

Sources and Studies  
in the History of Mathematics and  
Physical Sciences

THOMAS HAWKINS

# EMERGENCE OF THE THEORY OF LIE GROUPS

An Essay in the  
History of Mathematics  
1869–1926



Springer

# Emergence Of The Theory Of Lie Groups

**Armand Borel**



## **Emergence Of The Theory Of Lie Groups:**

*Emergence of the Theory of Lie Groups* Thomas Hawkins, 2012-12-06 This book is both more and less than a history of the theory of Lie groups during the period 1869-1926. No attempt has been made to provide an exhaustive treatment of all aspects of the theory. Instead I have focused upon its origins and upon the subsequent development of its structural aspects, particularly the structure and representation of semisimple groups. In dealing with this more limited subject matter considerable emphasis has been placed upon the motivation behind the mathematics. This has meant paying close attention to the historical context, the mathematical or physical considerations that motivate or inform the work of a particular mathematician as well as the disciplinary ideals of a mathematical school that encourage research in certain directions. As a result readers will obtain in the ensuing pages glimpses of and I hope the flavor of many areas of nineteenth and early twentieth century geometry, algebra and analysis. They will also encounter many of the mathematicians of the period including quite a few not directly connected with Lie groups and will become acquainted with some of the major mathematical schools. In this sense the book is more than a history of the theory of Lie groups. It provides a different perspective on the history of mathematics between roughly 1869 and 1926. Hence the subtitle *Essays in the History of Lie Groups and Algebraic Groups*. Armand Borel, 2001 Algebraic groups and Lie groups are important in most major areas of mathematics occurring in diverse roles such as the symmetries of differential equations and as central figures in the Langlands program for number theory. In this book Professor Borel looks at the development of the theory of Lie groups and algebraic groups highlighting the evolution from the almost purely local theory at the start to the global theory that we know today. As the starting point of this passage from local to global the author takes Lie's theory of local analytic transformation groups and Lie algebras. He then follows the globalization of the process in its two most important frameworks: transcendental differential geometry and algebraic geometry. Chapters II to IV are devoted to the former; Chapters V to VIII to the latter. The essays in the first part of the book survey various proofs of the full reducibility of linear representations of  $SL(2, \mathbb{C})$ , the contributions of H. Weyl to representation and invariant theory for Lie groups and conclude with a chapter on E. Cartan's theory of symmetric spaces and Lie groups in the large. The second part of the book starts with Chapter V describing the development of the theory of linear algebraic groups in the 19th century. Many of the main contributions here are due to E. Study, E. Cartan and above all to L. Maurer. After being abandoned for nearly 50 years the theory was revived by Chevalley and Kolchin and then further developed by many others. This is the focus of Chapter VI. The book concludes with two chapters on various aspects of the works of Chevalley on Lie groups and algebraic groups and Kolchin on algebraic groups and the Galois theory of differential fields. The author brings a unique perspective to this study. As an important developer of some of the modern elements of both the differential geometric and the algebraic geometric sides of the theory he has a particularly deep appreciation of the underlying mathematics. His lifelong involvement and his historical research in the subject give him a

special appreciation of the story of its development

### **Emergence of the Theory of Lie Groups** Thomas

Hawkins,2000-07-19     The Rise and Development of the Theory of Series up to the Early 1820s Giovanni

Ferraro,2007-12-20 The manuscript gives a coherent and detailed account of the theory of series in the eighteenth and early nineteenth centuries It provides in one place an account of many results that are generally to be found if at all scattered throughout the historical and textbook literature It presents the subject from the viewpoint of the mathematicians of the period and is careful to distinguish earlier conceptions from ones that prevail today     *The Princeton Companion to Mathematics* Timothy Gowers,June Barrow-Green,Imre Leader,2010-07-18 The ultimate mathematics reference book This is a one of a kind reference for anyone with a serious interest in mathematics Edited by Timothy Gowers a recipient of the Fields Medal it presents nearly two hundred entries written especially for this book by some of the world s leading mathematicians that introduce basic mathematical tools and vocabulary trace the development of modern mathematics explain essential terms and concepts examine core ideas in major areas of mathematics describe the achievements of scores of famous mathematicians explore the impact of mathematics on other disciplines such as biology finance and music and much much more Unparalleled in its depth of coverage The Princeton Companion to Mathematics surveys the most active and exciting branches of pure mathematics Accessible in style this is an indispensable resource for undergraduate and graduate students in mathematics as well as for researchers and scholars seeking to understand areas outside their specialties Features nearly 200 entries organized thematically and written by an international team of distinguished contributors Presents major ideas and branches of pure mathematics in a clear accessible style Defines and explains important mathematical concepts methods theorems and open problems Introduces the language of mathematics and the goals of mathematical research Covers number theory algebra analysis geometry logic probability and more Traces the history and development of modern mathematics Profiles more than ninety five mathematicians who influenced those working today Explores the influence of mathematics on other disciplines Includes bibliographies cross references and a comprehensive index Contributors include Graham Allan Noga Alon George Andrews Tom Archibald Sir Michael Atiyah David Aubin Joan Bagaria Keith Ball June Barrow Green Alan Beardon David D Ben Zvi Vitaly Bergelson Nicholas Bingham B la Bollob s Henk Bos Bodil Branner Martin R Bridson John P Burgess Kevin Buzzard Peter J Cameron Jean Luc Chabert Eugenia Cheng Clifford C Cocks Alain Connes Leo Corry Wolfgang Coy Tony Crilly Serafina Cuomo Mihalis Dafermos Partha Dasgupta Ingrid Daubechies Joseph W Dauben John W Dawson Jr Francois de Gandt Persi Diaconis Jordan S Ellenberg Lawrence C Evans Florence Fasanelli Anita Burdman Feferman Solomon Feferman Charles Fefferman Della Fenster Jos Ferreir s David Fisher Terry Gannon A Gardiner Charles C Gillispie Oded Goldreich Catherine Goldstein Fernando Q Gouv a Timothy Gowers Andrew Granville Ivor Grattan Guinness Jeremy Gray Ben Green Ian Grojnowski Niccol Guicciardini Michael Harris Ulf Hashagen Nigel Higson Andrew Hodges F E A Johnson Mark Joshi Kiran S Kedlaya Frank Kelly Sergiu Klainerman Jon Kleinberg Israel Kleiner Jacek

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**Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences** Ivor Grattan-Guinness, 2004-11-11 First published in 2004 Routledge is an imprint of Taylor Francis an informa company

**The Britannica Guide to The History of Mathematics** Erik Gregersen Associate Editor, Astronomy and Space Exploration, 2010-08-15 Traces the origins and development of arithmetic geometry trigonometry analytic geometry and calculus from the ancient civilizations to the present

**History of Original Ideas and Basic Discoveries in Particle Physics** Harvey B. Newman, Thomas Ypsilantis, 2012-12-06 The International Conference on the History of Original Ideas and Basic Discoveries held at the Ettore Majorana Centre for Scientific Culture in Erice Sicily July 27 August 4 1994 brought together sixty of the leading scientists including many Nobel Laureates in high energy physics principal contributors in other fields of physics such as high Tc superconductivity particle accelerators and detector instrumentation and thirty six talented younger physicists selected from candidates throughout the world The scientific program including 49 lectures and a discussion session on the Status and Future Directions in High Energy Physics was inspired by the conference theme The key experimental discoveries and theoretical breakthroughs of the last 50 years in particle physics and related fields have led us to a powerful description of matter in terms of three quark and three lepton families and four fundamental interactions The most recent generation of experiments at e e and proton proton colliders and corresponding advances in theoretical calculations have given us remarkably precise determinations of the basic parameters of the electroweak and strong interactions These developments while showing the striking internal consistency of the Standard Model have also sharpened our view of the many unanswered questions which remain for the next generation the origin and pattern of particle masses and families the unification of the interactions including gravity and the relation between the laws of physics and the initial conditions of the universe

**Basics of Representation Theory** Udayan Bhattacharya, 2025-02-20 Delve into the captivating world of Basics of Representation Theory a comprehensive guide designed for students researchers and enthusiasts eager to explore the intricate symmetries and structures that underpin modern mathematics Our book offers a detailed introduction to foundational concepts providing a solid understanding of group actions linear representations and

character theory From there it explores the algebraic structures of irreducible representations breaking down the decomposition into irreducible components and examining the properties of characters Readers will journey through diverse topics including the representation theory of symmetric groups Lie groups and algebraic groups as well as advanced topics such as the representation theory of finite groups the Langlands program and applications in quantum mechanics and number theory With a wealth of examples illustrations and exercises Basics of Representation Theory ensures a hands on approach to learning encouraging practical exploration and problem solving The book also includes numerous references and further reading suggestions for those who wish to delve deeper into specific topics Written in a clear and accessible style this book caters to all levels from undergraduate students encountering representation theory for the first time to experienced researchers seeking fresh insights With its comprehensive coverage and diverse applications Basics of Representation Theory is an invaluable resource for anyone interested in the beauty and depth of this field      *Essentials of Abstract Algebra*

Sachin Nambeesan,2025-02-20 Essentials of Abstract Algebra offers a deep exploration into the fundamental structures of algebraic systems Authored by esteemed mathematicians this comprehensive guide covers groups rings fields and vector spaces unraveling their intricate properties and interconnections We introduce groups exploring their diverse types from finite to infinite and abelian to non abelian with concrete examples and rigorous proofs Moving beyond groups we delve into rings explaining concepts like ideals homomorphisms and quotient rings The text highlights the relevance of ring theory in number theory algebraic geometry and coding theory We also navigate fields discussing field extensions Galois theory and algebraic closures and exploring connections between fields and polynomial equations Additionally we venture into vector spaces examining subspaces bases dimension and linear transformations Throughout the book we emphasize a rigorous mathematical foundation and intuitive understanding Concrete examples diagrams and exercises enrich the learning experience making abstract algebra accessible to students mathematicians and researchers Essentials of Abstract Algebra is a timeless resource for mastering the beauty and power of algebraic structures      Elements of the History of Mathematics

N. Bourbaki,2013-12-01 Each volume of Nicolas Bourbakis well known work The Elements of Mathematics contains a section or chapter devoted to the history of the subject This book collects together those historical segments with an emphasis on the emergence development and interaction of the leading ideas of the mathematical theories presented in the Elements In particular the book provides a highly readable account of the evolution of algebra geometry infinitesimal calculus and of the concepts of number and structure from the Babylonian era through to the 20th century      The Mathematics of Frobenius in Context Thomas Hawkins,2013-07-23 Frobenius made many important contributions to mathematics in the latter part of the 19th century Hawkins here focuses on his work in linear algebra and its relationship with the work of Burnside Cartan and Molien and its extension by Schur and Brauer He also discusses the Berlin school of mathematics and the guiding force of Weierstrass in that school as well as the fundamental work of d Alembert Lagrange and Laplace and of Gauss Eisenstein and

Cayley that laid the groundwork for Frobenius's work in linear algebra. The book concludes with a discussion of Frobenius's contribution to the theory of stochastic matrices.

*A History of Algebra* Bartel L. van der Waerden, 2013-06-29

*The Lie Theory of Connected Pro-Lie Groups* Karl Heinrich Hofmann, Sidney A. Morris, 2007

Lie groups were introduced in 1870 by the Norwegian mathematician Sophus Lie. A century later Jean Dieudonné quipped that Lie groups had moved to the center of mathematics and that one cannot undertake anything without them. If a complete topological group  $G$  can be approximated by Lie groups in the sense that every identity neighborhood  $U$  of  $G$  contains a normal subgroup  $N$  such that  $G/N$  is a Lie group, then it is called a pro-Lie group. Every locally compact connected topological group and every compact group is a pro-Lie group. While the class of locally compact groups is not closed under the formation of arbitrary products, the class of pro-Lie groups is. For half a century, locally compact pro-Lie groups have drifted through the literature, yet this is the first book which systematically treats the Lie and structure theory of pro-Lie groups, irrespective of local compactness. This study fits very well into the current trend which addresses infinite-dimensional Lie groups. The results of this text are based on a theory of pro-Lie algebras which parallels the structure theory of finite-dimensional real Lie algebras to an astonishing degree, even though it has had to overcome greater technical obstacles. This book exposes a Lie theory of connected pro-Lie groups and hence of connected locally compact groups and illuminates the manifold ways in which their structure theory reduces to that of compact groups on the one hand and of finite-dimensional Lie groups on the other. It is a continuation of the author's fundamental monograph on the structure of compact groups (1998, 2006) and is an invaluable tool for researchers in topological groups, Lie theory, harmonic analysis, and representation theory. It is written to be accessible to advanced graduate students wishing to study this fascinating and important area of current research, which has so many fruitful interactions with other fields of mathematics.

*Theory of Group Representations and Applications* Asim Orhan Barut, Ryszard Rączka, 1986

Lie algebras Topological groups Lie groups Representations Special functions Induced representations

*Discrete Causal Theory* Benjamin F. Dribus, 2017-04-26

This book evaluates and suggests potentially critical improvements to causal set theory, one of the best motivated approaches to the outstanding problems of fundamental physics. Spacetime structure is of central importance to physics beyond general relativity and the standard model. The causal metric hypothesis treats causal relations as the basis of this structure. The book develops the consequences of this hypothesis under the assumption of a fundamental scale with smooth spacetime geometry viewed as emergent. This approach resembles causal set theory but differs in important ways, for example, the relative viewpoint emphasizing relations between pairs of events and relationships between pairs of histories is central. The book culminates in a dynamical law for quantum spacetime derived via generalized path summation.

*The History of Combinatorial Group Theory* B. Chandler, W. Magnus, 2012-12-06

One of the pervasive phenomena in the history of science is the development of independent disciplines from the solution or attempted solutions of problems in other areas of science. In the Twentieth Century, the creation of specialties within the sciences has accelerated to

the point where a large number of scientists in any major branch of science cannot understand the work of a colleague in another subdiscipline of his own science Despite this fragmentation the development of techniques or solutions of problems in one area very often contribute fundamentally to solutions of problems in a seemingly unrelated field Therefore an examination of this phenomenon of the formation of independent disciplines within the sciences would contribute to the understanding of their evolution in modern times We believe that in this context the history of combinatorial group theory in the late Nineteenth Century and the Twentieth Century can be used effectively as a case study It is a reasonably well defined independent specialty and yet it is closely related to other mathematical disciplines The fact that combinatorial group theory has so far not been influenced by the practical needs of science and technology makes it possible for us to use combinatorial group theory to exhibit the role of the intellectual aspects of the development of mathematics in a clearcut manner There are other features of combinatorial group theory which appear to make it a reasonable choice as the object of a historical study

**The Columbia History of Twentieth-century French Thought** Lawrence D. Kritzman, Brian J. Reilly, 2006 Unrivaled in its scope and depth The Columbia History of Twentieth Century French Thought assesses the intellectual figures movements and publications that helped shape and define fields as diverse as history and historiography psychoanalysis film literary theory cognitive and life sciences literary criticism philosophy and economics More than two hundred entries by leading intellectuals discuss developments in French thought on such subjects as pacifism fashion gastronomy technology and urbanism Contributors include prominent French thinkers many of whom have played an integral role in the development of French thought and American British and Canadian scholars who have been vital in the dissemination of French ideas *Reader's Guide to the History of Science* Arne Hessenbruch, 2013-12-16 The Reader's Guide to the History of Science looks at the literature of science in some 550 entries on individuals Einstein institutions and disciplines Mathematics general themes Romantic Science and central concepts Paradigm and Fact The history of science is construed widely to include the history of medicine and technology as is reflected in the range of disciplines from which the international team of 200 contributors are drawn **History and Philosophy of Modern Mathematics** William Aspray, Philip Kitcher, 1988 History and Philosophy of Modern Mathematics was first published in 1988 Minnesota Archive Editions uses digital technology to make long unavailable books once again accessible and are published unaltered from the original University of Minnesota Press editions The fourteen essays in this volume build on the pioneering effort of Garrett Birkhoff professor of mathematics at Harvard University who in 1974 organized a conference of mathematicians and historians of modern mathematics to examine how the two disciplines approach the history of mathematics In History and Philosophy of Modern Mathematics William Aspray and Philip Kitcher bring together distinguished scholars from mathematics history and philosophy to assess the current state of the field Their essays which grow out of a 1985 conference at the University of Minnesota develop the basic premise that mathematical thought needs to be studied from an



interdisciplinary perspective The opening essays study issues arising within logic and the foundations of mathematics a traditional area of interest to historians and philosophers The second section examines issues in the history of mathematics within the framework of established historical periods and questions Next come case studies that illustrate the power of an interdisciplinary approach to the study of mathematics The collection closes with a look at mathematics from a sociohistorical perspective including the way institutions affect what constitutes mathematical knowledge

The book delves into Emergence Of The Theory Of Lie Groups. Emergence Of The Theory Of Lie Groups is a crucial topic that needs to be grasped by everyone, from students and scholars to the general public. The book will furnish comprehensive and in-depth insights into Emergence Of The Theory Of Lie Groups, encompassing both the fundamentals and more intricate discussions.

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  6. In chapter 5, this book will draw a conclusion about Emergence Of The Theory Of Lie Groups. This chapter will summarize the key points that have been discussed throughout the book.
- The book is crafted in an easy-to-understand language and is complemented by engaging illustrations. This book is highly recommended for anyone seeking to gain a comprehensive understanding of Emergence Of The Theory Of Lie Groups.

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## **Emergence Of The Theory Of Lie Groups Introduction**

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