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The Queer Duck of Biology

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To those who dare navigating the unknown
and making the world interesting to live in.

Preface

> Science is the creation of scientists, and every scientific advance bears somehow the mark of the man who made it.[1]
>
> Anne Roe, 1961

History of science is told through the endeavors, often heroic, of its primary characters. Historians tend to center on the heroes whose names and scientific accomplishments at times precede the disciplines in which they played a major role. Rarely is the history of a discipline "rewritten" by its practitioners to leave out the hero who indefatigably fought and strived toward its establishment. One such hero is Nicolas Rashevsky and mathematical biology the discipline he institutionalized.

The reasons behind this "rewriting" of history accompanied me on my journey of uncovering the intellectual identity of Nicolas Rashevsky. In what constitutes the first detailed biography of mathematical biologist Nicolas Rashevsky (1899–1972), spanning key aspects of his long scientific career, this book captures Rashevsky's ways of thinking about the place mathematical biology should have in biology and his personal struggle for the acceptance of his views. Through his character and his struggles, I set out to unearth all that was involved in establishing a new way of thinking in biology in the early twentieth century.

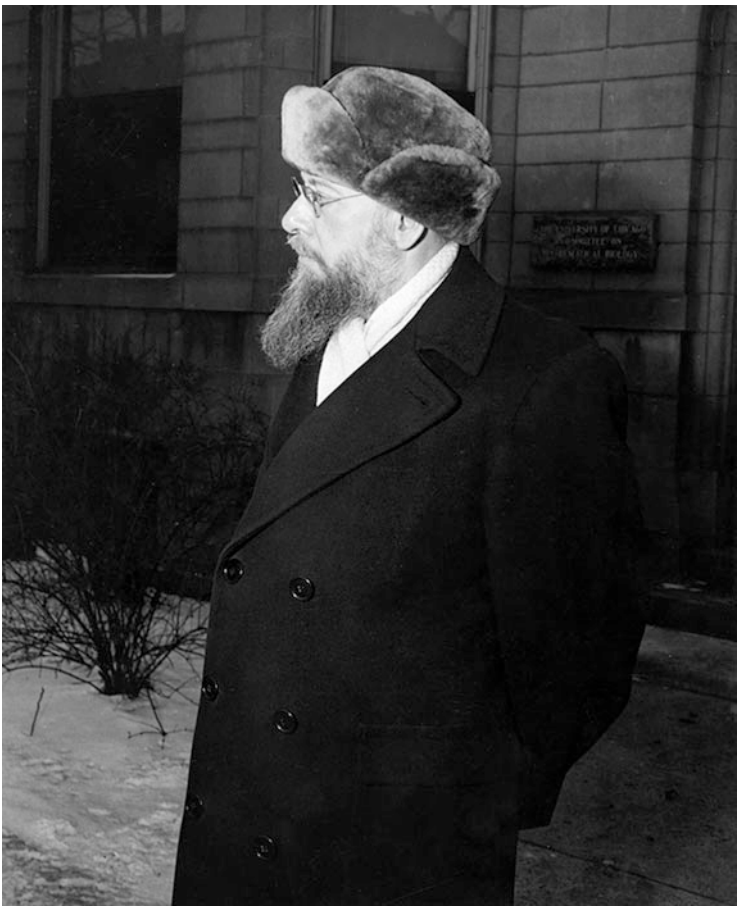
Nicolas Rashevsky is one of the unique cases in twentieth-century biology, who crossed over to biology with the aim of discovering and explaining all the properties of the living world in terms of fundamental principles and parameters that govern the life sciences and can lead to "laws of nature." While this book discusses the ways in which he succeeded and the ways in which he failed to reach his goal, it is his motivation, path, and struggles that are of particular interest, as these led to the establishment and institutionalization of a new discipline in biology: mathematical biology. Examining Rashevsky's intellectual life provides an invaluable facet in

[1] Roe, A. "The psychology of the scientist," in Obler, Paul C., and Herman A. Estrin eds. *The new scientist*. 1962, pg. 82–94.

discipline-crossing act that accounts for the source of significant innovation and the structure of modern biology.

Tracking Rashevsky's struggle for the acceptance of his dream by the social and political organizations that constitute science provides new insights into the dynamics of "outsiders" and "boundary crossers" in biology as promoters of innovative thinking. While looking forward to new groundbreaking developments in twenty-first-century biology which are and will continue to be introduced by innovative and unorthodox thinkers, Rashevsky's story allows us to observe and learn about the problem of introducing a novel way of looking at biology. *Errare humanum est*, here is to learning from past mistakes!

Seoul, South Korea Maya M. Shmailov
March 2016



Nicolas Rashevsky, at the University of Chicago, ©*Special Collections Research Center, University of Chicago Library*, used with permission

Introduction

Over five rainy summer days of August 1961, a group of 102 participants hailing from dozens of countries around the world gathered at Western Carolina College in Cullowhee, North Carolina. The participants were roughly divided into "traditionally-trained biologists," mathematicians, statisticians, engineers, physicists, chemists, and a new variation of scientists—mathematical biologists. Sponsored by the National Institutes of Health and the Air Force Office of Scientific Research and organized by the prominent biostatistician Henry L. Lucas (1916–1977), the meeting was convened to address a central objective: the creation of an institutional and intellectual framework for what had come to be known as "mathematical biology."

At the time, "mathematical biology" was emerging from a period of isolation and incubation into a stage of rapid growth. As such, its history—present and future—needed to be discussed and plotted. In particular, the agenda was rich with important topics, primarily the subject of communication across disciplines, the transgression of disciplinary boundaries set by methodology, practices, perspectives, and attitudes as well as the training of scientists in the new discipline. The conference proceedings were published in a volume entitled "The Cullowhee Conference on Training in Biomathematics."[2]

The Cullowhee conference was one of a series of conferences in the 1960s that dealt with the application of physico-mathematical methods to biology. On some level, this conference marks the official recognition of a new discipline whose moniker, *Mathematical Biology,* was coined by a Ukrainian-born theoretical physicist named Nicolas Rashevsky. In fact, it even constitutes some sort of celebration. While during the conference participants employed the terms Biomathematics and "Mathematical Biology" interchangeably, Rashevsky repeated throughout the discussions that he was prejudiced toward the latter because he believed that the former did not do justice to its practitioners and their episteme. For Rashevsky,

[2]HL Lucas, *The Cullowhee Conference on Training in Biomathematics* (North Carolina State University, Raleigh, 1962).

practicing mathematical biology translated into biology being the subject and mathematics the tool to investigate it. His field of practice was neither Bio-Mathematics nor Theoretical Biology: it was Mathematical Biology. The primary reason for this configuration was that during the mid-1920s, Rashevsky—who was then in his mid-twenties—envisioned a new field of biology similar in structure and aim to *Mathematical Physics*.[3]

Rashevsky was a boundary crosser, both as a scientist and as a person. Having trained as a theoretical physicist, he decided to turn his attention to biological sciences and as such became an "outsider" in biology. When a scholar approaches the study of disciplinary boundary crossers, he or she must address the question as to why and how one decides to transgress his or her comfort zone into an unknown land. Is this a discrete act that recognizes and responds to a need and merely introduces a methodology, a set of concepts, or instruments from one discipline to another in order to tackle a specific problem? Or is it a tendency inherent in an "outsider" that may be observed repeatedly throughout his or her scientific life? In the case of Rashevsky, the latter seems to be the case. Rashevsky's outsiderness expressed itself in a wide range of disciplines, including biology, medicine, sociology, and psychology. "You name it; he had a theory on it," reminisced Alvin Weinberg, one of Rashevsky's first students.[4] Zigzagging from the problem of cell division to the challenges of automobile driving, Rashevsky's 45 years of scientific work provides more than its share of boundary crossing.[5] This fluid movement between disciplines coupled with Rashevsky's attempts to replace the biological problems presented by nature with mathematical investigations of simplified hypothetical cases antagonized biologists to the extent that they ultimately neglected the man who single-mindedly attempted to revolutionize their field.

Rashevsky's career as a mathematical biologist began while he was working as a mathematical physicist at the Westinghouse Research Laboratories in Pittsburgh (1924–1934), flourished at the Division of Biological Science at the University of Chicago (1934–1964), and dissipated with his resignation from the University of Chicago and move to Ann Arbor, Michigan, where he worked at the Mental Research Institute (1964–1970) until his retirement at the age of 70.[6] Rashevsky published more than 500 articles and seven books and was appointed to serve as an ex officio member on the board of University Publications at the University of Chicago. Rashevsky also established a journal for publishing research in the field of Mathematical Biology: the *Bulletin of Mathematical Biology*, used by

[3]N. Rashevsky, *Mathematical Biophysics: Physico-Mathematical Foundations of Biology* (University of Chicago Press, 1938), pg. vii.

[4]Lou Gross and Alvin Weinberg, video recorded interview, May 15, 2004 (hereinafter "GWI, 2004"), courtesy of Lou Gross.

[5]For a comprehensive summary, see N Rashevsky, *Mathematical Biophysics Physico-Mathematical Foundations of Biology, Vol. 1 and 2* (Dover Publications, New York, New York, 1960).

[6]TH Abraham, "Nicolas Rashevsky's Mathematical Biophysics," *Journal of the History of Biology* 37, no. 2 (2004), 333–385.

mathematical biologists to this very day. In 1969, Rashevsky formed a nonprofit organization, *Mathematical Biology, Incorporated*, the precursor of the current *Society for Mathematical Biology,* which provided (and still provides) an institutionalized venue for research in the field.

Rashevsky's crossing over into biology was not motivated by the pursuit of a solution to a specific problem nor was it an attempt to mathematically evaluate a domain in biology. Rather, the tall, blue-eyed Ukrainian had a dream. Rashevsky had his mind set on the "building-up of a systematic mathematical biology similar in its structure and aims to mathematical physics."[7] He was in pursuit of fundamental laws governing life processes and began his quest convinced that only a persistent search for such laws employing physico-mathematical reasoning could eventually unravel the mysteries of life. Applying a physico-mathematical approach, his method was abstraction and approximation of the biological phenomena, which he believed would lead to insights into the processes governing the phenomena. As such, Rashevsky's program reflected two intersecting vocations: first, to establish a novel field of research in biology that would unveil its mystery, and, second, to demonstrate via the results of research in that field that mathematical biology can efficiently approach and engage biological problems in all their complexity.

While this study focuses primarily on Rashevsky's scientific career in the biological sciences, it also sheds some light on his attempts to introduce mathematical thinking into sociology and history. In his late forties, Rashevsky turned to sociological and historical pursuits, investing in the study of social behavior and the mathematics of history. While these studies did not evolve into his primary interest, they did play a role in the way Rashevsky was perceived by his colleagues in the biological sciences and affected his scientific occupations.

Although fellow biologists often viewed Rashevsky as a loser in their arena, he never viewed his scientific achievements as unaccomplished. Even when Rashevsky made a sharp turn from his previous methodology to a new and ambitious pathway in the mid-1950s, he still perceived his research in mathematical biology to be a promising and significant scientific field of research. He was quick to admit his failures, but these did not distract him from his path. He examined the reasons for the possible failure and came up with new, at times grander, solutions, adopting new agenda toward the realization of his dream.

Rashevsky's scientific biography positions him as an important figure in the history of science in general and in the history of the twentieth-century life sciences in particular. His colleagues and students recollected his attempts to connect mathematical reasoning to domains of biology, thereby establishing mathematical biology, yet tagged him as one who failed to successfully market and interest his experimentally oriented colleagues in the life sciences. Historians of science were quick to explain Rashevsky's failure, yet they did not seem to recognize that

[7]N. Rashevsky, *Mathematical Biophysics: Physico-Mathematical Foundations of Biology* (University of Chicago Press, 1938), pg. vii.

Rashevsky was the first to offer—and the first to attempt to establish—an ambitious program of mathematical biology that would encompass the entire spectrum of the life sciences. Although he is often accused of failing, researchers who adopted his approach placed mathematical biology on the landscape of the biological sciences as a discipline indispensable for answering complex questions on the nature of life.

Wherever the truth may lay, exploring Rashevsky's scientific biography enables us to examine a scientist's ability to transgress from his comfort zone into an unknown domain and construct a new hybrid within, constantly laboring to keep his dream alive. Current scholarship emphasizes the constraints imposed by disciplinary boundaries, characterizing disciplines as relatively closed intellectual structures. Rashevsky's story illuminates the problem of introducing a new view into biology. It shows how a separate institutional and professional niche is carved within an existing intellectual ecosystem via the differentiation of goals, methods, and an evolution of expertise in the newly carved scientific niche. It illustrates the strategies and motives of a particular outsider as well as the motivations and strategies of professional associations that sponsored or critiqued his activities. It tracks the difficulties an outsider encounters in trying to publish research and garner funding for research and teaching and the role played by peer reviewers and journals in changing the disciplinary organization of knowledge.[8] Examination of Rashevsky's intellectual biography helps to understand how an outsider's standpoint was developed and deployed in biology with the "insiders"—the biologists—rarely sharing the outsider's perspectives and methodology.

This inquiry is aimed at more than chronicling Rashevsky's scientific work. Rashevsky's biography is in fact the biography of the development of mathematical biology as a discipline.[9] Thus, this study also aims to sketch the dynamics of how and why a new scientific discipline took root, grew, flourished, and was eventually overtaken in a particular social and academic setting—the University of Chicago. Contributing to the academic study of the institutionalization of knowledge. I aim to answer the question: what are the changes that a field of practice experiences as it metamorphoses from being a disperse, sporadic area of research to a discipline with an intellectual and professional identity able to command its own techniques,

[8]For more information on disciplinarity, the reader is invited to review HH Bauer, "Barriers against Interdisciplinarity: Implications for Studies of Science, Technology, and Society (STS)." *Science, Technology, & Human Values* 15, no. 1 (1990); L Hunt, "The Virtues of Disciplinarity," *Eighteenth Century Studies* (1994); R.C. Post, "Debating Disciplinarity," (2009); D.R. Shumway and E. Messer-Davidow, "Disciplinarity: An Introduction," *Poetics Today* 12, no. 2 (1991); TF Gieryn, *Cultural Boundaries of Science: Credibility on the Line* (University of Chicago Press, 1999); _____, "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists," *American Sociological Review* (1983); Timothy Lenoir, *Instituting Science: The Cultural Production of Scientific Disciplines* (Stanford University Press, California, 1997); TS Kuhn, *The Structure of Scientific Revolutions* (University of Chicago Press, Chicago, 1970).

[9]Lawrence Stark to Rashevsky, September 22, 1964, Box 10, Folder "Gordon Research Conference," NRP-SCRC.

methodologies, and intellectual orientations?[10] This study trains a spotlight on the academic, institutional, cultural, and political factors shaping the construction and definition of scientific knowledge and the development of a new discipline in the context of the early departments in which it emerged. In particular, this study illustrates how a new discipline is developed through the actions, struggles, successes, and failures of an outsider entering the inside with an ambitious dream of building a new hybrid from within the "inside."

Approaching Rashevsky as an "outsider" in biology, I ask three interconnected questions. First, what is the place of science in the realization of his dream? In particular, I examine the evolution of his scientific ideas and his approach toward the role physics and mathematics should play in biology. I discuss the dynamics of his research program and the attitude of the "insiders," the biologist toward his approach. Second, what role did his personality play in promoting his scientific agenda? I focus on his rhetoric in scientific publications, his correspondence with associates and administration, and his public relations skills in his attempts to craft an agenda and promote his dream. Third, what is the impact of the type of institution, be it the University of Chicago where he developed his agenda or government agencies that financially supported his program, on an "outsider's" research program? While my primary focus is on Rashevsky's interactions with the administration at the University of Chicago, his relations with the Rockefeller

[10]On institutionalization of knowledge and for discussions on discipline building and professionalization of science, see D. Riesman and C. Jencks, *The Academic Revolution* (Doubleday, 1969); J. Ben-David, *The Scientist's Role in Society* (Prentice Hall Englewood Cliffs, NJ, 1971); Shumway and Messer-Davidow, "Disciplinarity: An Introduction" H. Zuckerman and R.K. Merton, "Patterns of Evaluation in Science: Institutionalisation, Structure and Functions of the Referee System," *Minerva* 9, no. 1 (1971); RK Merton, "The Institutional Imperatives of Science," *Sociology of Science* (1972); A. Thackray and R.K. Merton, "On Discipline Building: The Paradoxes of George Sarton," *Isis* 63, no. 4 (1972); Rosenberg, "Toward an Ecology of Knowledge: On Discipline, Context and History." A. Oleson Voss, J.(Eds.) "The Organization of Knowledge in Modern America, 1860-1920," *Johns Hopkins University Press, Baltimore* (1979); R.E. Kohler, *From Medical Chemistry to Biochemistry: The Making of a Biomedical Discipline* (Cambridge University Press, 1982); P Abir-Am, "Beyond Deterministic Sociology and Apologetic History: Reassessing the Impact of Research Policy Upon New Scientific Disciplines (Reply to Fuerst, Bartels, Olby and Yoxen)," *Social Studies of Science* (1984); WO Hagstrom, "The Differentiation of Disciplines," *Interdisciplinary Analysis and Research: Theory and Practice of Problem-focused Research and Development* (1986); Lenoir, *Instituting Science: The Cultural Production of Scientific Disciplines*; Harold L. Wilensky, "The Professionalization of Everyone?," *The American Journal of Sociology* 70, no. 2 (1964); G Millerson, *The Qualifying Associations: A Study in Professionalization* (Routledge & Paul, 1964); E. Mendelsohn, *The Emergence of Science as a Profession in Nineteenth-Century Europe* (College Division [Bobbs-Merrill], 1964); Gieryn, "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists"; A Abbott, *The System of Professions: An Essay on the Division of Expert Labor* (University of Chicago Press, 1988); G Griffin, P Medhurst, and T Green, "Strep Comparative Report: The Relationship between the Process of Professionalization in Academe and Interdisciplinarity. A Comparative Study of Eight European Countries," (Hull: STREP Research Integration Project, 2005).

Foundation, the NSF, and the NIH are also examined. [11] I am especially concerned with the manner in which the administration at the University of Chicago perceived Rashevsky's person and scientific agenda, and the role the university's academic agenda played in promoting, or otherwise frustrating, Rashevsky's dream.

In the following pages, I trace chronologically Rashevsky's career in science, focusing mainly on his scientific research in mathematical biology, from 1926 to 1972. Chapter 1 provides a sketch of Rashevsky's life and reviews Rashevsky's scientific background. The chapter also observes the factors influencing crystallization of his interest in biology. It provides an account of Rashevsky's decision in 1926 to cross over from theoretical physics to biology and sets out his interests against the backdrop of the current attempts to mathematize biology, elucidating the contrast between his convictions regarding the applicability of mathematical biology and those of his peers. This chapter examines Rashevsky's initial attempts (1926–1933) to apply mathematical methods to the problems of cell division and nerve excitation while still working at Westinghouse. By examining the first arc of his intellectual trajectory, in particular his theory of nervous excitation and inhibition, this chapter demonstrates how Rashevsky's "outsiderness" unmasked the problem of acceptance of his approach by the insiders.

Chapter 2 examines Rashevsky's move to the University of Chicago and the institutional and academic conditions that facilitated this move. The focus is on factors that enabled Rashevsky to introduce his research agenda into his institution and to translate theoretical ideas into a research program. I explore the rationale behind the reorganization of the division of biological sciences at the University of Chicago, initiated by the university's president Robert Maynard Hutchins and implemented by the dean of the Biological Division, William Taliaferro, in an effort to foster an interdisciplinary approach in biological research. I examine how despite the supportive environment for interdisciplinary research, Rashevsky encountered problems finding a place in the department of physiology, chaired by a devout empiricist Anton Carlson, and was forced to transfer to the department of psychology. By examining the institutional and academic conditions, I try to delineate not only the problem of acceptance of his approach to biology by the insiders (the biologists) but also the challenge of institutional acceptance facing the "outsider."

In the section entitled "*An Experiment in Scientific Procedure: the Cold Spring Harbor Symposia on Quantitative Biology*," I provide an account of Rashevsky's first public encounter (1934) with leading scientists who were investigating the interplay between basic sciences and experimental physiology. In reviewing Rashevsky introducing his debut of methodology to his colleagues, I examine not only his exposition of the physico-mathematical approach but also the reaction to his approach. Rashevsky's presentation and the discussions that followed revealed a

[11] Detailed analysis of Rashevsky's relationship with the Rockefeller Foundation has been provided by historian of science Tara Abraham in "*Nicolas Rashevsky's Mathematical Biophysics*," 2004.

tension between the experientially minded biologists and those who believed in the possibility of mathematization of biology, and it sheds light on the divide between these two groups of scientists.

Chapter 3 explores the development of Rashevsky's scientific agenda highlighting the role of mathematical reasoning in biology and the first steps towards institutionalization of mathematical biology at the University of Chicago in 1935–1947. The first part of this chapter focuses on Rashevsky's studies in cell physiology, the central nervous system, and sociology applying his newly developed method of approximation. The second part of this chapter demonstrates Rashevsky's preoccupation with institutionalization of his program and efforts to garner support for his program. It focuses on his role of "outsiderness" played out in the process of institutionalization of his program. Surrounded by a cadre of young students, with common theoretical and methodological interests, Rashevsky designed a training program in mathematical biology. This chapter examines the factors that led the university's administration to form, in 1938, a separate "department" under the *Section of Mathematical Biophysics*, a precursor to the more solid and independent *Committee on Mathematical Biology,* established in 1948, to accommodate Rashevsky and his group. I further explore how Rashevsky, challenged by finding a suitable venue for disseminating his group's research results, garnered the support of Warren Weaver at the Rockefeller Foundation to establish in 1939 a journal dedicated to mathematical biology entitled *Bulletin of Mathematical Biophysics*.

Chapters 4 and 5 follow Rashevsky into the 1950s and 1960s. Chapter Four explores Rashevsky's scientific agenda between the years 1948–1960. It examines Rashevsky's search for formal principles that would advance development of a theory of complex biological phenomena. I detail the transformative period in his research agenda in 1948–1954. I discuss the two principles Rashevsky formulated and believed to constitute a part of the permanent foundation of mathematical biology: the principle of organic form and that of relational biology. The principle of relational biology was introduced by Rashevsky in 1954 when Rashevsky came to realize that the reductionist treatment of physiology had led him to lose sight of the organisms themselves. Rashevsky was now propagating "throw away the physics and keep the organization." He radically departed from the fold of mechanism and adopted the holistic approach to biology, while still highlighting the role of a mathematical approach to biology.

Despite the transformation of his scientific agenda, Rashevsky and his group were prolific in their intellectual and research output. However, the backbone of Rashevsky's dream—namely, his institution—was in danger. This chapter explores three factors that contributed to the feeling that Rashevsky's project was facing perilous times: (1) a change of administration within the division and the university; (2) the university's poor fiscal situation; and (3) the "Red Scare"—an anticommunist movement which was directed at un-American activities and affected Rashevsky's committee, as several of its members were believed to be pro-communism. The chapter further demonstrates that despite the scientific, institutional, and political hardships, Rashevsky was far from giving up on his dream.

While his program encountered difficulties, Rashevsky still regarded his research approach as promising significant scientific advance and vigorously fought to keep it alive. This chapter ends with the discussion of the role governmental agencies played in resurrecting Rashevsky's program at the University of Chicago, following its fall in the mid 1950s.

Chapter 5 follows Rashevsky into the 1960s, accounting for his untimely resignation in 1964 and his move to the Mental Health Research Institute at the University of Michigan until his retirement in 1969. The chapter primarily centers on the external, institutional, and social settings surrounding Rashevsky's mathematical biology rather than Rashevsky's scientific ideas. Discussion of these settings unfolds a detailed account of developments of "extrascientific" factors that dictated the future of Rashevsky's scientific ideas at the University of Chicago. I draw from correspondence in administrative records, correspondence in Rashevsky's archives, and personal interviews, to provide the reader with a fly on the wall perspective of the debates that emerged during the period leading to Rashevsky's resignation. I discuss the institutional settings and the political climate at the division of biological sciences and examine how personal and institutional elements achieve critical importance. The energetic debates between Rashevsky's proponents and the members of administration and leading figures at the division of biological sciences underline the particular focal features of not only intellectual but also political roots of the debate over the place mathematical biology should have at the University of Chicago. By providing a detailed chronology of events, I try to examine how the administration perceived Rashevsky's enterprise and the place it envisaged for his approach at the division.

In the final chapter of this book, I conclude by examining the implications of these findings. I discuss the theoretical findings of this research and question what lessons they might hold for the development of new scientific disciplines. I discuss how the definition and conception of mathematical biology as a discipline within biology resulted largely from Rashevsky's identity as an "outsider" and his efforts to secure resources to institutionalize his enterprise and legitimize its work.

Contents

List of Abbreviations

AAAS	American Association for the Advancement of Science
BMB	Bulletin of Mathematical Biology
CSHS	Cold Spring Harbor Symposia
NBC	National Broadcasting Company
NCSU	North Carolina State University
NIH	National Institutes of Health
NSF	National Science Foundation

Abbreviations for Archival Sources

NRP-SCRC	Nicolas Rashevsky papers, unsorted collection, Special Collections Research Center, University of Chicago
RLP-SCRC	Ralph Lillie papers, Special Collections Research Center, University of Chicago
HOP-SCRC	Office of the President, Hutchins Administration Records, Special Collections Research Center, University of Chicago
KOP-SCRC	Office of the President, Kimpton Administration Records, Special Collections Research Center, University of Chicago
BOP-SCRC	Office of the President, Beadle Administration Records, Special Collections Research Center, University of Chicago
VPO-SCRC	Office of the Vice-President, Records, Special Collections Research Center, University of Chicago
ARP-TUL	Anatol Rapoport's Papers, University of Toronto Archives Center
MBP-NCSU	Department of Biomathematics Papers, North Carolina State University Library
RAC	Warren Weaver Papers, Rockefeller Foundation Archive Center, Sleepy Hollow