



Mapping the Development of Biological Sciences and Philosophical Thought: A Bibliometric Analysis of Global Research Trends

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abstract

This study aims to map the development of research at the intersection of biological sciences and philosophical thought, and to identify prevailing global trends within this interdisciplinary field. A bibliometric analysis approach was employed, utilizing data systematically retrieved from the Scopus database. A total of 95 English-language publications issued between 2021 and September 2025 were analyzed using VOSviewer to examine keyword co-occurrence patterns and visualize conceptual relationships among research topics. The findings reveal twelve distinct thematic clusters representing the intellectual structure of the field, encompassing themes such as evolution, philosophy of biology, ethics, biotechnology, and environmental issues. Overlay and density visualization analyses further indicate that topics pertaining to biotechnology, human enhancement, and ethical implications have emerged as prominent and rapidly developing research trends within the contemporary literature. Collectively, these findings demonstrate that the relationship between biological sciences and philosophical thought continues to evolve dynamically in parallel with ongoing scientific and technological advancements. This study further underscores the growing importance of interdisciplinary collaboration between biological sciences and philosophy in addressing the conceptual, ethical, and societal challenges inherent in modern biological research, while simultaneously offering a strategic roadmap for prospective scholarly inquiry at this productive disciplinary interface.

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1. Introduction

In recent decades, the relationship between biological sciences and philosophical thought has undergone significant development, driven by rapid scientific progress and the increasing complexity of interdisciplinary inquiry. Although this interaction has deep historical roots, most notably since the publication of Darwin's *On the Origin of Species*, developments in molecular genetics, neuroscience, biotechnology, and evolutionary theory have reshaped philosophical

discussions about life, human nature, and the structure of scientific explanation (Mayr, 1982; Kitcher, 2004). These advances highlight the enduring importance of philosophical reflection in interpreting biological discoveries and addressing the ethical issues that arise from contemporary practices.

A considerable amount of literature has examined foundational topics in the philosophy of biology, such as adaptation, natural selection, and the levels of selection (Okasha, 2006; Sterelny & Griffiths, 1999). In recent years, these discussions have expanded through interdisciplinary engagement with cognitive science and neurobiology. Arnellos and Moreno (2022) investigate the irreducibility of minimal perception, while studies on teleology (Gambarotto, 2022) and regional developments in the philosophy of biology (Lorenzano, 2023) illustrate the widening scope of this field. This expansion shows that philosophical inquiry continues to adapt as biological knowledge advances (Brigandt, 2013; Dupré, 2018).

The emergence of the Extended Evolutionary Synthesis (EES) has further intensified conceptual debates. Proponents such as Laland et al. (2015) argue that classical evolutionary theory must expand to incorporate developmental bias and epigenetic inheritance, while others like Pigliucci (2007) and Müller (2007) have questioned the necessity of such an extension. This ongoing discussion demonstrates the essential role of philosophy in evaluating explanatory power and methodological assumptions in biological theory. Furthermore, advancements in biotechnology challenge traditional perspectives, where Fernández Mateo (2023) highlights the philosophical implications of human enhancement technologies. At the societal level, challenges such as biodiversity loss underscore the necessity of ethical engagement, as discussed by Sandler (2014) and Ratti (2020) regarding the ethics of species and systems biology.

Despite this rich and expanding intellectual landscape, systematic mapping of global scholarship remains limited. Research tends to be fragmented across subfields, lacking a comprehensive understanding of how themes interconnect. Bibliometric analysis provides a systematic approach to examine the development of scientific literature and identify patterns of research production (Aria & Cuccurullo, 2017; Donthu et al., 2021). Furthermore, bibliometric methods enable the visualization of intellectual structures and thematic relationships within a research field (Zupic & Čater, 2015; Van Eck & Waltman, 2010).

Previous bibliometric studies in related areas have tended to focus on narrower subfields, such as bioethics (Sandler, 2014) or specific biological disciplines (Ratti, 2020; O'Malley, 2017), without offering a comprehensive and integrated mapping of the full intersection between biological sciences and philosophical thought. Moreover, existing reviews have largely relied on narrative and qualitative approaches rather than systematic quantitative methods (Brigandt et al., 2015; Zupic & Čater, 2015). To the best of our knowledge, no previous study has conducted a comprehensive keyword co-occurrence bibliometric mapping of the full intersection between biological sciences and philosophical thought using Scopus-indexed data from 2021 to 2025. The present study addresses this gap by providing a holistic, data-driven, and visual mapping of thematic clusters and emerging research trends across this interdisciplinary field, thereby complementing and extending previous scholarly efforts by offering a more systematic perspective on how biological and philosophical knowledge structures are interconnected globally (Pal et al., 2025; Van Eck & Waltman, 2014).

2. Method

The data for this study were retrieved from the Scopus database, selected for its comprehensive coverage of peer-reviewed literature and its reliable, structured metadata, which are essential for

accurate bibliometric analysis. Data collection was conducted on November 12, 2025. Using the search query : TITLE-ABS-KEY ("biological sciences" AND "philosophical thought"). To ensure data relevance and consistency, the dataset was limited to english language journal articles published between 2021 and September 2025. This initial search resulted yielded 95 publications.

All retrieved records were exported in CSV format and underwent a manual data *cleaning* process to remove duplicates and ensure consistency in bibliographic information including authors, titles, abstracts, keywords, and citations. This process was conducted to maintain the accuracy and reliability of the bibliometric mapping. The overall research procedure used in this study is presented in Figure 1.

The bibliometric analysis was conducted using VOSviewer software (version 1.6.20), a tool widely used for constructing and visualizing bibliometric networks (Van Eck & Waltman, 2010). In this study, keyword co-occurrence analysis was applied to identify the conceptual structure of the research field. A minimum occurrence threshold of 3 was established to filter the most relevant keywords, and improve the clarity of the visualized.

In the visualization result, each keyword is represented as a node, where node size indicates the frequency of occurrence. The distance between nodes indicates the strength of their relationship among keywords, while different colors represent distinct thematic clusters. To improve analytical accuracy, a manual screening process was conducted to remove general and non-informative keywords such as (e.g., "article," "priority journal," and "study"). Through this systematic procedure, VOSviewer enabled the mapping of research trends and the intellectual structure of studies linking biological sciences and philosophical thought.

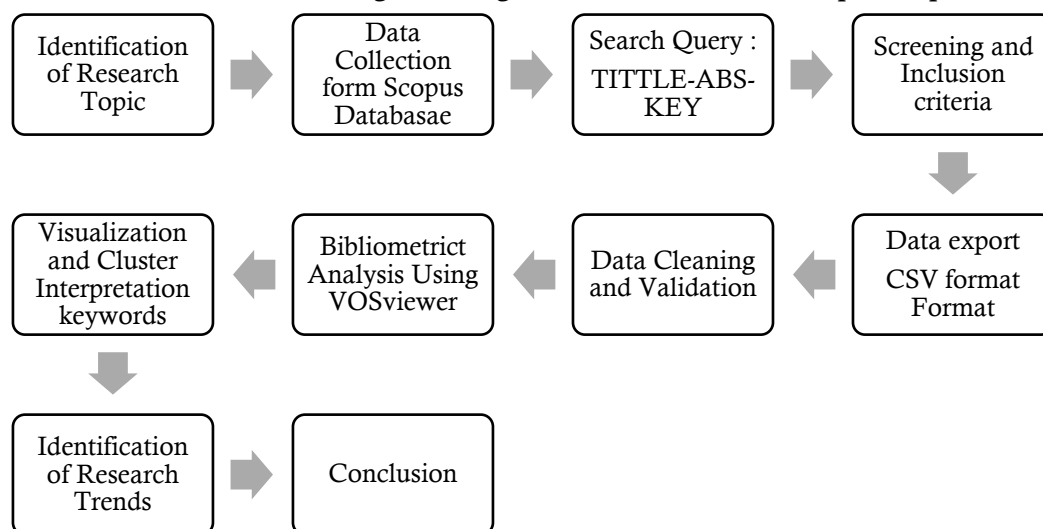


Figure 1. Research procedure flowchart

3. Result and Discussion

The analysis of Scopus-indexed publications reveals that the disciplines contributing most to the topic of biological sciences and philosophical thought are Social Sciences (50.0%) and Arts and Humanities (30.0%). This distribution highlights the central role of philosophical and social perspectives in interpreting contemporary biological issues. The dominance of Social Sciences reflects the increasing integration of biological knowledge within broader societal and ethical contexts, particularly in relation to biotechnology, environmental sustainability, and human values.

This finding reflects the growing integration of interdisciplinary perspectives in contemporary science. Similar arguments were proposed by Brigandt (2013), who emphasized that modern biological research increasingly depends on interdisciplinary collaboration and philosophical interpretation. Furthermore, Lorenzano (2023) highlighted that philosophical inquiry continues to evolve alongside rapid developments in biological sciences. These findings suggest that biology is no longer viewed solely as an empirical discipline, but also as a field requiring ethical and conceptual reflection. Therefore, the relationship between biological sciences and philosophical thought plays an important role in developing a more holistic and socially responsible understanding of science. The distribution of publications across subject areas is presented in Figure 2, revealing the disciplinary breadth of research at the intersection of biological sciences and philosophical thought.

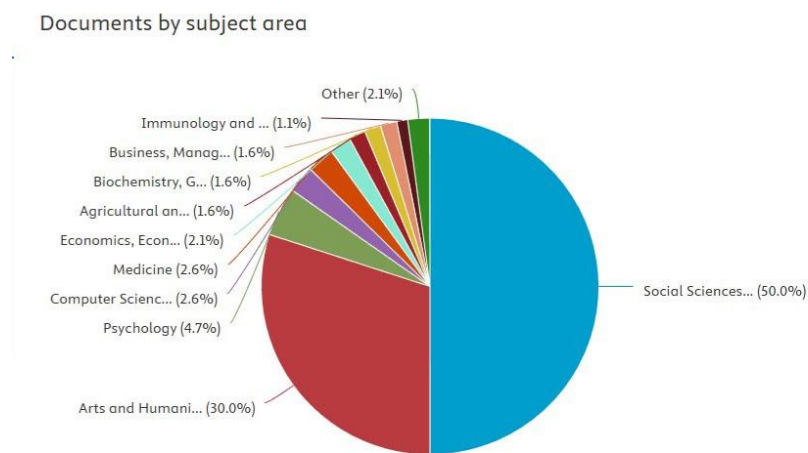


Figure 2. Distribution of publications by subject area

As illustrated in Figure 3, annual publication trends from 2021 to September 2025 demonstrate a fluctuating yet relatively stable trajectory of research interest in this interdisciplinary field. The number of publications peaked in 2023 with 24 documents, followed by a moderate decline in 2024 and a subsequent recovery in 2025. This pattern reflects the dynamic development characteristic of emerging interdisciplinary research domains, wherein periods of rapid scholarly growth are often succeeded by phases of consolidation and thematic refinement, as researchers collectively reassess and reorient the conceptual boundaries of the field.

These fluctuations may also reflect shifts in global research priorities, particularly concerning bioethics, biotechnology, and environmental challenges arising from rapid technological advancement. Zupic and Čater (2015) explained that interdisciplinary research fields commonly experience fluctuating publication patterns as theoretical frameworks and research focuses continue to evolve. The recovery observed in 2025 indicates that the field remains relevant and adaptive to contemporary scientific and societal developments. This trend demonstrates that interdisciplinary discourse connecting biology and philosophy continues to expand in response to emerging global issues

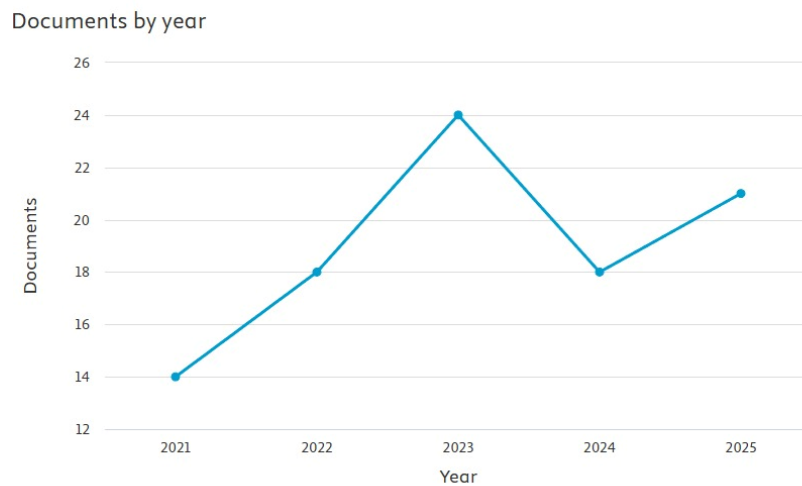


Figure 3. Annual publication trends (2021-2025)

As depicted in Figure 4, which presents the top ten countries by number of publications, research output in this interdisciplinary field is geographically concentrated among countries with strong and well-established academic traditions, most notably the United States, the United Kingdom, and Germany. This geographical dominance reflects the confluence of several structural factors, including the availability of substantial research funding, robust institutional support, advanced research infrastructure, and long-standing scholarly traditions in both biological sciences and philosophy. Countries endowed with strong academic ecosystems demonstrably tend to generate greater volumes of interdisciplinary research, owing to enhanced opportunities for cross-institutional collaboration and broader access to international scholarly networks. Notably, the pronounced concentration of publications among a limited number of nations simultaneously highlights the existence of considerable untapped potential for expanding research participation from underrepresented regions, particularly in the Global South, where interdisciplinary scholarship at the interface of biological sciences and philosophical thought remains considerably limited.

Nevertheless, this geographical concentration raises important concerns regarding epistemic dominance, wherein Western theoretical perspectives may disproportionately shape the conceptual frameworks, ethical orientations, and research priorities that define the field. Lorenzano (2023) emphasized the critical importance of epistemic diversification within the philosophy of biology as a means of fostering broader and more globally representative scholarly perspectives. Notwithstanding this concern, the gradually increasing contributions from previously underrepresented regions suggest that the field is progressively becoming more inclusive, pluralistic, and contextually sensitive in its scholarly orientation. This growing geographical participation reflects an expanding recognition that discussions at the intersection of biology and philosophy extend well beyond traditional Western-centered discourse, evolving toward a more globally representative and culturally diverse intellectual landscape. Furthermore, the increasing involvement of researchers from developing nations holds considerable potential for the emergence of alternative theoretical and ethical perspectives shaped by diverse cultural traditions, environmental contexts, and locally situated knowledge systems, thereby substantially enriching the scope and depth of interdisciplinary scientific discourse in this field.

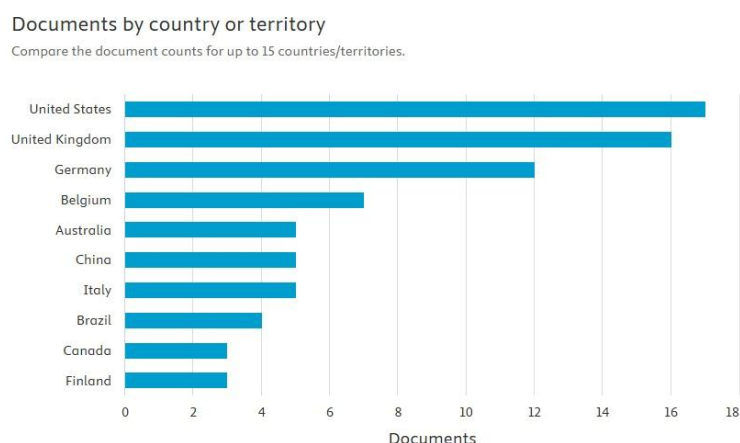


Figure 4. Top ten countries by number of publications

The keyword co-occurrence analysis conducted using VOSviewer identified twelve distinct thematic clusters representing the intellectual structure of the field, as systematically documented in Table 1. These clusters encompass a broad range of interconnected themes, including evolution, bioethics, cognition, biotechnology, environmental issues, digital humanities, and artificial intelligence, collectively reflecting the multidimensional nature of scholarly inquiry at the intersection of biological sciences and philosophical thought. The considerable diversity of these thematic clusters substantiates the inherently interdisciplinary complexity of this research domain, wherein biological and philosophical perspectives converge across multiple conceptual dimensions to address some of the most pressing scientific, ethical, and societal questions of the contemporary era.

Table 1. Keyword co-occurrence clusters identified through VOSviewer

No	Cluster	Primary Keyword
1.	Cluster 1	Philosophy of biology, system biology, environmental ethics
2.	Cluster 2	Evolution, natural selection, adaptation
3.	Cluster 3	Cognition, philosophy of mind, neurobiology
4.	Cluster 4	Bioethics, biotechnology, genetic engineering
5.	Cluster 5	Darwinism, evolutionary theory, history of science
6.	Cluster 6	Consciousness, identity, human nature
7.	Cluster 7	Human enhancement, transhumanism, morality
8.	Cluster 8	Epistemology, reductionism, methodology
9.	Cluster 9	Ecology, conservation, sustainability
10.	Cluster 10	Molecular biology, genetics, information theory
11.	Cluster 11	Paleontology, biology education, morphology
12.	Cluster 12	Digital humanities, artificial intelligence, big data

The strong relationship among clusters indicates that contemporary biological discussions increasingly intersect with ethical, philosophical, and technological concerns. For example, clusters related to evolution and natural selection are closely associated with bioethical discussions, suggesting that theoretical biological concepts significantly influence moral and societal debates. This finding supports Mateo (2023), who argued that rapid developments in biotechnology intensify philosophical discussions regarding morality, human enhancement, and scientific

This transformation reflects the increasing need for ethical and philosophical frameworks capable of guiding technological innovation responsibly. Mateo (2023) highlighted that rapid developments in biotechnology raise important philosophical concerns regarding human identity, morality, and the ethical boundaries of scientific intervention. Furthermore, the emergence of artificial intelligence-related discussions suggests that technological advancement is reshaping philosophical perspectives concerning human cognition, consciousness, and scientific responsibility.

The growing prominence of these themes indicates that contemporary biological sciences are no longer limited to empirical investigation but increasingly require ethical and philosophical evaluation to address societal implications. Therefore, interdisciplinary collaboration between biology and philosophy becomes increasingly important in ensuring responsible scientific development.

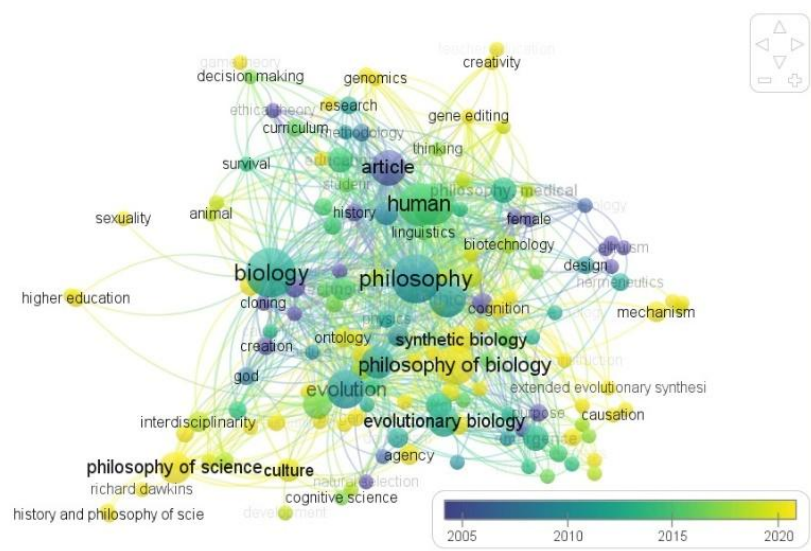


Figure 6. Evolution of research focus over time

The evolution of research focus over time, as depicted in Figure 6, is further elucidated through the density visualization, which highlights the concentration of research activity in core thematic areas such as philosophy of biology, evolution, and ethics. These areas exhibit the highest density within the visualization, collectively indicating their central importance, sustained scholarly attention, and intellectual maturity within the field. These foundational themes continue to function as the primary intellectual scaffolding guiding interdisciplinary discussions at the convergence of biology and philosophy.

In contrast, lower-density areas, including digital humanities, artificial intelligence, and advanced biotechnology, represent emerging research frontiers with considerable potential for future scholarly development and innovation. Van Eck and Waltman (2010) explained that density visualization serves as a powerful analytical tool for simultaneously identifying both well-established research themes and nascent scholarly opportunities within a given field. The emergence of these interdisciplinary topics within the lower-density zones of Figure 6 demonstrates that the field continues to evolve dynamically in response to rapid technological advancement and the growing complexity of contemporary societal challenges, signaling productive directions for future interdisciplinary inquiry at the intersection of biological sciences and philosophical thought.

whether ecological and evolutionary theories satisfy conventional criteria of scientific falsifiability, concluding that many explanatory principles operate as heuristic frameworks rather than strict empirical laws. Nyhart and Lidgard (2021) similarly revisited Simpson's foundational work on individuality and multilevel selection, demonstrating that classical evolutionary concepts remain philosophically contested and theoretically productive. These findings reinforce the claim that evolution-centred clusters retain their intellectual centrality within the interdisciplinary landscape.

Among the most rapidly emerging themes identified in the overlay visualization are biotechnology ethics, human enhancement, and transhumanism. These findings resonate strongly with Ćirković (2018), who examined post-postbiological evolutionary scenarios wherein artificial intelligence and distributed computing may fundamentally alter the trajectory of human biological development. Runehov (2008) further explored the philosophical and theological dimensions of human enhancement through cybernetics and neuropharmacology, highlighting profound questions about the boundaries of humanity. Can (2023) adds a critical cross-cultural dimension by evaluating transhumanist conceptions of human nature from an Islamic philosophical perspective, illustrating that ethical responses to biotechnology are culturally situated and epistemically diverse.

The emergence of artificial intelligence and digital humanities as distinct thematic clusters signals the expanding scope of philosophical engagement with technology. Zhang (2024) examines the philosophical implications of artificial general intelligence attaining self-awareness, arguing that biological and computational conceptions of consciousness are increasingly inseparable. Reinsborough (2020) demonstrates that art-science collaborations within synthetic biology contexts can serve as productive forums for responsible research and innovation dialogues, bridging the gap between scientific communities and broader publics. Collectively, these developments suggest that interdisciplinary discourse at the intersection of biology and philosophy must now incorporate technological epistemology as a core analytical domain.

The thematic clusters related to ecology, conservation, and sustainability reflect an enduring tension between holistic and reductionist approaches in biological philosophy. Ge and Xu (2014) demonstrated that even foundational ecological thinkers such as E.P. Odum held paradoxically hybrid positions combining holism with reductionism, indicating that this philosophical dichotomy resists simple resolution. Bartosch, Grandpierre, and Peng (2023) extend this debate toward a philosophy of cosmic life, arguing for an ecologically grounded and transcultural ontology of living systems. Such perspectives enrich the ethical and conceptual foundations required to address global sustainability challenges, reinforcing the present study's finding that ecology and environmental ethics constitute a structurally pivotal cluster within the broader intellectual network of biological sciences and philosophical thought.

4. Conclusion

This bibliometric study concludes that the relationship between biological sciences and philosophical thought represents a dynamic and continuously evolving interdisciplinary field. The analysis identified twelve thematic clusters reflecting the intellectual structure of the field, including evolution, bioethics, biotechnology, artificial intelligence, environmental issues, and digital humanities. These findings indicate that contemporary biological research increasingly intersects with philosophical, ethical, and societal considerations. The visualization analysis further demonstrates a significant shift from classical theoretical discussions toward more applied and future-oriented themes, particularly biotechnology ethics, human enhancement, and artificial intelligence. The results highlight that interdisciplinary research linking biology and philosophy

continues to evolve has become increasingly important in guiding scientific innovation and addressing the ethical implications of modern biological advancements. In addition, the strong interconnection among thematic clusters highlights the growing integration between empirical biological research and conceptual philosophical inquiry. This study contributes to the literature by providing a comprehensive mapping of global research trends related to biological sciences and philosophical thought. The findings offer valuable insights into the development of interdisciplinary discourse and help identify emerging research directions and knowledge gaps within the field. Future research is recommended to expand data sources beyond the Scopus database, incorporate comparative longitudinal bibliometric analyses, and explore qualitative approaches to examine ethical and philosophical issues in greater depth. Further interdisciplinary studies are also needed to better understand the societal implications of emerging biological technologies and scientific innovations.

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