)	USA	81	3.3%
6	Spain	190	7.8%	6	Max Planck Society	Germany	71	2.9%
7	UK	161	6.6%	7	United States Department of Agriculture (USDA)	USA	57	2.3%
8	Netherlands	159	6.5%	8	University of California Davis	USA	56	2.3%
9	Australia	118	4.9%	8	Utrecht University	Netherlands	56	2.3%
10	Brazil	108	4.4%	10	Helmholtz Association	Germany	50	2.1%

2. EMERGING RESEARCH FRONT

2.1 SUMMARY OF EMERGING RESEARCH FRONTS IN AGRICULTURAL, PLANT AND ANIMAL SCIENCES

In the area of Agricultural, Plant and Animal sciences, there is one emerging Research Front: "Application of new CRISPR gene editing technology in plant genome editing."

Table 6: Emerging Research Fronts in agricultural, plant and animal sciences

Rank	Emerging Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Application of new CRISPR gene editing technology in plant genome editing	15	271	2016.7

2.2 KEY EMERGING RESEARCH FRONT – “Application of new CRISPR gene editing technology in plant genome editing”

CRISPR technology is the third generation of gene editing technology following the earlier ZFN and TALEN technologies. Compared with the previous two generations, CRISPR shows great potential in fundamental research, gene therapy and crop genetic improvement due to its easy design and construction, low methylation sensitivity, accurate targeting and high cutting efficiency. Therefore, a research upsurge of CRISPR genome editing has been launched in the field of biotechnology. In 2013, it was first found that CRISPR/Cas9 system could be used to edit genomes efficiently, and it was subsequently applied to gene editing in human and mouse cells successfully. In the same year, CRISPR/Cas9 technology was listed in *Science* magazine as the 2013 Breakthrough of the Year. In 2016, researchers from the Chinese Academy of Sciences first successfully used CRISPR/Cas9 system to edit genomes in rice, wheat and other plants, and the related outcome was chosen as one of 10 breakthrough technologies by MIT Technology Review.

CRISPR gene editing technology has been one of the Top 10 hot Research Fronts or an emerging front for five consecutive years since it was selected as an emerging front in 2014. In 2017 and 2018, CRISPR technology and its application in agriculture was featured as one of Top 10 hot Research Fronts in the area of Agricultural, Plant and Animal Sciences. The current emerging Research Front also concerns CRISPR technology. Fifteen core papers constitute this emerging Research Front. Most papers involve the application of CRISPR /Cpf1 -- a new CRISPR editing system – to plant genome editing, focusing on the site directed mutagenesis of rice, cotton, corn, wheat, tomato and other plants for producing target mutants. The CRISPR/Cpf1 system was discovered in the MIT laboratory of Feng Zhang in 2015. Compared with Cas9, Cpf1 has many advantages, including shorter boot RNA, longer boot sequence, higher specificity, lower off-target effects, easier multi-site editing, enabling greatly expand the scope of genome editing, and higher knockout efficiency. Therefore, the CRISPR/Cpf1 system has become the most potentially useful tool for genome editing and has been recognized as one of the best new-generation gene editing tools; it has been rapidly employed in genome editing and targeted gene transcription regulation of plants such as rice and *Arabidopsis thaliana.*

3. ECOLOGY AND ENVIRONMENTAL SCIENCES

1. HOT RESEARCH FRONT

1.1 TREND OF THE TOP 10 RESEARCH FRONTS IN ECOLOGY AND ENVIRONMENTAL SCIENCES

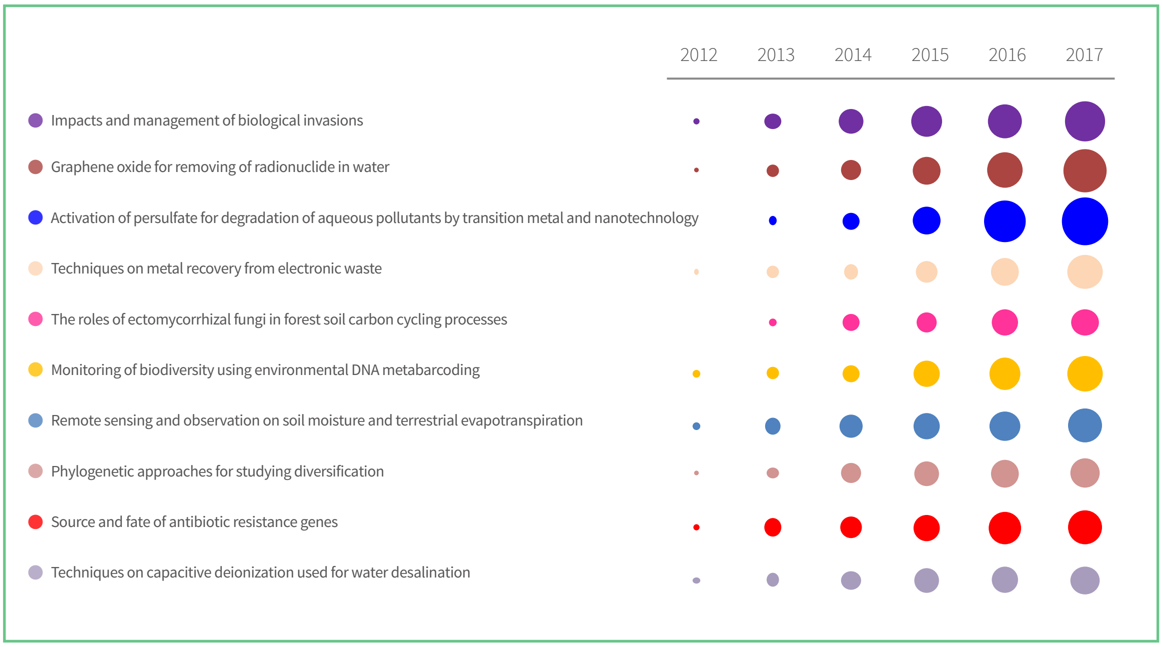
The Top 10 hot Research Fronts in ecology and environmental sciences are mainly distributed in two sub-areas that conform precisely to the name of the front: Ecology science and Environmental science (Table7 and Figure 2). The five hot Research Fronts in the ecology subfield mainly focus on: 1) the interaction and function of ecosystems, such as "Impacts and management of biological invasions" and "The roles of ectomycorrhizal fungi in forest soil carbon cycling processes"; 2) the monitoring of ecosystems, such as "Remote sensing and observation on soil moisture and terrestrial evapotranspiration"; and 3) the researching and monitoring of biodiversity, such as "Phylogenetic approaches for studying diversification" and "Monitoring of biodiversity using environmental DNA metabarcoding." The latter front has been listed as one of the Top 10 hot Research Fronts for the second consecutive year.The other five hot Research Fronts in the environmental science subfield mainly discuss: 1) the removal and control of pollutants, including "Graphene oxide for removing of radionuclide in water", "Activation of persulfate for degradation of aqueous pollutants by transition metal and nanotechnology" and "Techniques on metal recovery from electronic waste"; 2) sea water desalination, such as "Techniques on capacitive deionization used for water desalination"; and 3) emerging pollutants, such as "Source and fate of antibiotic resistance genes".

In terms of key research trends, the water environment problem is an important concern. Graphene oxide, transition metal and nanotechnology has become the major technical approach in the elimination of pollutants. Emerging environmental problems such as antibiotic resistance genes and electronic waste also have become important hot frontier issues.

Table 7: Top 10 Research Fronts in ecology and environmental sciences

Rank	Hot Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Impacts and management of biological invasions	24	2062	2015.2
2	Graphene oxide for removing of radionuclide in water	46	3360	2015.1
3	Activation of persulfate for degradation of aqueous pollutants by transition metal and nanotechnology	50	3344	2014.9
4	Techniques on metal recovery from electronic waste	29	1395	2014.8
5	The roles of ectomycorrhizal fungi in forest soil carbon cycling processes	11	1047	2014.6
6	Monitoring of biodiversity using environmental DNA metabarcoding	45	3770	2014.4
7	Remote sensing and observation on soil moisture and terrestrial evapotranspiration	24	2027	2014.4
8	Phylogenetic approaches for studying diversification	20	1931	2014.4
9	Source and fate of antibiotic resistance genes	17	1929	2014.4
10	Techniques on capacitive deionization used for water desalination	18	1914	2014.4

Figure 2: Citing papers for the Top 10 Research Fronts in ecology and environmental sciences



1.2 KEY HOT RESEARCH FRONT – "Activation of persulfate for degradation of aqueous pollutants by transition metal and nanotechnology"

Persulfate advanced oxidation technology is an emerging and promising technology for removing water pollutantsosal. Dissolving persulfate in water can produce persulfate ion ($S_2O_8^{2-}$), which will generate strong oxidizing sulfate radical ($SO_4^{-}\cdot$) after activation by light, heat, transition metal ion, etc. Compared with other oxidation technology, persulfate advanced oxidation technology can produce more stable and selective radical with longer half-time. This technology produces better effects on the degradation of many organic pollutants, including time efficiency and avoiding secondary pollution. Therefore, it is mainly applied to water restoration and wastewater treatment.

At present, hot research topics related to persulfate ion activator focus on metal catalysts such as zero-valent iron and transition metals, and nonmetal catalysts such as graphene oxide. These catalysts are economic and highly efficient, since only mild reaction conditions are required without external thermal or optical source, and they also have the advantages of lower energy consumption as well as operational convenience. Besides, nano-catalysts have bigger surface area and higher catalytic activity than traditional catalysts, making them widely used to improve reaction and degradation rate. The combination of nanotechnology and new persulfate ion activation technology can effectively improve the efficiency of water pollutants treatment, reduce energy consumption, and make recycling and operation easier. Therefore it is superior to the traditional technology of treating water pollutants. There are 50 core papers in this Research Front, mainly focusing on the use of zero-valent iron, transition metal ions including Fe^{2+}, Cu^{2+}, Mn^{2+}, etc., along with some bimetallic oxides such as $CuCo_2O_4$, $Fe_xCo_{3-x}O_4$, $CuFeO_2$, $MnFe_2O_4$, etc., and reduced graphene oxide, or doped graphene oxide, etc. as activator of persulfate system, applying nanotechnology to prepare a nano-catalyst or loading specific catalyst onto carbon nanotubes and nanocages, and conducting the mechanism, effects and impact parameter analysis of water pollutants treatment. The research group of Shaobin Wang from Curtin University in Australia contributed 10 core papers on graphene and other nanomaterials, and one of the papers, titled "Reduced graphene oxide for catalytic oxidation of aqueous organic pollutants," is the most frequently cited non-review paper.

According to the statistics on top countries and institutions (Table 8), most of the core papers (37) are from China, accounting for 74% of the core's total. The number of core papers published by Australia and the USA is 12 and 4, ranking 2nd and 3rd respectively. The number of core papers from other countries is small. The main institutions contributing core papers are based in Australia and China. Among them, Curtin University in Australia has the largest number of core papers. Other important institutions are located in China, including Harbin Institute of Technology (8 papers) and Tongji University (6 papers) ranked 2nd and 3rd respectively.

Table 8: Top countries/regions and institutions producing the 50 core papers in the Research Front "Activation of persulfate for degradation of aqueous pollutants by transition metal and nanotechnology"

Country Ranking	Country/ region	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	China	37	74.0%	1	Curtin University	Australia	10	20.0%
2	Australia	12	24.0%	2	Harbin Institute of Technology	China	8	16.0%
3	USA	4	8.0%	3	Tongji University	China	6	12.0%
4	Saudi Arabia	2	4.0%	4	Wuhan University	China	3	6.0%

Country Ranking	Country/ region	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
4	Taiwan, China	2	4.0%	4	Chinese Academy of Sciences	China	3	6.0%
6	Turkey	1	2.0%	4	Donghua University	China	3	6.0%
6	South Korea	1	2.0%	4	Hefei University of Technology	China	3	6.0%
6	Egypt	1	2.0%					
6	France	1	2.0%					
6	Germany	1	2.0%					
6	Indonesia	1	2.0%					
6	Italy	1	2.0%					

From the perspective of the countries and institutions that cite the core papers (Table 9), China is the most important source of citing papers. Chinese scientists and scholars participated in 1,065 citing papers, accounting for 65.3% of the total number. The USA has 171 articles, accounting for 10.5%, ranking 2nd, while Australia has 110 papers, accounting for 6.7%, ranking 3rd. The number and proportion of citing papers in other countries are small.

In terms of institutes that cite the core papers of this hot Research Front, the Chinese Academy of Sciences ranks 1st with 130 citing papers, followed by Tongji University with 89 and Harbin Institute of Technology with 75, accounting for 8.0%, 5.5% and 4.6% respectively. Curtin University, which publishes the largest number of core papers, has 70 citing papers, ranking 4th.

Table 9: Top countries/regions and institutions producing citing papers in the Research Front "Activation of persulfate for degradation of aqueous pollutants by transition metal and nanotechnology"

Country Ranking	Country/ region	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	China	1065	65.3%	1	Chinese Academy of Sciences	China	130	8.0%
2	USA	171	10.5%	2	Tongji University	China	89	5.5%
3	Australia	110	6.7%	3	Harbin Institute of Technology	China	75	4.6%
4	India	85	5.2%	4	Curtin University	Australia	70	4.3%
5	Iran	68	4.2%	5	Wuhan University	China	40	2.5%
6	South Korea	50	3.1%	6	Hunan University	China	38	2.3%
7	France	43	2.6%	7	CNRS	France	34	2.1%
8	Taiwan, China	42	2.6%	8	Sichuan University	China	32	2.0%
9	Spain	41	2.5%	9	Nanjing University	China	31	1.9%
10	Germany	36	2.2%	9	Tsinghua University	China	31	1.9%

1.3 KEY HOT RESEARCH FRONT – “Source and fate of antibiotic resistance genes”

In recent years, with the frequent use of health care medications and personal care products and the long-term abuse of antibiotics in the breeding industry, a large number of drug-resistant bacteria have emerged. The related antibiotic resistance genes (ARGs) rapidly appear and spread in the environment, which greatly affects the therapeutic effect of antibiotics and seriously threatens human health. According to statistics, about 700,000 people die of drug-resistant bacterial infections worldwide every year. Unlike traditional chemical contaminants, ARGs can exhibit unique environmental behaviors due to their inherent biological properties, such as transferring and spreading between different bacteria and self-expansion. They can persist, spread and diffuse in the environment, and bring great harm to environment and human health. In 2004, Michal Rysz and Pedro J. J. Alvarez suggested that ARGs be treated as environmental pollutants, and in 2006, Amy Pruden,, et al., clearly proposed ARGs as a new type of environmental pollutant. After that, the ecological environment problems caused by ARGs have attracted the attention of scholars from all over the world.

The core papers of this hot Research Front, “Source and fate of antibiotic resistance genes,” mainly focus on the distribution and environmental migration of ARGs in specific regions or specific pollutants, such as farms, livestock manure, sewage-treatment plant sludge, etc. The interaction of antibiotic resistance and microbial communities also proves to be a hot topic. The group of Yongguan Zhu at the Chinese Academy of Sciences published an article “Diverse and abundant antibiotic resistance genes in Chinese swine farms” in PNAS in 2013 which is the most frequently cited paper in this front, now cited 440 times. This paper mainly analyzes the abundance of antibiotic genes in swine farms and proposes antibiotics and metal abuse as the main sources of resistance genes.

According to statistics on countries and institutions (Table 10), the 17 core papers are basically from China and the USA. There are nine core papers apiece from the two countries, with each quantity accounting for 52.9% of the total number. There are very few papers from other countries. The main contributing institutions of the core papers are also from China and the USA -- namely the Chinese Academy of Sciences (4 papers), the University of Hong Kong (4 papers), Michigan State University (3 papers) and Washington University in St. Louis (3 papers).

Table 10: Top countries and institutions producing the 17 core papers in the Research Front “Source and fate of antibiotic resistance genes”

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	China	9	52.9%	1	Chinese Academy of Sciences	China	4	23.5%
1	USA	9	52.9%	2	University of Hong Kong	China	3	17.6%
3	Canada	1	5.9%	2	Michigan State University	USA	3	17.6%
3	Croatia	1	5.9%	2	Washington University in St. Louis	USA	3	17.6%
3	Denmark	1	5.9%					
3	Germany	1	5.9%					
3	Spain	1	5.9%					
3	Switzerland	1	5.9%					

In terms of countries that cite the core papers of this hot Research Front (Table 11), China is the most prolific country, contributing to 446 citing papers and accounting for 37.0% of the total. The USA ranks 2nd with 346 citing papers, or 28.7% of the total. The number and proportion of citing papers in other countries are both small. In terms of citing institutions, the Chinese Academy of Sciences contributed to 145 citing papers, accounting for 12.0% of the total, followed by the US Department of Agriculture with 40 and Zhejiang University with 36 citing papers, ranking 2nd and 3rd respectively.

Table 11: Top countries and institutions producing citing papers in the Research Front "Source and fate of antibiotic resistance genes"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	China	446	37.0%	1	Chinese Academy of Sciences	China	145	12.0%
2	USA	346	28.7%	2	United States Department of Agriculture (USDA)	USA	40	3.3%
3	UK	89	7.4%	3	Zhejiang University	China	36	3.0%
4	Canada	71	5.9%	4	University of Hong Kong	China	34	2.8%
5	Germany	68	5.6%	5	Consejo Superior De Investigaciones Cientificas (CSIC)	Spain	31	2.6%
6	Australia	61	5.1%	5	Michigan State University	USA	31	2.6%
7	France	57	4.7%	7	Nanjing Agricultural University	China	30	2.5%
8	Spain	53	4.4%	8	CNRS	France	25	2.1%
9	Denmark	40	3.3%	9	Washington University in St. Louis	USA	24	2.0%
10	Sweden	35	2.9%	10	University of Gothenburg	Sweden	22	1.8%

2. EMERGING RESEARCH FRONT

2.1 SUMMARY OF EMERGING RESEARCH FRONTS IN ECOLOGY AND ENVIRONMENTAL SCIENCES

In the area of Ecology and Environmental Sciences, there is one emerging Research Front: "The utility of microbial fuel cells in wastewater treatment".

Table 12: Emerging Research Fronts in ecology and environmental sciences

Rank	Emerging Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	The utility of microbial fuel cells in wastewater treatment	7	152	2016.6

2.2 KEY EMERGING RESEARCH FRONT – "The utility of microbial fuel cells in wastewater treatment"

In 1910, British botanist Michael C. Potter, after discovering that bacterial culture fluid could produce electricity, successfully produced the world's first microbial fuel cells (MFCs). In recent decades, environmental pollution and energy issues have become increasingly prominent. Since MFCs can directly convert the chemical energy stored in organic waste into electrical energy, the technology has gradually captured the attention of environmental researchers. Although a successful example of using microbial fuel cells to treat domestic sewage emerged in 1991, the battery power obtained by using MFCs to treat domestic sewage has not improved until recent years.

MFCs are devices that use microorganisms to oxidize organic pollutants at the anode, capture electrons, and transfer the electrons to the cathode, which could generate electric current and finally convert chemical energy directly into electric energy. In treating wastewater, MFCs technology can realize energy recovery from the fluid. At the same time, the technique displays higher degradation efficiency than traditional anaerobic biological treatment technology. It is a new type of technology for wastewater disposal that integrates wastewater recycling, sludge reduction and water quality harmlessness. In recent years, new MFC-based technologies have been continuously developed, while structures, materials, inoculants, etc., have been optimized, and the power density of output power has been greatly increased. MFCs is being applied to the treatment and degradation of more and more types of wastewater, organic matters or pollutants. It has become one of the emerging topics in waste resource utilization.

The main contents of this emerging Research Front include iron-based catalyst preparation and performance for enhancing MFCs redox reaction, and MFCs application technology for treating urine while producing electricity.

4. GEOSCIENCES

1. HOT RESEARCH FRONT

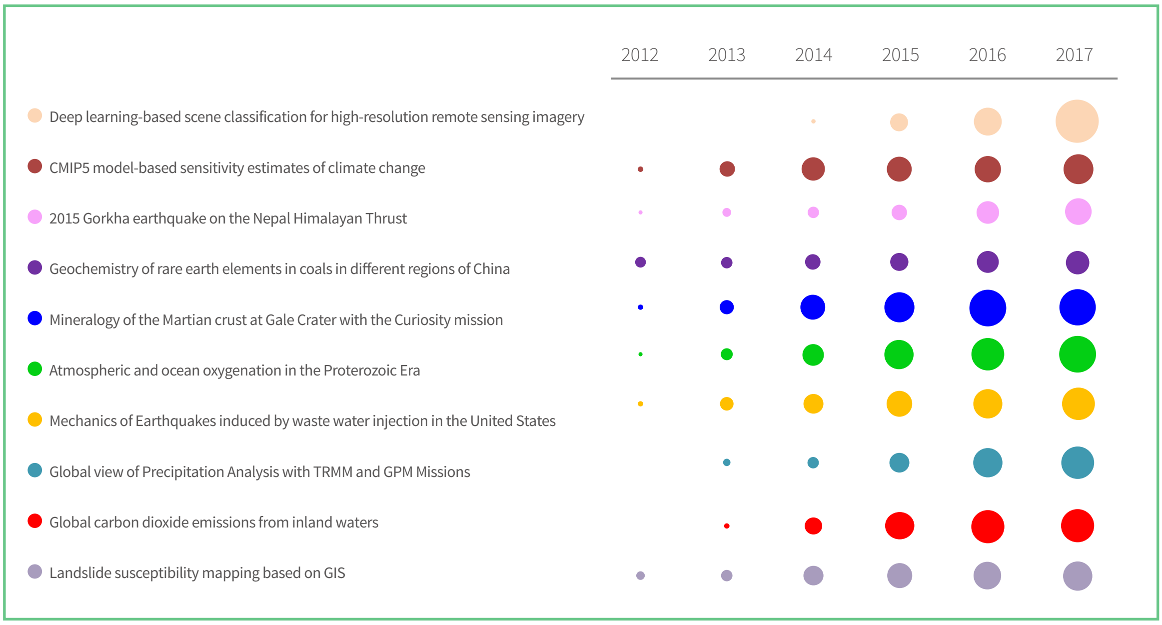
1.1 TREND OF THE TOP 10 RESEARCH FRONTS IN GEOSCIENCES

The Top 10 Research Fronts in geosciences mainly focus on climate change, geochemistry, and solid geophysics and geology. Topics examined in fronts related to climate change include CMIP5 model-based sensitivity estimates of climate change; atmospheric and ocean oxygenation in the Proterozoic Era; and global view of precipitation analysis with the TRMM and GPM missions. Research Fronts related to geochemistry include the geochemistry of rare earth elements in coals in different regions of China, and global carbon dioxide emissions from inland waters. Research Fronts in solid geophysics and geology examine the deep learning-based scene classification for high-resolution remote sensing imagery; the 2015 Gorkha earthquake on the Nepal Himalayan thrust; mineralogy of the Martian crust at Gale Crater with the Curiosity mission; and landslide susceptibility mapping based on GIS.

Table 13: Top 10 Research Fronts in geosciences

Rank	Hot Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Deep learning-based scene classification for high-resolution remote sensing imagery	38	1535	2015.6
2	CMIP5 model-based sensitivity estimates of climate change	16	1148	2014.9
3	2015 Gorkha earthquake on the Nepal Himalayan Thrust	14	1016	2014.9
4	Geochemistry of rare earth elements in coals in different regions of China	15	934	2014.9
5	Mineralogy of the Martian crust at Gale Crater with the Curiosity mission	26	2253	2014.6
6	Atmospheric and ocean oxygenation in the Proterozoic Era	24	1966	2014.6
7	Mechanics of Earthquakes induced by waste water injection in the United States	20	1677	2014.6
8	Global view of Precipitation Analysis with TRMM and GPM Missions	13	892	2014.6
9	Global carbon dioxide emissions from inland waters	9	1112	2014.4
10	Landslide susceptibility mapping based on GIS	32	1955	2014.3

Figure 3: Citing papers for the Top 10 Research Fronts in geosciences



1.2 KEY HOT RESEARCH FRONT – "Mineralogy of the Martian crust at Gale Crater with the Curiosity mission"

The Curiosity rover, part of NASA's Mars Science Laboratory mission, is the largest and most capable rover ever sent to Mars. It was launched on November 26, 2011 and arrived at Gale Crater in August 2012. Curiosity was designed to assess whether Mars ever had an environment that is able to support microbial life forms. In other words, its mission is to determine the planet's "habitability." The rover carries the largest and most advanced suite of instruments for scientific studies ever sent to the Martian surface, including three cameras, four spectrometers, two radiation detectors and one environmental sensor. "Curiosity rover lands on Mars" ranked 1st on the list of Science's 2012 Breakthroughs of the Year. The principal investigator of the Curiosity mission was one of Nature's "10 people who mattered" in 2012. The scientific research achievements since its landing have also been selected among NASA's annual highlights, attracting close attention worldwide.Curiosity rover used a drill carried at the end of its robotic arm to bore into a flat, veiny Martian rock and collect a sample from its interior. This is the first time in Mars exploration that any robot has drilled into a rock to collect a sample. Scientists identified sulfur, nitrogen, hydrogen, oxygen, phosphorus and carbon -- some of the key chemical ingredients for life, which shows that ancient Mars could have supported living microbes. Curiosity has recorded evidence of water-bearing minerals in rocks, and the observations suggest that a series of long-lived streams and lakes existed at some point between about 3.8 to 3.3 billion years ago. In 2015, Curiosity made the first detection of nitrogen on the surface, released during the heating of Martian sediments. The nitrogen was detected in the form of nitric oxide. The discovery adds to the evidence that ancient Mars was habitable for life.

The core papers of this hot Research Front, "Mineralogy of the Martian crust at Gale Crater with the Curiosity mission," focus on the aqueous environments at Gale Crater, volatile and organic analysis of Martian fines, elemental geochemistry of sedimentary rocks, and mineralogical analysis of the Martian surface.

The most-cited core paper (235 citations) in this Research Front is from a research team at Caltech. This paper highlights the fine-grained sedimentary rocks discovered by Curiosity, which are inferred to represent an ancient lake and preserve evidence of an environment that would have been suited to support a Martian biosphere founded on chemolithoautotrophy.

Analysis of countries and institutions producing core papers (Table14) shows the USA's predominance in this field. The USA-based researchers contributed to all 26 of the core papers. Researchers based in France and the UK contributed respectively to 18 and 13 papers. Among the Top 10 institutions, seven are from the USA. Caltech and NASA tie for first place, each contributing to 21 core papers (roughly 80.8% of the total), followed by the U.S. Department of Energy, France's CNRS, the Planetary Science Institute in Arizona, USA, and the University of California, Davis.

Table 14: Top countries and institutions producing the 26 core papers in the Research Front "Mineralogy of the Martian crust at Gale crater with the Curiosity mission"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	USA	26	100.0%	1	California Institute of Technology	USA	21	80.8%
2	France	18	69.2%	1	National Aeronautics & Space Administration (NASA)	USA	21	80.8%
3	UK	13	50.0%	3	United States Department of Energy (DOE)	USA	13	50.0%

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
4	Canada	11	42.3%	4	CNRS	France	12	46.2%
5	Spain	6	23.1%	4	Planetary Science Institute	USA	12	46.2%
6	Mexico	5	19.2%	4	University of California Davis	USA	12	46.2%
7	Germany	4	15.4%	7	University of Guelph	Canada	11	42.3%
7	Denmark	4	15.4%	8	University of Toulouse	France	9	34.6%
7	Australia	4	15.4%	8	State University of New York (SUNY) Stony Brook	USA	9	34.6%
10	Sweden	3	11.5%	8	Arizona State University	USA	9	34.6%

As for countries and institutions producing citing papers, the USA ranks 1st with 752. France also performs actively in this Research Front and ranks 2nd. In the Top 10 institutions list, there are six American institutions. NASA, Caltech, and France's National Center for Scientific Research (CNRS) are the top three institutions in publishing a significant number of citing papers (Table 15).

Table 15: Top countries and institutions producing citing papers in the Research Front "Mineralogy of the Martian crust at Gale Crater with Curiosity mission"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	752	71.0%	1	National Aeronautics & Space Administration (NASA)	USA	347	32.8%
2	France	225	21.2%	2	California Institute of Technology	USA	230	21.7%
3	UK	191	18.0%	3	CNRS	France	161	15.2%
4	Germany	146	13.8%	4	Planetary Science Institute	USA	91	8.6%
5	Canada	137	12.9%	5	United States Department of Energy (DOE)	USA	87	8.2%
6	Spain	76	7.2%	6	Johns Hopkins University	USA	70	6.6%
7	Italy	60	5.7%	7	University of Toulouse	France	70	6.6%
8	Australia	47	4.4%	8	University Nantes Angers Le Mans	France	69	6.5%
9	China	47	4.4%	9	Helmholtz Association	Germany	67	6.3%
10	Sweden	42	4.0%	10	University of New Mexico	USA	66	6.2%

1.3 KEY HOT RESEARCH FRONT – "Global carbon dioxide emissions from inland waters"

The global carbon cycle issue has become a hotspot in the field of global change and earth science research in recent years. The carbon cycle of terrestrial ecosystems is the most complex part of the global carbon cycle and is mostly affected by human activity. Though inland water only accounts for 2% of Earth's surface, since most of the terrestrial organic carbon fluxes into estuaries or the sea through rivers and lakes, inland water plays a significant role in the global carbon cycle system. For instance, rivers serve as the main channel connecting two major carbon pools, i.e., the sea and land, and carbon dioxide (CO_2) and methane (CH_4) emissions at the water-air interface constitute an unignorable part of the global carbon cycle. As a combination of atmospheric, terrestrial, and aquatic ecosystems, lake sediments store abundant information on the regional and global environmental change, and therefore have been under active investigation.

In 2018, nine core papers underpin the hot Research Front "Global carbon dioxide emissions from inland waters." The research mainly focuses on revealing the changing emissions of carbon dioxide and methane of inland waters (streams, rivers, etc.) and coastal oceans. A leading core paper titled "Global carbon dioxide emissions from inland waters" was contributed by Yale University and other research institutes in 2013. This Nature paper reveals the movement of carbon dioxide from inland waters to the atmosphere, and points out that the annual global CO_2 evasion rate of 2.1 Pg C yr−1 is higher than previous estimates. The analysis also predicts the global hotspots in stream and river evasion, with about 70% of the flux occurring over just 20% of the land surface. This hot Research Front as represented by the aforementioned paper will continuously enrich the understanding of carbon emissions from inland waters and their impact on the environment.

Table 16 shows the major countries and institutions that contributed to the Research Front. The USA contributed six core papers, accounting for two thirds of the total core papers. Belgium and France both published five core papers. Among all institutes, France's CNRS contributed the largest number of core papers (five papers).

Table 16: Top countries and institutions producing the nine core papers in the Research Front "Global carbon dioxide emissions from inland waters"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	USA	6	66.7%	1	CNRS	France	5	55.6%
2	Belgium	5	55.6%	2	Free University of Brussels	Belgium	3	33.3%
2	France	5	55.6%	2	University of Liege	Belgium	3	33.3%
4	Canada	3	33.3%	2	University of Paul Sabatier - Toulouse III	France	3	33.3%
5	Germany	2	22.2%	2	University of Toulouse	USA	3	33.3%
5	Brazil	2	22.2%	2	University of Washington Seattle	USA	3	33.3%
5	Netherlands	2	22.2%	2	U.S. Geological Survey	USA	3	33.3%
5	Sweden	2	22.2%	2	Yale University	USA	3	33.3%

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
9	Switzerland	1	11.1%					
9	UK	1	11.1%					
9	Norway	1	11.1%					
9	Kenya	1	11.1%					
9	Finland	1	11.1%					

With regard to the countries whose publications cite the core papers, the USA was the main contributor (346 papers, 44.1%). Although China did not participate in any core papers, China actively performed follow-up research and produced the second-largest quantity of citing papers (129 papers, 16.4%). In terms of top-rated institutes, the CNRS in France produced the largest number of citing papers. The Chinese Academy of Sciences ranked 3rd with 52, indicating its attention in this research field.

Table 17: Top countries and institutions producing citing papers in the Research Front "Global carbon dioxide emissions from inland waters"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	346	44.1%	1	CNRS	France	78	9.9%
2	China	129	16.4%	2	Swiss Federal Institutes of Technology Domain	Switzerland	54	6.9%
3	Germany	116	14.8%	3	Chinese Academy of Sciences	China	52	6.6%
4	UK	100	12.7%	4	Uppsala University	Sweden	45	5.7%
5	France	98	12.5%	5	U.S. Geological Survey	USA	44	5.6%
6	Sweden	92	11.7%	6	University of Washington Seattle	USA	37	4.7%
7	Canada	74	9.4%	7	University of Paris Saclay Comue	France	34	4.3%
8	Switzerland	71	9.0%	8	Helmholtz Association	Germany	32	4.1%
9	Brazil	69	8.8%	8	Sorbonne University	France	32	4.1%
10	Belgium	62	7.9%	10	Inst Recherche Developpement (IRD)	France	30	3.8%
				10	University of Delaware	USA	30	3.8%

2. EMERGING RESEARCH FRONT

2.1 SUMMARY OF EMERGING RESEARCH FRONTS IN GEOSCIENCES

Table 18: Emerging Research Fronts in geosciences

Rank	Emerging Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	The role of moist intrusions in winter arctic warming and sea ice decline	14	191	2016.9

2.2 KEY EMERGING RESEARCH FRONT – "The role of moist intrusions in winter arctic warming and sea ice decline"

"The role of moist intrusions in winter arctic warming and sea ice decline" was selected as the emerging Research Front of 2018 in geosciences.

Winter in the Arctic is long and sunless. The temperature usually drops several tens of degrees below 0 °C, and the sea ice continues to expand and thicken. In recent years, however, the Arctic climate has been in an abnormal state. Before the Arctic fully enters the winter, sea ice begins to melt. Arctic warming has had a big influence on the Northern Hemisphere's climate, with extreme weather events occurring much more frequently. For example, extreme-weather winters are becoming more common in the USA and European countries, as many eastern U.S. regions suffered very low temperatures in cold snaps. Earth-system scientists of are very concerned about the phenomenon of Arctic warming, and the causes and effects of Arctic's abnormally rising temperatures has gradually become an emerging research topic.

Among the 14 core papers in this emerging Research Front, six were contributed by Norway, two by the Chinese Academy of Sciences. The most-cited core paper in this emerging Research Front, titled "The role of moist intrusions in winter Arctic warming and sea ice decline," was authored by Woods Cian from Stockholm University in 2016. This paper has been cited 44 times and examines the trajectories followed by intense intrusions of moist air into the Arctic polar region during autumn and winter and their impact on local temperature and sea ice concentration. This emerging Research Front also discusses the impact of Ural Blocking on winter warm Arctic-Cold Eurasian anomalies and the changing of Arctic sea-ice as recorded during the Norwegian N-ICE2015 expeditionary cruise in the High Arctic.

5. CLINICAL MEDICINE

1. HOT RESEARCH FRONT

1.1 TREND OF THE TOP 10 RESEARCH FRONTS IN CLINICAL MEDICINE

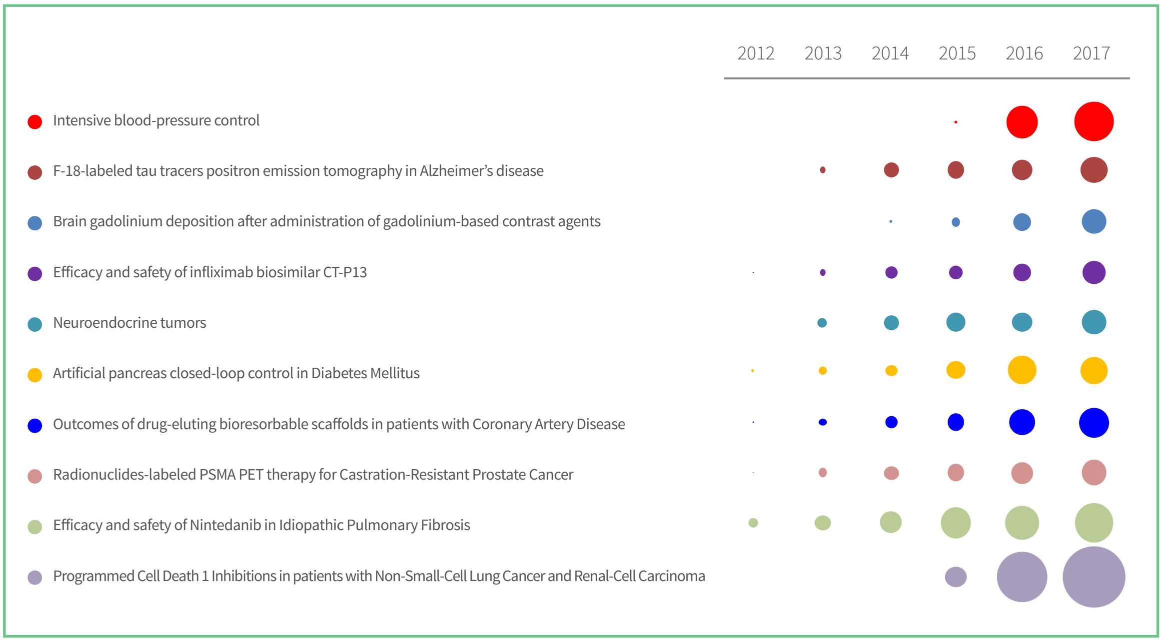
The Top 10 Research Fronts in clinical medicine focus on targeted therapy for tumors, new methods and standards for chronic-disease treatment, radionuclide-labeled imaging applications and adverse effects, and the efficacy of small molecule kinase inhibitors as well as the efficacy and safety of biological analogues.

The fronts related to tumor targeted therapy include PD-1/PD-L1 inhibition in the treatment of non-small-cell lung cancer and renal cell carcinoma, and radionuclides-labeled PSMA PET therapy for castration-resistant prostate cancer. On the topic of new methods and standards for chronic-disease treatment, the pertinent fronts concern intensive blood pressure control, drug-eluting bioresorbable scaffolds in coronary artery disease, and artificial pancreas closed-loop control in diabetes mellitus. The other three fronts, meanwhile, fall under the heading of radionuclide-labeled imaging and adverse effects: These fronts include F-18-labeled tau tracers positron emission tomography in Alzheimer's disease, brain gadolinium deposition after administration of gadolinium-based contrast agents, and radionuclides-labeled PSMA PET therapy for castration-resistant prostate cancer.

Table 19: Top 10 Research Fronts in clinical medicine

Rank	Hot Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Intensive blood-pressure control	9	1456	2016
2	F-18-labeled tau tracers positron emission tomography in Alzheimer's disease	32	1791	2015.9
3	Brain gadolinium deposition after administration of gadolinium-based contrast agents	29	1766	2015.9
4	Efficacy and safety of infliximab biosimilar CT-P13	26	1284	2015.9
5	Neuroendocrine tumors	17	1099	2015.6
6	Artificial pancreas closed-loop control in Diabetes Mellitus	24	1383	2015.5
7	Outcomes of drug-eluting bioresorbable scaffolds in patients with Coronary Artery Disease	35	2997	2015.2
8	Radionuclides-labeled PSMA PET therapy for Castration-Resistant Prostate Cancer	31	2709	2015.2
9	Efficacy and safety of Nintedanib in Idiopathic Pulmonary Fibrosis	39	4174	2015.1
10	Programmed Cell Death 1 Inhibitions in patients with Non-Small-Cell Lung Cancer and Renal-Cell Carcinoma	8	5430	2015

Figure 4: Citing papers for the Top 10 research fronts in clinical medicine



1.2 KEY HOT RESEARCH FRONT – "Intensive blood-pressure control"

Hypertension is a key risk factor for cardiovascular disease. The condition is commonly defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg. More than 1 billion people worldwide have been diagnosed with hypertension, with 9 million dying of related complications each year. The number of people in China with hypertension exceeds 300 million. Although large numbers of clinical studies have shown that blood-pressure control can reduce related cardiovascular risks, the target goal for antihypertensive treatment has been controversial for many years. In 2017, the American College of Cardiology and the American Heart Association (ACC/AHA) announced new guidelines for the prevention, detection, evaluation, and management of high blood pressure in adults. These guidelines redefined hypertension and its classification and reduced the target goal of antihypertensive treatment. The target goal for blood pressure control has once again raised great concern and discussion.

This hot Research Front "Intensive blood-pressure control" includes nine core papers, mainly examining the effects of regular versus intensive blood-pressure control on cardiovascular events, such as stroke and coronary heart disease. Among these papers, two reported the results of the SPRINT (Systolic Blood Pressure Intervention Trial) study, while the others concern on the evidence-based aspects of blood-pressure control benefits for patients with hypertension. The most-cited paper, with 1,152 citations, published in the New England Journal of Medicine in November 2015, announced early findings of the SPRINT study, which was funded by the National Institutes of Health. SPRINT was terminated early due to significant benefit observed in the intensive blood-pressure control group, documenting reduced risks of cardiovascular adverse events by 30% and all-cause mortality by 25% (while the risk of hypotension and syncope increased). This study significantly influenced the new ACC/AHA guideline revision, causing the target goal down-regulation in various hypertensive populations. Another paper, published in The Lancet in 2016 by Peking University First Hospital, confirmed the results of the SPRINT study, showing that intensive blood-pressure control can significantly reduce the occurrence of major vascular events compared with a non-intensive regimen. Studies such as SPRINT have added significant weight to active antihypertensive treatment strategies. Researchers in clinical settings, however, are still very cautious about the relationship between blood-pressure regulation and cardiovascular-disease prevention. In the era of precision medicine, more efforts will be made to explore the optimal target value of blood- pressure control in different groups in the treatment of hypertension. In terms of the number of core papers, Australia, Sweden, the UK, Israel, China, and Canada are on the list of the top 10 countries. The key contributing organizations include Case Western Reserve University in the USA and Peking University in China.

As for the citing papers, American researchers participated in more than 30% (535 articles) of this research, far more than the UK (131 articles) and Canada (125 articles), which ranked 2nd and 3rd respectively (Table 20). Among the Top10 institutions producing citing papers, five institutions are located in the USA, including Harvard University, Johns Hopkins University, and the National Institutes of Health, reflecting the USA's continuous focus on the area of intensive blood-pressure control.

Table 20: Top countries and institutions producing citing papers in the research front "Intensive blood-pressure control"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	535	36.7%	1	Harvard University	USA	66	4.5%
2	UK	131	9.0%	2	University of Alabama Birmingham	USA	55	3.8%

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
3	Canada	125	8.6%	3	Johns Hopkins University	USA	49	3.4%
4	Italy	114	7.8%	4	Wake Forest University	USA	40	2.7%
5	Germany	79	5.4%	5	National Institutes of Health (NIH) - USA	USA	39	2.7%
6	China	66	4.5%	6	University of Milano-Bicocca	Italy	36	2.5%
7	Australia	59	4.1%	7	Istituto Auxologico Italiano	Italy	35	2.4%
8	Spain	55	3.8%	8	Imperial College London	UK	33	2.3%
9	France	54	3.7%	8	University of Toronto	Canada	33	2.3%
10	Netherlands	52	3.6%	10	McMaster University	Canada	30	2.1%
				10	Tulane University	USA	30	2.1%
				10	University of Oxford	UK	30	2.1%

1.3 KEY HOT RESARCH FRONT – "Outcomes of drug-eluting bioresorbable scaffolds in patients with Coronary Artery Disease"

Coronary intervention has gone through three stages: balloon-expandable stents, bare metal stents and drug-eluting stents (DES). In recent years, the implantation of bioresorbable stents has appeared and is called the fourth stage of coronary intervention. Drug-eluting stents significantly reduce the rate of coronary restenosis after percutaneous coronary intervention (PCI) in patients with coronary heart disease. However, permanent stent implantation increases the risk of vascular inflammation and late stent thrombosis. Meanwhile, in order to prevent stent thrombosis, the prolongation of dual antiplatelet therapy duration increases the risk of bleeding, which partly offsets the clinical benefits. In lieu of permanent metal stents, bioresorbable stents provide only temporary vascular lumen support after implantation and then gradually degrade and resorb, restoring the integrity of vascular structure and function of vasoconstriction and vasodilation to a natural state. This reduces the occurrence of risk events due to the presence of permanent stents. In 2016, the US FDA approved the fully degradable scaffold (BVS) made by the company Abbott for clinical application.

This hot Research Front "Outcomes of drug eluting bioresorbable stents in patients with coronary artery diseases" includes 35 core papers, mainly involving clinical trials and meta-analysis of bioresorbable drug-eluting stents, aiming at assessing the safety and effectiveness of the devices. Although most of the existing clinical studies have verified the safety and effectiveness of bioresorbable drug-eluting stents to some extent, there are still shortcomings. For example, these clinical results have mostly been obtained in patients with simple coronary artery disease, and the clinical trial data for the treatment of complex coronary artery disease are rare. In addition, some clinical studies suggest that the risk of subacute and very late stent thrombosis increases after implantation of bioresorbable drug-eluting stents. Therefore, large-sample and long-term follow-up clinical data are essential for further evaluating the safety and efficacy of bioresorbable drug-eluting stents.

Among the Top 10 countries and institutions, the Netherlands contributes to 60% of the total core papers, with Erasmus University Rotterdam demonstrating a clear lead, contributing 20 core papers, accounting for 57.1%; the UK and the USA follow the Netherlands, with a contribution rate of 45.7%. The major producing institutions are Imperial College London in the UK and Abbott's Cardiovascular Products Division in USA, with contribution rates of 42.9% and 31.4%, respectively.

Table 21: Top countries and institutions producing the 15 core papers in the research front "Outcomes of drug-eluting bioresorbable scaffolds in patients with Coronary Artery Diseases"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	Netherlands	21	60.0%	1	Erasmus University Rotterdam	Netherlands	20	57.1%
2	UK	16	45.7%	2	Imperial College London	UK	15	42.9%
2	USA	16	45.7%	3	Abbott Vascular	USA	11	31.4%
4	Italy	9	25.7%	4	University of Amsterdam	Netherlands	7	20.0%
5	Poland	8	22.9%	5	Abbott Vascular	Belgium	6	17.1%
6	Japan	7	20.0%	5	Kyoto University	Japan	6	17.1%
6	Germany	7	20.0%	5	CARDIALYSIS	Netherlands	6	17.1%
8	France	6	17.1%	5	Auckland City Hospital	New Zealand	6	17.1%
8	New Zealand	6	17.1%	5	Jagiellonian University	Poland	6	17.1%
8	Spain	6	17.1%	5	University of Barcelona	Spain	6	17.1%
8	Switzerland	6	17.1%					
8	Belgium	6	17.1%					

In terms of the citing papers, the USA produced the most with 255, followed by Italy, the Netherlands, the UK and Germany. Additionally, it is worth mentioning that China ranks 9th with 58 papers. Among all institutions producing citing papers, Erasmus University Rotterdam (140 papers) and Imperial College London (128 papers) are the top 2, far ahead of the others.

Table 22: Top countries and institutions producing citing papers in the research front "Outcomes of drug-eluting bioresorbable scaffolds in patients with Coronary Artery Diseases"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	255	8.5%	1	Erasmus University Rotterdam	Netherlands	140	4.7%
2	Italy	195	6.5%	2	Imperial College London	UK	128	4.3%
3	Netherlands	179	6.0%	3	University of Amsterdam	Netherlands	54	1.8%
4	UK	160	5.3%	4	Vita-Salute San Raffaele University	Italy	52	1.7%

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
5	Germany	137	4.6%	5	Abbott Vascular	USA	48	1.6%
6	Switzerland	77	2.6%	6	Columbia University	USA	45	1.5%
7	Spain	72	2.4%	7	Cardiovascular Research Foundation	USA	40	1.3%
8	Japan	64	2.1%	7	EMO-GVM Centro Cuore Columbus	Italy	40	1.3%
9	China	58	1.9%	9	German Heart Center Munich	Germany	39	1.3%
10	France	51	1.7%	10	University of Bern	Switzerland	38	1.3%

2. EMERGING RESEARCH FRONT

2.1 SUMMARY OF EMERGING RESEARCH FRONTS IN CLINICAL MEDICINE

The Top 11 emerging Research Fronts in clinical medicine mainly focus on tumor targeted therapy, immunotherapy, prevention and control of infectious diseases, early identification and intervention of critical illness, and breakthrough therapy drugs. Among these, Tocilizumab for giant cell arteritis, and Venetoclax for relapsed or refractory chronic lymphocytic leukemia with 17p deletion, represent new breakthroughs in targeted therapy.

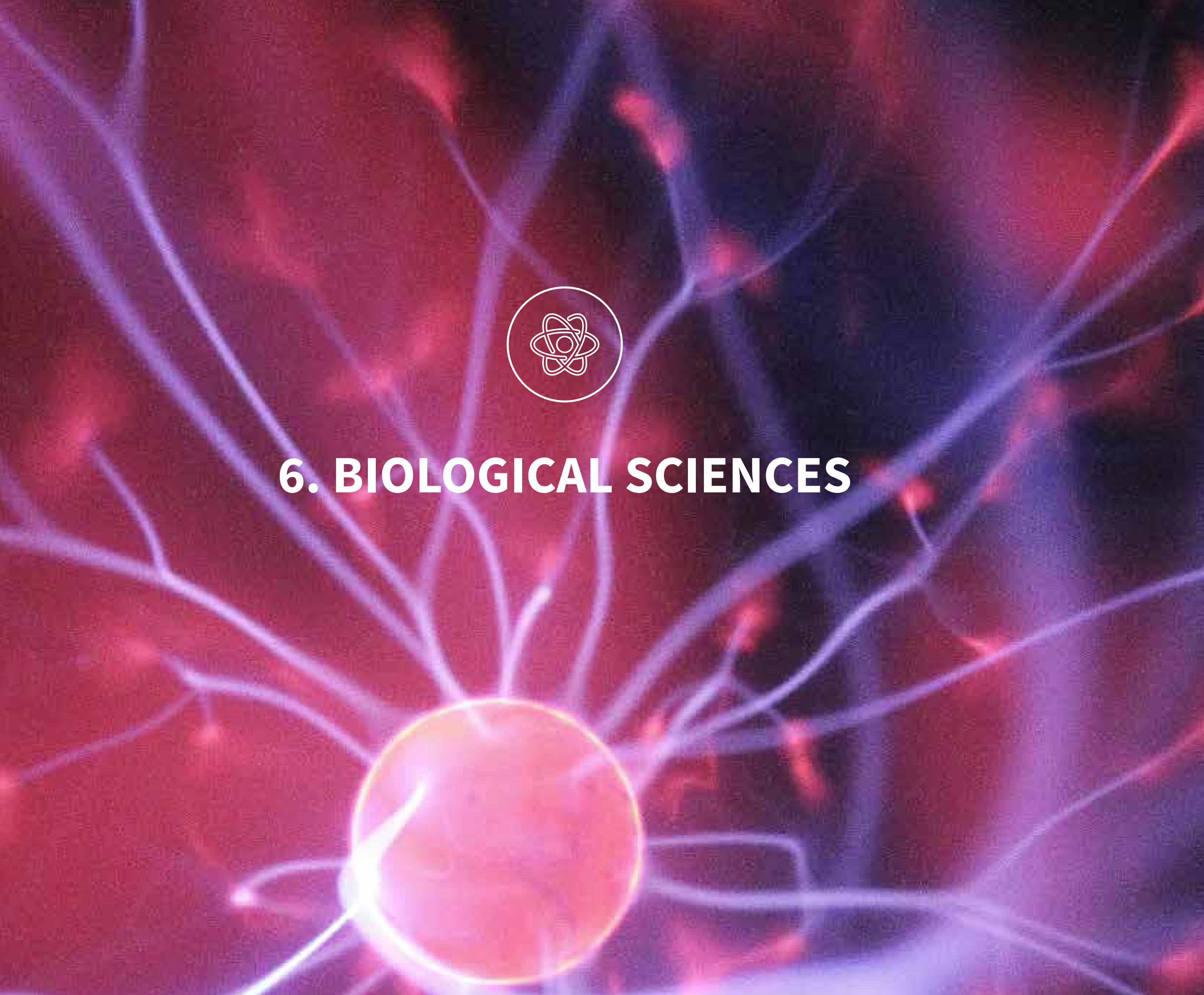
Table 23: Emerging Research Fronts in clinical medicine

Rank	Emerging Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Novel Synthetic Opioids Epidemic	10	111	2016.9
2	Venetoclax in relapsed or refractory Chronic Lymphocytic Leukaemia	4	155	2016.8
3	Effect of FOLFIRI chemotherapy combined with Cetuximab Or Bevacizumab in patients with KRAS Wild-Type Metastatic Colorectal Cancer	4	93	2016.8
4	Long Noncoding RNAs as biomarkers in human cancer progression and prognosis	7	140	2016.7
5	Rotavirus mortality estimation and efficacy of Rotavirus Vaccine	3	111	2016.7
6	Clinical scales to identify Acute Ischemic Stroke patients with Large Artery Occlusion	6	95	2016.7
7	Clinical trials of PD-1/PD-L1 Inhibitors for cancer patients	7	245	2016.6
8	Immune inhibitors for Atopic Dermatitis	7	206	2016.6
9	Effect of Early Goal-Directed Therapy (EGDT) On prognosis of Septic Shock	8	142	2016.6
10	Tocilizumab in Giant Cell Arteritis	5	113	2016.6
11	Airborne transmission of Mycobacterium Chimaera from Heater-Cooler Devices in cardiac surgery	5	99	2016.6

2.2 KEY EMERGING RESARCH FRONT – "Venetoclax in relapsed or refractory Chronic Lymphocytic Leukemia"

Chronic lymphocytic leukemia (CLL) is the most common type of leukemia in adults, accounting for nearly 30% of all leukemia. The 17p deletion mutation (del 17p) occurs in 10% of untreated CLL patients and 50% of relapsed patients. Prognosis for del 17p patients is usually very poor after standard chemotherapy, with a median survival time only 2 to 3 years. Drugs of B-cell antigen receptor (BCR) signaling pathway inhibitors have greatly promoted the treatment of CLL, as we noted in the 2015 Research Font report. B-cell lymphoma 2 (Bcl-2) signaling pathway, which plays a vitally important role in CLL cell apoptosis, has become the focus in relapsed or refractory chronic lymphocytic leukemia with 17p deletion study recently.

There are four core papers in this emerging Research Front "Venetoclax in relapsed or refractory Chronic Lymphocytic Leukemia.". Among these, a multicenter phase II study published in Lancet Oncology in May 2016 rolled in 107 adults with relapsed or refractory CLL with 17p deletion. During an average of 12.1 months of Venetoclax monotherapy period, the total response rate reached 79.4%. This result has had a positive impact on the FDA approval of Venclexta (venetoclax) monotherapy for patients with del 17p CLL who have previously been treated at least once. Venclexta is the first FDA-approved BCL-2 inhibitor and the first protein-protein interaction (PPI) small molecule drug.



6. BIOLOGICAL SCIENCES

1. HOT RESEARCH FRONT

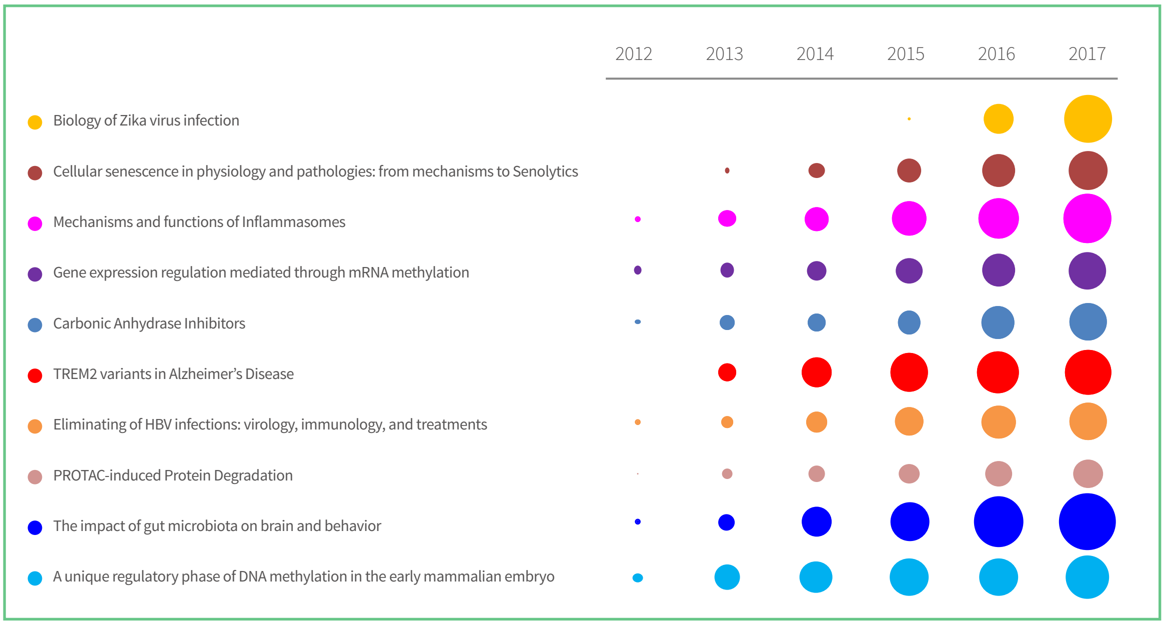
1.1 TREND OF THE TOP 10 RESEARCH FRONTS IN BIOLOGICAL SCIENCES

The Top 10 Research Fronts in biological sciences focus on mRNA methylation, the regulation of gene expression mediated by DNA methylation, biological research on viral infection, molecular mechanisms of cell senescence, the influence of intestinal microbes on brain and behavior, and the mechanism of immune response and disease occurrence. Among them, "Gene expression regulation mediated through mRNA methylation" is the continuation of the Research Front on mRNA methylation in 2017. Also last year, research on the Zika virus was selected as an Emerging front. This year, "Biology of Zika virus infection" has become a hot Research Front, and "ZIKA virus Protease inhibitor" has also become one of the emerging Research Fronts. In recent years, scientists have made important breakthroughs in the key drug targets of the Zika virus and laid an important foundation for the development of specific drugs for treatment.

Table 24: Top 10 Research Fronts in biological sciences

Rank	Hot Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Biology of Zika virus infection	38	2409	2016.4
2	Cellular senescence in physiology and pathologies: from mechanisms to Senolytics	22	2126	2015.5
3	Mechanisms and functions of Inflammasomes	45	4282	2015.4
4	Gene expression regulation mediated through mRNA methylation	42	4811	2015.3
5	Carbonic Anhydrase Inhibitors	47	2918	2015.3
6	TREM2 variants in Alzheimer's Disease	32	4087	2015.2
7	Eliminating of HBV infections: virology, immunology, and treatments	33	2545	2015.2
8	PROTAC-induced Protein Degradation	17	1502	2015.2
9	The impact of gut microbiota on brain and behavior	48	5275	2015.1
10	A unique regulatory phase of DNA methylation in the early mammalian embryo	28	3671	2015.1

Figure 5: Citing papers for the Top 10 Research Fronts in biological sciences



1.2 KEY HOT RESEARCH FRONT – "TREM2 variants in Alzheimer's Disease"

Alzheimer's disease (AD) is a complex condition which afflicts about 47 million people around the world. One of the main clinical symptoms of AD is the progressive decline of memory and cognition. At present, there is no cure for this disease. The triggering Receptor Expressed on Myeloid cells 2 (TREM2) is a cell surface receptor among the immunoglobulin superfamily, which is expressed on the microglia of the central nervous system.

The core papers in this hot Research Front record the breakthrough genetic research on AD since 2013, revealing that the mutation of TREM2 is highly correlated with the increase of AD. They also show that TREM2 is a common risk gene for many neurodegenerative diseases. The mutation in coding region R47H increases by nearly three times the risk of AD and also increases the risk of frontotemporal dementia, amyotrophic lateral sclerosis and Parkinson's disease.

The core papers in this hot Research Front also record how TREM2 participates in and affects AD's pathological process. The latest research reveals the specific details of TREM2's function. In the mouse model, TREM2 can reduce the pathology of AD and alleviate the cognitive deficit. This suggests that removing amyloid protein can be used as a new strategy for the treatment of AD. It can be achieved by increasing the expression of TREM2 or activating the TREM2 signaling pathway. This research strongly supports that TREM2 can serve as a therapeutic target for AD in the future. Therefore, this may be of great significance for the future treatment of AD and other neurodegenerative diseases.

According to analysis of this front's 32 core papers, the USA participated in 93.8% of the foundational reports, far ahead of other countries. The UK, Italy, Israel, Canada, and China also contributed to this Research Front by participating in several core papers. In terms of institutions, the University of Washington ranks 1st with 13 core papers, accounting for 40.6%, followed by the Mayo Clinic (6 core papers) and University College London and Harvard University (5 papers each).

Table 25: Top countries and institutions producing the 32 core papers in the Research Front "TREM2 variants in Alzheimer's Disease"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	USA	30	93.8%	1	Washington University	USA	13	40.6%
2	UK	6	18.8%	2	Mayo Clinic	USA	6	18.8%
3	Italy	5	15.6%	3	University College London	UK	5	15.6%
4	Israel	4	12.5%	3	Harvard University	USA	5	15.6%
4	Canada	4	12.5%	5	Weizmann Institute of Science	Israel	4	12.5%
6	Turkey	3	9.4%	5	University of Cambridge	UK	4	12.5%
6	Spain	3	9.4%	5	National Institutes of Health (NIH)	USA	4	12.5%
6	China	3	9.4%	5	Eli Lilly and Company	USA	4	12.5%
6	Germany	3	9.4%					

Analysis of citing papers demonstrates that the USA is again the most productive country, with 1,068 citing papers, accounting for 26.1% of the total. The UK contributed 345 citing papers and ranked 2rd, accounting for 8.4%. China and Germany had, respectively, 258 and 255 citing papers, ranking 3rd and 4th. The Top 10 countries in terms of citing papers also include Canada, France, Sweden, the Netherlands, Italy and Australia. The top 10 most prolific institutions in citing papers are based in the USA, the UK, Germany and France. Six of the top 10 citing institutions are in the USA, including Harvard University, the University of Washington, the Mayo Clinic, Columbia University, the University of Calif, San Francisco, and the University of Washington, Seattle. University College London in the UK, the Helmholtz Union in Germany, the German Cancer Research Center, and INSERM have also made important contributions to this Research Front.

Table 26: Top countries and institutions producing citing papers in the Research Front "TREM2 variants in Alzheimer's Disease"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	1068	26.1%	1	Harvard University	USA	184	4.5%
2	UK	345	8.4%	2	University College London	UK	129	3.2%
3	China	258	6.3%	3	Washington University in St. Louis	USA	122	3.0%
4	Germany	255	6.2%	4	Helmholtz Association	Germany	107	2.6%
5	Canada	131	3.2%	5	Institut National de la Sante et de la Recherche Medicale (INSERM)	France	97	2.4%
6	France	128	3.1%	5	Mayo Clinic	USA	97	2.4%
7	Sweden	118	2.9%	7	Deutsches Forschungszentrum Neurodegen Erkrankungen	Germany	86	2.1%
8	Netherlands	116	2.8%	8	Columbia University	USA	81	2.0%
9	Italy	115	2.8%	8	University of California San Francisco	USA	81	2.0%
10	Australia	106	2.6%	8	University of Washington Seattle	USA	81	2.0%

1.3 KEY HOT RESARCH FRONT – "The impact of gut microbiota on brain and behavior"

A large number of species of gut microbiota colonize the intestinal tract, forming a beneficial symbiotic relationship with their hosts. Much research has shown that intestinal microbes play important roles in the health of the body. The relationship between gut microbiota and human health has been a hot area in recent years. In 2013, it was rated as one of the 10 major scientific advances by the journal Science. The influence of gut microbiota on brain and behavior has become a new hot Research Front.

The papers making up the core of the hot Research

Front "The impact of gut microbiota on brain and behavior" have shown that normal gut microbes can affect the development and function of early brain as important environmental factors. At the other extreme of life, a healthy aging process is associated with a decrease in flora diversity. This research also showed that gut microbiota have an important impact on a host's stress response, anxiety, depression and cognitive function through the gut-brain axis, and that some mental disorders such as anxiety, depression, autism, schizophrenia and neurodegenerative diseases are closely related to intestinal microbes. Imbalance of gut microbiota may lead to gut-brain diseases (such as irritable bowel syndrome, inflammatory bowel disease and hepatic encephalopathy) and central nervous system diseases (such as Alzheimer's disease, Parkinson's disease, autism, depression, etc.).

Most of the current research focuses on various phenomena, such as the discovery that changes in gut microbiota can trigger the changes in brain function, or that some diseases can cause the changes in gut microbiota. However, questions on how best to analyze the essentials of gut microbiota, and the mechanism by which they contribute to various diseases, still await definitive answers. Many countries have placed a priority on this area of investigation, and research between gut microbiota and brain science is expected to become a very important emerging field.

Forty-eight core papers form the foundation of this hot Research Front. Ireland and the USA are the main contributing countries of these core papers, participating in 17 and 13 core papers respectively, accounting for 35.4% and 27.1% of the total core papers. The UK, the Netherlands, Canada, China and Switzerland contributed only to 3 to 5 papers. Institutions in Ireland showed outstanding performance among the core papers. University College of Cork, for example, contributed 17 core papers, while the Irish Ministry of Agriculture and Food Development (TEAGASC) contributed 7. McMaster University in Canada and Baylor College of Medicine in the USA also registered among prolific institutions in this front.

Table 27: Top countries and institutions producing the 48 core papers in the Research Front "The impact of the gut microbiota on brain and behavior"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	Ireland	17	35.4%	1	University College of Cork	Ireland	17	35.4%
2	USA	13	27.1%	2	TEAGASC	Ireland	7	14.6%
3	UK	5	10.4%	3	McMaster University	Canada	4	8.3%
4	Netherlands	4	8.3%	4	Baylor College of Medicine	USA	3	6.3%
4	Canada	4	8.3%					
6	China	3	6.3%					
6	Switzerland	3	6.3%					

Among the 10 countries involved in publishing reports that cite this Research Front's core papers, the USA is most active, contributing to 1,010 citing papers. Researchers from China and the UK, meanwhile, contribute respectively to 239 and 216 citing papers. Canada, Italy and Ireland also have many contributions.

In terms of institutions, the University College of Cork from Ireland ranks 1st with 158 citing papers. The USA holds 6 places in the Top10 institutions. Among them, Harvard University ranks 2nd among the Top 10 institutions by contributing to 110 citing papers.

Table 28: Top countries and institutions producing citing papers in the Research Front "The impact of the gut microbiota on brain and behavior"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	1010	19.1%	1	University College of Cork	Ireland	158	3.0%
2	China	239	4.5%	2	Harvard University	USA	110	2.1%
3	UK	216	4.1%	3	McMaster University	Canada	60	1.1%
4	Canada	188	3.6%	4	TEAGASC	Ireland	50	0.9%
5	Italy	171	3.2%	5	National Institutes of Health (NIH)	USA	47	0.9%
6	Ireland	170	3.2%	6	Massachusetts Institute of Technology (MIT)	USA	44	0.8%
7	Germany	146	2.8%	7	Institut National de la Sante et de la Recherche Medicale (INSERM)	France	42	0.8%
8	Australia	135	2.6%	8	CNRS	France	41	0.8%
9	France	129	2.4%	8	Cornell University	USA	41	0.8%
10	Netherlands	119	2.3%	8	University of California San Diego	USA	41	0.8%

2. EMERGING RESEARCH FRONT

2.1 SUMMARY OF EMERGING RESEARCH FRONTS IN BIOLOGICAL SCIENCES

Ten emerging Research Fronts have been selected in the biological sciences. The main research topics include circular RNAs, non-coding RNA, DNA replication, tumor occurrence and migration, Zika virus, and Alzheimer's disease. Among these fronts, "Using circular RNA as a new biomarker in the diagnosis of cancer" is the continuation of "Origin, identification and function of circular RNAs" in 2017. Non-coding RNA and Zika virus were also selected as Research Fronts for two consecutive years. The topic of AD pathogenic genes was also a hot Research Front in 2016. Two Research Fronts related to AD were selected this year. "The biomarker-based diagnosis of Alzheimer's disease" is an emerging Research Front, and "TREM2 gene mutation and Alzheimer's disease" becomes a hot Research Front.

Tumor-related research has also been selected among the top Research Fronts for several years. This year, the corresponding Research Fronts focus on the occurrence and migration of tumors, including three emerging Research Fronts: "Nuclear envelope rupture and repair during cancer cell migration," "Relationship between cellular reactive oxygen species (ROS) and tumorigenesis and intervention," and "Polycomb Repressive Complex and the Cancer Epigenome." This research provides new understanding of the process of tumorigenesis and migration, and offers new ideas for combatting malignant cells.

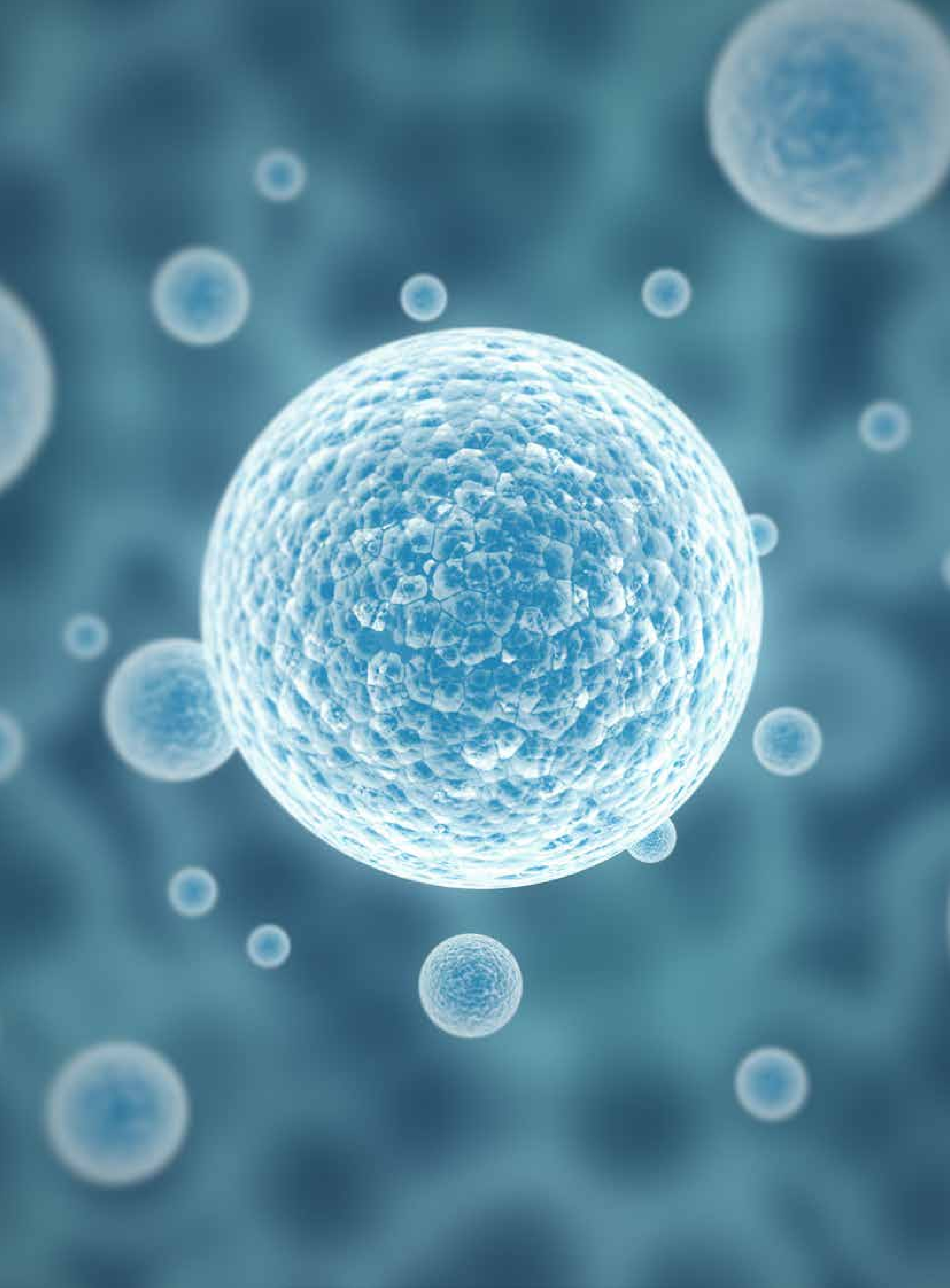
Table 29: Emerging Research Fronts in biological sciences

Rank	Emerging Research Fronts	Core papers	Citations	Mean Year of Core Papers
1	Using circular RNA as a new biomarker in the diagnosis of cancer	13	210	2017
2	The biomarker-based diagnosis of Alzheimer's disease	8	81	2017
3	ZIKA virus Protease inhibitor	16	364	2016.8
4	Polycomb Repressive Complex and the Cancer Epigenome	6	93	2016.8
5	Autoimmunity against a defective ribosomal insulin gene product in type 1 diabetes	4	89	2016.8
6	Relationship between cellular reactive oxygen species (ROS) and tumorigenesis and intervention	3	107	2016.7
7	Physiological Properties and Behavioral Correlates of Hippocampal Granule Cells and Mossy Cells	3	58	2016.7
8	Mechanisms for CMG helicase initiating cellular DNA replication	14	355	2016.6
9	Nuclear envelope rupture and repair during cancer cell migration	5	243	2016.6
10	Recognition patterns of noncoding RNA	5	153	2016.6

2.2 KEY EMERGING RESRACH FRONT – "Nuclear envelope rupture and repair during cancer cell migration"

Among the five core papers in this emerging Research Front, two important reports were published in Science in 2016. Researchers found that when a cell passes through a narrow gap, it not only destroys the cell membrane but also damages the cellular DNA. But cells can repair the broken DNA themselves. A molecule called ESCRT III complex seals the cleft in the nuclear envelope. Scientists believe that such nuclear-envelope rupture and DNA damage may exist widely in the human body. Repairing DNA damage and repairing the rupture of the nuclear envelope plays a vital role in the survival of compressed cells, which not only helps immune cells to survive but also enables cancer cells to benefit. Cancer cells that migrate to new sites in the body and begin to grow are the cause of death in most cancer patients.

The findings suggest that drugs that inhibit the repair of DNA damage and repair the nuclear envelope rupture may prevent cancer cells from metastases – an insight that might eventually allow researchers to design drugs to prevent cancer cells from migrating to new sites.



7. CHEMISTRY AND MATERIALS SCIENCE

1. HOT RESEARCH FRONT

1.1 TREND OF THE TOP 10 RESEARCH FRONTS IN CHEMISTRY AND MATERIALS SCIENCE

The hot Research Fronts in chemistry and materials science cover the topics of organic synthesis, batteries, nanotechnology, green chemistry, ultrafast science and radical polymerization. Compared with the previous years, both consistency and new development are highlighted in the 2018 Top10 hot Research Fronts. In the topic of organic synthesis, "*Meta*-selective C-H activation" has been a hot trend for two consecutive years, while "Merging photoredox and nickel catalysis" is an area of new focus in the field of photoredox catalysis. Perovskite solar cells have always been a hot topic in batteries, while "Lead-free perovskite solar cells" and "Perovskite/silicon tandem solar cells" become new points of focus. "Dendrite free lithium metal anodes" was an emerging Research Front in 2015 and now becomes a hot Research Front this year. The topic of nanotechnology accounts for three directions: optoelectronic materials, two-dimensional material, and nanocomposites. In the topic of green chemistry, deep eutectic solvents have become a hot Research Front this year. In the area of ultrafast science, serial femtosecond crystallography is highlighted as one of the Top 10 hot Research Fronts. In the topic of radical polymerization, "Photoinduced living radical polymerization" has been chosen among the Top 10 hot Research Fronts for the second time.

Table 30: Top10 Research Fronts in chemistry and materials science

Rank	Hot Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Dendrite free lithium metal anodes	34	2941	2015.9
2	*Meta*-selective C-H activation	34	2599	2015.5
3	Photoinduced living radical polymerization	34	3037	2015.3
4	Merging photoredox and nickel catalysis	23	2350	2015.2
5	All-inorganic perovskite nanocrystals optoelectronic materials	18	3951	2015.1
6	Perovskite solar cells	25	3361	2015.1
7	Borophene	19	1831	2015.1
8	High permittivity polymer nanocomposites	16	1959	2015
9	Protein structure determination by serial femtosecond crystallography	19	2190	2014.6
10	Deep eutectic solvents and their applications	18	2990	2014.2

Figure 6: Citing papers of the Top 10 Research Fronts in chemistry and materials science

1.2 KEY HOT RESEARCH FRONT – "*Meta*-selective C-H activation"

Achieving site selectivity in C–H functionalization reactions is a long-standing challenge in organic chemistry. While numerous *ortho*-selective arene functionalization methods have been extensively developed, *meta*-selective functionalization of electronically unbiased arenes remains a significant challenge. Recently, a number of elegant approaches have been developed, and "*meta*-selective C-H activation" has been selected among the Top10 Research Fronts in chemistry and materials science for two consecutive years.

In 2012, Jinquan Yu from the Scripps Research Institute developed an end-on-coordinating, nitrile-based template that is able to direct Pd(II)-catalysed *meta*-selective olefination of tethered arene substrates. In March 2015, Yu's group developed another approach to achieve *meta*-C−H functionalization by relaying the initial *ortho*-cyclopalladation to the *meta*-position using norbornene as mediator. One month later, Guangbin Dong from the University of Texas at Austin reported a related *meta*-selective arene arylation enabled by $AsPh_3$ ligand. In addition, Lutz Ackermann from the University of Gottingen and Christopher G. Frost from the University of Bath separately reported ruthenium(II)-catalyzed -selective C−H functionalization via σ-activation. Igor Larrosa from Queen Mary University of London reported one-pot direct *meta*-selective arylation of phenols using a traceless directing group relay strategy. Motomu Kanai of the University of Tokyo reported a *meta*-selective C–H borylation directed by the hydrogen bonding between the substrates and the catalyst.

In terms of contributing countries and institutions (Table 31), the USA, Germany, and India are active nations in producing the core papers. Researchers from the Scripps Research Institute, the University of Gottingen, and the Indian Institute of Technology have made notable progress in the field. Inspired by Yu's report, Debabrata Maiti of the Indian Institute of Technology developed a sulphonyl-tethered *meta*-directing group using the nitrile-containing template. Collaborating with Yu, Weiyin Sun of Nanjing University reported the first example of using a U-shaped nitrile template to direct Rh(III)-catalyzed remote *meta*-C−H activation.

Table 31: Top countries and institutions producing the 34 core papers in the Research Front "*Meta*-selective C-H activation"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	USA	12	35.3%	1	Scripps Research Institute	USA	10	29.4%
2	Germany	6	17.6%	2	University of Gottingen	Germany	6	17.6%
2	India	6	17.6%	3	Indian Institute of Technology (IIT)	India	5	14.7%
2	China	6	17.6%	4	University of Tokyo	Japan	2	5.9%
5	UK	3	8.8%	4	Chinese Academy of Sciences	China	2	5.9%
6	Japan	2	5.9%					

According to a count of the citing papers (Table 32), the USA, India, Germany, Japan, and the UK are closely involved in this field of research, while China is the most productive country. On the list of contributing organizations, the Scripps Research Institute, the Indian Institute of Technology, and the University of Gottingen show continuous interest. In addition, the Chinese Academy of Sciences, Zhejiang University, and Peking University make the list.

Table 32: Top countries and institutions producing citing papers in the Research Front "*Meta*-selective C-H activation"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	China	409	42.6%	1	Chinese Academy of Sciences	China	80	8.3%
2	USA	172	17.9%	2	Scripps Research Institute	USA	55	5.7%
3	India	117	12.2%	3	Indian Institute of Technology (IIT)	India	51	5.3%
4	Germany	70	7.3%	4	University of Gottingen	Germany	32	3.3%
5	Japan	58	6.0%	5	Zhejiang University	China	22	2.3%
6	UK	57	5.9%	6	Peking University	China	21	2.2%
7	Spain	26	2.7%	6	University of Science & Technology - China	China	21	2.2%
8	Canada	17	1.8%	8	IISER	India	20	2.1%
9	Italy	16	1.7%	9	CSIR India	India	19	2.0%
10	France	15	1.6%	9	Sichuan University	China	19	2.0%

1.3 KEY HOT RESEARCH FRONT – "Deep eutectic solvents and their applications"

The term "Deep Eutectic Solvent (DES)" was first coined in 2003 by Andrew P. Abbott, who harnessed the concept of mixing two solid organic materials to yield a fluid with a melting point far below that of either individual component. Generally, DESs are prepared by mixing a quaternary ammonium halide salt with metal salts or a hydrogen bond donor that has the ability to form a complex with the halide anion to achieve a significant depression of the freezing point. The most common DESs are mixtures of choline chloride with urea, ethylene glycol, or glycerol, generally in a 1:2 molar ratio. While DESs have some physical properties similar to traditional ionic liquids, they have many advantages, such as their ease of preparation and easy availability from relatively inexpensive components.

Physical properties, such as density, viscosity, conductivity, and surface tension have been characterized for a variety of DESs, while their toxicity and cytotoxicity are still being investigated. DESs have been applied to a wide-ranging area of research topics such as metal electrodeposition, metal electropolishing, metal extraction, organic synthesis, nanotechnology, biotransformation, catalysis, and gas separation.

Europe is the most active region in this area, as the EU has funded a number of projects in the scale-up and commercialization of DES-based processes. Researchers from the University of Leicester and Leiden University have made highlighted progress in this Research Front.

According to a count of the citing papers (Table33), China is the most productive country, followed by India, Spain and the USA. On the list of contributing organizations, the University of Malayaranks ranks 1st, while the Chinese Academy of Sciences occupies 3rd place.

Table 33: Top countries and institutions producing citing papers in the Research Front "Deep eutectic solvents and their applications"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	China	355	28.4%	1	University of Malaya	Malaysia	55	4.4%
2	India	105	8.4%	2	Sultan Qaboos University	Oman	51	4.1%

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
3	Spain	95	7.6%	3	Chinese Academy of Sciences	China	39	3.1%
4	USA	92	7.3%	4	Inha University	South Korea	33	2.6%
5	Iran	87	6.9%	5	Centre National De La Recherche Scientifique (CNRS)	France	30	2.4%
6	Malaysia	79	6.3%	5	Consejo Superior De Investigaciones Cientificas (CSIC)	Spain	30	2.4%
7	UK	74	5.9%	7	Khalifa University	United Arab Emirates	26	2.1%
8	Germany	70	5.6%	8	Indian Institute of Technology (IIT)	India	25	2.0%
9	Portugal	60	4.8%	9	South China University of Technology	China	24	1.9%
10	Oman	55	4.4%	10	Chemistry & Chemical Engineering Research Center of Iran	Iran	23	1.8%

2. EMERGING RESEARCH FRONT

2.1 SUMMARY OF EMERGING RESEARCH FRONTS IN CHEMISTRY AND MATERIALS SCIENCE

This year, eight research topics are selected as emerging Research Fronts in chemistry and materials science, mainly related to the preparation and application of catalysts, the synthesis of organic compounds, and the performance optimization and/or preparation of materials. Compared with the emerging Research Fronts of 2014 to 2017, there are more new research directions in 2018, half of which are related to catalysts. Catalyst research has always been the hot research trend in chemistry and material science, and this year's research on catalysts mainly focuses on four directions: electrocatalysts and photocatalysts for water splitting separately, dehydrogenation/hydrogenation catalysts and semiconductor photocatalysts. Electrocatalysts for water splitting was the emerging Research Front in 2017, mainly involving non-precious metal dual-function electrocatalysts. This year, its research direction turned to transition metal (non-precious metal) nano-array electrocatalysts for water splitting in the neutral environment. Photocatalysts for water splitting is a new emerging Research Front, and the research mainly covers the preparation and characterization of photocatalysts composed of graphite-phase carbon nitride and non-precious metal (cobalt nickel) compounds. The dehydrogenation/hydrogenation catalyst research mainly focuses on the preparation of transition metal (manganese) pincer complexes and its application in dehydrogenation/hydrogenation reactions. Semiconductor photocatalysts mainly involve the catalytic mechanism and applications of bismuth oxyhalides. In the area of organic compounds synthesis, the preparation/application of porphyrin heterocyclic compounds and the synthesis of sulfonyl compounds are newly appeared emerging Research Fronts. The former chiefly involves the synthesis/reactions of porphyrin macrocyclic compounds and corrole derivatives, while the latter mainly focuses on the preparation and applications of sulfonyl compounds. In the area of performance optimization and/or preparation of materials, polymers modified by carbon nanomaterials (carbon nanotubes and graphene) and stretchable materials and devices are the main interest.

Table 34: Emerging Research Fronts in chemistry and materials science

Rank	Emerging Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Transitional metal electrocatalysts for Water Splitting under near-neutral conditions	13	219	2017
2	The chemistry of Porphyrins and its applications	8	147	2017
3	Stretchable materials and device	4	128	2016.8
4	Manganese pincer complexes in hydrogenations/ dehydrogenation	20	607	2016.7
5	g-C3N4 and noble-metal-free photocatalysts for water splitting	7	193	2016.7
6	Organosulphur compounds	13	330	2016.6
7	Carbon nanomaterial modified polymer	7	235	2016.6
8	Bismuth Oxyhalides photocatalyst	5	124	2016.6

2.2 KEY EMERGING RESEARCH FRONT – "Stretchable materials and devices"

Stretchable materials and devices can seamlessly connect with complex curved surfaces, which significantly extends the capabilities of traditional rigid electronics in sensing, monitoring, as well as diagnostics; this capability plays an important role in some emerging fields, such as field-effect transistors, sensors, optoelectronic components (stretchable electrodes), nanogenerators, supercapacitors and heaters, wearable electronics, flexible energy devices and bio-inspired devices. Two strategies can be employed to make a device stretchable: 1) material innovation, which is realized by synthesizing intrinsically stretchable or integrating stretchable materials; 2) structural design, achieved by making the non-stretchable material stretchable with some special mechanical structure that can absorb the stress strain applied to the device through the material structure deformation. This emerging Research Front reflects the former strategy. The typical approach is to apply materials and nanostructures with varieties of properties on natural stretchable polymer substrates, and further combine with new materials and processing techniques to prepare components and devices with capable performance. A major challenge in this area comes from obtaining conductors with excellent tensile properties and stable electrical properties simultaneously, while the current mainstream technology relies primarily on sacrificing charge transport mobility to achieve better stretchability.

Three of the four core papers in this emerging Research Front are published by Professor Zhenan Bao from Stanford University in the USA, and lots of her team's work are cutting-edge and pioneering. For example, in 2016, abandoning the mainstream strategy (blending of nanofibers or nanowires into elastomers) for preparing flexible semiconductors, they presented a design concept for stretchable semiconducting polymers which introduced chemical moieties to promote dynamic non-covalent crosslinking of the conjugated polymers. These non-covalent crosslinking moieties are able to undergo an energy dissipation mechanism through breakage of bonds when strain is applied, while retaining high charge-transport abilities. The related research paper "Intrinsically stretchable and healable semiconducting polymer for organic transistors" has gained the highest citation total (124). In 2017, the team explored a concept based on the nanoconfinement of polymers to substantially improve the stretchability of polymeric semiconductors without affecting charge transport mobility. The related article, "Highly stretchable polymer semiconductor films through the nanoconfinement effect," has been cited 95 times. Recently, the team successfully developed a high-density, high-sensitivity, stretchable transistor array that, for the first time, can be mass-produced with the orderly assembly of metal nanowires. Hefei University of Technology in China has recently developed an elastic conductor material that combines the advantages of self-healing, high electrical conductivity, and excellent tensile and electromechanical stability.

8. PHYSICS

1. HOT RESEARCH FRONT

1.1 TREND OF THE TOP 10 RESEARCH FRONTS IN PHYSICS

The Top 10 Research Fronts in physics mainly focus on the subfields of high-energy physics, condensed matter physics, theoretical physics, and optics. In high-energy physics, the rare decays in B mesons, neutrino oscillation, and tetraquark and pentaquark states are still hot fronts this year. In condensed matter physics, the hot topics center on Weyl semimetals, spin-orbit-induced Mott insulators. In theoretical physics, many-body localized systems and application of holographic principles remain hot topics, while quantum thermodynamics and non-equilibrium dynamics of quantum many-body systems emerge as hot topics. In optics, dual-comb spectroscopy has attracted much attention.

Table 35: Top 10 Research Fronts in physics

Rank	Hot Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Studies of rare decays in B mesons	37	2536	2015.3
2	Holographic theory and its application in condensed matter physics	31	2145	2015.1
3	Studies of quantum thermodynamics and quantum information theory	49	4421	2014.9
4	Non-equilibrium dynamics of quantum many-body systems	36	3357	2014.8
5	Studies of dual-comb spectroscopy	36	2810	2014.8
6	Spin-orbit-induced Mott insulators	24	1948	2014.8
7	Studies of Weyl semimetal	38	9937	2014.7
8	Neutrino oscillation and the search for light sterile neutrinos	40	6773	2014.7
9	Many-body localized systems	36	4439	2014.7
10	Tetraquark and pentaquark states	27	2563	2014.6

Figure 7: Citing papers of the Top 10 Research Fronts in physics

1.2 KEY HOT RESEARCH FRONT – "Studies of Weyl Semimetals"

Weyl semimetals represent a new type of topological quantum state. In recent years they have attracted great interest for their special energy band structures, surface states, and transport properties. In July 2015, the first experimental discovery of a Weyl semimetal, tantalum arsenide (TaAs), was respectively reported by researchers from Princeton University and the Institute of Physics, Chinese Academy of Sciences. These two articles are core papers in this hot Research Front and have received the most citations, which are 897 and 750, respectively. The Weyl semimetal materials which obey Lorentz invariance, such as the TaAs family, are called type-I Weyl semimetals. In November 2015, a new Weyl semimetal material, WTe_2, was predicted by researchers from the Swiss Federal Institute of Technology in Zurich (ETH Zurich). The new material, dubbed type-II Weyl semimetal, has different physical properties from the TaAs family due to the violation of Lorentz's invariance. The relevant core paper in this hot Research Front received 453 citations.

The USA and China are the most active countries in the front, respectively participating in 25 and 24 core papers (Table 36), which are 65.8% and 63.2% of the total. Singapore, Switzerland, Taiwan Province of China, and the UK also demonstrate excellent performance. Princeton University and the Chinese Academy of Sciences contribute the highest numbers of core papers as individual organizations. In terms of core paper contribution, three of the top institutions are located in the USA, while China and Taiwan Province both are host to two. Singapore, Switzerland and the UK each have one.

Table 36: Top countries/regions and institutions producing the 38 core papers in the Research Front "Studies of Weyl Semimetals"

Country Ranking	Country/ Region	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country/ Region	Core Papers	Proportion
1	USA	25	65.8%	1	Princeton University	USA	15	39.5%
2	China	24	63.2%	2	Chinese Academy of Sciences	China	12	31.6%
3	Singapore	8	21.1%	3	United States Department of Energy (DOE)	USA	10	26.3%
4	Switzerland	7	18.4%	4	National University of Singapore	Singapore	8	21.1%
4	Taiwan, China	7	18.4%	5	Peking University	China	7	18.4%
6	UK	6	15.8%	6	Natl Tsing Hua Univ	Taiwan, China	6	15.8%
7	Germany	5	13.2%	6	Academia Sinica - Taiwan	Taiwan, China	6	15.8%
8	Japan	2	5.3%	6	Northeastern University	USA	6	15.8%
8	France	2	5.3%	6	ETH Zurich	Switzerland	6	15.8%
10	South Korea	1	2.6%	10	University of Oxford	UK	5	13.2%
10	Netherlands	1	2.6%					
10	Russia	1	2.6%					

In analyzing the citing papers (Table 37), we find that many of them are from researchers based in the USA or China, which account for 38.3% and 37.7% of the total citing papers – both far more than the shares of other countries. Germany, Japan and Russia rank 3rd to 5th. Among the top institutions, the Chinese Academy of Sciences and the Max Planck Society published the most citing papers, which account for 12.8% and 10.2% of the total citing papers. Princeton University, Nanjing University and Peking University follow.

Table 37: Top countries/regions and institutions producing citing papers in the Research Front "Studies of Weyl Semimetal"

Country Ranking	Country/ Region	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	683	38.3%	1	Chinese Academy of Sciences	China	228	12.8%
2	China	672	37.7%	2	United States Department of Energy (DOE)	USA	182	10.2%
3	Germany	248	13.9%	3	Max Planck Society	Germany	127	7.1%
4	Japan	217	12.2%	4	Princeton University	USA	111	6.2%
5	Russia	107	6.0%	5	Nanjing University	China	102	5.7%
6	Singapore	106	5.9%	6	Peking University	China	83	4.7%
7	Canada	91	5.1%	7	Russian Academy of Sciences	Russia	69	3.9%
8	Taiwan, China	85	4.8%	8	National University of Singapore	Singapore	67	3.8%
9	Switzerland	77	4.3%	9	Tsing Hua University	China	63	3.5%
10	UK	73	4.1%	10	University of Tokyo	Japan	61	3.4%

1.3 KEY HOT RESEARCH FRONT – "Neutrino Oscillation and search for Light Sterile Neutrino"

A neutrino is an elementary particle that carries no electric charge and passes through matter without being affected. In the Standard Model, neutrinos have no mass. The discovery of neutrino oscillations indicates that neutrinos have mass, which is the only phenomenon beyond the Standard Model with solid experimental evidence. Therefore, neutrino oscillation has been a hot Research Front. In addition, some experiments have observed phenomena that are inconsistent with the known neutrino oscillation models. A class of neutrinos named sterile neutrinos, which have larger mass and do not interact via any of the fundamental interactions other than gravity, has been theorized in order to make sense of these phenomena. Since large mass sterile neutrinos are difficult to detect directly, the search for light sterile neutrinos has become a hot topic in neutrino research.

In this high-energy physics Research Front, more than half the core papers are published through multi-country collaborations listing numerous authors. Therefore, our analysis is based on the countries where the experimental facilities are located, and we have also taken into account the countries in which the reprint authors of the core papers are situated. Analysis shows that China is the most active reprint country with 9 core papers, accounting for 22.5% of the total number of core papers (Table 38). The USA, Germany, Italy, and Russia also demonstrate excellent performance. The Daya Bay collaboration contributes the most core papers as an individual organization, followed by the University of Valencia and the T2K collaboration. In terms of impact, the two core papers in this front, in which the Daya Bay collaboration and the RENO collaboration separately report the precise measurement of the third mixing angle θ_{13}, have the highest citations: 1,220 and 1,038, respectively.

Table 38: Top countries and institutions producing the 40 core papers in the Research Front "Neutrino Oscillation and search for Light Sterile Neutrinos"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	China	9	22.5%	1	Daya Bay collaboration	China	8	20.0%
2	USA	7	17.5%	2	University of Valencia	Spain	4	10.0%
3	Spain	5	12.5%	3	T2K collaboration	Japan	3	7.5%
4	Italy	4	10.0%	4	RENO collaboration	South Korea	2	5.0%
5	South Korea	3	7.5%	4	Double Chooz collaboration	France	2	5.0%
5	Japan	3	7.5%	4	NOvA collaboration	USA	2	5.0%
6	UK	2	5.0%	4	Aldo Moro University	Italy	2	5.0%
6	India	2	5.0%	4	University of Southampton	UK	2	5.0%
6	France	2	5.0%	9				
6	Germany	2	5.0%	9				

In analyzing the citing papers (Table 39), we have found that 619 are from researchers based in the USA, accounting for 26.1% of the total citing papers. Germany, China, and Italy rank 2nd to 4th. Among the top institutions, the Spanish National Research Council (CSIC) and the Italian National Institute of Nuclear Physics (INFN) can each claim the most citing papers: 261, or 11.0% of the total. The Chinese Academy of Sciences, University of Valencia, and the French National Center for Scientific Research (CNRS) rank 3rd to 5th.

Table 39: Top countries and institutions producing citing papers in the Research Front "Neutrino Oscillation and search for Light Sterile Neutrino"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	619	26.1%	1	Consejo Superior De Investigaciones Cientificas (CSIC)	Spain	261	11.0%
2	Germany	408	17.2%	1	Italian National Institute of Nuclear Physics (INFN)	Italy	261	11.0%

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
3	China	356	15.0%	3	United States Department of Energy (DOE)	USA	217	9.1%
4	Italy	346	14.6%	4	Chinese Academy of Sciences	China	200	8.4%
5	India	332	14.0%	5	University of Valencia	Spain	193	8.1%
6	Japan	326	13.7%	6	French National Center for Scientific Research (CNRS)	France	172	7.2%
7	Spain	292	12.3%	6	Max Planck Society	Germany	172	7.2%
8	UK	268	11.3%	8	University of Tokyo	Japan	133	5.6%
9	France	192	8.1%	9	University of Chicago	USA	111	4.7%
10	Russia	168	7.1%	10	University of Paris Saclay ComUE	France	102	4.3%

2. EMERGING RESEARCH FRONT

One topic in physics is highlighted as an emerging Research Front: “Black holes and computational complexity,” mainly focusing on theoretical physics.

Table 40: Emerging Research Fronts in physics

Rank	Emerging Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Black holes and computational complexity	9	230	2016.6

In recent years, quantum information theory has become increasingly important in the study of quantum gravity and black hole physics. In 2016, a new conjecture was proposed by researchers at Stanford University, positing that the growth of black holes corresponds to the increase in computational complexity. This idea of the duality of computational complexity and gravitational action has attracted much attention. Nine core papers anchor this emerging Research Front. In terms of reprint authors, four core papers are from Stanford University, while two are from the Perimeter Institute of Theoretical Physics in Waterloo, Canada. And the University of Texas at Austin in USA, Durham University in the UK, and Eurasian National University in Kazakhstan each have one.

9. ASTRONOMY AND ASTROPHYSICS

1. HOT RESEARCH FRONT

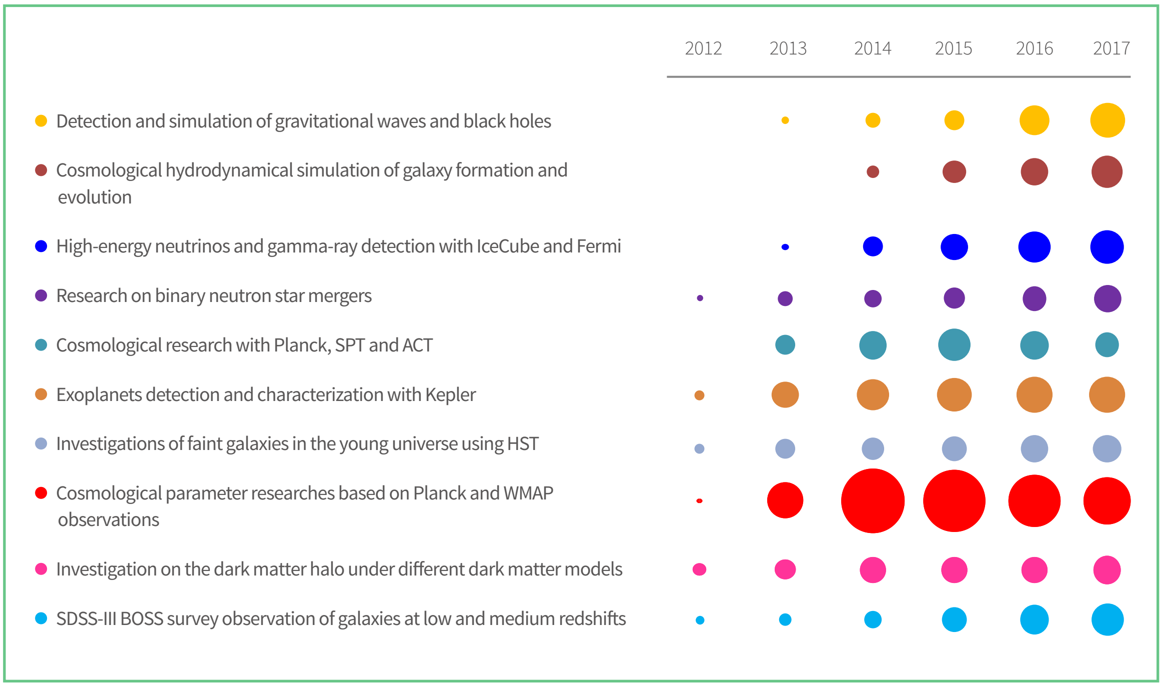
1.1 TREND OF THE TOP 10 RESEARCH FRONTS IN ASTRONOMY AND ASTROPHYSICS

The Top 10 Research Fronts in this area reflect ongoing focus on black holes, dark matter and dark energy, as well as on the origin and evolution of the universe, celestial bodies, and extraterrestrial life. Pertinent research topics in 2018 include gravitational waves and black holes, binary neutron star mergers, dark matter haloes, cosmological parameter, galaxy formation and evolution, high-energy neutrinos and gamma-ray, faint galaxies in the young universe, baryon acoustic oscillation, and exoplanets. In the context of two major scientific breakthroughs – the first-ever direct detection of gravitational waves in 2016, and the first observation of gravitational waves from a pair of inspiraling neutron stars in 2017 – the "Detection and simulation of gravitational waves and black holes" and "Research on binary neutron star mergers" emerged as hot Research Fronts this year. Several Research Fronts continue to show strong correspondence with specific space-based or ground-based observation platforms. For instance, two core papers focusing on cosmological parameter research employing Planck and WMAP observations have received nearly 7,000 citations and form the core of one of these hot Research Fronts for 2018.

Table 41: Top 10 Research Fronts in astronomy and astrophysics

Rank	Hot Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Detection and simulation of gravitational waves and black holes	40	2767	2015.9
2	Cosmological hydrodynamical simulation of galaxy formation and evolution	15	2340	2014.9
3	High-energy neutrinos and gamma-ray detection with IceCube and Fermi	23	2921	2014.8
4	Research on binary neutron star mergers	30	3090	2014.4
5	Cosmological research with Planck, SPT and ACT	16	2546	2013.9
6	Exoplanets detection and characterization with Kepler	31	5343	2013.8
7	Investigations of faint galaxies in the young universe using HST	20	3241	2013.6
8	Cosmological parameter researches based on Planck and WMAP observations	2	6585	2013.5
9	Investigation on the dark matter halo under different dark matter models	20	3213	2013.5
10	SDSS-III BOSS survey observation of galaxies at low and medium redshifts	11	2243	2013.5

Figure 8: Citing papers for the Top 10 Research Fronts in astronomy and astrophysics



1.2 KEY HOT RESEARCH FRONT – "High-energy neutrinos and gamma-ray detection with IceCube and Fermi"

One of the biggest mysteries in astrophysics is the origin of cosmic rays. High-energy cosmic rays, neutrinos, and gamma rays carry vital information on the origin and evolution of the universe and celestial bodies, and thus are known as "cosmic messengers." Scientists investigate cosmic rays and neutrinos, as well as gamma rays, to increase understanding of the turbulent cosmic environment. Neutrinos reveal the complex processes in the universe, while cosmic rays show the force and speed of violent activity, and high-energy gamma rays impart the origin of neutrinos and cosmic rays.

The detection of cosmic neutrinos employing Japan's Super-Kamiokande and America's Irvine-Michigan-Brookhaven detector in 1987 was awarded a Nobel Prize in Physics. In recent years, IceCube at the Amundsen–Scott South Pole Station and Fermi Gamma-ray Space Telescope (Fermi) have been at the cutting edge of detecting high-energy cosmic neutrinos and gamma rays.

To understand the mysteries of the cosmos, scientists have been engaged in comparing the neutrino data collected by IceCube with the gamma-ray data collected by Fermi. Completed in 2010 and currently the world's largest neutrino observatory, IceCube is located 2.4 km under the deep Antarctic ice, rigged to detect neutrinos that travel to Earth. The IceCube detector accomplished the first detection of high-energy neutrinos originating outside of our solar system, announced in 2013. Subsequently, new clues for the source of cosmic neutrinos, likely to have come from beyond our Milky Way galaxy, were discovered in 2016.

Launched in 2008, the Fermi Gamma-ray Space Telescope is a powerful space observatory that opens a wide window on the universe, monitoring the entire sky for gamma rays and keeping tabs on the activity of some 2,000 blazars, which emit neutrinos, among other materials. In July 2018, for the first time ever, Fermi verified the source of a high-energy neutrino which was detected by IceCube in 2017 from outside of our galaxy. This breakthrough research would push "multi-messenger astronomy" into a golden era.

This Research Front on "High-energy neutrinos and gamma-ray detection with IceCube and Fermi" consists of 23 core papers, including the milestone discovery of high-energy extraterrestrial neutrinos ("Evidence for High-Energy Extraterrestrial Neutrinos at the IceCube Detector"). As the primary funding country of IceCube and Fermi, the USA takes a predominant position in this front, participating in almost all of the core papers, followed by Japan, Germany and many other European countries. On the list of the Top 10 institutions in terms of core papers, seven are from the USA. Among institutions based in other nations, Stockholm University and the Helmholtz Association of German Research Centres contributed 16 and 15 core papers, respectively.

Table 42: Top countries and institutions producing the 23 core papers in the Research Front "High-energy neutrinos and gamma-ray detection with IceCube and Fermi"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	USA	22	95.7%	1	Department of Energy	USA	17	73.9%
2	Japan	18	78.3%	2	Stockholm University	Sweden	16	69.6%
3	Germany	17	73.9%	3	Helmholtz Association	Germany	15	65.2%
4	Sweden	16	69.6%	3	University of Maryland, College Park	USA	15	65.2%

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
5	UK	14	60.9%	5	University of Calfrornia-Irvine	USA	13	56.5%
6	Italy	11	47.8%	6	University of Wisconsin–Madison	USA	12	52.2%
7	Belgium	10	43.5%	6	Ohio State University	USA	12	52.2%
8	Australia	9	39.1%	8	National Aeronautics and Space Administration	USA	11	47.8%
8	France	9	39.1%	9	University Libre of Brussels	Belgium	10	43.5%
10	Austria	8	34.8%	9	Istituto Nazionale di Fisica Nucleare	Italy	10	43.5%
10	Canada	8	34.8%	9	Penn State University	USA	10	43.5%
10	New Zealand	8	34.8%					
10	Switzerland	8	34.8%					
10	South Korea	8	34.8%					
10	Spain	8	34.8%					

The USA also contributed a great number of citing papers (618), far ahead of Germany (365), followed by Italy, Japan, the UK, China, and France. Most of the top institutions producing citing papers in this Research Front are in Europe. Istituto Nazionale di Fisica Nucleare (Italy), Max Planck Society (Germany) and Centre national de la recherche scientifique (France) make up the top three, followed by two US-based organizations: the National Aeronautics and Space Administration (NASA) and the US Department of Energy.

Table 43: Top countries and institutions producing citing papers in the Research Front "High-energy neutrinos and gamma-ray detection with IceCube and Fermi"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	618	47.8%	1	Istituto Nazionale di Fisica Nucleare	Italy	188	14.5%
2	Germany	365	28.2%	2	Max Planck Society	Germany	186	14.4%
3	Italy	303	23.4%	3	Centre national de la recherche scientifique	France	177	13.7%
4	Japan	206	15.9%	4	National Aeronautics and Space Administration	USA	166	12.8%
5	UK	205	15.9%	5	Department of Energy	USA	166	12.8%
6	China	198	15.3%	6	Istituto Nazionale di Astrofisica	Italy	156	12.1%
7	France	185	14.3%	7	Helmholtz Association	Germany	140	10.8%
8	Spain	170	13.1%	8	Consejo Superior de Investigaciones Científicas	Spain	122	9.4%
9	Netherlands	127	9.8%	9	University of Maryland, College Park	USA	120	9.3%
10	Russia	126	9.7%	10	University Paris Diderot-Paris 7	France	109	8.4%

1.3 KEY HOT RESARCH FRONT – "Cosmological parameter research based on Planck and WMAP observations"

NASA's Cosmic Background Explorer (COBE) mission, launched in 1989, demonstrated for the first time that the cosmic microwave background radiation (CMB) conformed precisely to a black body (i.e., pure thermal radiation) at a temperature of 2.73 Kelvin, indicating that the universe today is derived from an extremely dense and hot early state. Two of COBE's principal investigators received the Nobel Prize in Physics in 2006 based on their research findings.

Encouraged by COBE, NASA launched the Wilkinson Microwave Anisotropy Probe (WMAP) mission in 2001 expecting a more accurate mapping of CMB temperature fluctuations across the full sky. The observations played a key role in the accurate measurement of the composition of the universe, thus establishing the standard cosmological model (ΛCDM) and enabling the era of precision cosmology.

As a successor of COBE and WMAP, the third-generation CMB observation mission named Planck was developed by the European Space Agency (ESA) and launched in 2009. The mission is devoted to high-precision observations of CMB temperature fluctuation anisotropy at microwave and infrared wavelengths. CMB research based on Planck's multi-batch high-precision observation data has continued to lead the Research Fronts in astronomy in recent years.

Two core papers based on WMAP and Planck missions form a key hot Research Front in astronomy and astrophysics in 2018. A study reported by the WMAP team in 2013 summarized the nine-year WMAP data and shrunk the allowable volume of the six-dimensional Delta CDM parameter space by a factor of 68,000 relative to pre-WMAP measurements. Another core paper contributed by the Planck Collaboration in 2014 presented the first cosmological results based on Planck measurements of the CMB temperature and lensing-potential power spectra, and fitted a set of high-precision cosmological parameters, including the degree of cosmic flatness, the age of the universe, the ratio of common matter and dark matter and dark energy, the expansion rate of the universe (Hubble constant), etc. It is believed that the aforementioned research will exert extensive influence on space astronomy.

As the primary funding agencies of WMAP and Planck missions, the performance of the USA and ESA member countries and partners is the most impressive. The USA, the UK, Canada, and Germany all contributed in the two core papers. NASA, Princeton University, University of Toronto, University of British Columbia, Max Planck Society, and Oxford University are major contributors to this Research Front.

Analysis of the citing papers indicates that the USA contributed nearly one third of the total and is far ahead of the UK (1,230) and Germany (1,002). Italy, France, and China ranked 4th to 6th, respectively. French institutions showed outstanding performance in citing papers. The French National Center for Scientific Research and Sorbonne University ranked 1st and the 10th among the Top 10 citing institutions. Italy (National Institute for Nuclear Physics; National Institute for Astrophysics) and the USA (US Department of Energy; University of California, Berkeley) both have two institutions ranked among the Top 10. The Chinese Academy of Sciences ranked 6th with 364 citing papers.

Table 44: Top countries and institutions producing citing papers in the Research Front "Cosmological parameter researches based on Planck and WMAP observations"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	2008	35.3%	1	French National Center for Scientific Research	France	611	10.7%
2	UK	1230	21.6%	2	Max Planck Society	Germany	500	8.8%
3	Germany	1002	17.6%	3	National Institute for Nuclear Physics	Italy	497	8.7%
4	Italy	825	14.5%	4	Department of Energy	USA	444	7.8%
5	France	724	12.7%	5	Spanish National Research Council	Spain	389	6.8%
6	China	656	11.5%	6	Chinese Academy of Sciences	China	364	6.4%
7	Japan	630	11.1%	7	National Institute for Astrophysics	Italy	361	6.3%
8	Spain	610	10.7%	8	University of Tokyo	Japan	334	5.9%
9	India	499	8.8%	9	University of California, Berkeley	USA	319	5.6%
10	Canada	478	8.4%	10	Sorbonne University	France	310	5.4%

2. EMERGING RESEARCH FRONT

2.1 SUMMARY OF EMERGING RESEARCH FRONTS IN ASTRONOMY AND ASTROPHYSICS

There are two emerging Research Fronts in astronomy and astrophysics: "Optimization of dark energy models based on various data sets" and "Investigations of the relations between cosmological first-order phase transition and gravitational waves." We will give further analysis of the first one.

Table 45: Emerging Research Fronts in astronomy and astrophysics

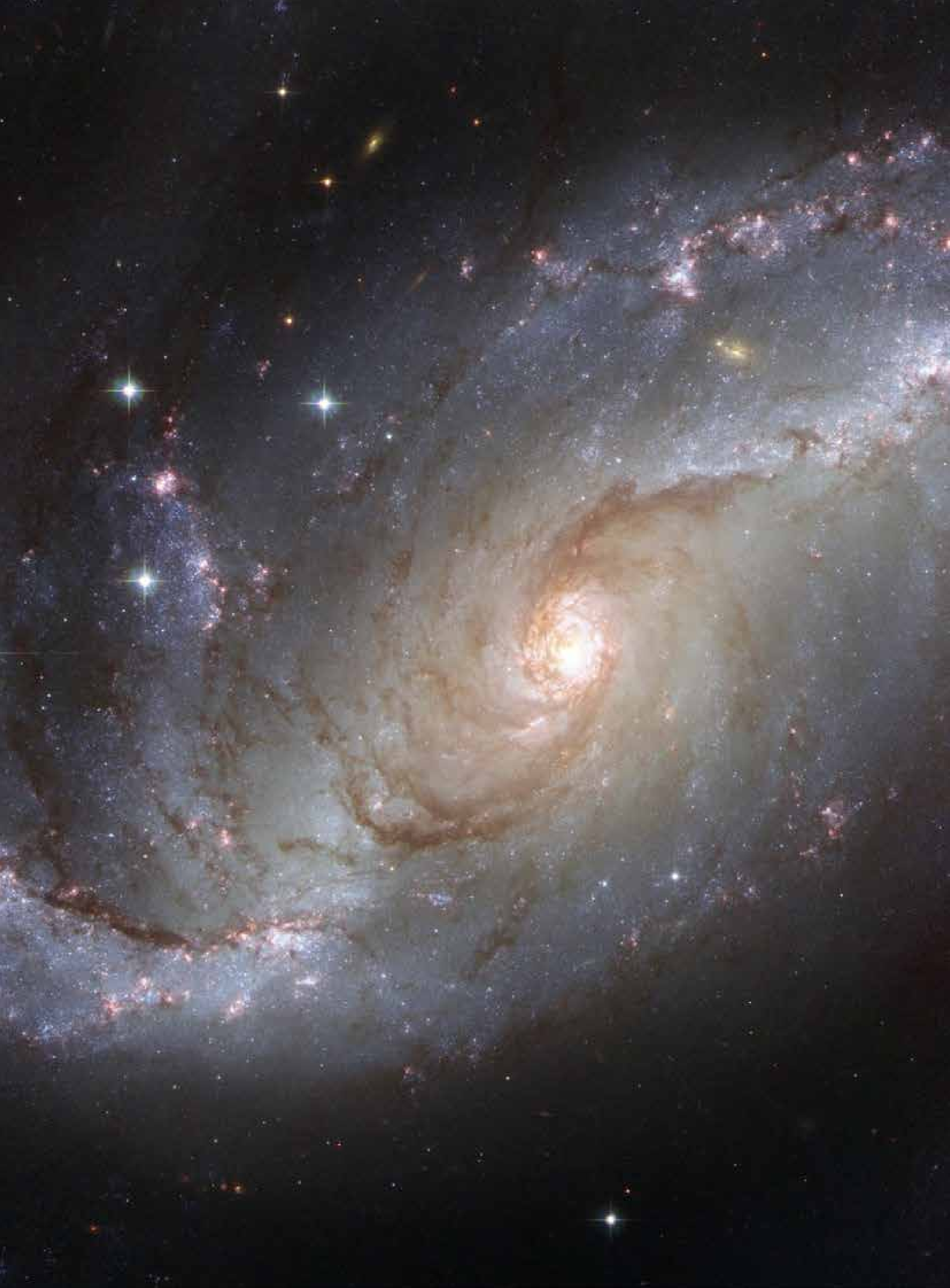
Rank	Emerging Research Fronts	Core Papers	Citation	Mean Year of Core Papers
1	Optimization of dark energy models based on various data sets	6	123	2016.7
2	Investigations of the relations between cosmological first-order phase transition and gravitational waves	6	122	2016.7

2.2 KEY EMERGING RESARCH FRONT – "Optimization of dark energy model based on various data sets"

More is unknown than known about dark energy, an as-yet-unexplained form of energy which is hypothesized to permeate all of space, tending to accelerate the expansion of the universe, and it is the most accepted hypothesis to explain the observations since the 1990s which indicated that the universe was expanding at an accelerating rate. In 1998, observations of distant Type Ia supernovae by two independent projects demonstrated the unexpected result that the universe seemed to be undergoing an accelerating expansion. The evidence for dark energy has continued to grow by different observations, such as the CMB, baryon acoustic oscillations, and large-scale structure. In 2013, the Planck space mission released the most accurate and detailed map ever made of the oldest light in the universe by mapping the CMB and the new estimate of dark energy was 68.3 percent.

Theorists proposed three main explanations for dark energy: According to one theory, dark energy results from conditions described in a long-discarded version of Einstein's theory of gravity, one that contained what was called a "cosmological constant." Maybe there is some strange kind of energy-fluid that filled space. Maybe there is something wrong with Einstein's theory of gravity and a new theory could include some kind of field that creates this cosmic acceleration. For now, the source of cosmic acceleration as well as the nature of dark energy await future determination.

This Research Front brings together six papers focusing on dark energy models. The research topics include (1) using dynamical dark energy to solve the three sigma tension on the value of the Hubble constant H-0 between the direct measurement and the indirect constraint, (2) testing coupled dark energy models with their cosmological background evolution, (3) using running vacuum models challenging the concordance model, (4) using 38 measurements of the Hubble parameter H(z) between redshifts $0.07 \le z \le 2.36$ to place constraints on model parameters of constant and time-varying dark energy cosmological models, (5) theoretical challenges, cosmological implications, and observational signatures of dark matter and dark energy interactions, and (6) new constraints on interacting dark energy from cosmic chronometers.



10. MATHEMATICS, COMPUTER SCIENCE AND ENGINEERING

1. HOT RESEARCH FRONT

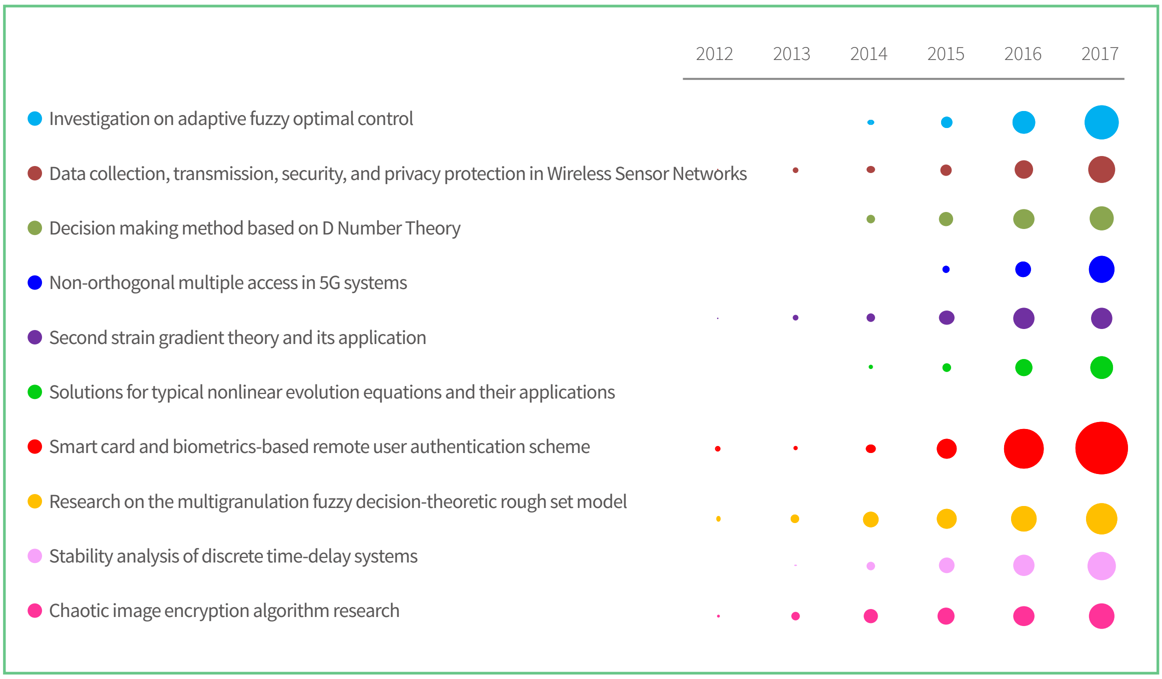
1.1 TREND OF THE TOP 10 RESEARCH FRONTS IN MATHEMATICS, COMPUTER SCIENCE AND ENGINEERING

The Top 10 Research Fronts in mathematics, computer science and engineering mainly focus on: second strain gradient theory; solutions for partial differential equations; remote user authentication; decision-making method based on D number theory; fuzzy decision-theoretic rough set model; chaotic image encryption algorithm; adaptive fuzzy optimal control; stability analysis of discrete time-delay systems; non-orthogonal multiple access in 5G systems; and wireless sensor networks. The Top 10 Research Fronts in 2018 show both continuity and new development when compared with the fronts selected between 2013 and 2017. The strain gradient theory and its application have been consecutively selected as a hot or emerging Research Front for years. Solutions of partial differential equations and their applications have also constituted an important research topic in recent years. In computer science and engineering, remote user authentication continues to be a hot Research Front in 2018, while all the remaining research topics here are selected as hot Research Fronts for the first time.

Table 46: Top 10 Research Fronts in mathematics, computer science and engineering

Rank	Hot Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Investigation on adaptive fuzzy optimal control	39	1679	2016.2
2	Data collection, transmission, security, and privacy protection in Wireless Sensor Networks	31	827	2016.1
3	Decision making method based on D Number Theory	43	1353	2016
4	Non-orthogonal multiple access in 5G systems	22	826	2016
5	Second strain gradient theory and its application	47	1576	2015.6
6	Solutions for typical nonlinear evolution equations and their applications	28	817	2015.6
7	Smart card and biometrics-based remote user authentication scheme	46	4211	2015.3
8	Research on the multigranulation fuzzy decision-theoretic rough set model	47	1816	2015.3
9	Stability analysis of discrete time-delay systems	17	1176	2015.1
10	Chaotic image encryption algorithm research	25	1114	2015

Figure 9: Citing papers for the Top 10 Research Fronts in mathematics, computer science and engineering



1.2 KEY HOT RESEARCH FRONT – "Non-orthogonal multiple access in 5G systems"

With the rapid development of mobile internet, social networks, and the Internet of Things, the explosive growth of data poses great challenges to limited spectrum resources and imposes higher demands on future mobile networks. As the next-generation mobile communication technology, the fifth-generation mobile communication (5G) urgently needs to solve the problem of simultaneous and reliable access of mass terminals.

To maintain optimum system throughput and low cost of receiving, 4G uses orthogonal multiple access (OMA) technology, and its data service transmission rate reaches 100 megabits or even gigabits per second, which can meet the needs of broadband mobile communication applications in the next period. However, in order to increase the efficiency of 5G spectrum by 5~15 times, the research community proposes to adopt a new type of multiple access multiplexing, namely non-orthogonal multiple access (NOMA). OMA technology can only allocate a single radio resource to a user, such as frequency division or time division, while NOMA can allocate one resource to multiple users. In some scenarios, such as near-far effect scenarios and wide-coverage multi-node access scenarios, especially in uplink-intensive scenarios, NOMA methods using power multiplexing can boast significant performance over traditional orthogonal access, more suitable for the deployment of future systems.

In the 22 core papers anchoring this hot Research Front, the most-cited paper investigated the performance of NOMA in a cellular downlink scenario with randomly deployed users. The analytical results showed that NOMA can achieve superior performance in terms of ergodic sum rates. However, the outage performance of NOMA depended critically on the choices of the users' targeted data rates and allocated power. As a review paper, the second-most-cited paper summarized some of the phased achievements of NOMA technology in theoretical research and implementation technology in recent years, such as low-density spreading CDMA (LDS-CDMA), sparse coded multiple access (SCMA), multi-user shared access (MUSA), and pattern-division multiple access (PDMA), as well as the challenges, opportunities, and future research trends for NOMA design. Other core papers discuss the ergodic capacity of MIMO NOMA systems, beamforming, power allocation strategy, user fairness, and so on.

Ten countries contributed to the core papers. The UK, China, and the USA rank in the top three (Table 47). At the institutional level, Lancaster University in the UK published 10 core papers, seven of which were published in collaboration with second-ranked Princeton University.

Analysis of the citing papers (Table 48) indicates that China has a high engagement in this area. Among the Top 10 institutions, Lancaster University continues its leading position in producing citing papers. Chinese institutions occupy six positions, with the Chinese Academy of Sciences ranking 1st with 33 citing papers. Southwest Jiaotong University and Beijing University of Posts and Telecommunications are among the top institutions in contributing to core and citing papers.

Table 47: Top countries and institutions producing the 22 core papers in the Research Front "Non-orthogonal multiple access in 5G systems"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	UK	11	50.0%	1	Lancaster University	UK	10	45.5%
1	China	11	50.0%	2	Princeton University	USA	8	36.4%

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
3	USA	8	36.4%	3	Southwest Jiaotong University	China	4	18.2%
4	South Korea	5	22.7%	4	Beijing University Posts & Telecommunications	China	3	13.6%
5	Canada	2	9.1%	5	China Mobile	China	2	9.1%
6	Sweden	1	4.5%	5	Tsinghua University	China	2	9.1%
6	Cyprus	1	4.5%	5	Gwangju Institute of Science & Technology	South Korea	2	9.1%
6	Greece	1	4.5%	5	Queen Mary University London	UK	2	9.1%
6	Japan	1	4.5%					
6	Australia	1	4.5%					

Table 48: Top countries and institutions producing citing papers in the Research Front "Non-orthogonal multiple access in 5G systems"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	China	181	21.9%	1	Lancaster University	UK	51	6.2%
2	UK	90	10.9%	2	Chinese Academy of Sciences	China	33	4.0%
3	USA	54	6.5%	3	Xidian University	China	24	2.9%
4	South Korea	48	5.8%	4	Princeton University	USA	21	2.5%
5	Canada	27	3.3%	5	Beijing University Posts & Telecommunications	China	19	2.3%
6	Australia	24	2.9%	5	Southwest Jiaotong University	China	19	2.3%
7	Greece	21	2.5%	7	Southeast University - China	China	17	2.1%
8	Japan	17	2.1%	7	Tsinghua University	China	17	2.1%
9	Sweden	11	1.3%	9	Aristotle University of Thessaloniki	Greece	16	1.9%
10	Germany	9	1.1%	10	Queen Mary University of London	UK	14	1.7%

1.3 KEY HOT RESEARCH FRONT – "Solutions for typical nonlinear evolution equations and their applications"

As one of the three scientific revolutions of the twentieth century, nonlinear science can be used to investigate numerous nonlinear phenomena in the natural sciences and engineering. The nonlinear evolution equation is a class of nonlinear mathematical physics partial differential equations and equation sets which describe states and processes that evolve over time. Most of the research on nonlinear problems boiled down to finding a solution to nonlinear evolution equations. Solutions for nonlinear equations can effectively explain or predict the changes of states and quantities of practical issues, and profoundly reveal the nature of nonlinear problems. Accordingly, solving nonlinear evolution equations has been an important issue for researchers in related fields.

Research breakthroughs, especially the new solving methods for nonlinear evolution equations, have been constantly emerging in recent year with the vigorous development of symbolic computing. With the establishment of a series of methods for the constructions of rational, exact, or soliton solutions – such as the Darboux transform, the Backlund transform, Hirota's bilinear method, the Painleve analysis method, and the Lax pair method – nonlinear evolution equations that could not be solved in the past can now be successfully solved. Furthermore, the application of solutions for nonlinear evolution equations are no longer limited to the field of fluid, but are expanding to nonlinear optics, condensed matter physics, and plasma etc.

Research on nonlinear evolution equations continues to constitute a hot Research Front. In 2017, "Soliton solutions for nonlinear evolution equations and its applications" was selected as one of the hot Research Fronts. In 2018, the hot Research Front "Solutions for typical nonlinear evolution equations and their applications" discussed the rational, exact, or soliton solutions for a series of typical nonlinear evolution equations including the Korteweg-de Vries equation, the Gross-Pitaevskii equation, the Kadomtsev-Petviashvili equation, the nonlinear Schrödinger equation, the Boussinesq equation, the Hirota bilinear equation, etc., and their applications in fluid dynamics, electromagnetics, and so on. It is worth noting that the "soliton solutions for nonlinear Schrödinger equations and its applications in fluid mechanics, and optical fiber communication," which is closely related to the above-mentioned hot Research Front, is also selected as an Emerging Research Front of 2018, focusing on soliton solutions for the shallow-water wave equation and the Kadomtsev-Petviashvili equation and their applications in fluid mechanics and fiber-optic communications.

Analysis of countries and institutions producing core papers shows China's predominance in this field. China-based researchers contributed to all core papers (Table 49), in cooperation with the USA, South Africa, and the UK. Among the top institutions, seven are based in China, while three are respectively situated in the USA, the UK, and South Africa. It is worth mentioning that Chinese scientists showed very impressive performance in this Research Front. The reprint authors of all the core papers are Chinese researchers. Among them, Wenxiu Ma, at the University of South Florida, showed the greatest impact and made important contributions to the development of soliton and integrable system theory. His team produced nearly half the core papers (13 papers) in this Research Front. Seven of the top 10 most-cited papers were from his team. Meanwhile, Shoufu Tian from the China University of Mining and Technology contributed actively with 9 core papers, and 2 of the core papers rank among the top 10 most-cited papers.

Table 49: Top countries and institutions producing the 28 core papers in the Research Front "Solutions for typical nonlinear evolution equations and their applications"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	China	28	100.0%	1	University of South Florida	USA	13	46.4%
2	USA	13	46.4%	2	Beijing Jiaotong University	China	12	42.9%
3	South Africa	8	28.6%	3	China University of Mining & Technology	China	9	32.1%
4	UK	5	17.9%	4	North-West University	South Africa	8	28.6%

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
				5	University of Cambridge	UK	5	17.9%
				6	University of Science & Technology - Beijing	China	3	10.7%
				6	Beijing Information Science and Technology University	China	3	10.7%
				6	Shanghai University of Electric Power	China	3	10.7%
				6	Shaoxing University	China	3	10.7%
				10	Dalian University of Technology	China	2	7.1%
				10	Xuzhou University of Technology	China	2	7.1%
				10	University of Shanghai Science and Technology	China	2	7.1%

In terms of the citing papers (Table 50), more countries were involved in the research. China not only contributed most of the core papers, but also actively participated in 232 citing papers, accounting for 28.4% of the total and ranking 1st. The USA, Egypt, South Africa and Saudi Arabia were ranked 2nd to 5th, respectively.

At the institutional level, Chinese institutions are also outstanding in terms of following up this Research Front. Half of the Top 10 institutions are based in China, and the China University of Mining and Technology contributed the highest numbers of citing papers.

Table 50: Top countries and institutions producing citing papers in the Research Front "Solutions for typical nonlinear evolution equations and their applications"

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	China	232	28.4%	1	China University of Mining & Technology	China	45	5.5%
2	USA	36	4.4%	2	University of South Florida	USA	23	2.8%
3	Egypt	29	3.5%	3	North-West University	South Africa	19	2.3%
3	South Africa	29	3.5%	4	University of Cambridge	UK	18	2.2%
5	Saudi Arabia	27	3.3%	5	Taibah University	Saudi Arabia	16	2.0%
6	UK	19	2.3%	5	Wuhan Donghu University	China	16	2.0%
7	Turkey	16	2.0%	7	Ben Suef University	Egypt	15	1.8%
8	Iran	14	1.7%	8	Beijing Jiaotong University	China	14	1.7%
9	Pakistan	13	1.6%	8	Shandong University of Science and Technology	China	14	1.7%
10	Algeria	4	0.5%	10	Beijing University Posts & Telecommunications	China	13	1.6%
10	India	4	0.5%					

1.4 KEY HOT RESEARCH FRONT – "Smart card and biometrics-based remote user authentication scheme"

The intelligent terminal can easily acquire network resources and services, thus providing great convenience to our lives. However, it also brings severe security risks that threaten secure communication in public networks. Once the information being transmitted through the network is maliciously stolen and tampered with by others, the result will be incalculable loss.

A smart card contains an embedded integrated circuit and is able to store and process a large amount of information. The smart card-based user authentication scheme requires little maintenance of a password table or verification table on a remote server and limited traffic and computation load, and allows user allows users to freely set and change passwords. At present, the method has been widely used in the authentication between remote users and servers to ensure the legitimacy and correctness of both sides of the communication. Biometric-based authentication uses a person's physiological and behavioral characteristics such as a fingerprint, iris, voice, handwriting, etc., to identify individuals through image processing and pattern recognition. Due to the unforgeable nature of biometrics, biometric-based authentication is, theoretically, safer and more reliable than other traditional authentication techniques.

Forty-six core papers of this hot Research Front mainly focus on the smart card-based biometric authentication (e.g., remote two-way biometric authentication using fuzzy extractor), multi-server remote user authentication based on smart card and distributed authentication, anonymous authentication schemes based on biometrics and smart cards, etc.

China is the most active country, participating in 38 core papers (exclude Taiwan, China), which was 82.6% of the total amount and far ahead of other countries. India, the USA, and South Korea also show good performance. Among the Top 10 institutions, Chinese institutions occupy six positions and rank high. Nanjing University of Information Science & Technology contributes 25 core papers and ranks 1st, followed by Wuhan University, the Chinese Academy of Sciences, and Xidian University. As for other countries, three institutions on the list of Top 10 institutions are in India. Saudi Arabia, Australia, and South Korea each have one placement among the Top 10 institutions.

Table 51: Top countries/regions and institutions producing the 46 core papers in the Research Front "Smart card and biometrics-based remote user authentication scheme"

Country Ranking	Country/ region	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	China	38	82.6%	1	Nanjing University of Information Science & Technology	China	25	54.3%
2	India	11	23.9%	2	Wuhan University	China	7	15.2%
3	USA	6	13.0%	3	Chinese Academy of Sciences	China	6	13.0%
3	South Korea	6	13.0%	4	Xidian University	China	5	10.9%
5	Saudi Arabia	5	10.9%	4	King Saud University	Saudi Arabia	5	10.9%
6	Australia	4	8.7%	6	Peking University	China	4	8.7%
6	Canada	4	8.7%	6	Hunan University of Science and Technology	China	4	8.7%

Country Ranking	Country/ region	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
8	Taiwan, China	3	6.5%	6	Indian Institute of Technology (IIT)	India	4	8.7%
9	France	2	4.3%	6	IIIT Hyderabad	India	4	8.7%
10	UK	1	2.2%	10	La Trobe University	Australia	3	6.5%
10	Slovenia	1	2.2%	10	Thapar University	India	3	6.5%
10	Iran	1	2.2%	10	Kyung Hee University	South Korea	3	6.5%

Analysis of citing papers demonstrates that China is still the most important participant in this hot Research Front. China contributes nearly 30% (1,249) of the total citing papers, followed by the USA and India. Seven Chinese institutions rank among the Top 10 institutions and occupy the top five positions. The rest of the Top 10 citing institutions were the King Saud University (Saudi Arabia), the International Institute of Information Technology Hyderabad (India), and the Indian Institute of Technology.

Table 52: Top Country/regions and institutions producing citing papers in the Research Front "Smart card and biometrics-based remote user authentication scheme"

Country Ranking	Country/ region	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	China	1249	29.7%	1	Nanjing University of Information Science & Technology	China	398	9.5%
2	USA	225	5.3%	2	Chinese Academy of Sciences	China	110	2.6%
3	India	167	4.0%	3	Xidian University	China	75	1.8%
4	Taiwan, China	79	1.9%	4	Beijing University Posts & Telecommunications	China	74	1.8%
5	Saudi Arabia	76	1.8%	5	Wuhan University	China	69	1.6%
6	South Korea	71	1.7%	6	King Saud University	Saudi Arabia	61	1.4%
7	Australia	59	1.4%	7	Hunan University of Science and Technology	China	57	1.4%
8	UK	53	1.3%	8	Iiit Hyderabad	India	53	1.3%
9	Canada	43	1.0%	9	Nanjing University of Posts and Telecommunications	China	52	1.2%
10	Singapore	32	0.8%	10	Indian Institute of Technology (IIT)	India	50	1.2%

2. EMERGING RESEARCH FRONT

2.1 SUMMARY OF EMERGING RESEARCH FRONTS IN MATHEMATICS, COMPUTER SCIENCE AND ENGINEERING

“Soliton solutions for nonlinear Schrödinger equations and its applications in fluid mechanics, and optical fiber communication” and “Research on Consensus of Multi-agent Systems” were selected as Emerging Research Fronts of 2018 in mathematics, computer science and engineering.

Table 53: Emerging Research Fronts in mathematics, computer science and engineering

Rank	Emerging Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Soliton solutions for nonlinear Schrödinger equations and its applications in fluid mechanics, and optical fiber communication	10	250	2016.6
2	Research on the consensus of multi-agent systems	8	186	2016.6

2.2 KEY EMERGING RESEARCH FRONT – “Research on the Consensus of Multi-agent Systems”

Inspired by the clustering phenomenon observed in fields ranging from the exact sciences to social and life sciences, such as swarm behavior of animals or social insects, etc., researchers have proposed the concept of a multi-agent system. A multi-agent system is a loosely coupled network of problem-solving entities with certain communication, sensing, computing, and execution capabilities that work together to find answers to problems that are beyond the individual capabilities or knowledge of each entity.

Recently, due to the wide applications in many fields, such as cooperative operations of multiple Unmanned Aerial Vehicles (UAV) and autonomous underwater robots, etc., coordination controls of multi-agent systems have gained much attention from various scientific communities and have achieved some important research results.

The emerging Research Front “Research on the consensus of multi-agent systems” comprises a series of research works, including the consensus of multi-agent systems using aperiodic sampled-data control, the robust $H\infty$ control problem on consensus of multi-agent network, the collaboration mechanism for multi-agent system with incomplete information, and the consensus of the nonlinear multi-agent system, etc. Chinese institutions such as Zhejiang University, Guangdong University of Technology, and East China University of Science and Technology have contributed in all core papers in this emerging front. Research institutions from Australia, Canada, the UK, and Singapore are also actively involved in this research topic.

11. ECONOMICS, PSYCHOLOGY AND OTHER SOCIAL SCIENCES

1. HOT RESEARCH FRONT

1.1 TREND OF THE TOP 10 RESEARCH FRONTS IN ECONOMICS, PSYCHOLOGY AND OTHER SOCIAL SCIENCES

The Top 10 Research Fronts of 2018 related to the social sciences focus on psychology, sociology, economics and management. Around 40% of the Research Fronts focus on psychology, including “Sleep and memory consolidation,” “Intervention and training in schizophrenia,” “Psychological and behavioral research on social class and social problems” and “DSM-5 approach to internet gaming addiction.”

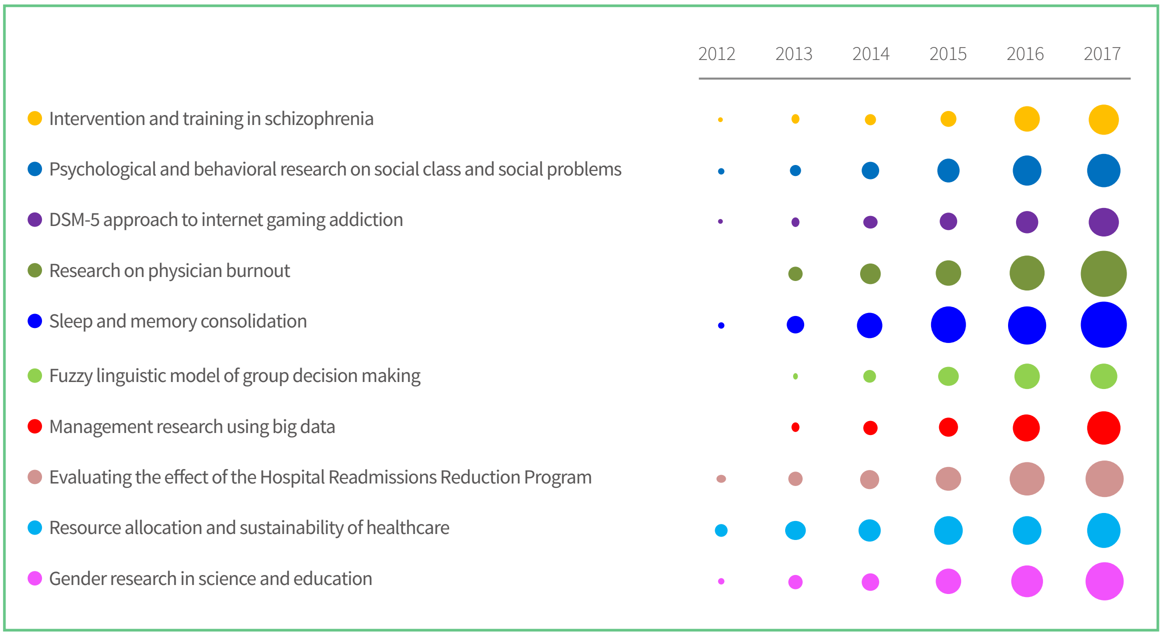
In sociology, policy evaluation pertaining to healthcare has been a research issue in recent years. Following previous Research Fronts devoted to “Social impact of the Affordable Care Act in the United States” in 2015 and 2017, and “Social investigation of human papillomavirus (HPV) vaccination” in 2017, three topics related to medical policy and healthcare are among the Top 10 Research Fronts: “Research on physician burnout,” “Evaluating the effect of the Hospital Readmissions Reduction Program” and “Resource allocation and sustainability of healthcare,” further illustrating that the healthcare sector continues to receive heightened social attention.

Research methods in the field of economic management have always emerged among the top Research Fronts in economics, psychology and other social science; these include “Multi-regional Input-Output Analysis Tool” in 2014, “Data envelopment analysis method” in 2016 and “Application of Partial Least Squares Structural Equation Models in commercial research” in 2017. In 2018, the topics mainly focus on decision analysis and research methods and research paradigm changes in the context of big data, namely “Fuzzy linguistic model of group decision making” and “Management research using big data.”

Table 54: Top 10 Research Fronts in economics, psychology and other social sciences

Rank	Hot Research Fronts	Core Papers	Citations	Mean Year of Core Papers
1	Intervention and training in schizophrenia	19	877	2015.5
2	Psychological and behavioral research on social class and social problems	21	1014	2015.3
3	DSM-5 approach to internet gaming addiction	19	929	2015.3
4	Research on physician burnout	21	1626	2015.2
5	Sleep and memory consolidation	22	2171	2014.9
6	Fuzzy linguistic model of group decision making	22	1198	2014.9
7	Management research using big data	10	843	2014.9
8	Evaluating the effect of the Hospital Readmissions Reduction Program	24	1264	2014.8
9	Resource allocation and sustainability of healthcare	15	1148	2014.8
10	Gender research in science and education	18	1239	2014.7

Figure 10: Citing papers for the Top 10 Research Fronts in economics, psychology and other social sciences



1.2 KEY HOT RESEARCH FRONT – “Sleep and memory consolidation”

Memory is one of the most important research topics in psychology and cognitive science. Sleep has been demonstrated to play an important role in memory consolidation. However, the neural mechanism of sleep in memory consolidation is still unclear. Scientists have recently made breakthroughs in this issue, contributing to one of the top Research Fronts in psychology and neurocognitive science.

Recent research has elucidated the neural mechanisms by which sleep acts in consolidating and enhancing new memories. Scientists have revealed how sleep helps neurons form branches that are specifically connected to dendrites to promote long-term memory. These findings also show that different types of learning form synapses on different branches of the same neuron, suggesting that learning can lead to specific structural changes in the brain. Meanwhile, rapid eye movement (REM) and non-rapid eye movement (NREM) sleep periods both contribute to the consolidation of memory when the brain goes to sleep, and different sleep stages encode different kinds of information. NREM sleep affects the formation of dendritic spines, which is essential for the consolidation of procedural memory. In REM sleep, theta waves are generated in the memory-related brain regions such as the hippocampus, confirming that REM sleep consolidates contextual memory.

Of the 22 core papers in this Research Front, there are 4 review articles, of which a 2013 paper in Physiological Reviews is the most cited. The paper systematically reviews the understanding of sleep and memory, and points out that previous studies have focused more on the function of REM sleep, while recent studies have revealed the important role of slow-wave sleep (SWS) on memory consolidation, also explaining the electrophysiological, neurochemical, and genetic mechanisms of this process.

Besides the review articles, most of the core papers employ the experimental method to study how the brain manages and consolidates information. An article published in Science in 2014 reports the use of mice to perform a rotating rod experiment to verify that non-REM sleep plays an important role in procedural memory consolidation. Papers published in Science in 2016 and 2017, also based on experiments, verify the inhibitory projection between the hippocampus and the medial septum during REM sleep. In addition, the development of in vivo imaging technology provides an important basis for studying the mechanism of sleep and memory consolidation.

In this Research Front, 11 core papers include authors based in the United States, accounting for 50% of the core group. Italy takes second place by contributing to 6 core papers. Germany, Switzerland and United Kingdom can each claim contributing authors on 4 core papers, taking third place. China-based authors contribute to 2 core papers. At the institutional level, authors from the Italian National Research Council are credited on 5 core papers, accounting for 22.7%, which is the highest total of any organization. The University of Tubingen in Germany and New York University in the United States contribute to 4 core papers, respectively. In addition, authors affiliated with University College London contribute to 3 core papers.

Table 55: Top countries and institutions producing the 38 core papers in the Research Front “Sleep and memory consilidation”

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	USA	11	50.0%	1	Consiglio Nazionale Delle Ricerche (CNR)	Italy	5	22.7%
2	Italy	6	27.3%	2	Eberhard Karls University of Tubingen	Germany	4	18.2%

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
3	Germany	4	18.2%	2	New York University	USA	4	18.2%
3	Switzerland	4	18.2%	4	University College London	UK	3	13.6%
3	UK	4	18.2%					
6	Canada	3	13.6%					
7	China	2	9.1%					
7	Austria	2	9.1%					
7	Netherlands	2	9.1%					
10	France	1	4.5%					

In terms of citing papers, the United States occupies first place with 643, accounting for 44% of the total – more than twice that of the UK, which ranks second. Germany places third with 243 citing papers, indicating that the United States, Germany and UK are the most important countries in this Research Front. China and Japan take ninth place with 52 citing papers, accounting for 3.6% of the total.

In regard to the citing institutions, University College London has the greatest number of citing papers, followed by the University of Tubingen in Germany, New York University in the United States, the University of Zurich in Switzerland, Harvard University in the United States, the French National Center for Scientific Research, and the National Institute for Health and Medical Research (INSERM) of France, each contributing more than 50 citing papers.

Table 56: Top countries and institutions producing citing papers in the Research Front “Sleep and memory consolidation”

Country Ranking	Country	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	643	44.0%	1	University College London	UK	94	6.4%
2	UK	268	18.3%	2	Eberhard Karls University of Tubingen	Germany	73	5.0%
3	Germany	243	16.6%	3	New York University	USA	64	4.4%
4	Switzerland	133	9.1%	4	University of Zurich	Switzerland	63	4.3%
5	Italy	108	7.4%	5	Harvard University	USA	61	4.2%
6	Canada	99	6.8%	6	CNRS	France	55	3.8%
7	France	91	6.2%	7	Institut National De La Sante Et De La Recherche Medicale (INSERM)	France	50	3.4%
8	Netherlands	68	4.7%	8	Consiglio Nazionale Delle Ricerche (CNR)	Italy	43	2.9%
9	China	52	3.6%	9	Max Planck Society	Germany	39	2.7%
9	Japan	52	3.6%	10	University of Oxford	UK	38	2.6%

1.3 KEY HOT RESEARCH FRONT – "Management research using big data"

Big data, also known as massive data, refers to the immense and complex datasets that cannot be dealt with using traditional data-processing applications. The term can also be defined as a large quantity of unstructured or structured data. The emergence of big data is an inevitable outcome of the development of information technology. The exponential growth of data volume has changed people's lifestyles, as well as the patterns of business operation and even the paradigm for research itself. From an academic point of view, the emergence of big data has led to novel research on a wide range of topics, and has prompted the development of various statistical methods for treating big data. In short, big-data analysis is becoming more and more prominent in modern research.

This Research Front focuses on changes in management research brought by big data as well as on business-value analysis based on large datasets. Big data enables predictive analysis rather than the analytics of the past, making it possible to fine-tune measurement and management, and enabling companies to make better predictions and smarter decisions to achieve specific goals. Also, big data makes business intelligence and analytics (BI&A) an important emerging research area in management disciplines.

In the core papers of this Research Front, big-data science and predictive analysis are often applied to supply-chain management while also being widely used in studying market development trends and consumer-buying patterns. Examples include the use of big-data analysis to mine and analyze user behaviors and preferences and subsequently to provide user-friendly products and services. Meanwhile, organizational performance and the quality of decision making are also reflected in the core papers, as are predictive analysis, case studies and survey research.

Ten core papers anchor this front. Eight of these papers include at least one author listing in the United States, accounting for 80% of the total. Three core papers include at least one author affiliation in the UK, France and Australia, giving each nation a share of second place. Two core papers include at least one author listing each in China and India, while authors based in the Netherlands and South Africa both account for 1 paper. At the institutional level, the University of Wollongong in Australia has 3 core papers, making it the largest producer of foundational papers, accounting for 30% of the total. The University of Toulouse in France, Symbiosis International University in India, the University of Kent in the UK, the University of Plymouth in the UK and the University of Massachusetts Dartmouth in the United States each contribute 2 core papers.

Table 57: Top countries and institutions producing the 9 core papers in the research front "Management research using big data"

Country Ranking	Country	Core Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Core Papers	Proportion
1	USA	8	88.9%	1	University of Wollongong	Australia	3	33.3%
2	UK	3	33.3%	2	University of Toulouse	France	2	22.2%
2	France	3	33.3%	2	Symbiosis International University	India	2	22.2%
2	Australia	3	33.3%	2	University of Kent	UK	2	22.2%
5	China	2	22.2%	2	University of Plymouth	UK	2	22.2%
5	India	2	22.2%	2	University of Massachusetts--Dartmouth	USA	2	22.2%
7	Netherlands	1	11.1%					
7	South Africa	1	11.1%					

From the aspect of citing papers, the United States scores first place by fielding 245 papers, accounting for 39.1%, making it the most important country in this Research Front. China and the UK both have more than 100 citing papers, followed by Australia, France, Germany and South Korea.

The citing institutions are evenly distributed in this Research Front. The University of Wollongong has the largest number of citing papers (15). The Chu De Toulous in France and Wellcome Trust Sanger Institute in the UK have more than 9 citing papers.

Table 58: Top countries/regions and institutions producing citing papers in the research front “Management research using big data”

Country Ranking	Country/ region	Citing Papers	Proportion	Institution Ranking	Institution	Affiliated Country	Citing Papers	Proportion
1	USA	245	39.1%	1	University of Wollongong	Australia	15	2.4%
2	China	131	20.9%	2	Chu De Toulouse	France	11	1.8%
3	UK	110	17.6%	3	Wellcome Trust Sanger Institute	UK	10	1.6%
4	Australia	56	8.9%	4	Chinese Academy of Sciences	China	9	1.4%
5	France	42	6.7%	4	City University of Hong Kong	China	9	1.4%
5	Germany	42	6.7%	4	Georgia Institute of Technology	USA	9	1.4%
7	South Korea	32	5.1%	4	Neoma Business School	France	9	1.4%
8	Spain	23	3.7%					
9	Taiwan, China	22	3.5%					
10	Canada	20	3.2%					
10	India	20	3.2%					

2. EMERGING RESEARCH FRONT

2.1 SUMMARY OF EMERGING RESEARCH FRONTS IN ECONOMICS, PSYCHOLOGY AND OTHER SOCIAL SCIENCES

“Trustworthiness of management research” is selected as the Emerging Research Front of 2018 in Economic, Psychology and other Social Sciences.

Table 59: Emerging Research Fronts in economics, psychology and other social sciences

Rank	Emerging Research Fronts	Core Papersrsrs	Citations	Mean Year of Core Papers
1	Trustworthiness of management research	8	87	2016.6

2.2 KEY EMERGING RESEARCH FRONT – "Trustworthiness of management research"

The classic paradigm of management research is the process of proposing a hypotheses based on theories and previous studies, collecting data, constructing models, conducting statistical analysis, and then determining the results. This process is based on the logic that we can discover and verify a universal law and cognition through theoretical analysis and statistical sampling. However, recent years have seen instances of academic misconduct in management research, such as "playing with models," "playing with data" and "playing with hypotheses." Examples include formulating the hypothesis from the data rather than the theory first, and selectively reporting significant results. All these behaviors will make the theoretical model imperfect and affect the reliability and trustworthiness of the study.

These types of academic misconduct fall within the so-called the "grey zone" of academia. Although these behaviors are not as intolerable as fraud, falsification and plagiarism (FFP), they also lead to academic scandals and journal withdrawals. These behaviors are called "questionable research practices (QRPs)" and are related to the trustworthiness of management research and the quality of research and publication. Some scholars have studied and concluded that there are subjective and objective reasons to result in QRPs: the subjective aspect may be on account of achieving a certain publishing aim; while the objective aspect may be because the researcher has not received strict research training.

Therefore, the issue of "the trustworthiness of management research" has recently become one of the important topics in the field. This emerging front includes 8 core papers. The authors reanalyze empirical research or retracted papers, compare the doctoral theses and journal papers, and do semi-structured interviews to reveal possible academic misconduct. Finally, suggestions and advices are given to authors, reviewers, and journal editors to improve and maintain the trustworthiness and quality of management research.

APPENDIX

RESEARCH FRONTS: IN SEARCH OF THE STRUCTURE OF SCIENCE

▪ David Pendlebury

When Eugene Garfield introduced the concept of a citation index for the sciences in 1955, he emphasized its several advantages over traditional subject indexing.[1] Since a citation index records the references in each article indexed, a search can proceed from a known work of interest to more recently published items that cited that work. Moreover, a search in a citation index, either forward in time or backward through cited references, is both highly efficient and productive because it relies upon the informed judgments of researchers themselves, reflected in the references appended to their papers, rather than the choices of indexing terms by cataloguers who are less familiar with the content of each publication than are the authors. Garfield called these authors "an army of indexers" and his invention "an association-of-ideas index". He recognized citations as emblematic of specific topics, concepts, and methods: "the citation is a precise, unambiguous representation of a subject that requires no interpretation and is immune to changes in terminology."[2] In addition, a citation index is inherently cross-disciplinary and breaks through limitations imposed by source coverage. The connections represented by citations are not confined to one field or several – they naturally roam throughout the entire landscape of research. That is a particular strength of a citation index for science since interdisciplinary territory is well recognized as fertile ground for discovery. An early supporter of Garfield's idea, Nobel laureate Joshua Lederberg, saw this specific benefit of a citation index in his own field of genetics, which interacted with biochemistry, statistics, agriculture, and medicine. Although it took many years before the Science Citation Index (now the Web of Science) was fully accepted by librarians and the researcher community, the power of the idea and the utility of its implementation could not be denied. This year marks the 53th anniversary of the Science Citation Index, which first became commercially available in 1964. [3]

While the intended and primary use of the Science Citation Index was for information retrieval, Garfield knew almost from the start that his data could be exploited for the analysis of scientific research itself. First, he recognized that citation frequency was a method for identifying significant papers—ones with "impact"— and that such papers could be associated with specific specialties. Beyond this, he understood that there was a meaningful, if complex, structure represented in this vast database of papers and their associations through citations. In "Citation indexes for sociological and historical research," published in 1963, he stated that citation indexing provided an objective method for defining a field of inquiry.[4] That assertion rested on the same logical foundation that made information retrieval in a citation index effective: citations revealed the expert decisions and self-organizing behavior of researchers, their intellectual as well as their social associations. In 1964, with colleagues Irving H. Sher and Richard J. Torpie, Garfield produced his first historiograph, a linear mapping through time of influences and dependencies, illustrated by citation links, concerning the discovery of DNA and its structure. [5] Citation data, Garfield saw, provided some of the best material available for building out a picture of the structure of scientific research as it really was, even for sketching its terrain. Aside from making historiographs of specific sets of papers, however, a comprehensive map of science could not yet be charted.

Garfield was not alone in his vision. During the same era, the physicist and historian of science, Derek J. de Solla Price, was exploring the characteristic features and structures of the scientific research enterprise. The Yale University professor used the measuring tools of science on scientific activity, and he demonstrated in two influential books, of 1961 and 1963, how science had grown exponentially since the late 17th century, both in terms of number of researchers and publications.[6, 7] There was hardly a statistic about the activity of scientific research that his restless mind was not eager to obtain, interrogate, and play with. Price and Garfield became acquainted at this time, and Price, the son of a tailor, was soon receiving data, as he said, "from the cutting- room floor of ISI's computer room." [8] In 1965, Price published "Networks of scientific papers," which used citation data to describe the nature of what he termed "the scientific research front." [9] Previously, he had used the term "research front" in a generic way, meaning the leading edge of research and including the most knowledgeable scientists working at the coalface. But in this paper, and using the short-lived field of research on N-rays as his example, he described the research front more specifically in terms of its density of publications and time dynamics as revealed by a network of papers arrayed chronologically and their inter-citation patterns. Price observed that a research front builds upon recently published work and that it displays a tight network of relationships.

"The total research front of science has never been a single row of knitting. It is, instead, divided by dropped stitches into quite small segments and strips. Such strips represent objectively defined subjects whose description may vary materially from year to year but which remain otherwise an intellectual whole. If one would work out the nature of such strips, it might lead to a method for delineating the topography of current scientific literature. With such a topography established, one could perhaps indicate the overlap and relative importance of journals and, indeed, of countries, authors, or individual papers by the place they occupied within the map, and by their degree of strategic centralness within a given strip."[10]

The year is 1972. Enter Henry Small, a young historian of science previously working at the American Institute of Physics in New York City who now joined the Institute for Scientific Information in Philadelphia hoping to make use of the Science Citation Index data and its wealth of title and key words. After his arrival, Small quickly changed allegiance from words to citations for the same reasons that had captivated and motivated Garfield and Price: their power and potential. In 1973, Small published a paper that was as groundbreaking in its own way as Garfield's 1955 paper introducing citation indexing for science. This paper, "Cocitation in the scientific literature: a new measure of relationship between two documents," introduced a new era in describing the specialty structure of science.[11] Small measured the similarity of two documents in terms of the number of times they were cited together, in other words their co- citation frequency. He illustrated his method of analysis with an example from recent papers in the literature of particle physics. Having found that such co-citation patterns indicated "the notion of subject similarity" and "the association or co-occurrence of ideas," he suggested that frequently cited papers, reflecting key concepts, methods, or experiments, could be used as a starting point for a co-citation analysis as an objective way to reveal the social and intellectual, or the socio-cognitive, structure of a specialty area. Like Price's research fronts, consisting of a relatively small group of recent papers tightly knit together, so too Small found co-citation analysis pointed to the specialty as the natural organizational unit of research, rather than traditionally defined and larger fields. Small also saw the potential for co-citation analysis to make, by analogy, movies and not merely snapshots. "The pattern of linkages among key papers establishes a structure or map for the specialty which may then be observed to change through time," he stated. "Through the study of these changing structures, co-citation provides a tool for monitoring the development of scientific fields, and for assessing the degree of interrelationship among specialties."

It should be noted that the Russian information scientist Irena V. Marshakova-Shaikevich also introduced the idea of co-citation analysis in 1973.[12]

Since neither Small nor Marshakova-Shaikevich knew of each other's work, this was an instance of simultaneous and independent discovery. The sociologist of science Robert K. Merton designated the phenomenon "multiple discovery" and demonstrated that it is more common in the history of science than most recognize. [13,14] Both Small and Marshakova-Shaikevich contrasted co-citation with bibliographic coupling, which had been described by Myer Kessler in 1963. [15] Bibliographic coupling measures subject similarity between documents based on the frequency of shared cited references: if two works often cite the same literature, there is a probability they are related in their subject content. Co-citation analysis inverts this idea: instead of the similarity relation being established by what the publications cited, co-citation brings publications together by what cites them. With bibliographic coupling, the similarity relationships are static because their cited references are fixed, whereas similarity between documents determined by co-citation can change as new citing papers are published. Small has noted that he preferred co-citation to bibliographic coupling because he "sought a measure that reflected scientists' active and changing perceptions."[16]

The next year, 1974, Small and Belver C. Griffith of Drexel University in Philadelphia published a pair of landmark articles that laid the foundations for defining specialties using co-citation analysis and mapping them according to their similarity. [17,18] Although there have since been significant adjustments to the methodology used by Small and Griffith, the general approach and underlying principles remain the same. A selection is made of highly cited papers as the seeds for a co-citation analysis. The restriction to a small number of publications is justified because it is assumed that the citation histories of these publications mark them as influential and likely representative of key concepts in specific specialties, or research fronts. (The characteristic hyperbolic distribution of papers by citation frequency also suggests that this selection will be robust and representative.) Once these highly cited papers are harvested, they are analyzed for co-citation occurrence, and, of course, there are many zero matches. The co-cited pairs that are found are then connected to others through single-link clustering, meaning only one co-citation link is needed to bring a co-cited pair in association with another co-cited pair (the co-cited pair A and B is linked to the co-cited pair C and D because B and C are also co-cited). By raising or lowering a measure of co-citation strength for pairs of co-cited papers, it is possible to obtain clusters, or groupings, of various sizes. The lower the threshold, the more papers group together in large sets and setting the threshold too low can result in considerable chaining. Setting a higher threshold produces discrete specialty areas, but if the similarity threshold is set too high, there is too much disaggregation and many "isolates" form. The method of measuring co-citation similarity and the threshold of co-citation strength employed in creating research fronts has varied over the years. Today, we use cosine similarity, calculated as the co-citation frequency count divided by the square root of the product of the citation counts for the two papers. The minimum threshold for co-citation strength is a cosine similarity measure of .1, but this can be raised incrementally to break apart large clusters if the front exceeds a maximum number of core papers, which is set at 50. Trial and error has shown this procedure yields consistently meaningful research fronts.

To summarize, a Research Front consists of a group of highly cited papers that have been co-cited above a set threshold of similarity strength and their associated citing papers. In fact, the Research Front should be understood as both the co-cited core papers, representing a foundation for the specialty, and the citing papers that represent the more recent work and the leading edge of the Research Front.

The name of the Research Front can be derived from a summarization of the titles of the core papers or the citing papers. The naming of Research Fronts in Essential Science Indicators relies on the titles of core papers. In other cases, the citing papers have been used: just as it is the citing authors who determine in their co-citations the pairing of important papers, it is also the citing authors who confer meaning on the content of the resulting Research Front. Naming Research Fronts is not a wholly algorithmic process, however. A careful, manual review of the cited or citing papers sharpens accuracy in naming a Research Front.

In the second of their two papers in 1974, [19] Small and Griffith showed that individual research fronts could be measured for their similarity with one another. Since co- citation defined core papers forming the nucleus of a specialty based on their similarity, co-citation could also define research fronts with close relationships to others. In their mapping of research fronts, Small and Griffith used multidimensional scaling and plotted similarity as proximity in two dimensions.

Price hailed the work of Small and Griffith, remarking that while co-citation analyses of the scientific literature into clusters that map on a two dimensional plane “may seem a rather abstruse finding,” it was “revolutionary in its implications.” He asserted: “The finding suggests that there is some type of natural order in science crying out to be recognized and diagnosed. Our method of indexing papers by descriptors or other terms is almost certainly at variance with this natural order. If we can successfully define the natural order, we will have created a sort of giant atlas of the corpus of scientific papers that can be maintained in real time for classifying and monitoring developments as they occur.”[20] Garfield remarked that “the work by Small and Griffith was the last theoretical rivet needed to get our flying machine off the ground.”[21] Garfield, ever the man of action, transformed the basic research findings into an information product offering benefits of both retrieval and analysis. The flying machine took off in 1981 as the ISI Atlas of Science: Biochemistry and Molecular Biology, 1978/80. [22] This book presented 102 research fronts, each including a map of the core papers and their relationships laid out by multidimensional scaling. A list of the core papers was provided with their citation counts, as well as a list of key citing documents, including a relevance weight for each that was the number of core documents cited. A short review, written by an expert in the specialty, accompanied these data. Finally, a large, foldout map showed all 102 research fronts plotted according to their similarities. It was a bold, cutting edge effort and a real gamble in the marketplace, but of a type wholly characteristic of Garfield.

The ISI Atlas of Science in its successive forms—another in book format and then a series of review journals [23,24] —did not survive beyond the 1980s, owing to business decisions at the time in which other products and pursuits held greater priority. But Garfield and Small both continued their research and experiments in science mapping over the decade and thereafter. In two papers published in 1985, Small introduced an important modification to his method for defining research fronts: fractional co-citation clustering. [25] By counting citation frequency fractionally, based on the length of the reference list in the citing papers, he was able to adjust for differences in the average rate of citation among fields and therefore remove the bias that whole counting gave to biomedical and other “high citing” fields. As a consequence, mathematics, for example, emerged more strongly, having been underrepresented by integer counting. He also showed that research fronts could be clustered for similarity at levels higher than groupings of individual fronts. [26] The same year, he and Garfield summarized these advances in “The geography of science: disciplinary and national mappings,” which included a global map of science based on a combination of data in the Science Citation Index and the Social Sciences Citation Index, as well as lower level maps that were nested below the areas depicted on the global map. [27] "The reasons for the links between the macro-clusters are as important as their specific contents," the authors noted. "These links are the threads which hold the fabric of science together."

In the following years, Garfield focused on the development of historiographs and, with the assistance of Alexander I. Pudovkin and Vladimir S. Istomin, introduced the software tool HistCite. Not only does the HistCite program automatically generate chronological drawings of the citation relationships of a set of papers, thereby offering in thumbnail a progression of antecedent and descendant papers on a particular research topic, it also identifies related papers that may not have been considered in the original search and extraction. It is, therefore, also a tool for information retrieval and not only for historical analysis and science mapping. [28, 29] Small continued to refine his co-citation clustering methods and to analyze in detail and in context the cognitive connections found between fronts in the specialty maps. [30, 31] A persistent interest was the unity of the sciences. To demonstrate this unity, Small showed how one could identify strong co- citation relationships leading from one topic to another and travel along these pathways across disciplinary boundaries, even from economics to astrophysics.[32, 33]

In this, he shared the perspective of E. O. Wilson, expressed in the 1998 book Consilience: The Unity of Knowledge. [34] Early in the 1990s, Small developed SCI- MAP, a PC based system for interactively mapping the literature. [35] Later in the decade, he introduced Research Front data into the new database Essential Science Indicators (ESI), intended mainly for research performance analysis. The Research Fronts presented in ESI had the advantage of being updated every two months, along with the rest of the data and rankings in this product. It was at this time, too, that Small became interested in virtual reality software for its ability to create immersive, three-dimensional visualizations and to handle large datasets in real time. [36, 37] For example, in the late 1990s, Small played a leading role in a project to visualize and explore the scientific literature through co-citation analysis that was undertaken with Sandia National Laboratories using its virtual reality software tool called VxInsight. [38,39] This effort, with farsighted support of Sandia's senior research manager Charles E. Meyers, was an important step forward in exploiting rapidly developing technology that provided detailed and dynamic views of the literature as a geographic space with, for example, dense and prominent features depicted as mountains. Zooming into and out of the landscape allowed the user to travel from the specific to the general and back. Answers to queries made against the underlying data could be highlighted for visual understanding.

In fact, this moment—the late 1990s—was a turning point for science mapping, after which interest in and research about defining specialties and visualizing their relationships exploded. There are now a dozen academic centers across the globe focusing on science mapping, using a wide variety of techniques and tools. Developments over the last decade are summarized and illustrated in Indiana University professor Katy Borner's 2010 book, which carries a familiar-sounding title: Atlas of Science – Visualizing What We Know.[40]

The long interval between the advent of co-citation clustering for science mapping and the blossoming of the field, a period of about 25 years, is curiously about the same time it took from the introduction of citation indexing for science to the commercial success of the Science Citation Index. In retrospect, both were clearly ideas ahead of their time. While the adoption of the Science Citation Index faced ingrained perceptions and practice in the library world (and by extension among researchers whose patterns of information seeking were traditional), delayed enthusiasm for science mapping— a wholly new domain and activity—

can probably be attributed to a lack of access to the amount of data required for the work as well as technological limitations that were not overcome until computing storage, speed, and software advanced substantially in the 1990s. Data are now more available and in larger quantity than in the past and personal computers and software adequate to the task. Today, the use of the Web of Science for information retrieval and research analysis and the use of Research Front data for mapping and analyzing scientific activity have found not only their audiences but also their advocates.

What Garfield and Small planted many seasons ago has firmly taken root and is growing with vigor in many directions. A great life, according to one definition, is "a thought conceived in youth and realized in later life." This adage applies to both men. Clarivate Analytics is committed to continuing and advancing the pioneering contributions of these two legends of information science.

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About Institutes of Science and Development, Chinese Academy of Sciences

In November 2015, the CAS was identified in the National High-end Think Tanks Building Pilot Program as one of the first 10 high-caliber think-tank organizations directly under the CPC Central Committee, the State Council and the Central Military Commission of the CPC. It clarifies that priority should be given to the establishment of Institutes of Science and Development, Chinese Academy of Sciences (CASISD). CASISD was founded in January 2016. The orientation of CASISD is a research and support organization supporting the Academic Divisions of CAS (CASAD) to play its role as China's highest advisory body in science and technology. It is an important carrier and a comprehensive integration platform for the CAS to build a high-impact national S&T think tank, and an innovation center bringing together elite research forces from both inside and outside the CAS and across the world.

The missions of CASISD are to offer scientific and policy evidence to the government for its macroscopic decision-making through:

- Finding out trends and directions of S&T development in light of scientific rules and conducting research into major issues concerning socioeconomic progress and national security from the point of view of S&T impact by focusing on such areas as S&T development strategy, S&T and innovation policy, ecological civilization and sustainable development strategy, forecasting and foresight analysis, strategic information.
- Capitalizing the CAS advantage in integrating research institutions, academic divisions and universities, pooling together elite research talent both at home and abroad, and building an international strategy and policy research network featuring opening and cooperation.

About the National Science Library, Chinese Academy of Sciences

The National Science Library, Chinese Academy of Sciences (NSLC) is the largest research library in China. NSLC reserves information resources in natural sciences and high-tech fields for the researchers and students of Chinese Academy of Sciences and researchers around the country. It also provides services in information analysis, research information management, digital library development, scientific publishing (with its 17 academic and professional journals), and promotion of sciences. NSLC is a member in the International Federation of library Associations and Institutes (IFLA). It also is a member of Electronic Information for Libraries (EIFL) and Confederation of Open Access Repositories (COAR).

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Clarivate™ Analytics is the global leader in providing trusted insights and analytics to accelerate the pace of innovation. Building on a heritage going back more than a century and a half, we have built some of the most trusted brands across the innovation lifecycle, including the Web of Science™, Cortellis™, Derwent™, CompuMark™, MarkMonitor® and Techstreet™. Today, Clarivate Analytics is a new and independent company on a bold entrepreneurial mission, to help our clients radically reduce the time from new ideas to life-changing innovations. For more information, please visit clarivate.com.

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