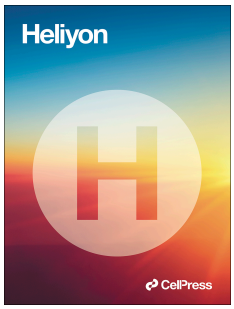

Global research Activity on olfactory marker protein (OMP): A bibliometric and visualized analysis

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Global Research Activity on Olfactory Marker Protein (OMP): A Bibliometric and Visualized Analysis

Short running title: Olfactory Marker Protein Research: Bibliometric Insights

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Abstract

Olfactory marker protein (OMP) is extensively studied in mature olfactory receptor neurons (ORNs) for understanding olfaction physiology. However, no bibliometric analysis on this topic exists. We conducted a bibliometric analysis of OMP research articles, wherein the publication count was assessed by year, country, journal, and author, collaboration by country, and productivity of the authors. Additionally, key terms and research themes were identified. Using the search phrase "olfactory marker protein" in Scopus, we retrieved 691 original research articles by 2487 authors since 1974. Publications showed an increasing trend, with the United States leading in quantity and collaboration. Our thematic map highlights "Olfactory bulb, regeneration, olfactory" as the primary research domain, while "olfaction, olfactory sensory neuron, glomerulus" and "olfactory receptor neurons, apoptosis, olfactory dysfunction" emerge as essential future research topics. These bibliometric findings offer insights into the global OMP research landscape, guiding researchers in potential collaborations and intriguing future research fields.

Keywords: Olfactory marker protein; olfactory receptor neurons; Scopus; Bibliometrix; VOSviewer

1. Introduction

Olfactory marker protein (OMP), a unique 19 kDa protein initially characterized by Frank Margolis in 1972 [1]. It plays a pivotal role in the olfactory system. Its multifaceted involvement spans from localizing in cilia, dendrites, somas and axons to collaborating with other proteins in odor transduction [2], OMP's presence extends from olfactory receptor neurons (ORNs) to the glomeruli in the olfactory bulb (OB), influencing the refinement of the glomerular map and axon pruning [2,3]. It is indispensable for establishing the neural network that discriminatively codes odor information [4-6], making it a widely employed marker in studying olfaction physiology, especially due to its significant expression in mature ORNs [1,7,8].

Despite its comprehensive expression in various tissues, including non-olfactory tissues such as the colon, bladder, pancreas, thyroid gland, hypothalamus, pituitary gland, and various other brain regions, including retinal horizontal cells [9] in several vertebrate species [10-13], the exact function of OMP remains poorly understood. While OMP has been explored in physiological studies [14], a bibliometric analysis of OMP literature is notably absent.

Existing bibliometric studies on olfaction have primarily focused on topics such as olfactory dysfunction [15], and its associations with anxiety or depression [16] and even COVID-19 [17]. However, OMP, despite its critical role, has not received dedicated bibliometric attention. This bibliometric study aims to address this gap by delving into OMP-related publications. The study is driven by several research questions, aiming to determine:

1. the distribution of publications concerning the quantity, countries, collaborations, journals, and authors,

2. the principal journal in the field by applying Bradford's law, and

3. the current keywords, co-occurrence keywords, and predominant clusters or themes linked to research on OMP.

The choice of bibliometric methods is motivated by the need for a comprehensive and quantitative understanding of the landscape of OMP literature. Bibliometric analysis provides a systematic and objective approach to map the trends, collaborations, and impact of publications in a specific field. It allows for a macroscopic view of the research landscape, offering insights into the evolution and current state of OMP-related research.

While systematic reviews excel at synthesizing qualitative data, bibliometric methods offer a quantitative lens, providing a more extensive overview of the research landscape. This focus on numbers, collaborations, and trends facilitates a comprehensive analysis that complements the depth provided by systematic reviews. The exclusion of mixed methods is justified by the study's need for a focused and quantitative assessment. Bibliometrics, emphasizing numerical data and patterns, aligns closely with the research objectives, enabling a clear and structured analysis of existing OMP literature.

2. Materials and methods

2.1. Data Source and Literature Inclusion Criteria

On 3 November 2022, each document was retrieved from the Scopus database. Documents were selected by searching their title-abstract-keyword for the term "olfactory marker protein". The initial exploration identified 747 documents related to olfactory marker protein. The selected documents were limited to research articles published in English-language journals, with no specific time limitations. Out of these, 691 articles met the inclusion criteria established for the study and were subsequently analyzed (Fig. 1).

The data was extracted from the database in scopus.csv format. The articles were carefully screened for duplicates as well as content based on titles, abstracts, and, if necessary, complete texts. Unrelated articles were omitted. Fig. 1 depicts the process flow diagram for study selection [18].

2.2. Data Analysis

Bibliometric analyses and the creation of a network map for co-occurrence author keywords were performed using the R package Bibliometrix (version 4.1.3) and VOSviewer (version 1.6.18). Through cluster analysis, a network map composed of nodes and links was generated. Clusters were identified by assessing the frequency of which the same key terms appeared in the various articles.

3. Results

From 1974 through November 2022, 691 original articles related to OMP were published in the Scopus database with 25033 citations. The mean citation count per article stood at 36.23, while the average annual citation rate per article was 2.50.

3.1. Publication by Year

Fig. 2 depicts the trend of OMP-related articles from 1974 to 2022. The inaugural publication on OMP dates back to 1974, authored by Margolis et al. The article, titled "Denervation in the primary olfactory pathway of mice: Biochemical and morphological effects" was featured in the Brain Research journal [19]. During the period from 1971 to 1991, the annual publication rate for OMP-related articles remained below 10 articles. However, since 1992, there has been a discernible uptick in academic interest in this research domain, evidenced by a consistent rise in the number of publications up to the present. Notably, the most frequently cited article, "Olfactory marker protein during ontogeny: Immunohistochemical localization" was published in the Developmental Biology journal in 1980, co-authored by Margolis himself [20].

3.2. Publication by Country

Based on the total number of publications per country, Table 1 presents the top ten countries in terms of OMP-related publications. The United States has contributed the most to this field of study, with the most publications (n = 383). Furthermore, Japan ranks second for publications (n = 97) followed by Germany (n = 72), Italy (n = 41), and France (n = 37).

Utilizing country collaboration networks, an analysis was undertaken to illustrate the collaborative patterns among countries in the realm of OMP. The count of publications per country was established based on the nationalities of associated authors. Fig. 3 illustrates the bibliographic collaboration among the top 17 countries engaged in OMP research. The visualization reveals two clusters, denoted by red and blue. Both clusters are interconnected, with the United States exhibiting the largest nodes and displaying extensive connections to numerous countries. Notably, a significant proportion of the prominent countries involved in OMP research is situated in Europe and other affluent regions.

3.3. Publication by Journal

This study identified 691 articles that have been published in 229 journals. Applying Bradford's law of scattering, we identified the primary journals within the study area and subsequently divided the total number of publications into three zones, as outlined in Table 2. There are nine core journals (zone 1) with 238 articles, 41 journals with 226 articles (zone 2), and 179 journals with 227 articles (zone 3).

Table 3 presents the top 10 core journals ranked by the quantity of published articles. The predominant focus among the leading ten journals is on neurology and neuroscience. The Journal of Comparative Neurology holds the highest number of published articles at 54, followed by the Journal of Neuroscience with 47, and Brain Research with 38 articles.

3.4. Publication by Authors

A sum of 2487 authors contributed to articles on OMP. Merely 14 articles were authored by a single individual, as the majority involved collaborative efforts, resulting in a collaboration index of 3.66. Table 4 outlines the most productive authors based on both the total number of publications and the total citations.

Margolis FL from the United States is the most prolific author, having authored 60 research articles and also ranks first in terms of the total amount of citations (3537 citations). Margolis FL has the greatest contribution in this area, as he is the topmost author and authored the earliest publication related to OMP. He has concentrated on this research area for an extended period (Fig. 4). In addition, the study reveals majority of the top ten authors are from the United States except for the fourth (Germany), ninth (Australia) and tenth (Italy).

3.5. Keywords Analysis

A thorough analysis of author keywords was conducted to uncover prevalent themes or clustered topics. Following the approach suggested by Cobo et al. [21], a thematic map was created using co-occurrence keywords, emphasizing density and centrality, and segmented into four topological zones (Fig. 5). The vertical axis illustrates density, while the horizontal axis represents centrality. Centrality indicates the degree of interconnection among different themes, while density gauges the cohesion between nodes [22].

Fig. 5 illustrates a thematic map showcasing frequently co-occurring keywords in OMP research, identified from author keywords. This analysis has found seven clusters, with the top three terms representing each cluster. The clusters "immunohistochemistry, olfactory system, transgenic mice" imply a driving theme in the upper right quadrant, denoted by high density and centrality (motor themes). These topics are crucial for future investigations and warrant further exploration. The lower-right quadrant, identified as basic themes, exhibits strong centrality but low density, signifying their importance as fundamental subjects in research and

integral to the field's advancement. Notable clusters in this quadrant include "OMP, olfactory epithelium, neurogenesis." Another well-developed cluster, "olfactory bulb, regeneration, olfactory," bridges the motor and basic themes, displaying high density and serving as a structural component within the study field. The upper-left quadrant, classified as niche themes, is characterized by high density but low centrality. This quadrant encompasses subjects such as "bromodeoxyuridine, olfactory receptors, microglia," which are highly specialized, specific, underrepresented, and rapidly evolving. In the lower-left quadrant, denoted as emerging or declining themes, both centrality and density are low. Clusters for "olfaction, olfactory sensory neuron, glomerulus" and "olfactory receptor neurons, apoptosis, olfactory dysfunction" are evident in this theme, suggesting topics that are either emerging or experiencing a decline in research focus.

Employing VOSviewer software, terms in the title, abstract, or keywords of each article were considered if they occurred at least three times, utilizing the full counting method. The analysis aimed to explore the prevailing trends in co-occurrence keywords. Utilizing co-occurrence keywords that appeared at least three times, a network map was generated, including 143 keywords out of a total of 1454 keywords (Fig. 6, top). The size and label of nodes correspond to the intensity or frequency of co-occurrences between two keywords, with thicker connection lines indicating stronger co-occurrence. The colors of nodes and lines are indicative of distinct clusters and time variations (Fig. 6, bottom).

According to the map, the co-occurrence keyword for OMP (“omp”) was the most commonly used keyword with an average publication year of 2004.59. The terms related to neurodegeneration, lectin, mouse model, microglia, nerve growth factor, olfactory function and chitosan appeared in 2016 onwards. The terms like “sars-cov2” and "covid-19," were the new terms in the field of OMP research, which appeared in the year 2021.

4. Discussion

The present study intended to provide a comprehensive evaluation of the available literature on OMP using bibliometric indicators. Our bibliometric analysis indicates that the number of publications showed an increasing trend from 1992 onwards. The vast number of publications in this field of study reflects the development of OMP research since its discovery in 1972 [1]. There are also a substantial number of authors (2487) involved in the publication of OMP-related research. The OMP is well-known for its role as an olfactory receptor neuron marker [23]. However, research in this field continues to expand as its functional relevance [2], potential impacts following diseases such as SARS-coronavirus 2 (SARS-CoV-2) [24] are still not fully understood, and its role as a marker in various diseases such as COVID-19 [25] and neurodegeneration [26,27] continues.

Concerning global distribution, it is unsurprising that the United States has emerged as a prominent contributor to OMP research, a trend noted in previous studies [15-17]. Various bibliometric investigations across different fields [28,29] have consistently identified the United States as a global leader in terms of publication quantity, quality, and collaborative participation. Our findings align with these observations. Other than the United States, numerous European countries and other affluent countries have significantly contributed to the production of high-quality articles and actively engaged in collaborative efforts within OMP research. The heightened publication output in these countries can be attributed to factors such as research funding, economic robustness, and the availability of research facilities [30]. It is recommended that low-income countries prioritize applied research by including socioeconomic and cultural factors in the solution of their day-to-day challenges, which inquiry is frequently neglected in research-intensive nations [31].

Interestingly, most of the articles related to OMP research were published in neurology or neuroscience-related journals, not otorhinolaryngology-related journals. This could be due to

OMP which is widely expressed in the olfactory system and most of the research is related to understanding molecular and olfactory information processing [2]. The journals with the most published articles were the Journal of Comparative Neurology followed by the Journal of Neuroscience and Brain Research. Journal of Comparative Neurology was established in 1891 and is the oldest continually published basic neuroscience journal. This journal is indexed in Scopus as well as Web of Science (Q1 under the Zoology category). Similarly, the Journal of Neuroscience ranks second, also indexed in both Scopus and Web of Science (Q1 under the Neuroscience category).

Keyword analysis presents an invaluable tool for discerning the trajectory of research trends [32]. In the context of OMP research, a nuanced evaluation of keywords has uncovered several intriguing developments, shedding light on potential future directions. Notably, keywords such as neurodegeneration, lectin, mouse model, microglia, nerve growth factor, olfactory function, and chitosan have emerged as prominent trends since 2016. These keywords collectively point toward a heightened focus on understanding the mechanisms underlying neurodegeneration and the regeneration of olfactory neurons, particularly within mouse models.

The identification of lectin as a trending keyword is of particular significance, given its demonstrated ability to induce apoptosis in mature olfactory receptor cells [33]. Furthermore, lectin histochemistry has proven to be a diagnostic and prognostic tool, offering insights into the pathophysiology of diseases related to the olfactory system and aiding in the identification of potential therapeutic targets [34]. Microglia, expressing different lectin types, have also come to the forefront, influencing their phenotypic changes and functional control [35]. The involvement of nerve growth factor, implicated in the growth, maintenance, and regeneration of olfactory receptor cells in the olfactory bulb, adds another layer to the evolving narrative [36,37].

Our thematic map unveils key areas that are pivotal to the ongoing development of OMP research, with themes such as "olfactory marker protein, olfactory epithelium, neurogenesis" forming the bedrock of the field's foundation. Concurrently, themes like "immunohistochemistry, olfactory system, and transgenic mice" represent well-established domains, indicative of active and mature study fields. However, it is the emergence of novel study clusters surrounding "olfaction, olfactory sensory neuron, glomerulus" and "olfactory receptor neurons, apoptosis, olfactory dysfunction" that signals the potential trajectories for future research and development.

Intriguingly, within the niche theme, a cluster focusing on "bromodeoxyuridine, olfactory receptors, microglia," has developed internal ties with OMP research, although its current contribution to the field's growth remains relatively minor. Meanwhile, the cluster centered around "olfactory bulb, regeneration, olfactory" stands out as a well-developed entity, serving as a bridge between the motor theme and the foundational topics.

A notable observation from this study is the emergence of new co-occurrence keywords such as "sars-cov2" and "covid-19" around 2021, underscoring the evolving landscape of OMP research. COVID-19, short for coronavirus disease 2019, is an infectious ailment triggered by SARS-CoV-2 [38]. Initially recognized in December 2019 in Wuhan, China, it evolved into a pandemic by March 2020 [38]. Subsequently, there has been a swift rise in the volume of publications related to COVID-19 research, particularly those investigating its impact on the olfactory system [24, 25, 39-41]. OMP has been used as a marker to determine the effects of COVID-19 on mature olfactory neurons [15, 17, 42]. This intersection of OMP research with COVID-19 opens up avenues for interdisciplinary collaboration and underscores the dynamic nature of ongoing developments in the field.

There are several limitations of this study. First, while this study focuses on the quality of journal sources, it may overlook some journals that are not included in the Scopus database.

Second, for the keyword analysis, encompassing a thematic map and trending keywords, this study exclusively considered English-language articles due to the inability to analyse articles in other languages. Third, only keywords with high frequency are selected. Thus, some essential keywords with low frequency may be disregarded. Fourth, to maintain the formality and completeness of the listed literature, editorials, book chapters, and conference papers are excluded, which may have caused the omission of certain representative works.

5. Conclusion

Employing carefully selected bibliometric indicators, this study systematically examines literature related to OMP. It encompasses analysis of the annual publication trends, the collaborations of countries, authors' productivity and a keyword analysis. The findings unveil a substantial surge in OMP research over the past decade, with the United States and other high-income countries prominently leading the field on a global scale. Beyond the assessment of influential papers, this study furnishes valuable insights for prospective research on olfactory receptor neurons, apoptosis, and olfactory dysfunction. The outcomes of this bibliometric study offer researchers a comprehensive overview of the global OMP landscape, providing guidance for potential collaborations and identifying intriguing avenues for future research.

CRediT authorship contribution statement

S.A.A. and R.Z. designed the study and wrote the initial draft of the article. M.H.M.N. and A.R.J. collected, analysed, and interpreted the data. K.F.A., C.A.N.I., A.H.A. and Z.O. reviewed and edited the final draft of the article. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

Declaration of competing interest

The authors declare no conflict of interest.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, [R.Z.], upon reasonable request.

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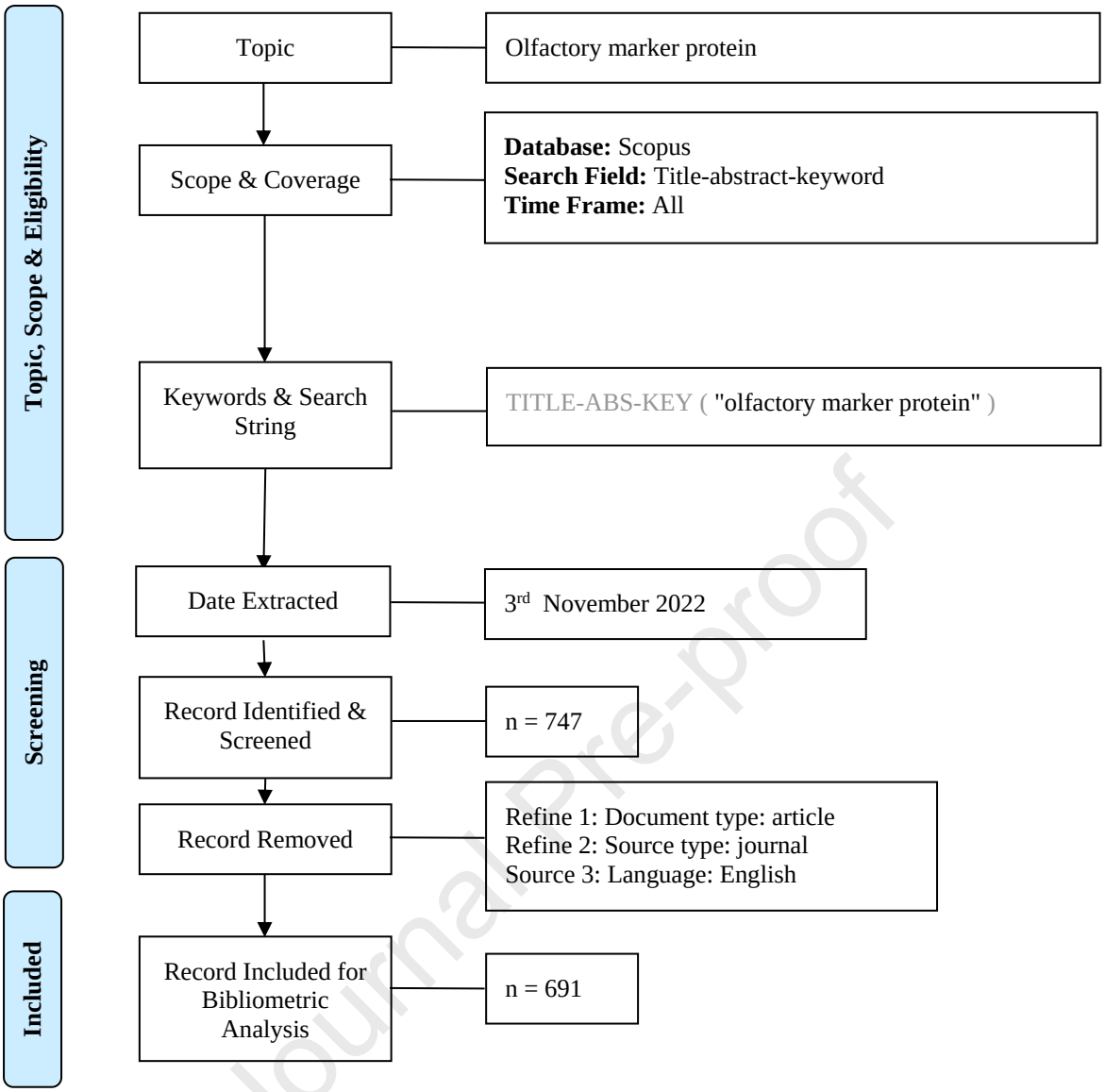

Fig. 1. PRISMA flowchart [18].

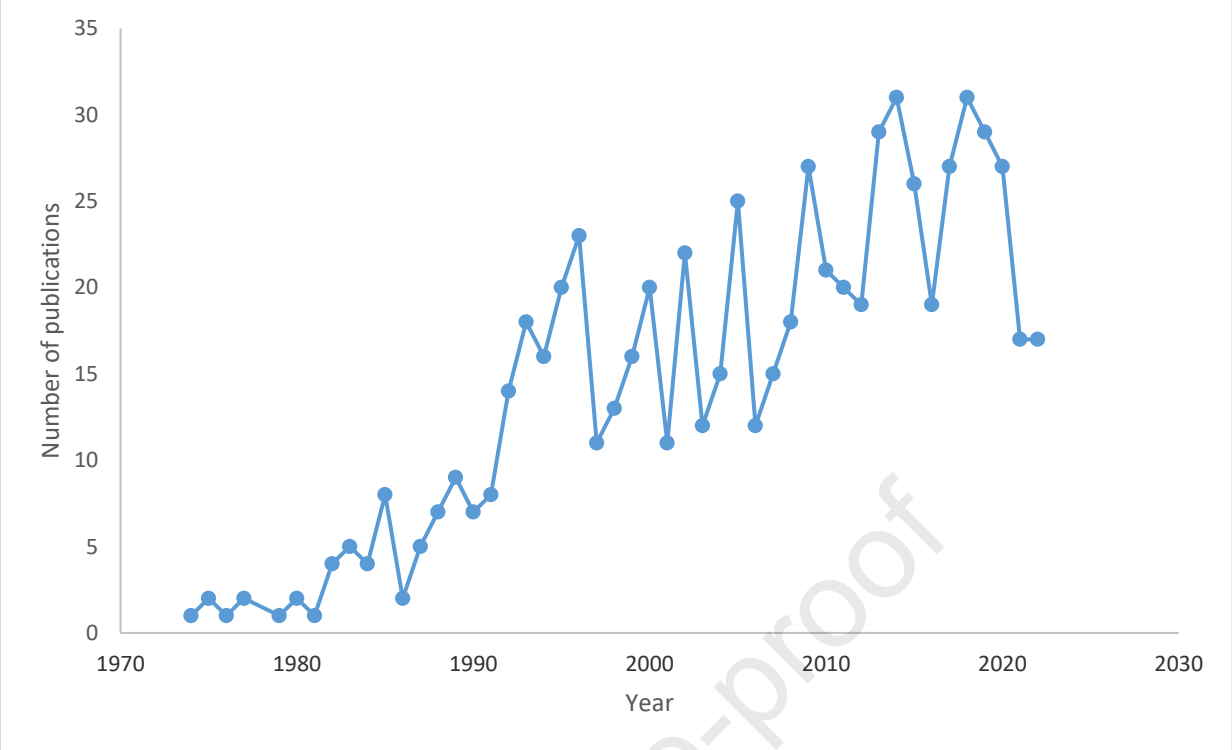

Fig. 2. Publication trend on the OMP research.

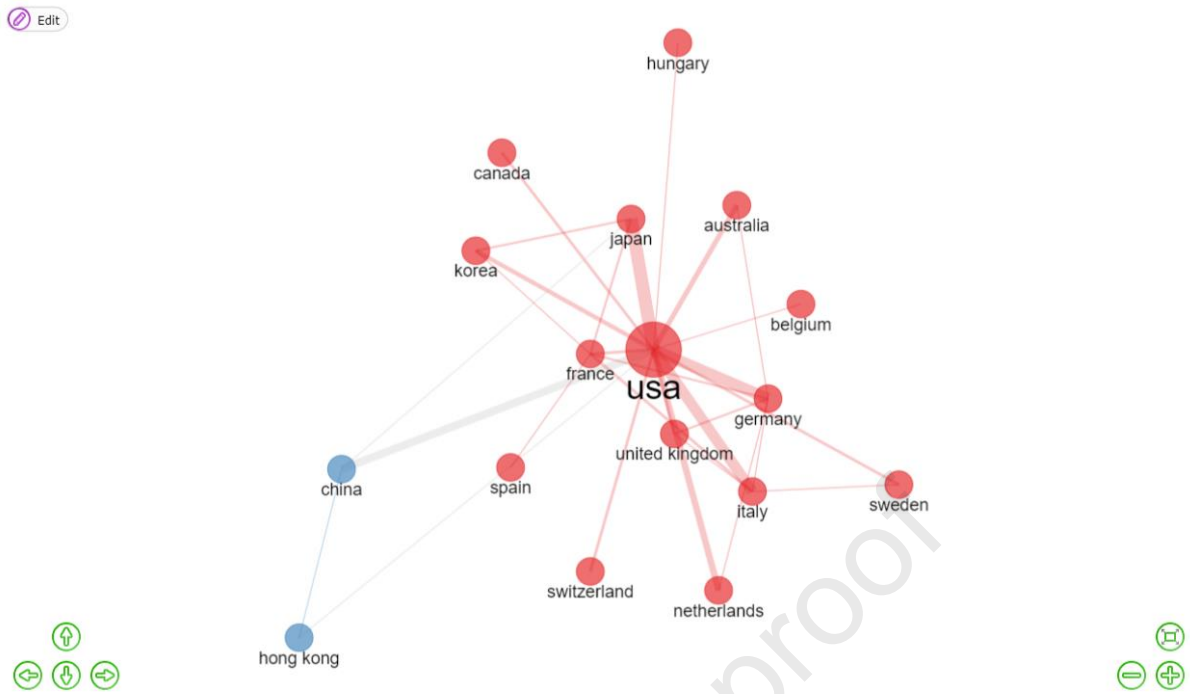

Fig. 3. Collaboration of countries publishing articles related to OMP.

Note: The size of the circles represents the number of collaborations with other countries.

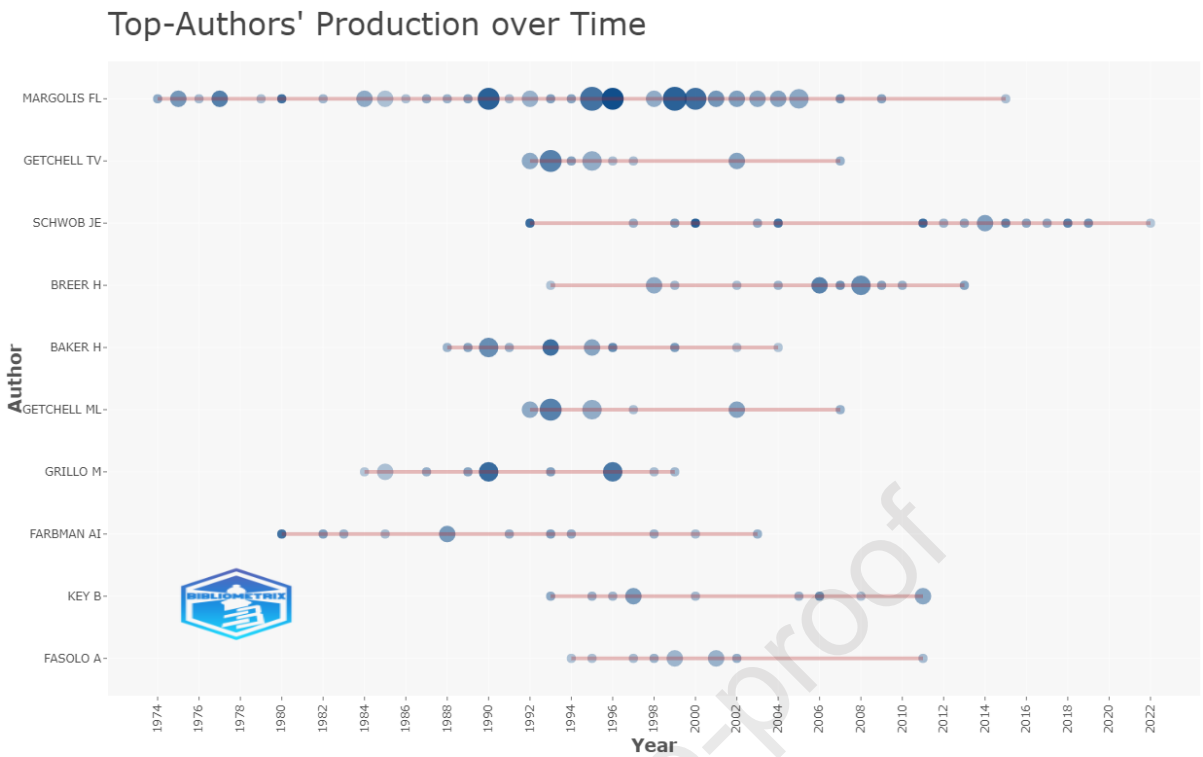

Fig. 4. The top authors' production over time.

Note: The size of the circles represents the frequency of articles published in a year; the intensity of the circles' color represents the papers' relevancy.

Fig. 5. Thematic map of publications related to OMP.

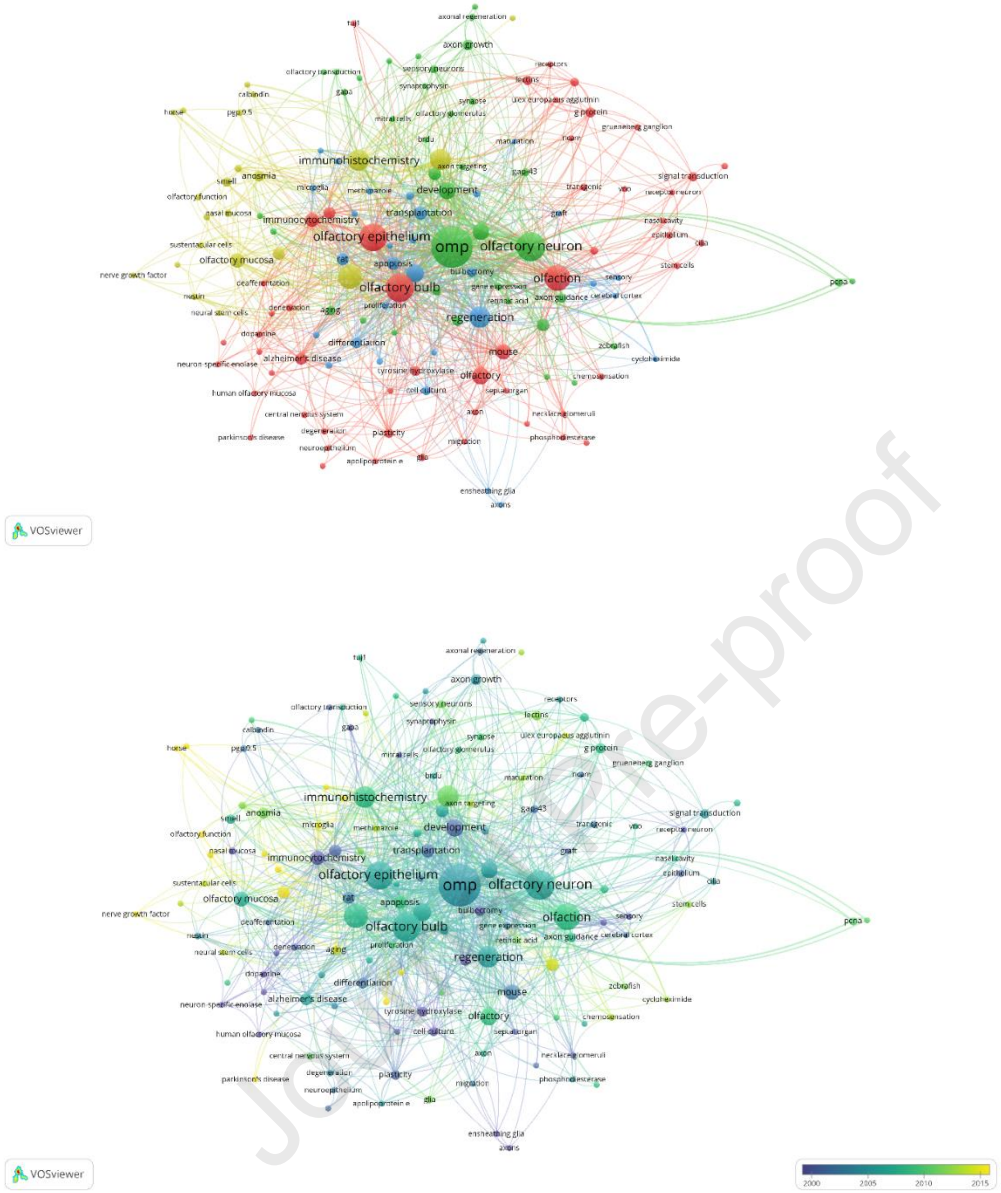

Fig. 6. Co-occurrence keywords related to OMP. A total of 143 out of 1454 keywords reached the threshold.

Note: The size of the label and the circle of an item is determined by the weight of the item. The higher the weight of the item, the larger the label and circle associated with it. The colour indicates timeline of the year of publication.

Table 1

Top ten countries in terms of OMP-related publications.

Rank	Country	TP
1	United States	383
2	Japan	97
3	Germany	72
4	Italy	41
5	France	37
6	South Korea	32
7	Australia	29
8	China	28
9	Spain	21
10	United Kingdom	20

TP: total publications

Table 2

Bradford's zones and their number of publications and journals.

Zone	Number of publications	Number of journals	Percentage of journals
1	238	9	3.9
2	226	41	17.9
3	227	179	78.2

Table 3

Top ten journals in terms of OMP-related publications.

Rank	Journal	CiteScore	TP
1	Journal of Comparative Neurology	6.1	54
2	Journal of Neuroscience	9.9	47
3	Brain Research	6.6	38
4	Neuroscience	6.8	21
5	NeuroReport	3.0	19
6	PloS One	6.0	16
7	Proceedings of the National Academy of Sciences USA	19.2	16
8	European Journal of Neuroscience	6.3	14
9	Chemical Senses	7.8	13
10	Journal of Neuroscience Research	8.2	11

TP: total publications

Table 4

Top ten authors in terms of OMP-related publications.

Rank	Author	Affiliation	TP	TC
1	Margolis FL	University of Maryland School of Medicine, Baltimore, United States	60	3537
2	Getchell TV	UK HealthCare, Lexington, United States	17	716
3	Schwob JE	Tufts University School of Medicine, Boston, United States	16	1119
4	Breer H	Universität Hohenheim, Stuttgart, Germany	15	507
5	Baker H	Weill Cornell Medicine Feil Family Brain & Mind Research Institute, New York, United States	14	982
6	Getchell ML	UK HealthCare, Lexington, United States	14	535
7	Grillo M	Pfizer Inc., New York, United States	13	831
8	Farbman AI	Northwestern University, Evanston, United States	12	1089
9	Key B	The University of Queensland, Brisbane, Australia	11	444
10	Fasolo A	Università degli Studi di Torino, Turin, Italy	10	218

TP: total publications; TC: total citations

Declaration of interests

☐ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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