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The past and future of transient receptor potential
A scientometric analysis

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Abstract

Background: Thermoreceptors include TRPV1 and TRPM8. TRPV1 and TRPM8 are TRP channels. TRP ion channels are widely expressed in many different tissues and cell types, and are involved in different physiological processes. Research on the structure and basic physiological functions of TRPV1 is relatively perfect, and the relationship between the pathogenesis of other members of the TRP family and specific diseases and TRPV1 remains to be explored in depth.

Methods: Articles regarding TRP were culled from the Web of Science Core Collection, and knowledge maps were generated using the CiteSpace software.

Results: In total, 19,862 articles were included. The number of published articles on this topic has rapidly increased since 2000, with more than 1000 articles published per year by 2020. MAKOTO TOMINAGA was the author with the most articles. The countries with the most articles were the United States and China. However, the number of articles in the U.S. was 3 times that in China. The organizations that publish the most articles are Harvard University in the US and Seoul Natl University in South Korea. TRP and the pathogenesis of diseases, such as neuropathy and stroke, are hotspots of current research.

Conclusion: To our knowledge, this is the first study to provide an overview of the literature on TRP. Research on TRPs is developing rapidly.

Abbreviations: TRP = transient receptor potential.

Keywords: bibliometrics, CiteSpace, hotspots, transient receptor potential, trends

1. Introduction

Transient receptor potential (TRP) channels are the vanguard of sensory systems in response to temperature, touch, pain, osmolarity, pheromones, taste, and other stimuli. TRP is expressed at the end of a specific sensory element in the skin.[1,2] After the skin is stimulated by cold and heat, it activates the TRP protein family. TRPV3 is a subtype protein that senses heat, and TRPM8 is a "cold sense" protein.[3] Since it was reported in 2005, TRP has attracted considerable interest, and in light of recent events in the Nobel Prize in Physiology or Medicine, more people have followed TRP. Recent evidence suggests that David Julius exploited cryoelectron microscopy (cryo-EM) to visualize conformational transitions of the capsaicin receptor, TRPV1. It describes the conformational transition of TRPV1 and reveals the ion passage of this capsaicin receptor upon stimulation.[4] Research on TRP involves important diseases in many departments and accounts for the majority of tumor research. In the future, TRP will become a breakthrough for people to overcome various diseases. However, few writers have been able to draw on any systematic research into TRP. This study systematically reviews the data for TRP, and the knowledge was mapped from the extracted bibliographic records using CiteSpace to analyze the TRP research status, aiming to provide research directions in this field and prospects for future research hotspots. This is the first study to undertake a longitudinal analysis of TRP. The reader should bear in mind that the study is based on Bibliometrics Visualization Analysis.

2. Methods

Literature was extracted from the Web of Science Core Collection, and the search and download process were carried out on October 6, 2021, to eliminate substantial errors

NJ, CP, SZ, and BC contributed equally to this work.

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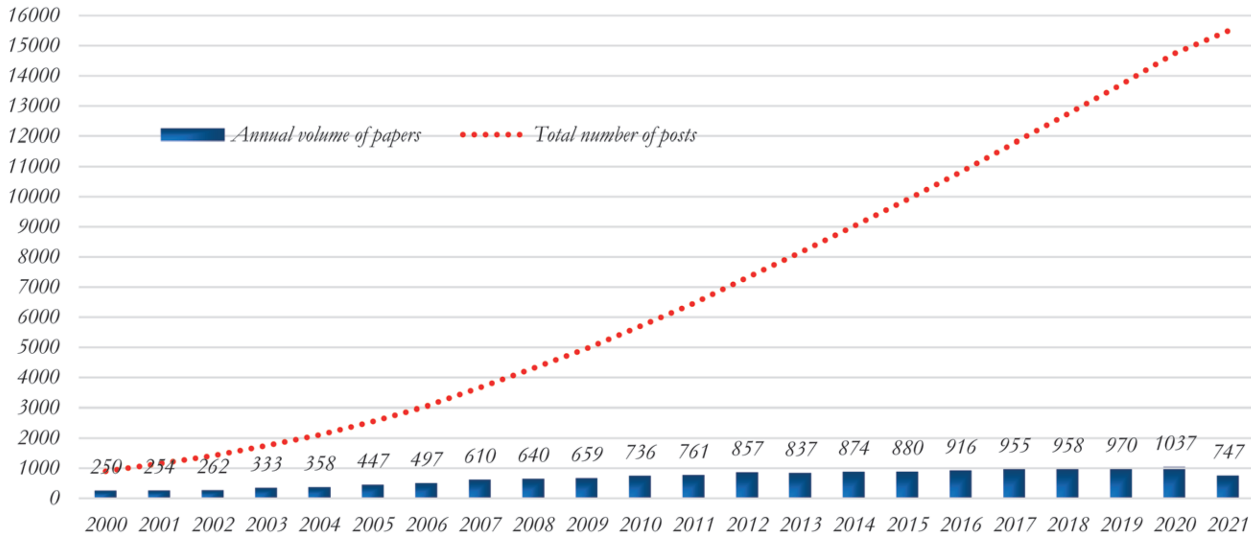

Figure 1. The number of articles published annually of annual articles related to TRP have been steadily increasing from 2000 to 2021. TRP = transient receptor potential.

caused by daily database updates. The search terms were as follows: TS = ("Transient Receptor Potential" OR "TRP") and invalid documents were eliminated. The search period ranged from June 5, 2001 to June 5, 2021, resulting in 19,862 records fetched. The retrieved papers were exported and saved as plain text files and stored in download_txt format. Given that the data were directly downloaded from the database, ethical approval was not required, and Microsoft Office Excel 2019 and CiteSpace were used to analyze the articles. Analyze the distribution of countries visually, authors and co-cited authors, co-cited references, keyword cluster analysis, and timelines.

3. Results

3.1. Publication outputs

In total, 19,862 articles were examined in the present study. Figure 1 shows the chronological distribution of the publications from 2000 to 2021. As shown in the diagram, the number of articles steadily increased. The histogram represents the number of articles published per year, and the red dotted line represents the cumulative number of articles published. The were of articles in 2020 has reached 1037. As of the search date, there are already 747 articles in 2021, and it is expected that the number of articles published this year will exceed 1500.

3.2. Funding agency

To a certain extent, funding agencies can reflect the hotspots in this field. The more funding there is, the more important is the research field. As shown in Table 1, the top 10 funding agencies include six in the United States and two in Japan, one from the European Union, and one from China. The top two institutions are from the United States, namely *the United States Department of Health Human Services* (5260, 26.483%) and *National Institutes of Health NIH USA* (5243, 26.397%). The third is an institution from China, *the National Natural Science Foundation of China NSFC* (1482, 7.461%).

Table 1

Funding agency of relevant papers on TRP published from 1990 to 2021.

No.	Funding agency	Record	% of 19,862
1	United States Department of Health Human Services	5260	26.483
2	National Institutes of Health NIH USA	5243	26.397
3	National Natural Science Foundation of China NSFC	1482	7.461
4	European Commission	1398	7.039
5	NIH National Heart Lung Blood Institute NHLBI	1255	6.319
6	NIH National Institute of Neurological Disorders Stroke NINDS	1222	6.152
7	Ministry of Education Culture Sports Science And Technology Japan MEXT	969	4.879
8	NIH National Institute of Diabetes Digestive Kidney Diseases NIDDK	804	4.048
9	Japan Society for the Promotion Of Science	789	3.972
10	NIH National Institute of General Medical Sciences NIGMS	719	3.62

TRP = transient receptor potential.

3.3. Analysis of authors and author collaboration

In total, 14,44 author were chosen/selected from 19,862 publications. The top 10 most productive authors contributed 619 articles (3.12%) to the TRP research (Table 2). MAKOTO TOMINAGA contributed the most articles (113 articles), followed by YASUO MORI and LUTZ BIRNBAUMER with 38 and 37 publications, respectively (Table 3). Their centrality scores were low, with only one researcher reaching above 0.05. The co-citation network map of the authors contained 1741 links, and there was active collaboration among the productive authors (Fig. 2).

3.4. Distribution of countries/regions and institutions

From 415 countries and 841 units, 19,862 papers were published. As shown in Table 3, the most significant number of

Table 2

Top 10 authors in the number of papers published.

No.	Freq	Degree	Centrality	Author	Year	Half-life
1	113	25	0.03	MAKOTO TOMINAGA	2006	8.5
2	78	27	0.04	YASUO MORI	2006	8.5
3	77	16	0.06	LUTZ BIRNBAUMER	2007	6.5
4	63	13	0.02	VINCENZO DI MARZO	2007	5.5
5	60	10	0.02	INSUK SO	2007	5.5
6	59	20	0.04	BERND NILIUS	2007	2.5
7	53	13	0.03	THOMAS VOETS	2007	6.5
8	39	6	0	LUCIANO DE PETROCELLIS	2007	5.5
9	39	9	0.04	WOLFGANG LIEDTKE	2007	3.5
10	38	15	0.03	THOMAS GUDERMANN	2008	6.5

Table 3

Top 10 countries/regions and institutions related to pyroptosis.

No.	Country	Year	Centrality	Count (%)	Institution	Year	Centrality	Count (%)
1	USA	1990	1.3	6386 (32.15)	Harvard Univ	1999	0.07	226 (1.14)
2	China	2003	0.02	2165 (10.90)	Seoul Natl Univ	2003	0.02	216 (1.09)
3	Japan	2003	0.04	1377 (6.93)	Johns Hopkins Univ	1999	0.07	191 (0.96)
4	Germany	2003	0.06	1150 (5.79)	Duke Univ	1998	0.04	188 (0.95)
5	England	2004	0.07	745 (3.75)	Kyoto Univ	1998	0.04	182 (0.92)
6	South Korea	2003	0.03	566 (2.85)	Univ Maryland	1998	0.04	181 (0.91)
7	Italy	2005	0.03	544 (2.74)	Katholieke Univ Leuven	2001	0.05	165 (0.83)
8	Canada	2007	0.03	519 (2.61)	Chinese Acad Sci	2005	0.01	134 (0.67)
9	Japan	1990	0.13	488 (2.46)	CNR	1998	0.03	125 (0.63)
10	Germany	1991	0.19	486 (2.45)	Univ Cambridge	1998	0.03	118 (0.59)

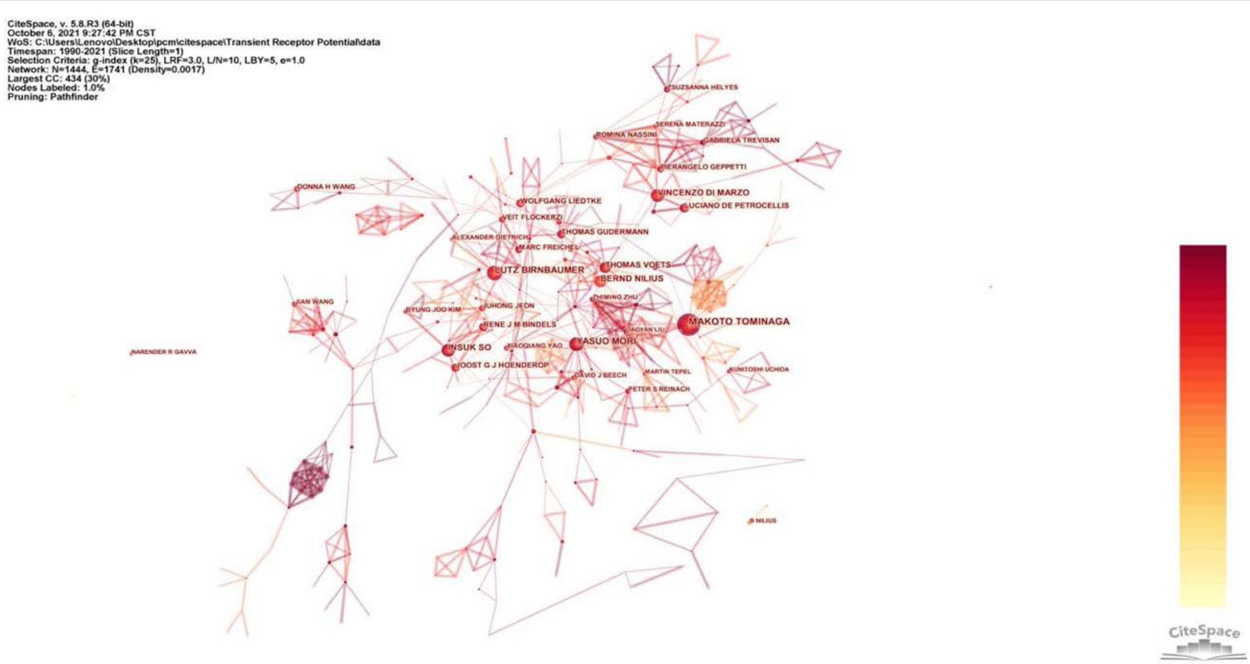

Figure 2. Map of authors' collaborations related to TRP research. TRP = transient receptor potential.

publications came from the USA (6386, 32.15%), which is far more than 3 times higher than that of China (2165, 10.90%). Other countries that published more than 1000 articles included Japan (1377, 6.93%) and Germany (1150, 5.79%). Among the top 3 institutions, 2 of institutions are found to be in the USA: Harvard University and Johns Hopkins University. The second-ranked institution is Seoul National University of South Korea, as indicated by the purple circles in Figures 3 and 4. Each circle in the figure represents a country, and the size of the circle indicates the country's publication output. The lines between the circles denote cooperation between countries; the wider the lines, the closer the cooperation.

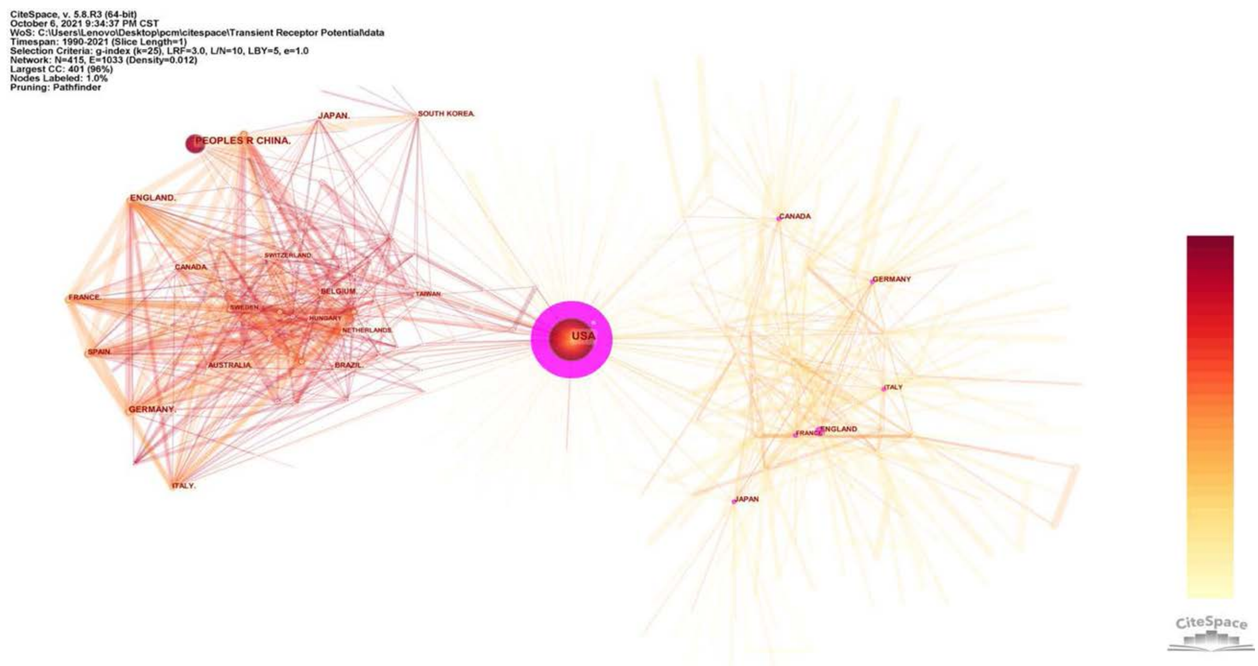

Figure 3. Distribution of publications from different countries/regions.

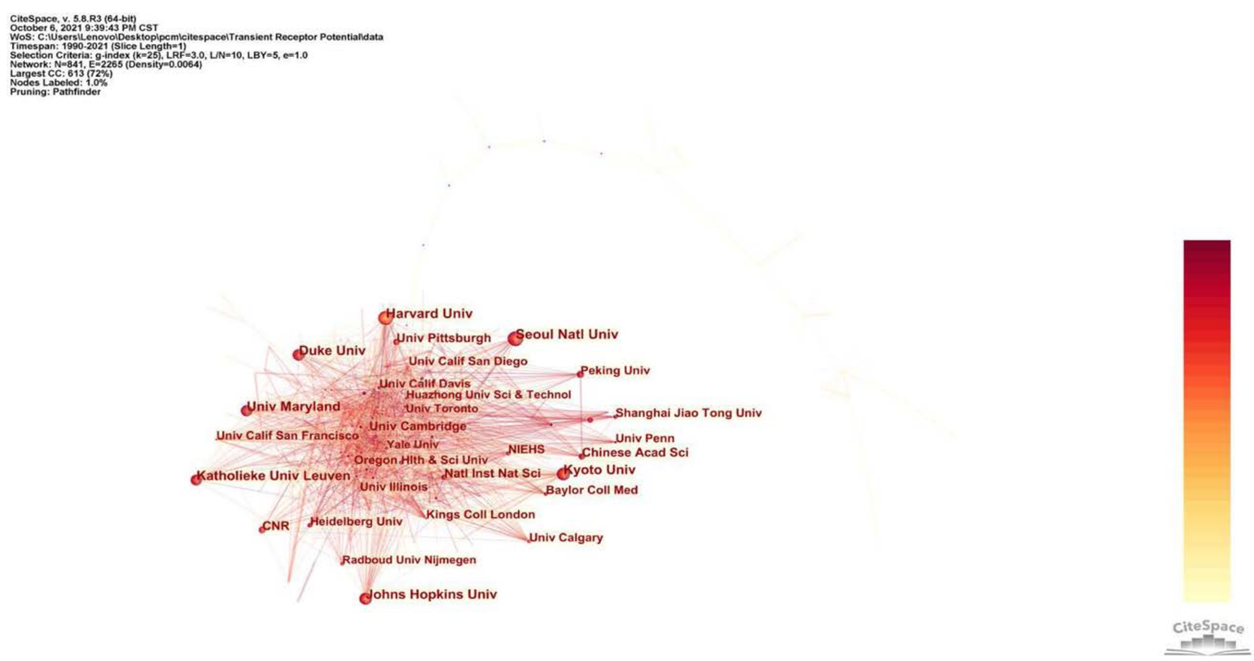

Figure 4. Distribution of publications from different institutions.

3.5. Co-occurrence of keywords and analysis of research hotspots

Keywords were extracted from titles and abstracts of all 19,862 publications. Figure 5 shows the keywords mentioned most frequently in publications; there were 1126 nodes and 7864 links in the network map. In terms of frequency, these terms “activation”(2973 times), “expression”(2518 times), “receptor”(1962 times), “channel”(1702 times), “ion channel”(1264 times), “rat”(1237 times), “mechanism”(1192 times), “cell”(1189 times), “pain”(1094 times), “protein”(976 times) appeared most. The top 20 keywords in terms of their frequency of use are listed in Table 4. By analyzing the evolution trend of keywords over time, one can better understand the dynamic trend of the TRP research field. For the documents selected in the WOS database, keywords were used to analyze the years. Documents with a node of 1126 and a line of 7864 were drawn as keyword co-occurrence time zone diagrams, as shown in Figure 6. We found that the initial research

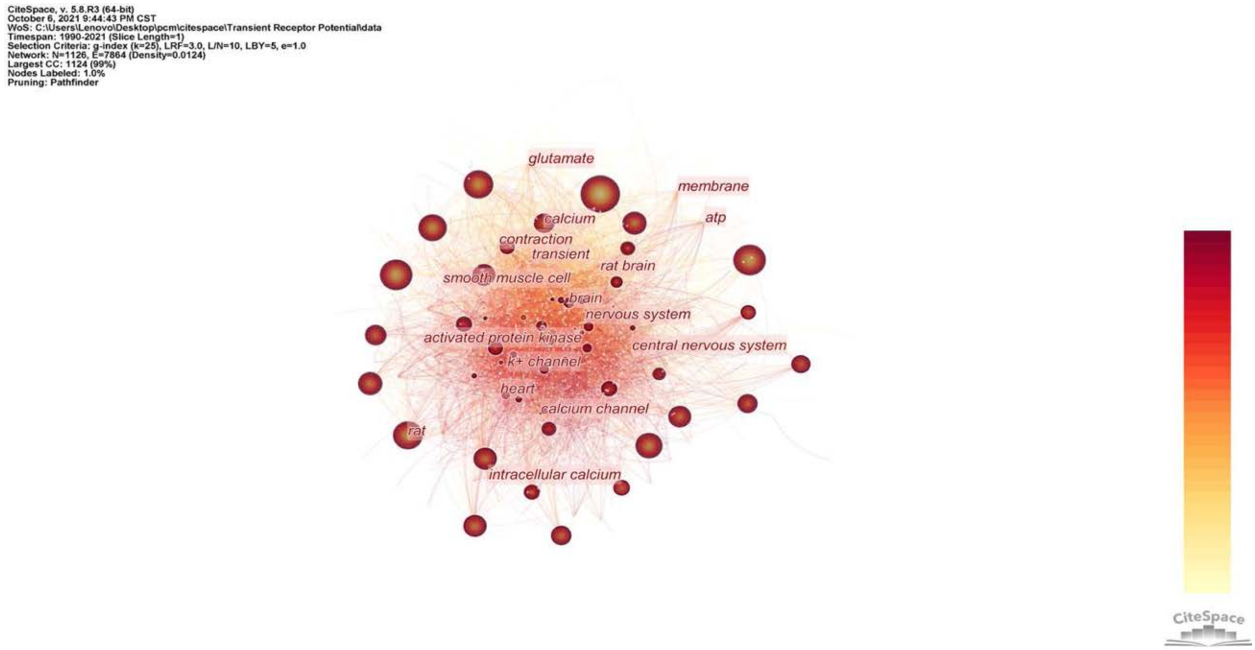

Figure 5. Map of co-occurring keywords related to TRP research. TRP = transient receptor potential.

Table 4

Top 20 keywords related to TRP.

No.	Freq	Degree	Centrality	Keyword	No.	Freq	Degree	Centrality	Keyword
1	2973	43	0.02	activation	11	969	32	0.01	capsaicin receptor
2	2518	36	0.02	expression	12	795	45	0.02	inhibition
3	1962	33	0.01	receptor	13	785	37	0.01	neuron
4	1702	41	0.01	channel	14	767	53	0.03	calcium
5	1264	33	0.01	ion channel	15	689	34	0.01	cation channel
6	1237	52	0.03	rat	16	630	41	0.02	mice
7	1192	42	0.01	mechanism	17	622	30	0.01	in vitro
8	1189	30	0.01	cell	18	567	36	0.01	release
9	1094	26	0	pain	19	566	43	0.02	sensory neuron
10	976	37	0.01	protein	20	532	38	0.02	identification

TRP = transient receptor potential.

focused on channels, activation, acetylcholine, etc. The keywords that appeared in the second stage were cgrp and hypertrophy.

A clustering analysis of the keywords was performed. The results are presented in Figure 7 and Table 5. There were 8 clusters of keywords, which are #0"breast cancer cell," #1"ventricular myocyte," #2"sensory neuron," #3"store-operated channel," #4"hippocampal slice," #5"cerebral ischemia-reperfusion cell," #6"design syntnesis," #7"adrenergic receptor".

Keywords with strong burst strength are another important indicator to reflect research hotspots, frontiers, and emerging trends over time. There are 553 hot keywords from 1990 to 2021 (附件 S1). For the focus and hotspot of research in this field, we display the keywords in 3 parts. As shown in Table 6, The top 10 keywords with the longest research time in the past 30 years are displayed. As shown in Table 7, The top 15 keywords from 2015 to 2021 are displayed. Table 8 displays 25 keywords from 2019 to 2021. Most notably, 25 keywords have continued to 2021, and the bursts are still ongoing, indicating that these research directions have received great attention in recent years and have the potential to become new research hotspots in the future.

3.6. Co-citation of reference

The top 20 TRP articles with the highest citations are shown in Table 9 and Figure 8. The authors of these papers are Clapham,[5] Nilius et al,[6] Bautista et al,[7] Venkatachalam and Montell,[8] Ramsey et al,[9] Kwan et al,[10] Liao et al,[11] Clapham et al,[12] Jordt et al,[13] Story et al,[14] Bandell et al,[15] Macpherson et al,[16] Montell et al,[17] Cao et al,[18] Julius,[19] Paulsen et al,[20] Montell,[21] Gao et al,[22] McNamara et al,[23] and Moran et al.[24] Among the first 20 articles, there were 4 reviews[8,9,23,24] and 16 original articles. These articles provide foundational research on TRP, including the discovery of TRP channels, the structure of related proteins, and their correlation with diseases.

4. Conclusion

This study used scientometric tools to identify the knowledge base and research hotspots of TRPs. The number of published articles on this topic has rapidly increased since 2000, with more than 1000 articles published per year by 2020. The top 3 funded projects are the United States Department of Health Human Services, National Institutes of Health NIH USA, and National Natural Science Foundation of China NSFC.

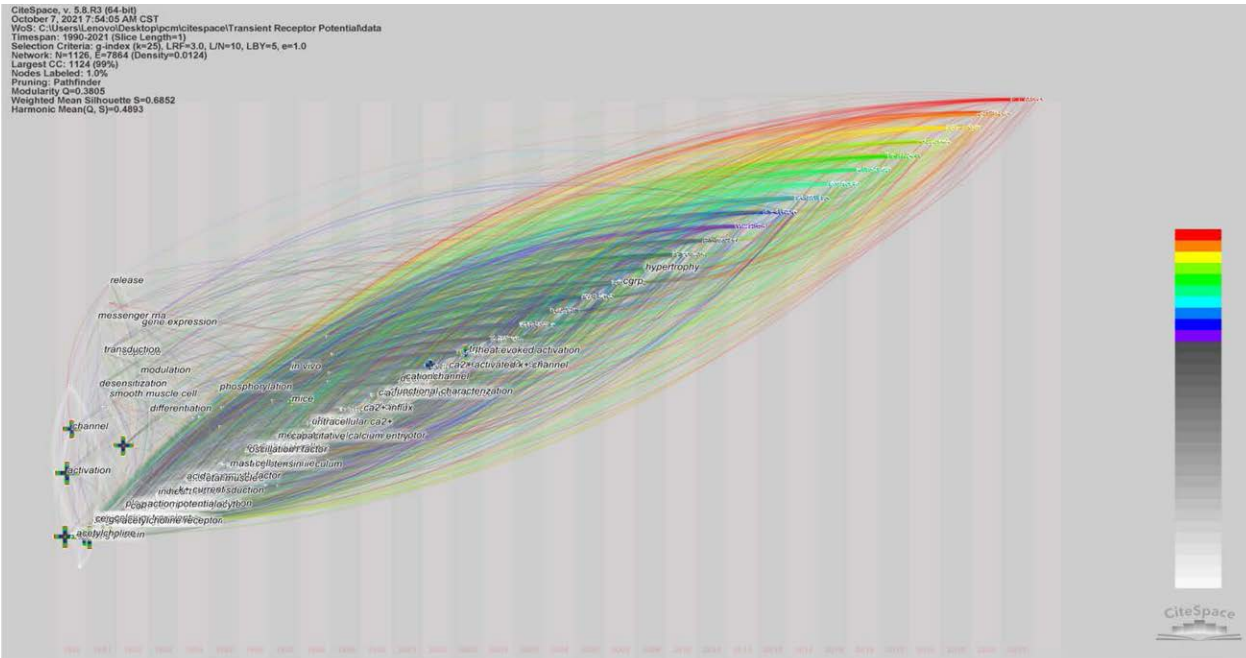

Figure 6. Timeline viewer related to TRP. TRP = transient receptor potential.

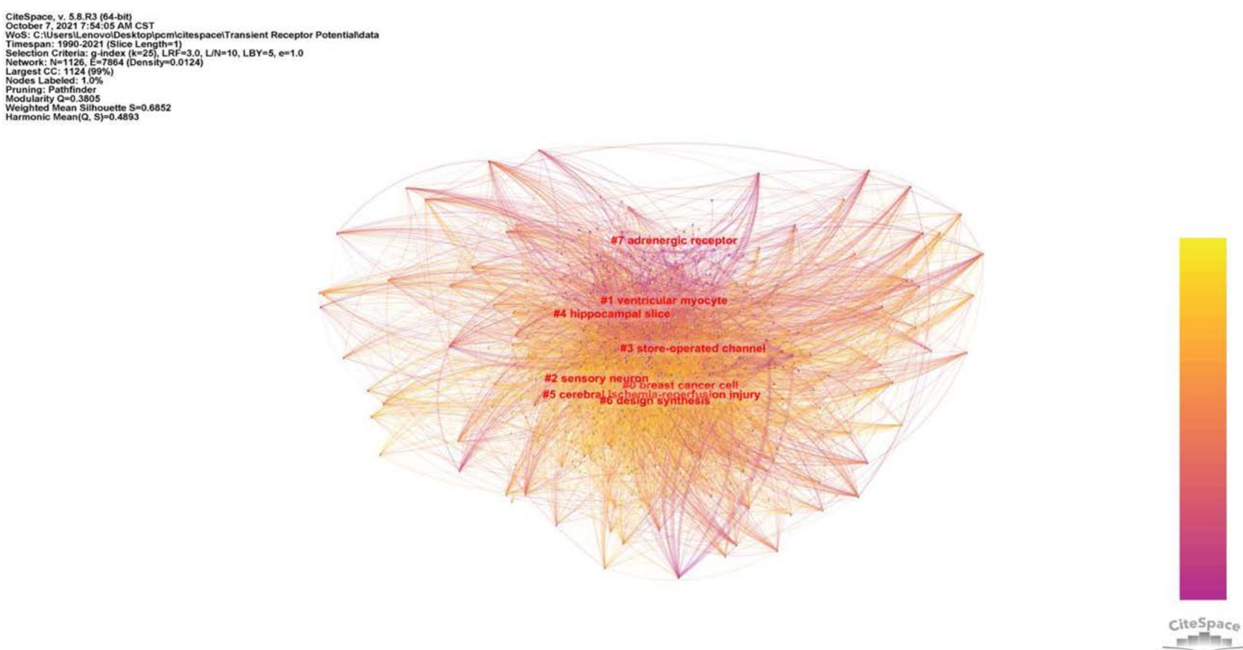

Figure 7. The term co-occurrence network in TRP research. TRP = transient receptor potential.

MAKOTO TOMINAGA was the author with the most articles. The countries with the most articles were the United States and China. However, the number of articles in the U.S. was 3 times bigger than that in China. The organizations that publish the most articles are Harvard University in the US and Seoul Natl University in South Korea. The keywords focus on these 8 areas, namely #0 "breast cancer cell," #1 "Ventricular myocyte," #2 "sensory neuron," #3 "store-operated channel," #4 "hippocampal slice," #5 "cerebral ischemia-reperfusion cell," #6 "design syntnesis," and #7 "adrenergic receptor."

This hotspot visualization study shows the historical progress of the TRP. Although TRP was first reported in the literature in the 1960s, there have been no breakthrough discoveries. For example, in 1969, when photosensitivity-deficient mutant flies were exposed to continuous light and showed only TRP, this gene was named TRP. Since the discovery of the conduction of cold and heat by TRP receptors in 2002, TRP-related research has become more concentrated and rapidly developed. The mammalian TRP pathway superfamily comprises 28 species, of which 27 are found in humans. Through the classification of sequence homology, the entire superfamily is divided into six subfamilies, namely TRP1-7, TRPV1-6, TRP m1-8, TRPML1-3, TRPP3, and TRPP2. TRPV3 is a subtype protein that senses heat, and TRPM8 is a "cold sense" receptor protein. Current

Table 5

Top 8 subjects of cluster analysis.

Cluster ID	Size	Year	Cluster label (LLR)
#0	210	2004	transient receptor; calcium-sensing receptor; risk factors; interleukin-1 receptor antagonist; cxcl12|expression; proliferation; ion channel; cancer; pathway
#1	184	1997	transient receptor; potential channels; heart failure; trpc channels; potential canonical channels|activation; channel; mechanism; in vivo; involvement
#2	184	2008	transient receptor; potential vanilloid type; chemokine receptor; renal injury; deoxycorticosterone acetate-salt|pain; expression; neuron; thermosensation; nociceptor
#3	184	2003	transient receptor; endothelial barrier dysfunction; tumor necrosis factor-alpha; store-operated calcium ion; growth|protein; expression; domain; cloning; period
#4	180	1999	transient receptor; potential ankyrin; neuron differentiation; social preference; anxiolytic-like behavior|long term; ischemic penumbra; animal models; uveal melanoma; superior colliculus
#5	151	2012	transient receptor; potential canonical channel; myocardial infarction; neurotrophic factor; tooth development|oxidative stress; dopamine d-4 receptor; soce; adp-ribose; ip3r
#6	22	2008	identification; expression; inflammation; capsaicin receptor; primary afferent neuron|transient receptor; potential canonical; non-selective cation channel; artemisia annua; membrane-delimited activator
#7	9	1998	secretion gene therapy; adeno-associated virus; ocular neovascularization; vascular endothelial growth factor; feline|ions sodium; ions calcium; opioid morphine; transgenic mouse; myocardial contractility

Table 6

Top 10 keywords with the strongest citation bursts from 1990 to 2021.

Keywords	Year	Strength	Begin	End	1990–2021
depolarization	1990	9.53	1991	2009	
messenger rna	1990	38.23	1991	2007	
calcium current	1990	12.85	1992	2008	
dentate gyrus	1990	7.45	1993	2009	
cloning	1990	34.91	1991	2006	
transient outward current	1990	27.75	1991	2006	
d aspartate receptor	1990	15.3	1991	2006	
transient	1990	15.09	1991	2006	
potassium current	1990	10.67	1992	2007	
transient forebrain ischemia	1990	9.33	1992	2007	

Table 7

Top 15 keywords with the strongest citation bursts from 2015 to 2021.

Keywords	Year	Strength	Begin	End	1990–2021
rat model	1990	14.27	2015	2021	
exposure	1990	11.13	2015	2021	
pathogenesis	1990	10.54	2015	2021	
trpv1 channel	1990	10.23	2015	2021	
food intake	1990	10.23	2015	2021	
multiple sclerosis	1990	9.44	2015	2021	
potential vanilloid 1	1990	8.91	2015	2021	
behavior	1990	8.21	2015	2021	
insulin resistance	1990	6.58	2015	2021	
efficacy	1990	5.91	2015	2021	
inflammatory response	1990	4.95	2015	2021	
ischemic stroke	1990	4.73	2015	2021	
recognition	1990	3.63	2015	2021	
role	1990	15.11	2016	2021	
trpa1	1990	11.98	2016	2021	

research has been conducted on specific diseases, such as chronic pain, neurology, oncology, dermatology, pulmonology, cardiology, urology, and some rare diseases.[25]

This article describes the longitudinal development process of the TRP. With people's in-depth understanding and research on TRP, it is believed that there will be further breakthroughs in the future, which will bring good news to the pathogenesis, research, and development of new drugs.

Author contributions

All authors have read and approved the manuscript and have ensured that this is the case.

Conceptualization: Nan Jiang, Ciming Pan, Changwu Dong.

Data curation: Ciming Pan.

Investigation: Nan Jiang.

Methodology: Shuhan Zhang, Bin Cheng.

Table 8

Top 25 keywords with the strongest citation bursts from 2019 to 2021.

Keywords	Year	Strength	Begin	End	1990–2021
model	1990	14.85	2019	2021	
fibrosis	1990	10.75	2019	2021	
management	1990	10.72	2019	2021	
reveal	1990	10.19	2019	2021	
mechanism	1990	9.54	2019	2021	
stroke	1990	8.06	2019	2021	
regeneration	1990	7.23	2019	2021	
delivery	1990	6.83	2019	2021	
trpv	1990	6.07	2019	2021	
performance	1990	5.88	2019	2021	
nanoparticle	1990	5.69	2019	2021	
volume	1990	5.64	2019	2021	
trpv1	1990	5.55	2019	2021	
trpm8	1990	5.48	2019	2021	
bradykinin	1990	5.16	2019	2021	
mortality	1990	5.12	2019	2021	
potential ankyrin 1	1990	5.09	2019	2021	
nadph oxidase	1990	4.77	2019	2021	
generation	1990	4.76	2019	2021	
nerve	1990	4.61	2019	2021	
neuropathy	1990	4.55	2019	2021	
exercise	1990	4.55	2019	2021	
antibody	1990	4.52	2019	2021	
diagnosis	1990	4.28	2019	2021	
receptor potential a1	1990	3.9	2019	2021	

Table 9

The top 20 TRP articles with the most citations (up to October 6, 2021).

No.	Freq	Degree	Centrality	Author	Year	Source	DOI	Main conclusion
1	265	1	0	Clapham DE	2003	NATURE	10.1038/nature02196	TRP channels are the vanguard of our sensory systems, responding to temperature, touch, pain, osmolarity, pheromones, taste and other stimuli.
2	220	2	0	Nilius B	2007	PHYSIOL REV	10.1152/physrev.00021.2006	Strong indications of the involvement of TRP channels in several diseases come from correlations between levels of channel expression and disease symptoms.
3	211	11	0.03	Bautista DM	2006	CELL	10.1016/j.cell.2006.02.023	TRPA1 is an important component of the transduction machinery through which environmental irritants and endogenous proalgesic agents depolarize nociceptors to elicit inflammatory pain.
4	201	3	0	Venkatachalam K	2007	ANNU REV BIOCHEM	10.1146/annurev.biochem.75.103004.142819	The TRP superfamily is divided into 7 subfamilies: the 5 group 1 TRPs (TRPC, TRPV, TRPM, TRPN, and TRPA) and two group 2 subfamilies (TRPP and TRPML). TRP channels are important for human health as mutations in at least 4 TRP channels underlie disease.
5	194	1	0	Ramsey IS	2006	ANNU REV PHYSIOL	10.1146/annurev.physiol.68.040204.100431	The aim of this review is to provide a basic framework for understanding the function of mammalian TRP channels, particularly as they have been elucidated in heterologous expression systems.
6	155	6	0.01	Kwan KY	2006	NEURON	10.1016/j.neuron.2006.03.042	TRPA1 is apparently not essential for hair-cell transduction but contributes to the transduction of mechanical, cold, and chemical stimuli in nociceptor sensory neurons.
7	154	7	0	Liao MF	2013	NATURE	10.1038/nature12822	Like voltage-gated channels, TRPV1 exhibits 4-fold symmetry around a central ion pathway formed by transmembrane segments 5–6 (S5–S6) and the intervening pore loop, which is flanked by S1–S4 voltage-sensor-like domains. TRPV1 has a wide extracellular 'mouth' with a short selectivity filter. The conserved 'TRP domain' interacts with the S4–S5 linker, consistent with its contribution to allosteric modulation.

(Continued)

Table9
(Continued)

No.	Freq	Degree	Centrality	Author	Year	Source	DOI	Main conclusion
8	148	6	0	Clapham DE	2001	NAT REV NEURO-SCI	10.1038/35077544	The channel subunits have six transmembrane domains that most probably assemble into tetramers to form non-selective cationic channels, which allow for the influx of calcium ions into cells. Three subgroups comprise the TRP channel family; the best understood of these mediates responses to painful stimuli.
9	147	9	0.02	Jordt SE	2004	NATURE	10.1038/nature02282	These findings identify a cellular and molecular target for the pungent action of mustard oils and support an emerging role for TRP channels as ionotropic cannabinoid receptors.
10	145	11	0.05	Story GM	2003	CELL	10.1016/S0092-8674(03)00158-2	The characterization of ANKTM1, a cold-activated channel with a lower activation temperature compared to the cold and menthol receptor, TRPM8.
11	142	10	0.01	Bandell M	2004	NEURON	10.1016/S0896-6273(04)00150-3	TRPA1 activation elicits a painful sensation and provide a potential molecular model for why noxious cold can paradoxically be perceived as burning pain.
12	141	11	0.01	Macpherson LJ	2007	NATURE	10.1038/nature05544	Covalent modification of reactive cysteines within TRPA1 can cause channel activation, rapidly signaling potential tissue damage through the pain pathway.
13	141	6	0.01	Montell C	2002	CELL	10.1016/S0092-8674(02)00670-0	TRP cation channels display an extraordinary assortment of selectivities and activation mechanisms, some of which represent previously unrecognized modes for regulating ion channels. The biological roles of TRP channels appear to be equally diverse and range from roles in pain perception to male aggression.
14	129	6	0.01	Cao EH	2013	NATURE	10.1038/nature12823	TRPV1 opening is associated with major structural rearrangements in the outer pore, including the pore helix and selectivity filter, as well as pronounced dilation of a hydrophobic constriction at the lower gate, suggesting a dual gating mechanism. Allosteric coupling between upper and lower gates may account for rich physiological modulation exhibited by TRPV1 and other TRP channels.
15	127	6	0	Julius D	2013	ANNU REV CELL DEV BI	10.1146/annurev-cellbio-101011-155833	Nociception is the process whereby primary afferent nerve fibers of the somatosensory system detect noxious stimuli. Three members of the transient receptor potential (TRP) ion channel family--TRPV1, TRPM8, and TRPA1--as molecular detectors of thermal and chemical stimuli that activate sensory neurons to produce acute or persistent pain.
16	124	9	0.02	Paulsen CE	2015	NATURE	10.1038/nature14367	The TRPA1 ion channel (also known as the wasabi receptor) is a detector of noxious chemical agents encountered in our environment or produced endogenously during tissue injury or drug metabolism. A blueprint for structure-based design of analgesic and anti-inflammatory agents.
17	123	1	0	Montell Craig	2005	Sci STKE	10.1126/stke.2722005re3	The TRP superfamily is divided into 7 subfamilies, the first of which is composed of the “classical” TRPs’ (TRPC subfamily).
18	116	14	0.04	Gao Y	2016	NATURE	10.1038/nature17964	The locations of annular and regulatory lipids and showed that specific phospholipid interactions enhance binding of a spider toxin to TRPV1 through formation of a tripartite complex.
19	112	12	0.02	McNamara CR	2007	P NATL ACAD SCI USA	10.1073/pnas.0705924104	TRPA1 is the principal site of formalin's pain-producing action in vivo, and that activation of this excitatory channel underlies the physiological and behavioral responses associated with this model of pain hypersensitivity.
20	111	7	0.01	Moran MM	2011	NAT REV DRUG DISCOV	10.1038/nrd3456	This Review focuses on recent developments in the TRP channel-related field, and highlights potential opportunities for therapeutic intervention.

TRP = transient receptor potential.

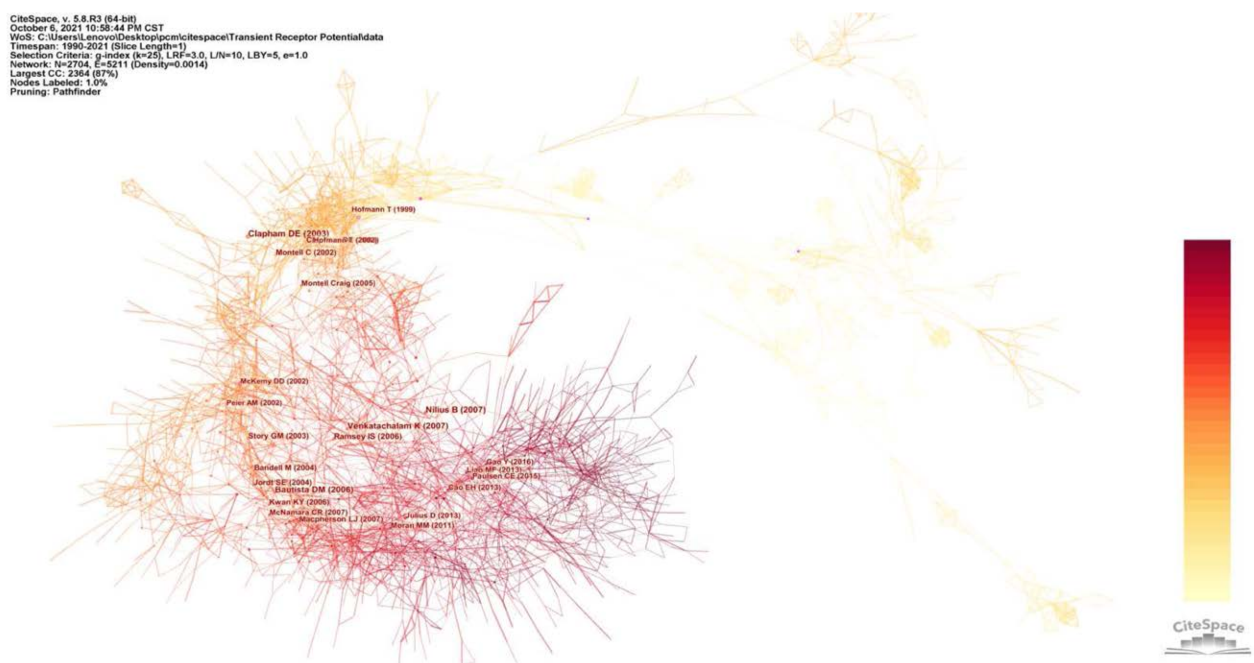

Figure 8. Document co-citation analysis in TRP research. TRP = transient receptor potential.

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