

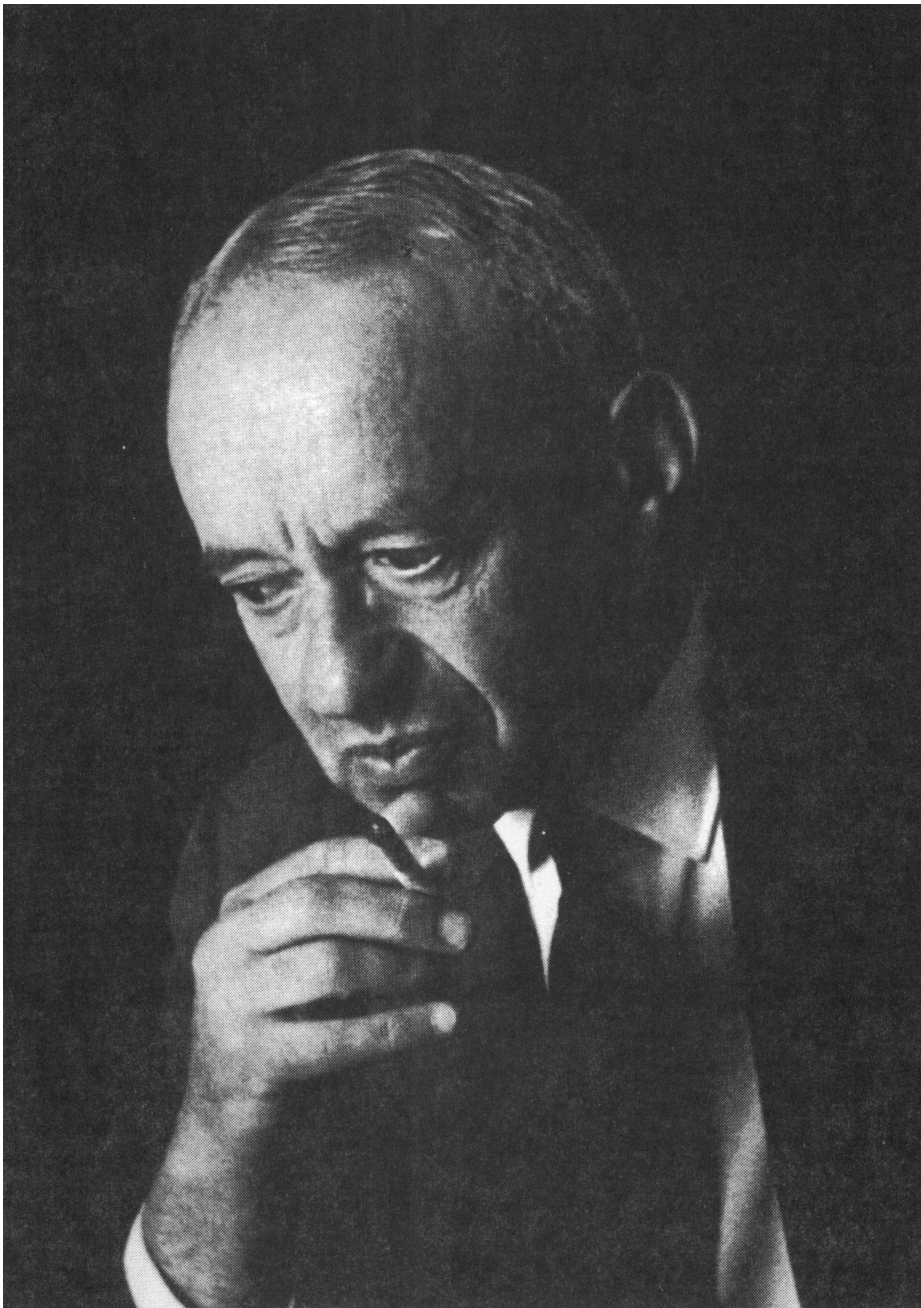
# Proceedings of the Tarski Symposium



**PROCEEDINGS OF  
SYMPOSIA IN  
PURE MATHEMATICS**

**VOLUME XXV**

**PROCEEDINGS  
OF THE  
TARSKI SYMPOSIUM**



ALFRED TARSKI

To

ALFRED TARSKI

with admiration, gratitude, and friendship

PROCEEDINGS OF SYMPOSIA  
IN PURE MATHEMATICS

VOLUME XXV

**PROCEEDINGS**  
**of the**  
**TARSKI SYMPOSIUM**

An international symposium held to honor Alfred Tarski  
on the occasion of his seventieth birthday

Edited by  
LEON HENKIN  
and  
JOHN ADDISON    C. C. CHANG  
WILLIAM CRAIG    DANA SCOTT  
ROBERT VAUGHT

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1974

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HELD AT THE UNIVERSITY OF CALIFORNIA, BERKELEY  
JUNE 23-30, 1971

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## FOREWORD

Alfred Tarski has been known to four generations of logicians and students as a scholar of extraordinary breadth and depth. His influence on the development of foundational studies in logic, mathematics, and the philosophy of science is due not only to his own investigations and numerous writings, but also to his influence as a teacher and a source of energy and organization in the international scientific community during the past half century. It was only natural, therefore, that as his 70th birthday approached the idea should have arisen in many quarters to utilize the occasion for an international symposium, not only to render public acknowledgement of Tarski's immense contribution, but to assess the impact and present status of the many domains to which he put his hand.

The symposium was held at the University of California, Berkeley, during June 23–30, 1971. The University joined with two international organizations in sponsoring the event: The Association for Symbolic Logic, and the International Union for the History and Philosophy of Science—Division of Logic, Methodology, and the Philosophy of Science. The major source of support was the National Science Foundation.

Robert Vaught, a colleague and former student of Tarski's, served as the Chairman of the Organizing Committee. When he arose at the opening session of the Symposium he spoke of the enthusiasm evinced by all who had been asked to help in preparing for the event. There was an almost tangible feeling of admiration and friendship for Tarski which bound together the 300 or so registered participants, a feeling that informed the meetings with a sense of liveliness impossible to convey in this volume which sets forth the principal scientific contributions of the invited speakers.

The Symposium Organizing Committee consisted of the following: J. W. Addison, Rudolf Carnap, C. C. Chang, Alonzo Church, Paul Cohen, William Craig, Solomon Feferman, Kurt Gödel, Leon Henkin, Bjarni Jónsson, H. Jerome Keisler, Stephen C. Kleene, Roger C. Lyndon, Richard Montague, Andrzej Mostowski, W. V. Quine, Abraham Robinson, Julia Robinson, Dana Scott,

Robert Vaught.<sup>1</sup> This group set up the policies within which the symposium was developed, and delegated the working out of details to a Symposium Executive Committee consisting of Addison, Chang, Craig, Henkin, Scott, and Vaught (Chairman).

From the beginning, the main problem of the Executive Committee was to cope with the wealth of ideas to which Tarski had given impetus, and somehow to encompass these in a coherent meeting of one week's duration. An early list drawn up by the Committee of the principal areas in which Tarski had worked, read as follows: general theory of algebras, foundations of geometry, algebraic logic, theory of models, metamathematical applications to algebra, decision methods, undecidable theories, classical set theory, foundational investigations in the theory of sets, philosophy and methodology of deductive sciences, measure theory, nonclassical logic, infinitary logic, definability. Realizing that this list was still not comprehensive—where, for example, would we fit in Tarski's work in sentential logic, or in the algebra of topology?—the Committee nevertheless looked at its list in awe, and wondered whether to seek to expand the Symposium from a week to a month.

In the end, practical considerations constrained the meeting to eight days. A good number of scholars who clearly should have been present could not be accommodated, or in some cases were unable to attend. Altogether 35 papers were presented in response to invitations from the Executive Committee to speak in specified areas, and another 25 papers were presented in sessions open for contributed work by participants. The programs of these two series of papers, as presented, are given immediately following this Foreword. Several of the invited addresses, at the express request of the Organizing Committee, took the form (at least in part) of a survey—either of the current literature, or of the historical development—of some area of foundational studies. In particular, the papers of the following speakers encompassed surveys of the indicated fields: Rabin (decidability), Julia Robinson (undecidability), Mostowski (set theory), Chang/Vaught (model theory), and Jónsson (general algebra). A portion of the papers of Henkin/Monk and of Hanf were devoted to surveys of the algebras of logic, and of Boolean algebra, respectively. The last five invited papers on the program, presented on the afternoon of June 30, were given (at the invitation of the Executive Committee) within a Symposium on Truth in Natural and Formal Languages.

In addition to the invited addresses and the contributed papers, a great many informal meetings and conversations contributed to the total scientific impact of the symposium. Students, professors, and other research workers from Canada, France, Israel, Poland, England, Hungary, Germany, China, India, Sweden, Egypt, and Japan, as well as from all parts of the United States, attended the symposium and took part in the many discussions. An invited speaker from the

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<sup>1</sup>Regretfully, Carnap and Montague did not live to see the symposium to whose organization they contributed.

USSR regretfully had to withdraw at the last moment. Among the formal events listed in the symposium program were a reception tendered by the University of California to participants, a two-day excursion to the Monterey Peninsula, and a banquet on the last evening. At the banquet gifts were presented to Professor Tarski, Mrs. Tarski, Mrs. Dale Ogar, Secretary of the Symposium, and Mrs. Roselyn Witherspoon, Assistant Secretary.

The list of papers in this volume differs in several respects from the program as presented at the symposium itself. The papers of Bernays, Birkhoff/Lipson, Cohen, Eršov, Karp, Schwabhäuser/Szczerba, Jan Tarski, and Woodger were included in this volume by invitation of the Organizing Committee, although not presented at the symposium itself. The symposium papers of Chang/Vaught and of Adams/Suppes were separated and each appears here as two distinct contributions. The papers of Erdős and of McKenzie were enriched through the collaboration of Hajnal and Shelah, respectively. The following symposium speakers chose a different title for their published contributions: Erdős/Hajnal, Feferman, Fraïssé, Gaifman, Keisler, Levy, McKenzie/Shelah, Mostowski, Shelah, Szmielew. Regretfully, the authors of several excellent talks delivered at the symposium are not represented by papers in this volume: Ax, Davidson, Jensen, Kaplan, Rabin, and Julia Robinson.

Special mention should be made of the role of Alfred Tarski in connection with these PROCEEDINGS. As an invited speaker, he was of course asked to contribute a paper to the volume. He agreed to do so, but elected to write on a subject different from the foundations of geometry, on which his symposium talk was based. In fact, the title he chose for his paper was *A formalization of set theory without variables*. Although this title suggests a rather specialized study, the material of the paper as Tarski developed it ranged widely over the foundations of mathematics. Appropriate to its scope, the length of the paper grew beyond what could be accommodated in this volume. Accordingly, the Editors recommended that it be published not as a part of the symposium proceedings, but as a separate companion volume to appear also in the American Mathematical Society series *PROCEEDINGS OF SYMPOSIA IN PURE MATHEMATICS*. Author and publisher agreed, and the two volumes will inaugurate a subseries of the AMS series to be co-sponsored by the Association for Symbolic Logic.

The arrangement of papers within this volume may be described roughly as an ordering which moves from algebraic to set-theoretical aspects of the foundations of mathematics, then proceeds to philosophical questions, and finally arrives at deductive aspects of empirical sciences. A more detailed description now follows.

We begin with Jónsson's survey of recent work in the general theory of algebraic structures. Gaifman next deals metamathematically with general operations on algebraic structures. The Birkhoff/Lipson paper deals with structures having several domains of elements, there follow papers by McKenzie/Shelah, Hanf, Craig, and Henkin/Monk, dealing with special classes of algebraic structures, and

then come papers by Szmielew and Schwabhäuser/Szczerba on geometric structures. A re-examination of the decision problem for elementary algebra and geometry, by A. Robinson, then follows.

Several papers on model theory are introduced by an historical survey, split at the year 1945 between the papers of Vaught and Chang. Shelah's paper deals with a problem of first-order model theory, while Feferman's is concerned with a variety of languages and those of Karp, Morley, and Fraïssé are involved in part or in whole with models of infinitary languages. Eršov deals with models of equational logic, and Ehrenfeucht deals with highly nonclassical logics arising from the ultra-intuitionistic studies of Essenin-Volpin.

The first of a series of papers on set theory is a survey of problems and results by Erdős/Hajnal. Then come axiomatic studies by Bernays, Church, and Levy, followed by examinations of models of set theories by Cohen, Keisler, Mostowski, Silver, and Solovay.

Philosophical papers by Quine, Mates, and Popper are focused on Tarski's theory of truth, Scott gives a reinterpretation of many-valued logic, and then Adams, Jan Tarski, and Suppes deal with the employment of the methodology of deductive sciences in empirical theories. The last paper is a personal tribute to Tarski by Woodger, to whom all readers of this volume are grateful for his translation of Tarski's early papers as well as for his own foundational research.

The volume closes with a list of Tarski's doctoral students, and a bibliography of his published work to date.

The Editors wish to thank the following persons who assisted in the preparation of this volume. For help in reading papers: Daniel Andler, Miroslav Benda, John Burgess, Geoffrey Chew, Herbert Enderton, Gebhard Fuhrken, Steven Glazer, George Grätzer, Dick Grandy, Haragauri N. Gupta, Michel Jean, Kenneth Kunen, Roger Maddux, George McNulty, Telis Menas, George Myro, Richard S. Pierce, Charles Pinter, Raphael M. Robinson, Lee Stanley, Jerome Wakefield, Ulf Wostner; for translating Eršov's paper from Russian into English: Benjamin F. Wells, III; for secretarial and administrative assistance far beyond the call of duty: Mrs. Dale Ogar; for technical handling of the manuscripts in the Editorial Office of the American Mathematical Society: Miss Ellen Swanson and Miss Margaret Reynolds.

THE EDITORS  
APRIL 1972

## PROGRAM OF INVITED ADDRESSES AT THE SYMPOSIUM

### June 23

Robert Connick, Vice Chancellor, University of California, Berkeley

Dana Scott, President, Association for Symbolic Logic

*Introductory and welcoming remarks*

Michael Rabin, International Business Machines, New York, and Hebrew University

*Decidability*

Julia Robinson, University of California, Berkeley

*Introduction to undecidability*

Andrzej Ehrenfeucht, University of Southern California

*Logic without iterations*

James Ax, State University of New York, Stony Brook

*My favorite decision problems*

### June 24

Wanda Szmielew, Mathematical Institute, Warsaw

*Some recent results connected with Tarski's axiomatic treatment of geometry*

Solomon Feferman, Stanford University

*Model theory and foundations*

Roland Fraïssé, Université de Marseilles-Aix

*The  $\alpha$ -isomorphisms between relations; Karpian families of local isomorphisms; utilization for calculus of infinite formulas*

Alonzo Church, University of California, Los Angeles

*Set theory with a universal set*

Robert Solovay, University of California, Berkeley

*Supercompact cardinals and the GCH*

**June 25**

Paul Erdős, University of Calgary

*Problems and results in combinatorial set theory. II*

Andrzej Mostowski, Mathematical Institute, Warsaw

*Influence of Tarski's writings on the theory of models for set theories*

Haim Gaifman, Hebrew University

*Well-ordered classes*

Ronald Jensen, University of California, Berkeley

*The fine structure of the constructible hierarchy*

Jack Silver, University of California, Berkeley

*Indecomposable ultrafilters and  $0^\#$*

**June 26**

Azriel Levy, Hebrew University

*On the independence of the axiom of subsets*

Alfred Tarski, University of California, Berkeley

*The story of a mathematical error*

**June 28**

C. C. Chang, University of California, Los Angeles

Robert L. Vaught, University of California, Berkeley

*Model theory 1915–1971*

Abraham Robinson, Yale University

*A decision method for elementary algebra and geometry—revisited*

H. Jerome Keisler, University of Wisconsin, Madison

*Suslin and Kurepa models*

Michael Morley, Cornell University

*Some applications of topology in  $L_{\omega_1, \omega}$*

Saharon Shelah, University of California, Los Angeles

*Loś conjecture and the number of nonisomorphic models*

**June 29**

Bjarni Jónsson, Vanderbilt University

*Some recent trends in general algebra*

Leon Henkin, University of California, Berkeley

J. Donald Monk, University of Colorado, Boulder

*Cylindric algebras and related structures*

William Hanf, University of Hawaii

*Primitive Boolean algebras*

William Craig, University of California, Berkeley

*Diagonal relations*

Ralph McKenzie, University of California, Berkeley

*Simple algebras*

**June 30**

Dana Scott, Princeton University

*Consequence and axiomatizability in many-valued logic*

Patrick Suppes, Stanford University

Ernest Adams, University of California, Berkeley

*Model theoretic aspects of fundamental measurement theory*

David Kaplan, University of California, Los Angeles

*Not substitutional quantification again!*

W. V. Quine, Harvard University

*Truth and disquotation*

Benson Mates, University of California, Berkeley

*Austin, Strawson, Tarski, and Truth*

(Read by Leonard P. Sasso, Jr.)

Karl Popper, London School of Economics and Political Science

*Philosophical comments on Tarski's theory of truth*

Donald Davidson, Princeton University

*Coherence, correspondence, and convention T*



## PROGRAM OF CONTRIBUTED PAPERS AT THE SYMPOSIUM

### June 23

- N. S. Mendelsohn and R. Padmanabhan, University of Manitoba  
*Equational theory of abelian groups*
- R. Padmanabhan, University of Manitoba  
*Equational theory of idempotent algebras*
- H. Subramanian and T. R. Sundararaman, State University of New York,  
Buffalo  
*Pre-complete varieties of rings*
- B. Banschewski and E. Nelson, McMaster University  
*On residual finiteness and finite embeddability*
- G. Epstein, ITT Gilfillan, Inc.  
*Aspects of Post algebra*

### June 24

- K. Prikry, University of Wisconsin  
*On a problem of Erdős, Hajnal, and Rado*
- R. v. B. Rucker, Rutgers University  
*Martin's axiom and saturated models*
- J. Cornwell, Reed College  
*A new class theory*
- D. Pincus, University of Washington  
*On cardinal representatives*
- R. K. Gostanian, New York University  
*The next admissible ordinal*
- K. Rasmussen, The University of Leeds  
*Some results concerning constructible models of set theory*

**June 25**

- S. D. Comer, Vanderbilt University  
*Elementary properties of structures of sections*
- J. Rosenthal, State University of New York, Stony Brook  
*A new proof of a theorem of Shelah*
- J. M. Dunn, Indiana University  
*A Kripke-style semantics for R-Mingle*
- T. Koranda, Colgate University  
*A geometric interpretation of the propositional calculus*
- J. T. Smith, San Francisco State College  
*Foundations of metric geometry of arbitrary dimension*

**June 28**

- J. R. Buchi and D. Siefkes, Purdue University  
*Axiomatization of the monadic second order theory of countable ordinals*
- R. Ladner, Simon Fraser University and the University of California, Berkeley  
*Mitotic recursively enumerable sets*
- G. Sacerdote, University of Illinois  
*Elementary properties of free groups*
- L. Sasso, University of California, Berkeley  
*Degrees of unsolvability of partial functions*

**June 29**

- J. F. Post, Vanderbilt University  
*A new antinomy and nonleveled concepts of truth*
- S. H. Levy, Johns Hopkins University  
*On the nature of arithmetic truths*
- S. K. Thomason, Simon Fraser University  
*Semantics for tense logics*
- M. Sawazaki, California State College at Long Beach  
*A set theoretical model of the liar paradox*
- R. S. Pomeroy, University of California, Davis  
*Tarski's 'semantic truth' and the testing of rhetorical theories*

## NOTE ON BIBLIOGRAPHIC REFERENCES

The bibliographic references following each article start with the authors' names. Consecutive articles by the same author are indicated by a three em line. Titles are in the language of the article; however, titles are in English for Russian publications. Pertinent information concerning volumes and issues is then included. The name of the publisher is given for books. For journal articles, the name of the journal is given in abbreviated form, using the Mathematical Reviews standard abbreviations; a list of these abbreviations is given in the Mathematical Reviews Index issues, currently being published in June and December.

When an article or book has been reviewed in Mathematical Reviews, the Mathematical Review number is given at the end of the reference. For the first 19 volumes (published prior to 1959) the form is MR 1, 34 which is the volume and page number, respectively. For subsequent volumes the listing is in the form MR 20 #932 which gives the volume number and number of the review.

## Ph.D. STUDENTS OF ALFRED TARSKI

Following the name and the 1972–73 position of each of Tarski's Ph.D. students,<sup>1</sup> there appears the date when the Ph.D. degree was awarded and the title of the Ph.D. dissertation. Mostowski's degree was awarded by Warsaw University, all of the others by the University of California, Berkeley. The following students are currently working on Ph.D. dissertations under Tarski's supervision: Michael Kwatinetz, Charles Martin, Judith Ng, B. F. Wells, III. Mention should also be made of Tarski's student M. Presburger, who was awarded the M.A. degree by Warsaw University in 1928, and whose dissertation *Über die Vollständigkeit eines gewissen Systems der Arithmetik ganzer Zahlen, in welchem die Addition als einzige Operation hervortritt* is widely quoted in the literature. In addition to his own students Tarski has had a significant influence on the Ph.D. dissertations of many other students with whom he had contact, in particular Adolf Lindenbaum, Leonard Gillman, and Dana Scott.

Andrzej Mostowski, Professor, Warsaw University  
1938

*O niezależności definicji skończoności w systemie logiki (On the independence of finiteness definitions in a system of logic)*

Bjarni Jónsson, Professor, Vanderbilt University  
September 1946

*Direct decompositions of finite algebraic systems*

Louise Hoy Chin Lim, Associate Professor, University of Arizona  
June 1948

*Distributive and modular laws in relation algebras*

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<sup>1</sup> Julia Robinson has at various times served as Lecturer and Research Mathematician at the University of California, Berkeley. Richard Montague was Professor of Philosophy at the University of California, Los Angeles, at the time of his tragic death in April, 1970, while helping to organize the Tarski Symposium. Robert Bradford, formerly Assistant Professor at the University of Southern California, is now employed as an applied mathematician.

Julia Bowman Robinson

June 1948

*Definability and decision problems in arithmetic*

Wanda Szmielew, Professor, University of Warsaw

June 1950

*Arithmetical properties of abelian groups*

Frederick Burtis Thompson, Professor, California Institute of Technology

January 1952

*Some contributions to abstract algebra and metamathematics*

Anne C. Davis Morel, Associate Professor, University of Washington

January 1953

*A study in the arithmetic of order types*

Robert Lawson Vaught, Professor, University of California, Berkeley

September 1954

*Topics in the theory of arithmetical classes and Boolean algebras*

Chen-Chung Chang, Professor, University of California, Los Angeles

June 1955

*Cardinal and ordinal factorization of relation types*

Solomon Feferman, Professor, Stanford University

June 1957

*Formal consistency proofs and interpretability of theories*

Richard Merritt Montague (Deceased)

June 1957

*Contributions to the axiomatic foundations of set theory*

H. Jerome Keisler, Professor, University of Wisconsin

June 1961

*Ultraproducts and elementary classes*

James Donald Monk, Professor, University of Colorado

June 1961

*Studies in cylindric algebra*

Haim Gaifman, Associate Professor, Hebrew University

September 1962

*Two contributions to the theory of Boolean algebras*

William Porter Hanf, Professor, University of Hawaii

January 1963

*Some fundamental problems concerning languages with infinitely long expressions*

Robert Earl Bradford

January 1965

*The axiom of choice in the arithmetic of cardinals*

Haragauri N. Gupta, Professor, University of Saskatchewan  
September 1965

*Contributions to the axiomatic foundations of geometry*

John Doner, Assistant Professor, Purdue University  
September 1968

*An extended arithmetic of ordinal numbers and its metamathematics*

Don Pigozzi, Assistant Professor, Iowa State University  
June 1970

*Amalgamation and interpolation properties of cylindric algebras*

George McNulty, Postdoctoral Fellow, University of Manitoba  
June 1972

*The decision problem for equational bases of algebras*

## **ALFRED TARSKI**

### **BIBLIOGRAPHY**

We have attempted to set down a complete bibliography of the published writings by Alfred Tarski through April 1972. In general, the order of titles is chronological, by date of publication, with exceptions noted below.

If an abstract or summary of a paper, or a part of a paper, has been published, it is listed beneath the title of the paper itself (under the same number), even though its publication preceded that of the paper; however, an abstract reporting results not subsequently incorporated in a longer paper, is listed by itself with a separate number. All abstracts and summaries are identified as such. Translations of a given work into languages other than the original are listed below the original title; the same number is used with an added letter, different letters for translations into different languages. Where several editions of a given work have appeared, these are listed immediately after the first edition. Where a paper was reprinted in some collection, this is noted immediately beneath the original title, under the same number. If a paper was published in several parts, the later ones are listed immediately after the first part. After certain titles the notation “[Restricted Distribution]” is given, to indicate a work not available to all persons; in some cases such works have been reproduced by processes other than printing (e.g., bound volumes of mimeographed papers).

After the list of books, papers, and abstracts (147 numbered items), the numbers 148–151 are used for various collections: project reports, published contributions to discussions at scholarly meetings, reviews, and problems.

At the end of the bibliography appears a list of journals, and series of books, to which reference is made by abbreviation in the numbered entries of the bibliography.

In addition to the published writings of Alfred Tarski listed in the bibliography below, the following works were edited by him (in collaboration with others):

*The axiomatic method, with special reference to geometry and physics*, North-Holland, Amsterdam, 1959; *Logic, methodology and philosophy of science* (Proceedings of the 1960 International Congress), Stanford Univ. Press, Stanford, Calif., 1962; *The theory of models* (Proceedings of the 1963 International Symposium at Berkeley), North-Holland, Amsterdam, 1965.

1. *Przyczynek do aksjomatyki zbioru dobrze uporządkowanego* (*A contribution to the axiomatic of well-ordered sets*), *Rev. Philos.* **24** (1921), 85–94. (Polish)
2. *O wyrazie pierwotnym logistyki*. Teza doktorska (*On the primitive term of logistic*), Doctoral Thesis, *Rev. Philos.* **26** (1923), 68–89. (Polish) [See 105.]
- 2a. *Sur le terme primitif de la logistique* (French edition of a part of [2]), *Fund. Math.* **4** (1923), 196–200.
- Sur les truth-fonctions au sens de MM. Russell et Whitehead* (French edition of a part of [2]), *Fund. Math.* **5** (1924), 59–74.
3. *Sur quelques théorèmes qui équivalent à l'axiome du choix*, *Fund. Math.* **5** (1924), 147–154.
4. *O równoważności wielokątów* (*On the equivalence of polygons*), *Przegląd Mat.-Fiz.* **2** (1924), 47–56. (Polish)
5. *Sur les ensembles finis*, *Fund. Math.* **6** (1924), 45–95.
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