# THE ANNALS of MATHEMATICAL STATISTICS

FOUNDED AND EDITED BY H. C. CARVER, 1930-1938 EDITED BY S. S. WILKS, 1938-1949

# THE OFFICIAL JOURNAL OF THE INSTITUTE OF MATHEMATICAL STATISTICS

# **Contents**

1	PAGE
On the jackknife statistic, its extensions, and its relation to $e_n$ -transformations H. L. Gray, T. A. Watkins and J. E. Adams	1
Weak convergence of $U$ -statistics and von Mises' differentiable statistical functions R. G. MILLER AND PRANAB KUMAR SEN	31
Linearized rank estimates and signed-rank estimates for the general linear hypothesis Charles H. Kraft and Constance van Eeden	42
The calculations of distributions of two-sided Kolmogorov-Smirnov type statistics ${\bf Marc\ Nof}$	58
A composite nonparametric test for a scale slippage alternative Melvin N. Woinsky	65
Existence and consistency of modified minimum contrast estimatesD. LANDERS	74
Joint asymptotic distribution of the estimated regression function at a finite number of distinct points	84
The asymptotic inadmissibility of the sample distribution functionR. R. Read	86
Some admissible empirical Bayes procedures	96
Equivariant procedures in the compound decision problem with finite state component problem	102
Maximum likelihood estimation of a translation parameter of a truncated distribution $\mathbf{Michael}$ Woodroofe	113
Large sample tests for the equality of two covariance matrices M. W. J. LAYARD	123
Estimating the size of a multinomial populationLalitha Sanathanan	142
Parameter estimation for an R-dimensional plane wave observed with additive independent Gaussian errors	153
On the best obtainable asymptotic rates of convergence in estimation of a density function at a point	170
An elementary theorem on the probability of large deviations Timothy J. Killeen, Thomas P. Hettmansperger and Gerald L. Sievers	181
Consistency and asymptotic normality of MLE's for exponential models Robert H. Berk	193
Characterizations of the multivariate normal distribution using regression properties F. S. Gordon and A. M. Mathai	205
Some probability inequalities related to the law of large numbers R. J. Tomkins	230
The division of a sequence of random variables to form two approximately equal sums AIDAN SUDBURY AND PETER CLIFFORD	<b>2</b> 36

Continued on back cover

Vol. 43, No. 1—February 1972

### THE INSTITUTE OF MATHEMATICAL STATISTICS

(Organized September 12, 1935)

The purpose of the Institute of Mathematical Statistics is to encourage the development, dissemination, and application of mathematical statistics.

#### **OFFICERS**

President:

R. C. Bose, Department of Mathematics and Statistics, Colorado State University, Fort Collins, Colorado 80521

President-Elect:

Lucien LeCam, Department of Statistics, University of California, Berkeley, California 94720

Executive Secretary:

Leo Katz, Statistical Laboratory, Michigan State University, East Lansing, Michigan

Program Secretary:

R. V. Hogg, Department of Statistics, University of Iowa, Iowa City, Iowa 52240

George J. Resnikoff, Department of Statistics, California State College, Hayward, California 94542

Editor: Annals of Mathematical Statistics

Ingram Olkin, Editor, Annals of Statistics, Educational Testing Service, Princeton, New Jersey 08540. Address after June 15, 1972: Ingram Olkin, Department of Statistics, Stanford University, Stanford, California 94305

Editor: Annals of Probability (beginning January, 1973)

Ronald Pyke, Department of Mathematics, University of Washington, Seattle, Washington 98105

Managing Editor:
K. J. C. Smith, Department of Statistics, University of North Carolina, Chapel Hill, North Carolina 27514

Membership. Membership dues including a subscription to the ANNALS OF MATHE-MATICAL STATISTICS are \$20.00 per year for residents of the United States or Canada and \$12.00 per year for residents of other countries. Special rates of \$10.00 per year are available to students. Inquiries regarding membership in the Institute should be sent to the Treasurer of the Institute.

Subscription Rates. Current issues of the Annals of Mathematical Statistics are \$30.00 per volume (six issues of one calendar year). Members of the Institute of Mathematical Statistics pay different rates (see above). Single issues are \$5.75. Back numbers for all issues up to and including 1956 (Volume 27) are \$16.50 per volume, \$4.50 per issue; issues from 1957 through 1964 are \$22.00 per volume, \$5.75 per issue; from 1965 onward, \$33.00 per volume, \$5.75 per issue. Complete sets (Volumes 1 through 27) are \$275.00. If additional volumes are ordered at the same time complete sets are ordered the price is \$16.50 per volumes are ordered at the same time complete sets are ordered, the price is \$16.50 per volume for Volumes 28 through 35, and \$22.00 per volume for Volumes 36 through 40. Complete sets (Volumes 1 through 40) are \$500.00.

Communications concerning subscriptions, back numbers, payment of dues, membership, changes of address, etc., should be addressed to the Treasurer. Advertising correspondence should be directed to the Managing Editor.

Mail to the Annals of Mathematical Statistics should be addressed to either the Editor, Managing Editor or the Treasurer, as described above. It should not be addressed to Waverly Press.

#### PRINTED AT THE

WAVERLY PRESS, Inc., Baltimore, Maryland 21202 U.S.A. Second-class postage paid at Baltimore, Maryland 21202 and at additional mailing offices. Copyright © 1972 by the Institute of Mathematical Statistics

#### **EDITORIAL STAFF**

#### EDITOR

#### INGRAM OLKIN

#### ASSOCIATE EDITORS

R. L. Anderson
R. R. BAHADUR
PETER J. BICKEL
DAVID R. BRILLINGER
L. Brown
H. D. Brunk
THOMAS S FERGUSON

RONALD K. GETOOR

S. S. Ghurye
Jaroslav Hájek
W. J. Hall
James F. Hannan
David L. Hanson
Peter J. Huber
Donald L. Iglehart
J. H. B. Kemperman
J. F. C. Kingmaň

JOHN W. LAMPERTI
ALBERT W. MARSHALL
PETER NEY
JEROME SACKS
I. R. SAVAGE
J. SETHURAMAN
FRANK L. SPITZER
HENRY TEICHER

#### Managing Editor

K. J. C. SMITH

#### PAST EDITORS OF THE ANNALS

H. C. Carver, 1930-1938
S. S. Wilks, 1938-1949
T. W. Anderson, 1950-1952
E. L. Lehmann, 1953-1955
T. E. Harris, 1955-1958
William Kruskal, 1958-1961
J. L. Hodges Jr., 1961-1964
D. L. Burkholder, 1964-1967

Z. W. BIRNBAUM, 1967-1970

Published bimonthly by the Institute of Mathematical Statistics in February, April, June, August, October and December.

#### EDITORIAL POLICY

The main aim of the Annals of Mathematical Statistics is to publish original contributions to theoretical statistics and to probability theory. The emphasis is on quality, not just on formal novelty and correctness of the contents of a paper. Expository papers are also welcome, especially if they provide authoritative surveys of areas that have been in vigorous development.

#### NOTICE

Manuscripts submitted for publication in the Annals of Mathematical Statistics should be sent to the Editor at the following address: Ingram Olkin, Editor, Annals of Mathematical Statistics, Educational Testing Service, Princeton, New Jersey 08540. After June 1972, to Ingram Olkin, Department of Statistics, Stanford University, Stanford, California 94305. Manuscripts submitted for publication in the Annals of Probability should be sent to the Editor at the following address: Ronald Pyke, Editor, Annals of Probability, Department of Mathematics, University of Washington, Seattle, Washington 98105.

# NOTICE

The Council of the Institute of Mathematical Statistics at the annual meeting of the Institute recommended to the membership that as of January 1973,

#### THE ANNALS OF MATHEMATICAL STATISTICS

be superseded by the two journals:

## THE ANNALS OF STATISTICS

and

#### THE ANNALS OF PROBABILITY

under the Editorship of Ingram Olkin and Ronald Pyke, respectively. Both journals will become, subject to the vote of the membership, official journals of the Institute of Mathematical Statistics and will appear in alternate months. Further details about this change will be forthcoming from the office of the Executive Secretary.

From January, 1972, papers submitted for publication in each journal should be sent to the appropriate Editor. In cases of doubt, a paper may be sent to either Editor; because some papers might naturally be in either journal, some members of the Editorial Board will be common to both journals.

Editorial addresses are:

Ingram Olkin, Editor

Annals of Statistics

Educational Testing Service

Princeton, New Jersey 08540

Address after June 15, 1972: Ingram Olkin, Editor Annals of Statistics Department of Statistics Stanford University Stanford, California 94305

Ronald Pyke, Editor Annals of Probability Department of Mathematics University of Washington Seattle, Washington 98195

#### IMS INSTITUTIONAL MEMBERS

AEROSPACE CORPORATION El Segundo, California

THE AMERICAN COLLEGE TESTING PROGRAM IOWA City, IOWA

ARIZONA STATE UNIVERSITY

Tempe, Arizona

ARTHUR D. LITTLE, INC.

Cambridge, Massachusetts

BELL TELEPHONE LABORATORIES, TECHNICAL LIBRARY

New York, New York
Boeing Scientific Research Labora-Tories

Seattle, Washington

CALIFORNIA STATE COLLEGE, HAYWARD, DEPARTMENT OF STATISTICS

Hayward, California

CASE WESTERN RESERVE UNIVERSITY, DE-PARTMENT OF MATHEMATICS Cleveland, Ohio

CATHOLIC UNIVERSITY OF AMERICA, STA-TISTICAL LABORATORY Washington, D.C.

CHEVRON RESEARCH COMPANY Richmond, California

CIBA PHARMACEUTICAL COMPANY Summit, New Jersey

COLORADO STATE UNIVERSITY, STATISTICAL LABORATORY Fort Collins, Colorado

CORNELL UNIVERSITY, DEPARTMENT OF MATHEMATICS

Ithaca, New York
FLORIDA STATE UNIVERSITY, DEPARTMENT

OF STATISTICS
Tallahassee, Florida

FORD MOTOR COMPANY, SCIENTIFIC LAB-ORATORIES Dearborn, Michigan

GENERAL MOTORS CORPORATION, RESEARCH LABORATORIES Warren, Michigan

GEORGE WASHINGTON UNIVERSITY, DE-PARTMENT OF STATISTICS Washington, D.C.

INDIANA UNIVERSITY, THE LIBRARY Bloomington, Indiana

INTERNATIONAL BUSINESS MACHINES CORPORATION

Armonk, New York

IOWA STATE UNIVERSITY, STATISTICAL LABORATORY Ames, Iowa

JOHNS HOPKINS UNIVERSITY, DEPARTMENT OF BIOSTATISTICS, DEPARTMENT OF STATISTICS

Baltimore, Maryland
KANSAS STATE UNIVERSITY, DEPARTMENT
OF STATISTICS

OF STATISTICS
Manhattan, Kansas
Many Smarre II NIVERSITY DEPARTMENT OF

KENT STATE UNIVERSITY, DEPARTMENT OF MATHEMATICS
Kent, Ohio

KNOLLS ATOMIC POWER LABORATORY Schenectady, New York

MIAMI UNIVERSITY, DEPARTMENT OF MATHEMATICS

Oxford, Ohio 45056

MICHIGAN STATE UNIVERSITY, DEPARTMENT OF STATISTICS

East Lansing, Michigan

MINNESOTA MINING AND MANUFACTURING COMPANY, APPLIED MATHEMATICS AND STATISTICS

Saint Paul, Minnesota

NATIONAL SECURITY AGENCY Fort George G. Meade, Maryland

NEW MEXICO STATE UNIVERSITY, DEPART-MENT OF MATHEMATICAL SCIENCES Las Cruces, New Mexico

NORTHWESTERN UNIVERSITY, DEPARTMENT OF MATHEMATICS Evanston, Illinois

Ohio State University, Department of Mathematics, Statistical Laboratory

Columbus, Ohio

OKLAHOMA STATE UNIVERSITY, DEPARTMENT OF MATHEMATICS AND STATISTICS Stillwater, Oklahoma

OREGON STATE UNIVERSITY, DEPARTMENT OF STATISTICS Corvallis, Oregon

PENNSYLVANIA STATE UNIVERSITY, DE-PARTMENT OF MATHEMATICS LIBRARY University Park, Pennsylvania

PRINCETON UNIVERSITY, DEPARTMENT OF STATISTICS

Princeton, New Jersey

PURDUE UNIVERSITY LIBRARIES Lafayette, Indiana

THE RAND CORPORATION

Santa Monica, California

THE ROCKEFELLER UNIVERSITY New York, New York

ROCKLAND STATE HOSPITAL, RESEARCH CENTER

Orangeburg, New York

SANDIA CORPORATION, SANDIA BASE Albuquerque, New Mexico

SIMON FRASER UNIVERSITY, DEPARTMENT OF MATHEMATICS

Burnaby, British Columbia, Canada

SOUTHERN METHODIST UNIVERSITY, DE-PARTMENT OF STATISTICS Dallas, Texas

STANFORD UNIVERSITY, GIRSCHICK MEMORIAL LIBRARY
Stanford, California

STATE UNIVERSITY OF NEW YORK, BUFFALO, DEPARTMENT OF STATISTICS Amherst, New York

TEMPLE UNIVERSITY, DEPARTMENT OF MATHEMATICS Philadelphia, Pa.

THE TOBACCO INSTITUTE Washington, D.C.

Union Oil Company of California, Union RESEARCH CENTER

Brea, California

UNITED STATES ARMY RESEARCH AND DE-VELOPMENT CENTER

Aberdeen Proving Ground, Maryland

University of Alberta, Department of MATHEMATICS

Edmonton, Alberta, Canada

UNIVERSITY OF ARIZONA, DEPARTMENT OF MATHEMATICS Tucson, Arizona

UNIVERSITY OF BRITISH COLUMBIA, DE-PARTMENT OF MATHEMATICS

Vancouver, B.C., Canada

University of Calgary, Mathematics DEPARTMENT

Calgary 44, Alberta, Canada

University of California, Berkeley, STATISTICAL LABORATORY

Berkeley, California UNIVERSITY OF CALIFORNIA, DEPARTMENT OF MATHEMATICS

Davis, California

University of California, Department OF MATHEMATICS Irvine, California

University of California, Department OF MATHEMATICS Riverside, California

University of California, Department OF MATHEMATICS Santa Barbara, California

University of Guelph, Library, Serials DEPARTMENT Guelph, Ontario, Canada

OF ILLINOIS AT CHICAGO University CIRCLE, DEPARTMENT OF MATHEMATICS Chicago, Illinois

University of Illinois, Library, Serials DEPARTMENT Urbana, Illinois

University of Iowa, Division of Mathe-MATICAL SCIENCES

Iowa City, Iowa University of Manitoba, Department OF STATISTICS

Winnipeg-19, Manitoba, Canada

University of Maryland, Department OF MATHEMATICS College Park, Maryland

University of Massachusetts, Depart-MENT OF MATHEMATICS & STATISTICS Amherst, Massachusetts

University of Michigan, Department of STATISTICS

Ann Arbor, Michigan

University of Minnesota, Department OF STATISTICS

Minneapolis, Minnesota

University of Missouri, Department of STATISTICS Columbia, Missouri

University of Missouri at Rolla, De-PARTMENT OF MATHEMATICS Rolla, Missouri

UNIVERSITY OF MONTREAL, DEPARTMENT OF MATHEMATICS Montreal, Quebec, Canada

University of New Mexico, Department OF MATHEMATICS & STATISTICS Albuquerque, New Mexico

University of North Carolina, Depart-

MENT OF STATISTICS Chapel Hill, North Carolina University of Ottawa, Department of

MATHEMATICS Ottawa, Ontario, Canada

PENNSYLVANIA, UNIVERSITY THE  $\mathbf{OF}$ LIBRARY Philadelphia, Pennsylvania

UNIVERSITY OF PUERTO RICO, DEPART-MENT OF MATHEMATICS Mayaguez, Puerto Rico

University of Rochester Rochester, New York

University of Washington, Laboratory OF STATISTICAL RESEARCH Seattle, Washington

UNIVERSITY OF WISCONSIN, MADISON, DE-PARTMENT OF STATISTICS Madison, Wisconsin

UNIVERSITY OF WISCONSIN, MILWAUKEE, DEPARTMENT OF MATHEMATICS Milwaukee, Wisconsin

WAYNE STATE UNIVERSITY, DEPARTMENT OF MATHEMATICS Detroit, Michigan

West Chester State College West Chester, Pennsylvania

WESTAT RESEARCH, INC.

Bethesda, Maryland

WESTINGHOUSE ELECTRIC CORPORATION. RESEARCH LABORATORIES Pittsburgh, Pennsylvania