Research on Analysis Methods for Academic Communities Based on Paper Co-authorship Networks: A Case Study of the Annals of the Association of American Geographers (Postprint)

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Abstract

【Objective】To analyze co-authorship networks of academic papers, identify and examine academic communities, and discover developmental patterns and evolutionary trends of the field.

【Method】A fast community detection algorithm was employed to identify academic communities within the co-authorship network. A comprehensive metric that integrates scholars' individual paper impact and collaborative impact was established to assess the academic influence of scholars within these communities. Using the three communities with highest academic influence as case studies, the development and evolution of academic communities were analyzed and discussed from a life cycle perspective.

【Results】Data analysis based on the Annals of the American Association of Geographers demonstrates that the proposed comprehensive metric can effectively identify outstanding scholars in academic communities. The life cycle-based analysis method for academic communities in co-authorship networks can uncover research trends and shifts in topical focus across different academic communities.

【Limitations】Using a single journal as an example may lead to a relatively limited composition of academic communities. Incorporating journal data from multiple sources could further enhance the credibility of research findings.

【Conclusion】The academic community analysis method proposed in this paper can discover and interpret developmental directions and patterns of the field from different perspectives, providing more scientific guidance and understanding for research work of scholars in related fields.

Full Text

Research on Academic Community Analysis Methods Based on Co-author Networks: A Case Study of the *Annals of the Association of American Geographers*

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Abstract

[**Objective**] This study analyzes co-author networks to identify and examine academic communities, revealing patterns of domain development and transformation. [**Methods**] We employed a fast community detection algorithm to identify academic communities within co-author networks, established a comprehensive metric integrating paper influence and collaboration influence to evaluate scholars' academic impact, and analyzed the development and evolution of academic communities from a lifecycle perspective using the three most influential communities as case studies. [**Results**] Analysis of data from the *Annals of the Association of American Geographers* demonstrates that the proposed comprehensive metric effectively identifies outstanding scholars within academic communities, and that lifecycle-based analysis of communities in co-author networks can reveal research trends and hotspot changes in different academic communities. [**Limitations**] Using a single journal may result in relatively thin community composition; incorporating data from additional journals could further enhance the credibility of the findings. [**Conclusions**] The proposed academic community analysis method can discover and interpret domain development directions and patterns from multiple perspectives, providing more scientific guidance and understanding for scholars in related fields.

Keywords: *Annals of the Association of American Geographers*; Academic Community; Lifecycle Analysis; Scholar Evaluation
Classification Number: P208; TP311

1. Introduction

With the continuous development of science and technology, research collaboration has gradually become the mainstream mode of scientific inquiry. Collaborative research promotes rapid advancement across disciplines, and the proportion of co-authored articles in academic journals continues to increase. Co-author networks have emerged as a primary representation of academic collaboration networks, making related research on academic collaboration networks a current hotspot in scholarly investigation. An academic collaboration network is a network describing scholar cooperation relationships, where each scholar is typically represented as a node, and an edge connects two nodes if the scholars co-author a research paper. As a type of complex network, academic collaboration networks exhibit community structures where relatively densely connected nodes and their interconnections form clusters. These academic communities represent groups of scholars with relatively close collaborative ties in the network. Under current research paradigms, the composition and evolution of academic communities can, to a certain extent, reflect changing patterns of research hotspots within a field. Therefore, academic community analysis serves as an important approach for studying research collaboration and domain development.

In recent years, numerous scholars have conducted research on analysis methods for academic collaboration networks across different fields. Li Liang et al. employed centrality analysis, cohesive subgroup analysis, and core-periphery structure analysis from social network analysis (SNA) methods to conduct empirical research on academic collaboration networks in Chinese information science. Li Shengqing et al. examined the scientific collaboration network in the complex networks research field from 1975 to 2012, dividing it into four developmental stages to explain the evolution of co-authorship networks and characteristics of knowledge dissemination. These studies primarily utilized network node centrality and small-world effect indicators from SNA to analyze either individual nodes or overall network distributions, potentially yielding overly macroscopic results that make it difficult to deeply mine the evolutionary patterns of academic collaboration networks. Sun et al. analyzed the GIScience community from an academic community perspective, interpreting the development of geographic information science based on community collaboration patterns and their scales. However, this research focused mainly on changes in community size and network structure distribution, without analyzing domain evolution from the perspective of individual communities. Consequently, it could only reveal macro-level development distributions rather than identify direct driving factors of disciplinary development and topic evolution patterns.

Scholarly academic influence is crucial in academic community analysis. Evaluation of academic influence primarily involves citation impact metrics such as the H-index. Du Jian et al. proposed evaluating scholars by integrating citation influence and collaboration influence. For citation influence, they determined scholar weights based on author order, redistributed article citations, and constructed a harmonic citation impact metric. For collaboration influence, they normalized the h-degree (representing a node' s collaboration team size) and r-degree (representing collaboration frequency between nodes) metrics from network structure. However, their collaboration influence metric primarily compared outstanding nodes across different collaboration groups, whereas academic community networks typically comprise multiple collaboration teams, making it unsuitable for evaluating nodes within the same community. Therefore, constructing a comprehensive evaluation metric that combines paper influence and collaboration influence for scholars within an academic community enables comprehensive assessment of their academic impact and identification of outstanding scholars.

This paper constructs academic collaboration networks from bibliographic data, identifies academic communities, and proposes a method to analyze the development and evolution of academic communities in co-author networks from a lifecycle perspective. The rise and decline of each academic community in a collaboration network can, to a certain extent, reflect the development of its corresponding field, while the research directions of outstanding scholars in a community can also reflect that community' s research orientation and hotspots. Based on the characteristics of paper data, we comprehensively evaluate scholar influence within academic communities by combining collaboration influence and paper influence metrics. Compared with the traditional H-index, scholars with high comprehensive influence scores better represent outstanding scholars in academic communities, and their research directions play a crucial role in community development.

2. Academic Collaboration Network Model

The academic collaboration network model can be abstracted as a graph $G(V, E)$ consisting of a vertex set V and an edge set E. The number of nodes is denoted as $|V|$, and the number of edges as $M = |E|$. Each element v_i in the vertex set V represents a scholar who has published papers. Scholars v_i and v_j in a paper are connected by an edge $e_{i,j} \in E$, where the author order in the article determines the weight of edge $e_{i,j}$, as illustrated in [Figure 1: see original paper].

[Figure 1: see original paper]

2.1 Scholar' s Comprehensive Academic Influence

(1) Scholar Paper Influence

In the academic collaboration network model, scholar v_i' s paper influence FC_i depends not only on the citation count C of each article but also on the scholar' s rank r in the paper. Therefore, this study employs harmonic citation influence to evaluate scholar paper influence, calculated as shown in formula (1):

$$FC_i = \sum_{m=1}^{N} P_r^m \cdot C_m$$

where N is the total number of papers published by v_i, C_m represents the citation count of scholar v_i' s paper m, and P_r^m is a function of rank representing the percentage of total influence attributed to the scholar when they hold rank r in paper m. If a paper has n authors, the rank function for the r-th scholar is given by formula (2):

$$P_r = \frac{1/r}{\sum_{k=1}^{n} 1/k}$$

(2) Scholar Collaboration Influence

Numerous studies have employed node centrality metrics from social network analysis to evaluate scholar collaboration influence. Takeda et al. constructed an academic collaboration network using bibliographic data from AIS e-library conferences and evaluated scholar nodes using centrality metrics from social network analysis. Centrality metrics reflect scholars' ability to communicate and share in academic collaboration and can be represented by various indicators such as degree centrality, betweenness centrality, and eigenvector centrality. Among these, eigenvector centrality reflects the centrality of a scholar node' s neighboring nodes—that is, a scholar who collaborates with high-influence scholars will have correspondingly higher collaboration influence. This aligns with our understanding of collaboration patterns and is suitable for measuring nodes in our academic community network. Therefore, this study employs eigenvector centrality to measure scholar collaboration influence. We define scholar v_i' s collaboration influence FCO_i as shown in formula (3):

$$FCO_i = \frac{1}{\lambda} \sum_{v_j \in A(v_i)} a_{ij} \cdot FCO_j$$

where $A(v_i)$ is the set of adjacent scholar nodes to v_i, and λ represents the largest eigenvalue of the scholar adjacency matrix. Collaboration influence is meaningful only within connected networks, so scholar collaboration influence must be compared and calculated within the same academic community.

(3) Scholar Comprehensive Academic Influence Calculation

Evaluating scholars' comprehensive influence within communities helps effectively analyze community structure and distribution. A scholar's comprehensive influence relates to both paper influence and collaborator influence; generally, more influential scholars have greater both paper and collaboration influence. Since paper influence and collaboration influence lack quantitative classification metrics, have different dimensions, and are not highly dependent, we employ the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to integrate the two metrics FC_i and FCO_i into a final comprehensive scholar influence evaluation metric F_i.

The TOPSIS method constructs an original data matrix using scholars' collaboration influence FCO_i and paper influence FC_i, normalizes it, identifies the optimal vector Z^+ (with both optimal paper and collaboration influence) and the worst vector Z^- (with both worst paper and collaboration influence), calculates the distance D_i^+ between each scholar node and the optimal vector and the distance D_i^- from the worst vector, and obtains the relative closeness F_i of each scholar node to the theoretically optimal node. This relative closeness F_i serves as the ranking basis and represents our proposed comprehensive scholar influence evaluation metric.

2.2 Academic Community Influence

In academic collaboration network models, some scholars are relatively closely connected while others are more loosely connected. These densely connected scholar nodes cluster together to form academic communities. Scholars in the same academic community may come from the same university or research institution, or may establish collaborative relationships through participation in academic conferences. The influence of an academic community primarily derives from the academic influence of its internal scholars. A community' s academic influence FCM is the cumulative sum of its constituent scholars' comprehensive influence metrics F_i, as shown in formula (4):

$$FCM = \sum_{i \in C} F_i$$

where C represents the set of scholar nodes in a community, and $|C|$ denotes the number of scholars in the community.

3. Data and Methods

3.1 Data Source

The *Annals of the Association of American Geographers* (hereinafter referred to as the *Annals*) primarily publishes articles related to geographic theory, methods, and practice. From January 1, 1911, to December 31, 2014, the *Annals* published a total of 7,033 academic articles. As an authoritative journal in American geography, the *Annals* serves as a barometer of geographic research in the United States. It not only publishes the latest geographic research results from members worldwide but also includes outstanding presentations from annual conferences. The journal' s content reflects new advances in world geography, and its scholar participation distribution is the most extensive. The bibliographic data analyzed in this study comes from all articles published in the *Annals*, including authors, keywords, abstracts, titles, publication years, institutions, and correspondence addresses. The data source is the Social Science Citation Index database, containing 949 co-authorship records.

3.2 Research Methods

We selected 949 co-authored articles from the *Annals* between 1911 and 2014 as our data source. Using each scholar as a node and collaboration relationships as edges, we constructed an academic collaboration network with $N = 1,873$ nodes and $M = 1,501$ edges. Traditional community analysis primarily focuses on quantitative metrics such as network node measures, community identification, and community size and structure. Based on the academic collaboration network, we employed a fast community detection method to identify academic communities in the network and calculated each community' s academic influence. We selected the three most influential communities for lifecycle analysis. Using each of these three communities as research subjects, we calculated the comprehensive academic influence F_i of scholars within each community, identified outstanding scholars in each community, and compared these results with the classic H-index to validate the reliability of our proposed comprehensive academic influence metric.

(1) Academic Community Discovery

Using the visualization software Gephi, we conducted community detection on the academic collaboration network constructed from the *Annals* and obtained 462 qualified academic communities. [Figure 2: see original paper] shows the overall structure of this academic collaboration network; we selected the three highlighted, most influential communities for analysis. Academic communities in the network exhibit certain spatial clustering characteristics, specifically manifested as most scholars in a community coming from the same institution. For the three communities analyzed, scholars in each community primarily originated from a particular university. Given that people' s cognitive tendency toward communities aligns with geographic spatial communities, we named the topological network communities after the institution with the most scholars in each community.

(2) Community Influence

Analyzing the academic influence of various communities from a temporal perspective, we calculated community academic influence and community size across different time periods. As shown in [Figure 3: see original paper], the University of California, Santa Barbara (UCSB) community has the largest size and influence, with 89 scholars and a community academic influence FCM_1 greater than 1,200. The second most influential community is Ohio State University, with 19 scholars and an influence index FCM_2 of approximately 621. The third most influential community is Arizona State University, with 49 scholars and FCM_3 of approximately 618. We used these three communities as research subjects to analyze their growth and evolution from a lifecycle perspective.

(3) Community Lifecycle Analysis

Using the UCSB community, Ohio State University community, and Arizona State University community as examples, we analyzed the lifecycles of different academic communities. Based on the data characteristics of the three major communities and using four-year intervals, the structure of the three communities' academic collaboration networks changed significantly from 1978 to 2014. [Figure 4: see original paper] describes the changes in size and influence of the three communities during this period. Overall, all three communities grew slowly in size over time, with community influence growth trends generally consistent with size growth trends.

UCSB Community

The UCSB community is the most influential community, with research hotspots that change over time. The community' s research focus shifted from initial cartography to regional geography related to human-environment distribution, and later to economic geography, behavioral geography, social geography, urban geography, and other research directions. Based on community size and influence growth, the UCSB community' s lifecycle can be divided into four stages.

1) **Germination Stage (Before 1978).** After World War II, driven by wartime needs, cartography developed significantly. The community' s first collaboration began in 1957 when Robinson A. H. and Bryson R. A. from the University of Wisconsin co-published the article "A Method for Describing Quantitatively the Correspondence of Geographical Distributions" in the *Annals*, marking the community' s formation. During the germination period, Robinson A. H. at the University of Wisconsin and Jenks G. F. at the University of Kansas separately developed small communities focused on cartography research. In this period, Robinson A. H. and Clark W. from the University of Wisconsin were the core community members.

2) **Growth Stage (1978-1986).** This period was the golden age of new geography development in the United States, as many geographers attempted to make geography a science by emulating methods from other disciplines. In 1978, the Association of American Geographers began dividing into specialized groups, splitting geography into many different subdisciplines. In 1982, Hart J. F. published "Presidential Address: The Highest Form of the Geographer' s Art" in the *Annals*, criticizing extreme scientism in geography. Due to his anti-scientific theory in geography, it prompted Golledge R. G., Church R., Tobler W. R., and others from the academic community centered on Robinson A. H. to jointly publish "Commentary on the Highest Form of the Geographer' s Art" as a rebuttal. Hart J. F.' s article caused great controversy in geography but facilitated collaboration between Golledge R. G. and Tobler W. R., as well as the union of Jenks G. F.' s community and Robinson A. H.' s community, causing the community centered on Robinson A. H. to grow rapidly in size and influence. Golledge R. G. and Battersby S. E. from UCSB began to emerge during this stage. The debate between Hart J. F. and Golledge R. G. caused tremendous changes in American geographic research structure, dividing geography from traditional natural science into different research directions and ushering in an era of diverse development in American geography. Meanwhile, the controversy led many private universities to cancel geography programs, forcing many geographers to join public universities to continue their research, which also resulted in most well-developed geography programs being at public universities. In this

era, regional geography guided by Hart J. F. became one of the research priorities, while behavioral geography pioneered by Golledge R. G. also began rapid development.

3) **Stability Stage (1986-1998).** After the golden development period, the community structure initially formed. New members in this stage were generally students of outstanding scholars, representing emerging forces in the community with academic influence just beginning to develop, while community influence and size grew relatively steadily. Research in this stage mostly combined regional development to achieve geography applications in specific regions.

4) **Maturity Stage (1998-2014).** From 1998 to 2002, the community added only six members, but community influence increased 1.39 times. In the early 21st century, driven by economic globalization, connections between world cities became increasingly important. In 2000, Beaverstock J. V., Smith R. G., and Taylor P. J. published "World-City Network: A New Metageography?" at the AAG annual meeting. This article received 156 citations, further enhancing community influence and demonstrating that urban geography is an important research direction for this community. During this period, emerging scholars from the stability stage made significant contributions, and small groups in the community gradually developed their own size and influence. After 2002, Church R. L. developed a group of scholars engaged in geographic information science at North Carolina State University, continuously expanding influence. From 2010 to 2014, community size continued to grow, but the growth rate of influence slowed, suggesting the largest community may be entering a decline stage and could be surpassed by other growing communities.

Ohio State University Community

The Ohio State University community has only 19 members but ranks second in total influence, with main research areas in political geography and economic geography. The community' s lifecycle divides into three distinct stages.

1) **Germination Stage (Before 1986).** The UCSB community' s influence and size were basically dominant, while articles published by Ohio State University community and other institutions in the *Annals* during this stage were mostly individual publications without forming influential communities.

2) **Growth Stage (1986-2002).** During this stage, community size changes were not significant, but influence nearly doubled. In 1988, Cox K. R. and Mair A. published "Locality and Community in the Politics of Local Economic Development" in the *Annals*, with comprehensive citations reaching 219, making this community' s influence second only to the UCSB community. Thereafter, community influence did not change significantly until 1999, when Lobao L. and Rulli J. from Ohio State University and Brown L. A. from the University of Iowa published the influential human geog-

raphy paper "Macrolevel Theory and Local-level Inequality: Industrial Structure, Institutional Arrangements, and the Political Economy of Redistribution, 1970 and 1990" in the *Annals*, promoting the community' s influence enhancement. Human geography is an important research direction in the *Annals*, and this community' s human geography articles have high citation influence in the journal, pushing the community into the maturity stage.

3) **Maturity Stage (2002-2014).** In this stage, the number of community papers gradually increased, and the growth rates of both size and influence stabilized and slowed, with the community entering maturity. With technological development, Geographic Information Systems (GIS) and Remote Sensing (RS) played increasingly important roles in social and political geography research. A community structure centered on Ohio State University and collaborating with the University of Iowa, University of Washington, and University of Toronto, focusing mainly on political geography and economic geography, gradually formed.

Arizona State University Community

The Arizona State University community is an emerging community in the *Annals* academic collaboration network, with main research directions in climatological and meteorological geography. This community' s lifecycle division aligns with that of the Ohio State University community, mainly including three stages.

1) **Germination Stage (Before 1986).** Harman J. R., Harrington J. A., and Elton W. M. from Michigan State University formed a small academic community during this period, focusing on precipitation patterns in physical geography. Hehr J. G. from the University of Miami and Charton F. L. from the University of Illinois began collaborating with Harman J. R. during this time, gradually forming the germination of this academic community.

2) **Growth Stage (1986-2002).** In 1990, Balling R. C. and Wells S. G. from Arizona State University published the precipitation pattern paper "Historical Rainfall Patterns and Arroyo Activity within the Zuni River Drainage Basin, New Mexico" in the *Annals*, marking the formation of the Arizona State University community. In 1998, Cerveny R. S. from Arizona State University and Harman J. R. from Michigan State University collaborated on balanced environment and environmental science values, laying the foundation for later community union between the two universities. In the 21st century, as climate change issues became increasingly prominent and the topic of harmonious human-nature coexistence received high attention, articles on precipitation and climate patterns published by Arizona State University scholars centered on Balling R. C., using GIS spatial analysis methods to interpret environmental issues, made climate GIS and environmental geography research hotspots.

3) **Maturity Stage (2002–2014).** During this stage, the Arizona State University community officially united with the Michigan State University community. By 2014, the community had grown into a large community of 49 members, with 20 members from Arizona State University, forming an academic community combining meteorological geography and human geography. Both the size and influence of the community showed clear growth during this period. From the growth rate perspective, this community demonstrates the momentum of a rising star, and with continued enhancement, it may surpass the Ohio State University community and even the UCSB community in the future.

(4) Community Scholar Academic Influence Evaluation

We evaluated community scholar academic influence by identifying outstanding scholars within communities. As shown in [Figure 5: see original paper]–[Figure 7: see original paper], scholars with greater comprehensive influence have larger node radii, and different node colors represent different institutions.

UCSB Community

compares the comprehensive evaluation metric F_i with the H-index and total citation count. The results show that H-index rankings differ relatively little from comprehensive influence F_i rankings. Battersby S. E. ranks 9th by H-index but rises 3 places when using our metric F_i because it comprehensively considers both collaboration patterns and author order. Robinson A. H. published many articles in the *Annals* with high paper influence, ranking 3rd by H-index, but drops 4 places using F_i because many of his articles were published independently, resulting in relatively weak collaboration influence. Some scholars show large differences between H-index and F_i rankings; for example, Beaverstock J. V.' s F_i ranking rises 10 places compared to his H-index. Since he published only one article in the *Annals*, his H-index is low, but that article has high citation counts, indicating that the H-index is insensitive to highly influential papers, while the comprehensive influence metric F_i can objectively evaluate scholar influence by considering both paper and collaboration influence. Using comprehensive influence to evaluate and identify outstanding scholars can, to some extent, compensate for the H-index' s insensitivity to paper quantity and impact.

Ohio State University Community

The Ohio State University community has relatively few members but the most cross-institutional collaborations. As shown in , the top 17 scholars come from eight different institutions. Cox K. R. from Ohio State University ranks first in comprehensive influence, making Ohio State University the community core. The small community size results in average comprehensive influence far below that of the UCSB community. Comparing comprehensive influence with H-index in this community, except for Mair A. from the University of Virginia showing large ranking differences, the overall ranking trends basically align. Mair A. published only two articles in the *Annals*, resulting in a low H-index ranking. However, his close collaboration with Professor Cox K. R. and high article citation counts give him a relatively high comprehensive influence F_i ranking, again demonstrating the H-index' s insufficient sensitivity to a few highly cited papers.

Arizona State University Community

Compared with the UCSB community, the Arizona State University community has relatively lower overall comprehensive influence. shows the specific member distribution. The community structure is clearly characterized by Arizona State University as the core and the University of Utah and Dartmouth College as major collaborators. Only three scholars in the community have comprehensive influence exceeding 0.5, possibly because many community members joined only recently, resulting in relatively small community influence by 2014. The community' s overall scholar comprehensive influence is also lower than that of the UCSB and Ohio State communities. Comparing community scholar comprehensive influence F_i with H-index shows generally consistent trends, but Wells S. G. and Mings R. C. have H-index rankings of 21 while their comprehensive influence F_i ranks 3rd and 6th respectively, again demonstrating the H-index' s insensitivity to scholars with a few high-quality papers.

5. Conclusion

Using the *Annals* as an example, this study constructed an academic collaboration network based on co-authored papers, identified and evaluated academic communities, employed community lifecycle analysis to examine academic communities in the network, and analyzed the reasons for community growth and evolution. By adopting dual measures of scholar paper influence and collaboration influence to evaluate scholars within communities, we identified outstanding scholars and laid a foundation for analyzing community research trends.

Analysis of the three most influential academic communities revealed that: (1) In the development of American geography, especially human geography, scholars from the UCSB community have played a tremendous driving role; (2) Scholars from the Ohio State University community hold an important position in political and economic geography; (3) The Arizona State University community, as an emerging community combining meteorological climatology and human geography, is developing rapidly, reflecting that future geography development may tend toward research related to human living environments, with analysis and application of climate change and geographic associations in social development being promising directions. Additionally, the results demonstrate that the proposed community analysis method can analyze and explain changes in community research hotspots from the perspective of community scholars, and that scholars with high comprehensive influence identified by our metric play crucial roles in community lifecycles.

Since the *Annals* is a U.S. journal with a single data source, most community members come from the United States and Canada, and the research scope focuses primarily on European and American regions, indicating potential geographic bias that may result in relatively thin community composition. Incorporating data from journals with different sources could further enhance the credibility of research results. Current research involves relatively shallow content analysis, with lifecycle discussions focusing on inflection points and contributions of outstanding scholars. Future work will conduct in-depth analysis from semantic perspectives of articles in different communities, combine community scholars' research directions for deeper discussion of community growth, and explore potential trends in American geography development through research hotspot changes among outstanding scholars in each community.

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Author Contributions

Qing Yaxian: Data collection, cleaning, and analysis; experimentation and results analysis; manuscript drafting.
Li Rui: Research concept and design; study protocol development; final manuscript revision.
Wu Huayi: Paper framework design; manuscript editing.

Conflict of Interest Statement

All authors declare no conflict of interest.

Supporting Data

Supporting data is self-archived by the authors and available upon request at qingyaxian@whu.edu.cn.
[1] Qing Yaxian, Li Rui, Wu Huayi. OriginalAAGPapers.csv. All literature-related data from the *Annals of the Association of American Geographers*, 1911-2014.
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Note: Figure translations are in progress. See original paper for figures.