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Conceptualizing the interdisciplinary diffusion and evolution of emerging fields: The case of systems biology

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ABSTRACT

This paper contributes to the longitudinal study and representation of the diffusion of scholarly knowledge through bibliometrics. The case of systems biology is used to illustrate a means for considering the structure and different roles of journals in the diffusion of a relatively new field to diverse subject areas. Using a bipartite network analysis of journals and subject categories, a core–intermediary–periphery diffusion structure is detected through comparative analysis of betweenness centrality over time. Systems biology diffuses from a core of foundational, theoretical areas to more specific, applied, practical fields, most of which relate to human health. Next, cluster analysis is applied to subject category co-occurrence networks to longitudinally trace the movement of fields within the core–intermediary–periphery structure. The results of these analyses reveal patterns of systems biology's diffusion across both theoretical and applied fields, and are also used to suggest how the dynamics of a field's interdisciplinary evolution can be realized. The author concludes by presenting a typology for considering how journals may function to support attributes of the core–intermediary–periphery structure and diffusion patterns more broadly.

1. Introduction

Diffusion of scholarly knowledge is a complex process to measure, as can be inferred by the various aspects and methods through which researchers have investigated this topic. Inquiries mapping the diffusion of ideas through specific articles (Liu & Rousseau, 2012), research institutes (Boner, Penumarthy, Meiss, & Ke, 2006), medical subject headings (MeSH) (Leydesdorff, Rotolo, & Rafols, 2012), and essential science indicator (ESI) fields (Liu & Rousseau, 2010) are some of the perspectives through which dissemination and diffusion patterns have been studied. Diffusion indicators also vary among studies, and have included citations (Boner et al., 2006), publications (Liu & Rousseau, 2010) and collaborations between entities (Liu, Rousseau, & Guns, 2013). Developing a journal diffusion factor has also been explored (Frandsen, Rousseau, & Rowlands, 2006) as a means of capturing the breadth of influence of a particular journal title across the literature.

Diffusion and movement of ideas across academic or cognitive space (Liu & Rousseau, 2010; Liu, Rafols, & Rousseau, 2012) continues to be a focal area in informetrics. This paper contributes to the development of frameworks for studying the diffusion and evolution of knowledge across disciplines. The approach described in this article contributes to the ability to model and describe diffusion across disciplinary borders, considering the relationships among disciplines publishing on a particular topic or field as representing the field's interdisciplinary landscape. By investigating novel means of modeling the interdisciplinary trajectories of ideas through this analysis, we enhance our understanding and conceptualization of the

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processes that facilitate the spread, or movement, of scientific knowledge to diverse areas where further application of this knowledge can potentially enhance growth and discovery across a range of fields.

The purpose of this article is to extend the longitudinal study and representation of diffusion of scientific knowledge through the lens of journals and their Web of Science (WoS) subject categories. Specifically, this paper explores how certain journals' affiliate subject categories, in the context of a field's broader publication database, might be described as mechanisms for facilitating an evolving subject's diffusion into diverse disciplines. The Institute of Scientific Information (ISI) assigns subject categories (SCs) to journals that are included in the *Science Citation Index (SCI)*, accessible through Thomson Reuter's Web of Science (WoS) database. A journal's subject category assignment is based on various qualities, including journal title and citation patterns (Leydesdorff & Rafols, 2009).

As this paper is concerned with how knowledge diffuses into different disciplines via journals, subject categories provide an appropriate lens for parsing journals into disciplinary boundaries that are useful for studying development in the structure of a publication set. Subject categories provide a more detailed representation of the qualitative disciplinary distinctions among journals than the broader 22 *ESI* fields (Liu & Rousseau, 2010). Whereas journals are assigned to only one *ESI* field, journals can be assigned to one or more of the 200+ WoS subject categories depending on its scope, allowing for a more nuanced examination of interdisciplinary diffusion structure and its evolution.

For the present inquiry, systems biology is used as an empirical example to explore changes in disciplinary structure over time. Systems biology was selected based largely on the breadth of its potential interdisciplinary application, as well as its relatively recent post-genomic inception within bioscience, providing a focused time frame for the present inquiry. The sequence of analyses used in this case study reconcile prior efforts to describe the nature of a topic's diffusion with an interest to also explain the movement of ideas or change in an interdisciplinary publication structure over time. These results suggest how a network perspective of subject categories may yield insight into the overall structure of a relatively new field, and how the attributes of certain journals may contribute to structural changes in the network over the course of a field's development. Specifically, this paper expands consideration of journal attributes relevant to diffusion beyond subject categories alone, in order to suggest how such attributes may be used to categorize the functional role of a particular journal at a more macro level, i.e. in relation to all other journals in the network at a given point in time. In this paper, functional role refers to how one might broadly characterize the facilitation pattern of a particular journal in the diffusion of a scientific concept to other disciplines. This approach extends prior work on diffusion structure by suggesting a means for realizing how a journal longitudinally contributes to knowledge diffusion in the context of the overall network using an attribute of interest (in this case, subject categories), and proposing insight that might be gained from this more macro level approach. The output of this work contributes to efforts in information science to comprehensively and longitudinally describe the diffusion of scientific ideas, and suggests novel ways of considering journals' functions in supporting aspects of a field's interdisciplinary structure and evolution.

This paper is structured as follows: First, a brief background of systems biology and its interdisciplinary potential support the use of this field as an empirical example and the methods undertaken. Second, descriptive statistics of system biology's publication base provide an overview of the field's scholarly development to date. Next, a bipartite network analysis explores changes in the centrality of journals' affiliate subject categories over the 12-year time span considered. The results of this analysis suggest a core–intermediary–periphery diffusion pattern that is then more formally studied in the context of the journals facilitating this structure and their changing positions within this structure over time. The paper concludes by offering a typology for considering the role of journals in the structure of a topic's interdisciplinary diffusion that can be tested and expanded with future research.

2. Background

2.1. The case of systems biology

This paper uses systems biology as a case study for exploring the roles of journals in the diffusion of a field or subject area across disciplines over time. Systems biology is a field of biological science that focuses on the study of whole systems of biological components, including the interactions and emergent properties of their constituent parts and the implications of those properties for enhancing our understanding of biology and related fields. Systems biology is grounded in the fundamental concept that biological components exist in a nested hierarchy (cell, tissue, organ, organism, etc.), and that adopting a network perspective in examining the interrelationships within and across hierarchical levels can generate novel insight about biological processes and their structural and functional dynamics (Potters, 2010). Built on the tenets of molecular biology, systems biology aims to use principles of information transfer among molecular components to study the human organism as a complex adaptive system constantly interacting with developmental, ecological and environmental variables.

Traditional reductionist approaches to molecular biology have focused largely on single parts, i.e. specific genes, or collections of parts in isolation from the broader context in which they exist. Although these methods have produced a tremendous amount of data on individual genes, proteins, metabolic factors and short sequences of DNA, the systems approach has introduced a new paradigm emphasizing the holistic interrelationships and collaborative functioning of those elements in the context of the whole system. The inherent complexity of adopting a large, multi-scale approach to biological systems demands methods and technologies capable of analyzing significantly more data than fields like molecular biology have typically considered. Systems biology represents the fusion of biological thinking and mathematical