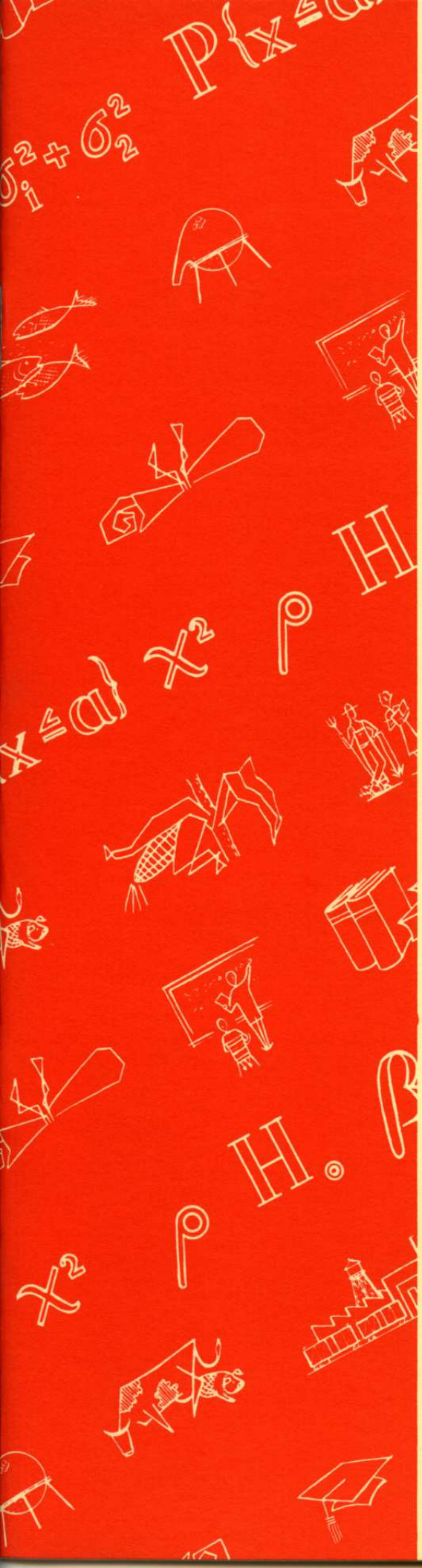

IOWA STATE UNIVERSITY BULLETIN

STATISTICAL LABORATORY

ESTABLISHED 1933

ANNUAL REPORT

July 1, 1967 to June 30, 1968

President W. R. Parks
Iowa State University of
Science and Technology
Ames, Iowa

Dear President Parks:

This is the annual report of the Statistical Laboratory at Iowa State University for the fiscal year July 1, 1967, through June 30, 1968. It reports on the research, consulting, teaching and operational work of the staff of the university statistical center.

The statistical center is composed of:

(1) The Statistical Laboratory, a research and service institute under the president's office;

(2) The teaching Department of Statistics in the College of Sciences and Humanities;

(3) The statistics department of the Agricultural and Home Economics Experiment Station;

(4) The statistics participant in the Sciences and Humanities Research Institute and the Engineering Research Institute; and

(5) The research field office of the Statistical Standards Division, Statistical Reporting Service, United States Department of Agriculture, which is located in the Statistical Laboratory.

The staff members of the Statistical Laboratory work in cooperation with many institutions and departments of Iowa State University. This annual report is a review of these activities as well as a record of the activities carried on solely by the Statistical Laboratory.

Respectfully submitted on behalf
of the Statistical Laboratory staff,

T. A. Bancroft

T. A. Bancroft
Director, Statistical Laboratory;
Head, Department of Statistics;
Head, Statistics Department,
Agricultural and Home Economics
Experiment Station

THE STATISTICAL LABORATORY

Iowa State University

ANNUAL REPORT 1967-1968

OUR 35th ANNIVERSARY

IOWA STATE UNIVERSITY BULLETIN
Ames, Iowa

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As the Statistical Laboratory ends another year, it reaches another milestone: its thirty-fifth anniversary. With the maturity of middle age and the vigor of youth, it continues to grow. The record of the year's activities included in this Annual Report is evidence of that growth.

However growth alone is not necessarily the best criterion of excellence. During its 35 years the contributions of the Statistical Laboratory have been impressive.

It has been instrumental in the development of two independent departments in the College of Sciences and Humanities: the affiliated Department of Statistics organized in 1947, and the degree program in Computer Science, which began offering courses last fall. The Department of Statistics celebrated its 20th anniversary at the beginning of the fiscal year, with record enrollments of both undergraduates and graduates, and of non-majors in service courses.

A cooperative agreement in the early '40's between the United States Department of Agriculture and the Statistical Laboratory, which established a climatological unit for research in the application of statistical methods to climatological problems, led to the formation in 1947 of a climatology curriculum within the Department of Agronomy.

In addition, the Statistical Laboratory developed computer services at Iowa State, which resulted in the establishment of the university's Computation Center in 1962.

Perhaps equally important, the Laboratory played an active role in helping to produce a minor revolution in the research approaches used at Iowa State. The use of statistics plus the offering of statistical training and consulting resulted in the statistical maturation of many research staff members in substantive fields. The Laboratory staff continues to cooperate closely with these research workers who now use statistics as a primary research tool. Information about the most recent developments in statistics continues to be offered through such programs as the Statistical Laboratory, Applied Statistics and Quantitative Genetics seminar series, open to staff members and graduate students from all departments.

Early off-campus support for statistics projects and research has continued, supplementing university research funds and making possible the study of many projects which could not otherwise have been undertaken. Both the consulting and research sections of this report record work completed under current grants and contracts with government agencies and other institutions and foundations. In addition to the Laboratory and the Department of Statistics, ISU's statistical center includes three sections devoted to research and research services: the statistics department of the Agricultural and Home Economics Experiment Station, the statistics participant in the Sciences and Humanities Research Institute and the Engineering Research Institute, and the research field office of the Statistical Standards Division, Statistical Reporting Service, United States Department of Agriculture.

Physically, the Statistical Laboratory is now distributed over three floors of the Service Building and an adjacent temporary building, but its influence reaches far beyond its physical confines. During the year staff members have been on assignment in Mexico, working with the Graduate College of the National School of Agriculture in Chapingo. Many other staff members have assisted with research projects around the world, consulting by mail. And books written by staff members are widely used, both in this country and abroad.

The most recent text was authored by professor emeritus George W. Snedecor, the Laboratory's founder and first director. *Statistical Methods,* first written during his early years with the Laboratory, became a best-seller of the Iowa State University Press and has been translated into several foreign languages. Its sixth edition, written by Snedecor and William G. Cochran, was published in the fall.

The Laboratory's influence has been felt in other ways over the years. Since it was the first statistical center of its kind to be established, it provided the impetus for other universities to establish similar research and service institutes. During the years some 20 other institutions, both in the United States and in foreign countries, have sought advisory assistance from Laboratory personnel in the organization of statistical centers.

However even while celebrating its 35th year, the Statistical Laboratory looks ahead to its next anniversary. In this computer age, statistics becomes increasingly important, not only as a tool for researchers but for all mankind. If man is to use the computer effectively, he must be able to program it. And to program effectively, he first must be able to analyze his business, political and social environment. Statisticians are trained to proceed beyond the collection of data to analyze and draw inferences from it, to make accurate predictions and decisions. It has been said that the amount of technical information available doubles every ten years. Statistics will be important in making possible the use of this information. The Statistical Laboratory is dedicated to a future of continued and improved statistical training and services for all who seek assistance.

PERSONNEL

T. A. Bancroft, director of the Statistical Laboratory, supervises the varied components of Iowa State's statistical center, which include: the Laboratory, an institute under the president's office; the Department of Statistics in the College of Sciences and Humanities; the statistics department of the Agricultural and Home Economics Experiment Station; and the statistics participant in the Sciences and Humanities Research Institute and the Engineering Research Institute. He reports to the president of the university through the vice president for research.

This year Dr. Bancroft was honored by the Iowa State University Alumni Association with a faculty citation, presented for long, outstanding and inspiring service. The citation read:

"Since 1950 Dr. Bancroft has been Director of the Statistical Laboratory and head of the Department of Statistics. Under his cosmopolitan leadership this statistical complex has remained a leading world center for research in statistics and for training graduate and undergraduate students. In addition to his heavy administrative duties, he has continued teaching and producing scholarly publications, pioneering in the area of incompletely specified models. His services as a consultant in statistics have been sought by agencies in many countries of the world."

The various components of the statistical center which Dr. Bancroft directs share personnel, which means that a staff member's salary may be budgeted from several sources, depending on the emphasis of his work. In addition, there are a number of cooperative research grants and contracts with federal agencies which provide funds for both staff and graduate students.

The members of the statistical center, including its affiliated fellows and graduate students, are listed below.

THE STATISTICAL LABORATORY STAFF FOR THE FISCAL YEAR 1967-68

Under the administrative direction of

W. Robert Parks, Ph.D. . . . President of the University
J. Boyd Page, Ph.D. . . . Vice President for Research; Dean of the Graduate College
Chalmer J. Roy, Ph.D. . . . Dean, College of Sciences and Humanities; Director, Sciences and Humanities Research Institute
Floyd Andre, Ph.D. . . . Dean, College of Agriculture; Director, Iowa Agriculture and Home Economics Experiment Station
Theodore A. Bancroft, Ph.D. . . . Director, Statistical Laboratory; Head, Department of Statistics; Head, Statistics Department, Iowa Agriculture and Home Economics Experiment Station

Professors

T. A. Bancroft
C. Philip Cox
Herbert T. David—on leave
Wayne A. Fuller
David V. Huntsberger
Oscar Kempthorne—Distinguished Professor, College of Sciences and Humanities
Masashi Okamoto—visiting
J. K. Sengupta—joint appointment with Department of Economics
George W. Snedecor—Professor Emeritus—in absentia
Norman V. Strand
Leroy Wolins—joint appointment with Department of Psychology
George Zyskind

Associate Professors

David F. Cox—joint appointment with Department of Animal Science
Carol Edwards Fuchs
Donald K. Hotchkiss—on assignment in Mexico
David Jowett
K. L. Mehra—visiting
C. C. Mosier—joint appointment with Computation Center
Edward Pollak—joint appointment with Department of Genetics
J. H. Sedransk
B. V. Sukhatme
James Walsh—joint appointment with Department of Psychology

Assistant Professors

Barry Arnold—joint appointment with Department of Mathematics
Harold Baker
Chien-pai Han
Roy Hickman
James L. Hutter—joint appointment with Department of History, Government and Philosophy
Shushikala Sukhatme
Richard D. Warren—joint appointment with Department of Sociology

Visiting Lecturers

Foster B. Cady—on assignment in Mexico, through fall quarter
W. D. Lawing
E. L. LeClerg—spring quarter
Richard Lund—on assignment in Mexico
Henry Tucker—on assignment in Mexico, through fall quarter

Instructors and Associates

Leon Burmeister
James S. DeGracie
G. L. Ghai
Leon Jordan—beginning winter quarter
William Kennedy
Richard Mensing
Abel Mexas—beginning winter quarter
Esmat Nouri
P. Papaioannou—beginning winter quarter
Carl Z. Roux—beginning first summer session
Donald Soults
Vincent Sposito—beginning spring quarter
Richard Stein
Victor Tang
Eric West—beginning winter quarter

Graduate Assistants

(The status of graduate students often changes. Students who have held the title of graduate assistant during the year are listed here.)

Joseph Abbey
George Battese
Richard Chamberlain
Sharon Earley
Gregory Fawcett
John Goebel
Bonnie Hanson
James Immordino
Charles Ingwell
Cary Isaki
Louis Jensen
Leon Jordan
James Mellon
Kenneth Merritt
Abel Mexas
P. Papaioannou
C. M. Patel
David Pyne
David Ray
Melvin Seibel
Jan Shoemaker
V. B. Solomon
Vincent Sposito
Jane Toben
James Veale
Eric West
Terral Wittgow

Other Graduate Students

NIH Trainees:

Thomas Fears
Ronald Jacobson
Roland Loup
Peter O'Brien
Charles Sampson

NDEA Fellows:

A. Ronald Gallant
George Lauer

NSF Fellows:

Justus Seely
Kenneth Mount

Supported Students:

Munir Ahmad, AID, Census Bureau, Pakistan
Yahia Zakaria Ahmed, Ford Foundation, UAR
Richard Allen, USDA Trainee
Sorachai Bhisalbutra, AID, Thailand
Gordon Booth, NADL
William Burke, USDA Trainee, Consumer
Alfonso Carrillo, Ford Foundation, Mexico
Shang-Wang Chang (joint statistics-mathematics), Department of Mathematics
Godfrey Coker, AID, Census Bureau, Sierra Leone
Isidoro David, Rockefeller Foundation, Philippines
Orville Doering, USDA Trainee, Consumer
Robert Fenley, USDA Trainee
Omer Guceliogl, Census Bureau, Turkey
John W. Hazard (joint statistics-forestry), U. S. Forest Service
Omar Henriquez, Rockefeller Foundation, Chile
Muzammil Husain, AID, Census Bureau, West Pakistan
Khadija Khatun, AID, Pakistan
Arlette Machado, AID, Venezuela
Angel Martinez, Ford Foundation, Mexico
Ahmed Memon, AID, Pakistan
Mallika Mokkhaves, AID, Thailand
Syed T. M. Naqvi, AID, Census Bureau, Pakistan
Carl Z. Roux, Government of Union of South Africa
Ahmed Salem, Government of UAR
Malte Sund, West Germany
Nantit Supamongkon, AID, Census Bureau, Thailand
Franklin Wolf (joint statistics-industrial engineering), Department of Industrial Engineering

Unsupported Students:

Farrukh Ahmad
Forrest Aspengren
Robert E. Albert
Acharee Chantalakhana
Hae Ja Chung
Richard Darman
Sudha Desai
Francis Giesbrecht
Y. Hongsakaphadana
Leopoldo Machado
Donald McElhone
Yupha Sirikiate Onthuam
Nell Sedransk
Tom Whitley
Chartsee Xumsai

General Office Staff

Margaret G. Kirwin, Administrative Assistant
Kathleen Ringgenberg, Accountant
Susan Alice Brown, Technical Writer-Editor
Avonelle Jacobson, Supervisor, Teaching Group
Shirley Saveraid, Secretary, Numerical Analysis-Programming Group
Iveta Zeliadt, Secretary, Experimental Design-Genetic Statistics Group
Jan Bates, Secretary
Norma Christian, Secretary
Judy Donald, Secretary
Marlene Sposito, Secretary

Survey Group

Anne Leicht, Secretary
Helen Ayres, Survey Supervisor—through summer
Marjorie Mason, Survey Supervisor
Betty Fell, Programmer
Clerks:
Helen Carney
Hazel Cook
Evelyn Green
Ava Klopf
Mabel Matthews—through winter quarter
Anna B. Woodrow

CONSULTING and JOINT RESEARCH

Through the consulting services provided by the Statistical Laboratory, researchers in many varied university departments are better able to use pertinent statistical methodology. Assistance is available for statistical design of experiments, statistical design of surveys, statistical analysis and interpretation of data, numerical analysis and programming of a statistical nature, and the development and extension of new statistical methods and techniques.

This consulting service is made possible by the budgetary allowance of the Statistical Laboratory and the financial support provided to some staff members by the Agricultural and Home Economics Experiment Station and the Engineering Research Institute. Large percentages of some staff members' time are budgeted for consulting, while other staff members concentrate on research or teaching.

There is much variation in the nature of the statistical approach, subject matter involved, complexity of the statistical treatment and the degree of involvement of the consultant in a given study. This report gives an overview of consulting services provided during the year but is not meant as a complete record of the work of each staff member involved in consulting.

Consulting in the Plant Sciences

Dr. David Jowett served during the year as leader of Agricultural Experiment Station Project 101, Statistical Services in the Animal Sciences and Plant Sciences. He consults primarily in the area of plant sciences, and has been assisted this year by graduate students Richard Chamberlain and James Mellon.

Chamberlain's completion of the adaption of the OMNITAB programming system to Iowa State's IBM 360 has made it possible to use the computer for time consuming operations which previously had to be done by desk calculator.

Analysis of dilution series was programmed using OMNITAB for a series of experiments on corn mosaic virus conducted by Dr. J. C. Tu of the Department of Botany and Plant Pathology. The analysis failed to converge satisfactorily for some of the experiments, and in general the assumptions for the analysis were not met, as indicated by the lack-of-fit chi-square. It was postulated that a virus inhibitor may be present in the infective expressed sap, whose biological activity was reduced more rapidly on dilution than the virus. Consequently a 10-fold dilution was as infective as the original sap. Further experiments were planned to test this hypothesis.

Dr. W. F. Buchele and a graduate student in agricultural engineering have designed a flame-weeder, and asked assistance from Dr. Jowett in assessing the relationship of plant damage to time of exposure and temperature. The relationship was close to being all or nothing, but ultimately by narrowing the range of exposure conditions and applying suitable transformations, a convincing fit was obtained to a proposed model.

Dr. Jowett analyzed diallel crosses for Dr. C. P. Wilsie and a graduate student in agronomy, and designed a partial diallel for Dr. Wilsie. The graduate student's diallel was arranged in a split-split plot, and he had obtained a negative sum of squares for error by following the computing formulae in the literature, which were in error. It is much easier, for these complex analyses, to write out the X-matrix and analyze on a general regression program than to attempt to figure out a calculating machine procedure.

Graduate student Omar Henriquez has been exploring further the description of artificially induced epiphytotics of Crown Rust in oats as a thesis topic, under Dr. Jowett's supervision. Dr. J. A. Browning and a graduate student in botany and plant pathology have obtained daily estimates of aerial spore concentrations over experimental plots in which an epiphytotic is developing. Henriquez has found that if these spore counts are accumulated over time the data will fit a logistic model fairly well. Dr. Edward Pollak pointed out that the logistic model implies that the daily spore release should be related to the accumulated spore data by a quadratic model, and this is the basis of the internal least squares fitting procedure of H. O. Hartley. However, individual days show marked deviations from this model, and Henriquez postulates that this is due to climatic conditions on the particular day. This would provide a tool to relate spore release to climate.

Dr. Jowett designed a survey for Dr. Don C. Norton, botany and plant pathology, to assess the soil microfauna, especially nematodes associated with soybeans in relation to soil characteristics. Fields have been selected systematically to express a range of soil characteristics, and then fields are sampled three times during the season. An estimate of variance is obtained by taking two soil samples at random in each field. This is a continuing project, and only the first year's data has been analyzed to date.

Another survey was designed in association with Hideo Tachibana, USDA collaborator in botany and plant pathology, to investigate crop losses due to *Rhi-*

zoctonia solani in soybeans. Two fields were examined by sampling 50 small plots in each, showing a range of expression of the disease. Regression analysis showed a strong linear relationship between yield and number of dead plants. However, when the dead plants were classified into early, mid-season and late killed plants, and partial regression coefficients computed, the relationship of yield was only significant with mid-season killed plants. Early killed plants apparently are largely compensated by growth of neighbors and late killed plants had frequently filled most of their pods before death.

Dr. Jowett and Dr. Oscar Kempthorne were consulted by a graduate student in agricultural economics on the design of experiments for a Bureau of Reclamation project to study the effects of irrigation and fertilizers on crops. A suitable sampling of the factor space was suggested, taking into account the fact that rain may occur, making irrigation superfluous at times. Experiments have been laid out in Colorado, Oregon and Mexico. Further studies are proposed, using data routinely collected on farm fields to relate returns on irrigation to soil conditions and climate.

Mellon has worked with several students in agronomy and elsewhere fitting multiple regression models to responses to applied fertilizers and soil test data. This type of work is difficult because of the large number of independent variables to be examined and doubts about the adequacy of the linear models being fitted. For example, a plot of residuals from fertilizer experiments conducted on tree seedlings by R. E. Phares, United States Forest Service collaborator with forestry, indicated that while a second order polynomial removed most of the treatment sums of squares, there was serious lack of fit which could lead to mistaken inferences in response to all factors.

A particularly difficult analysis was presented by Dr. J. D. Pesek and Dr. R. D. Powell of agronomy. In this three-factor experiment fertilizer applications ranged from zero to 1200 pounds per acre, and the plots were split into a four-parental diallel of corn strains. In these circumstances it is easy to run out of space in available regression programs. However, Mellon succeeded in sorting the independent variables and produced meaningful analyses.

Dr. E. L. LeClerg, who served as a visiting lecturer during spring quarter, consulted primarily with graduate students from the Departments of Agricultural Engineering, Agronomy and Horticulture. Some of the requests were for help in designing experiments to be conducted in the field during the summer of 1968. Others related to the statistical analysis of data from experiments previously conducted in the field or in the greenhouse.

In the area of design of experiments, advice included experimental plans for the use of infrared photography from airplanes in relation to detection of moisture stress in soybeans; the effect of different types of shading sorghum plants in the field upon carbohydrate accumulation and subsequent grain yield; the relation of various factors of soil and climatic environments on the justification for inoculation of alfalfa with *Rhizobium* spp. on nitrification; and methods of identification and correlation of characteristics of foreign alfalfa introductions by means of automated storage and retrieval procedures.

Dr. LeClerg provided assistance with computational procedures for analysis and summarization of data, including such diverse problems as: the morphology of flowering, fruiting and yield of several machine- and non-machine-harvestable varieties of strawberries; response of concord grapes to iron additives with and without 2-4-D herbicides; effect of five dosages of *Rhizobium* spp. on nodulation and yield of alfalfa; intra-station consideration of long-time records of precipitation and temperature relations; absorption of gamma rays passed through soil; fuel use, time and other machine inputs as related to various cultural practices for the production of corn; and the determination of plot size and method of estimating competition in stand on yields of corn in experimental plots.

Dr. Arnel Hallauer of agronomy asked Dr. LeClerg's help on the procedure of testing for homogeneity of variances in relation to a combined analysis of a series of corn experiments conducted at a number of locations over a number of years.

Dr. Oscar Kempthorne worked with a graduate student in agronomy on models for plant growth. Dr. Edward Pollak helped Dr. Kenneth Ware of forestry check work on genetic variances in forestry.

Consulting in the Animal Sciences

Agricultural Experiment Station Project 101, Statistical Services in Animal Sciences and Plant Sciences, has supported the work of Dr. David Cox, who holds a joint appointment with the Department of Animal Science, and graduate students Leon Burmeister and Melvin Seibel.

Dr. Cox was consulted by Dr. W. W. Marion on a comparison of methods of extracting and measuring the protein in turkey meat after different periods of storage. The interest was to see whether different methods and procedures gave the same estimates of protein and whether the relationship among the methods was the same at each storage time. The approach was to fit a model to yield of protein, studying such factors as bird differences, methods and storage times. Most factors were highly significant and a prediction of protein yield from different methods at various storage times was possible.

Another multiple-regression problem was posed by a graduate student in poultry science, working on an investigation of the major factors controlling secondary bone in laying hens. After the most suitable model was found, it was used to test the effects of various rations and management practices.

Dr. Cox and Professor C. Philip Cox were consulted by Dr. R. H. Ingraham, Department of Veteri-

nary Physiology and Pharmacology, on the analysis of a factorial switchback experiment investigating the effects of environmental stress on the milk production of cattle in Mexico. Dr. Cox prepared an analysis of the crossover design, which is investigating the benefits of cooling the drinking water of lactating dairy cattle housed in a semi-tropical climate in Mexico. Preliminary results showed that for cows producing over 40 pounds per day, an additional two pounds per day could be expected if the water were cooled.

Graduate students in swine nutrition who consulted with Dr. Cox included one who is investigating the interrelationships among measurements on hog carcasses. Correlations within homogeneous groups of animals were used to study these relationships and determine if there are easily made measurements that will predict total body fat accurately.

Another student is conducting feeding trials with sows extending through two lactations. Treatments included two levels of energy and two levels of antibiotics, used to determine weight changes in the sow and her offspring. The data were not balanced and required a more basic approach than that used in the ordinary analysis of variance, but the results are substantially the same.

Burmeister cooperated with Dr. F. B. Hembrough and a graduate student in veterinary physiology on the analysis of data pertaining to the effects of starvation and various protein diets on the elasticity of blood vessels in rats. Excised blood vessels were stretched and the length measured under various forces up to breaking. Functional models of length in relation to force applied were fitted and compared for the various dietary treatments.

Professor E. O. Wright and Dr. G. W. Reinbold, Department of Dairy and Food Industry, were interested in the possibility of replacing the standard plate count method of determining bacterial counts in milk with the faster loop count. Plots of the numbers of colonies observed by the two methods at first showed a very poor relationship. Upon transformation it became clear that there was a good relationship which was not, however, linear.

Dr. Maxine Hinton and a graduate student in food and nutrition consulted with Burmeister on a project designed to study physiological characteristics of teenage girls in relation to diet and physical appearance.

Associate Abel Mexas programmed an analysis of egg laying activity of *Empoasca fabiae,* the brown leaf hopper, on a range of alternate hosts. This data, from Dr. E. T. Hibbs, zoology and entomology, was balanced in the sense that, after censoring, the sub-class numbers were proportional. Significant effects were shown.

Dr. Edward Pollak provides consulting services on statistical aspects of genetics and breeding research, supported by Agricultural Experiment Station Project 1448. Typical of his work was a project of a graduate student in poultry science who needed help with the estimation of variance compounds.

Dr. Oscar Kempthorne consulted with Dr. A. W. Nordskog of poultry science on the interpretation of blood group data for poultry, and helped a graduate student in animal science with interpretation of data on stomach ulcers in swine.

Professor C. Philip Cox assisted a statistician at the National Animal Disease Laboratory on the probit analysis of experiments on rabies vaccine with special reference to interval estimation of the ED80.

Dr. C. E. Fuchs worked with a graduate student in fish and wildlife who investigated some of the factors that might influence the survival rate of duck eggs. Eggs were placed in both tree and ground cavities early and late in the summer for each of two years, for a number of plots. The number of surviving eggs was observed after 20 days and the proportion of survivors transformed. An analysis of variance was then performed; years were random with a factorial arrangement of treatments. Only differences between plots were found to be significant. Additional data and use of the median test found that the proportion of surviving eggs was apparently unaffected by type of ground cover, distance from water, height or size of nest opening. The variability of the data seems to have obscured any real effects.

Dr. Fuchs also was consulted by a graduate student in zoology to analyze data on ducks. Weight gain was investigated as a function of a hormone. Also weights of wild ducks were investigated as a function of year, season, time, sex and number of days on a reservation.

Another graduate student in zoology asked help from Dr. Fuchs on a study of the influence of diet on codling moths (Carpocapsa pomonella, lin.). Variables such as whether or not a mating is successful, proportion of eggs that hatch, weight of pupae, and longevity of the larval stage were observed. Two problems in the analysis were that it was felt necessary to remove family differences, and there were few and unequal numbers of pairs mated for each diet family combination. A two-factor factorial in a completely random design, diet and family being the factors, was set up by grouping families based on maternal or paternal grandmothers. An approximate analysis was performed using unweighted means. Preliminary results indicate no influence of diet on proportion of eggs that hatch, but a significant influence of family.

Consulting in Numerical Analysis-Programming

The Numerical Analysis-Programming Section, directed by William Kennedy, provided consulting services in statistically-oriented computer problems and developed a number of programs for solving problems with the computer.

Kennedy and Richard Stein assisted the Survey Group with computer problems which arose in connection with analysis of the child foot nutrition study data which the Survey Group had collected. Kennedy also developed a special computer program to analyze data obtained from an extensive creel census taken on the

Mississippi River, for a project conducted by the Iowa Conservation Commission. Stein performed a statistical analysis of test scores received from the Physical Education Department in connection with a study designed to compare commonly used exercises.

Donald Soults and Vincent Sposito worked with economists on applications of mathematical programming in economic forecasting. Both linear and nonlinear programming problems were solved using computer programs developed by the Numerical Analysis-Programming Section. Sposito added a new program, AUKLET, to the library. This program solves problems which arise with a convex objective function and concave constraints, using the sequential unconstrained minimization technique.

The factor analysis program, APTERYX, was revised to be compatible with the new 360/65 computer under a multiprogramming environment. New programs also were developed by Bonnie Hanson and Jane Toben. Mrs. Hanson's program, for a forestry project, was created for the analysis of building costs in several Iowa districts. Miss Toben's program, which analyzes yearly farm operation costs according to a general model, was done for a USDA agricultural economist.

Graduate student Richard Chamberlain, working under Dr. David Jowett with the support of Agricultural Experiment Station Project 101, has completed the adaptation of the OMNITAB programming system of the National Bureau of Standards to the IBM 360. This has enabled tackling less routine problems effectively on the computer.

This programming system permits programs for numerical and statistical analysis to be written in English. The immediate availability of a plot routine has been particularly useful in facilitating the display of data. Many requests for tapes of this version of OMNITAB have been received, from such places as the B. F. Goodrich Chemical Company, University of California at Berkeley, Eastman Chemical Products, First National City Bank of New York City, University of Michigan and the University of New South Wales.

In addition, Chamberlain has written programs for several new OMNITAB commands. Of particular interest have been the command YATES, which calculates contrasts for 2^n experiments, and DEVNOR, which generates normal deviates from values of the cumulative standard normal distribution.

Associate Abel Mexas has refurbished the part of the AARDVARK program which handles non-orthogonal analyses. This is a completely separate routine from the orthogonal analysis, and proceeds by building up the X-matrix from the data subscripts. It then computes additional reductions in the sums of squares by fitting the full model followed by a reduced model and computing the difference. The program will produce an analysis of variance table provided all model terms are estimable. The model may be non-orthogonal in any factor or factors. Such situations are common in consulting work and the program has found extensive usage.

Consulting in Engineering and the Physical Sciences

Dr. W. D. Lawing, who served during the year as a visiting lecturer, was consulted by staff members and graduate students in engineering. A project representative of his activities involved a graduate student in industrial engineering. A method of testing the goodness of fit of a survivor curve to certain types of physical property was devised. This method, applicable to situations where property records consist of only gross additions and annual plant balances, assumes that the differences between actual and expected annual balances for a number of years would follow a multivariate normal distribution.

Dr. Oscar Kempthorne assisted Dr. Willard Talbert of physics on the fitting of nuclear decay data, and helped a graduate student in physics on the fitting of a nonlinear model to physical data.

Dr. David Jowett was consulted by Dr. E. R. Baumann and a graduate student in civil engineering, who had collected data on the relationship of filter cake resistance and the ratio of concentration of impurities to concentration in the filtrate for a range of filter cake products. After transformation, the relationships were strongly linear. Interest was attached to the homogeneity of slopes and means. An analysis of covariance was performed to test the hypothesis of homogeneity.

Residuals from regression analysis have habitually been examined by probability plotting. Plotting residuals has on occasion been of assistance in identifying outliers. For example, a graduate student in chemical engineering requested help from Dr. Jowett in the design of an experiment to determine the effect of concentration of chlorine, carbon monoxide, and of temperature on the formation of phosgene. On analyzing the data according to a theoretically derived linear model, one serious outlier appeared on the residual plots. When this observation was omitted, estimates of the parameters closer to the theoretically expected values were obtained and the residual mean square was halved.

Consulting in the Behavioral and Social Sciences

Dr. Leroy Wolins, who has a joint appointment in statistics and psychology, does much of the consulting in the behavioral and social sciences. During the year he was assisted by Robert Boruch, a doctoral candidate in psychology, who handled much of the work in factor analysis.

Dr. Wolins has directed Boruch's research, which involves estimating separate variance components for a random variable for all combinations of the fixed variables crossing the random one. For example, in a three-way classification with one random variable, four variance components are estimated: σ_α^2, $\sigma_{\alpha\beta}^2$, $\sigma_{\alpha\gamma}^2$ and σ_e^2. In this research, b times c such components are estimated, one set for each combination of b and c. Boruch will be graduated with a minor in statistics.

Assistance also was given by Dr. Wolins to a graduate student in economics. This research examined the relationships between characteristics of school systems, such as size, wealth and quality of teachers, and average achievement of students in the system. The work indicated that there was little relationship. Only about three percent of the variance in average achievement was accounted for by the characteristics of the school system.

A graduate student in psychology sought statistical advice from Dr. Wolins on his project to test the hypothesis that the concept of living versus non-living could be taught. In previous research Piaget suggests the acquisition of this concept depends mostly on maturation. However this current research clearly indicates that performance on objective measures of attainment of this concept can be substantially enhanced by presenting a short description via documentary film to eight-year-old subjects.

Three objective measures of achievement were obtained for each subject: objects directly dealt with in the film, objects in the same class as objects dealt with in the film (e.g. spinach rather than lettuce, clouds rather than fog), and objects in classes different than those dealt with in the film (e.g. flowers rather than lettuce). There was no evidence for a treatment by measure interaction. The gain as a function of the treatment did not appear to depend on the specific stimuli used to assess the performance.

Dr. Marguerite Scruggs of the College of Home Economics is investigating relationships between the job advancement of industrial workers and the behavior of their wives. Interviewing was done by the Statistical Laboratory's Survey Group of wives of long-tenured production workers in metal-working factories. Dr. Wolins has assisted with the examination of this data to determine how the responses of the women are related to the rate of advancement of their husbands.

Dr. Wolins was consulted by Dr. Don Charles of psychology and Dr. James Magilton of veterinary anatomy on a joint investigation of the relation of the temperature of blood from the brain to cognitive activity and intelligence. The records obtained are continuous measurements taken from the upper part of the nose between the eyes. Separate records are obtained from the right and left sides.

The researchers are interested in qualitative and quantitative differences in the response as a function of the nature of the cognitive task and individual differences. Dr. Wolins has proposed an analysis which reduces the integral of the time series to digital form and fits individual curvatures. The coefficients of the polynomials will be analyzed by the conventional analysis of variance procedures. The data will be allowed to influence decisions about the need for a transformation and the nature of the function that fits the data.

Dr. Richard D. Warren, who holds a joint appointment in statistics and sociology, has continued to provide consulting services to staff members and graduate students on problems involving design and analysis of investigations in sociology and other social sciences.

Recent publications have provided discussions and illustrations of various alternative approaches which sociologists have been using or could be using for the analysis of complex relations. One of the areas of emphasis has been causal inference in the non-experimental research settings. Several graduate students and faculty members in sociology have been interested in studying the relative importance of these various approaches and application of these approaches to their research. Dr. Warren has had many consulting requests concerning the statistical representations, assumptions, computations and interpretations in the use of these various approaches for causal inferences. Theses and papers have been written covering such areas as causal inferences in sociological research, developing causal models, relative importance of and comparison of various alternatives, and application of the techniques to a given research area.

Several consulting requests have been in the area of measurement of sociological variables. Activities included developing questions and observational techniques to obtain the necessary data, coding and scoring the responses, comparison of alternative measures, and construction of scales and indexes.

Some of the topics on which Dr. Warren was consulted regarding the design and analysis of sociological studies included: housing values and satisfactions, role census, social power, adoption of farm practices, commercialization of farm firms in a subsistence farm economy, occupational and education aspirations of youth and their attainment, and impact of an education program. A wide range of statistical techniques have been used in the analyses of data from these studies.

Staff members and graduate students in family environment have requested Dr. Warren's assistance in designing and analyzing research studies. The purpose of one study is to provide an inventory of the consumer education needs of young families as judged by county home demonstration agents and members of family living subcommittees. Comparisons were made in regard to consumer education needs of three types of audiences and differences in opinions identified for the two types of judges. Another project was designed to examine the satisfactions and dissatisfactions of young mothers with their roles as homemakers and the associations of selected environmental factors with these satisfactions and dissatisfactions. A third study was designed to determine the variables and factors which influenced the acceptability and feasibility of effective lighting for study in dormitory rooms at Iowa State. A study in process involves the comparison of various washing alternatives on two fabric treatments of white shirts.

Dr. Roy D. Hickman has consulted with various students and faculty members regarding design and analysis of investigations in education and other social sciences. He assisted with the planning of an exper-

iment, conducted by a graduate student in education, designed to measure and evaluate physiological responses of automobile drivers. A number of relatively homogeneous subjects were tested over a planned route, using an experimental car designed and manufactured by the Ford Motor Company. Among the data collected were heartbeat, galvanic skin response, frequency of brake and accelerator applications, and steering reversal rate. Since drivers' responses were likely to vary with external driving conditions, a latin square arrangement of days and time of day was employed.

Other consulting typical of Dr. Hickman's activities includes: design and analysis of an experiment evaluating a new teaching method in an undergraduate course in education; data analysis and interpretation of an investigation of an audio-tutorial scheme of laboratory instruction utilized in an undergraduate agronomy course; and design of and methods to be used in drawing a restrictive sample of farmers for a study involving mailed questionnaires.

In the College of Home Economics, Dr. Hickman consulted with Dr. Geraldine Montag and Dr. Marjorie McKinley of institution management regarding an experimental training program for public school food service workers. A graduate student in food and nutrition sought assistance from Professor C. Philip Cox on the analysis of variance of results taken to evaluate a simple device for quantitating egg white stages during beating. Dr. Oscar Kempthorne was consulted by Dr. Frances Carlin, food science, on the interpretation of data relating to changes in food resulting from cooking.

Off-Campus Consulting and Advisory Assignments

Dr. David Jowett has received further work from East Africa, sent by S. A. Eberhardt, who is connected with the USDA/AID Corn-Sorghum Project. A factorial experiment on sorghum variety x stalk borer infestation method was subjected to analysis of covariance of yield on total length of borer tunnels. The independent variable, borer tunnel length, was highly significant for treatment effects, but very little of the error variance in yield could be explained by the covariate. The analysis of covariance did, however, yield useful inferences. After adjusting for borer tunnels there were still significant treatment effects, indicating important differences in yield due to factors other than borer activity.

The writing of the command YATES for the OMNITAB program has enabled Dr. Jowett to analyze several series of 2^n experiments by half-normal plots, notably a series of 2^6 agronomic experiments in single replicates carried out by A. Y. Allan in Kenya.

Dr. Wayne Fuller made several trips to Mexico as a consultant to the Ford Foundation on the three-year evaluation study of certain agricultural extension programs, in cooperation with Dr. Raymond Beneke and Dr. Lehman Fletcher, Department of Economics. A second survey was completed in two states in December and January. Dr. Richard Lund, on assignment in Mexico with the Ford Foundation cooperative project at Chapingo, assisted with the project, supervising the coding, punching and programming of data.

Dr. Richard Warren was asked to serve as statistical-methodological consultant in developing a field instrument for committee members working on the NC-90 project, "Factors affecting patterns of living in disadvantaged families." Most of the states of the north central region plus representatives from Texas, California, Nevada and Hawaii have participated in developing the project proposal, determining focus of the research, defining the concepts and writing operational definitions, developing the instrument for measuring the concepts, discussing sampling procedures and have been delegated specific responsibilities.

Survey Group

The Survey Group serves the entire university, providing both technical assistance and direct operational services for sampling, surveys and census-type studies. Consulting services are combined with operational work through the financing of the Statistical Laboratory, the Statistics Department, the Iowa Agricultural and Home Economics Experiment Station and the Sciences and Humanities Research Institute.

Professor Norman Strand and Dr. Donald Kaldor, Department of Economics, continue to cooperate on research supported by Agricultural Experiment Station Project 1477. Two years ago the Survey Group processed data for a statewide group of Iowa farm operators who quit farming during 1959-61, and a manuscript was prepared reporting the findings of a study of persons entering Iowa farming during 1959-60. Two hundred of those new Iowa farmers identified in 1959-60 are again being surveyed to discover their present occupation. The current study will determine those families still engaged in the farm operation and will obtain data on the financial and structural position of their farm businesses. These results will be compared with the findings of the 1959-60 survey and evaluated for significant changes.

Supported by Agricultural Experiment Station Project 113, the Survey Group continues to design and draw samples, perform field work, process and analyze data and provide technical assistance with statistical problems for various university departments. The type and extent of assistance required varies with the project, and the average operation is directed by Professor Norman Strand and Dr. Wayne Fuller.

Departments assisted during the year include agricultural extension, agronomy, economics, education, entomology and wildlife, forestry, industrial education, institution management and textiles and clothing.

Dr. Arnold Paulsen, Department of Economics, sought assistance with a study of school board-teacher relations. The project is an attempt to determine how the policies of school boards and superintendents affect the hiring and retaining of public school teachers, and how these policies are affected by the demand for and supply of teachers. Subsidiary information expected

from the study includes information about teachers' off-season activities such as non-teaching jobs, travel, and additional education.

The dimensions of Iowa welfare project with which the Survey Group assisted last year resulted in a statewide study of the topic. Now the data collected in the previous study are being supplemented with an additional sampling of families served by the Area XI Community College, with headquarters in Ankeny. The new data and previous data will be combined to help the school determine potential enrollment and the curriculum interests and needs of potential students.

On many projects the Survey Group works with other universities, institutes, state and federal agencies on studies jointly sponsored by the Statistical Laboratory. Long-term agreements for survey and statistical services continue with the United States Department of Agriculture and the Bureau of the Census.

During the year survey services have been provided for three projects sponsored by the Laboratory for Political Research at the University of Iowa. One project is concerned with public opinion regarding the Iowa State Legislature. There were samples of three groups of Iowans: local leaders, the electorate at large, and state legislators. Through personal interviews, identical questions were asked of all persons sampled to determine the conformity of opinions of the three groups. The other two projects with which the Survey Group assisted were concerned with attitudes in the Oelwein community regarding the local school situation, and the desirability of combining adjacent local governments into one governmental unit.

A study was conducted in metal-working trades through selected Iowa manufacturers employing metal workers. These manufacturers were queried about the kind and number of employees needed, and the vocational training required for the jobs to be filled.

An analysis of music appreciation has been carried out in 60 Iowa schools. A series of community concerts was presented—first to students in community schools during the day and then concerts were presented to adults in the evenings. Data are now being prepared for analysis to determine the likes and dislikes of the two age groups.

The Survey Group is assisting the Iowa Crop Improvement Association with a study of widely grown varieties of hybrid corn. The work began last fall with the drawing of a sample of approximately 4800 rural residents. After first determining the number of farmers in the sample, mail questionnaires were used to discover the total corn acreage and the acreage planted to particular hybrids by each farm operator. Iowa was divided into six districts of different climatic and soil conditions for purposes of the study. In each district the hybrids planted were ranked according to total acreage of each planted. The Iowa Crop Improvement Association used the most prevalent hybrids to plant this spring as a basis for checking yields.

Work is progressing on a project to monitor a subsample of Conservation Needs Inventory soil samples. Subsamples will be drawn of two classes of land: crop land and other land. The soil will be tested by USDA for undesirable residues. It is intended to be a continuing program, to check the same areas to determine differences in content of these materials from year to year.

Some of the soil sampling techniques developed by the Survey Group are now being used in foreign countries to obtain an inventory of soil quality. The Survey Group is currently cooperating on a project sponsored by the Soil Conservation Service, USDA, to draw a sample for a province of Thailand. The study will measure the soil characteristics and land use, similar to the conservation need studies conducted in this country.

During May and June the Survey Group conducted the biennial school census for the Ames Community School District. This is the sixth time the Survey Group has made this census survey, which enumerates all persons under 21 years of age who live in the district, people with certain handicaps, and blind people over 21 years of age.

Data processing and analysis of the data from the preschool nutrition study has continued. The results have been distributed to the researchers: home economists of the nutrition research departments of Agricultural Experiment Stations at Iowa State University, University of Illinois, Kansas State University, University of Nebraska and Ohio State University, working in cooperation with researchers from USDA. This study, conducted in the 12 states of the north central region, was planned to evaluate the nutrient quality of the diets of preschool children and determine feeding practices and other factors possibly related to diet quality. Papers are being written and submitted for publication.

The evaluations done this year on the study of Iowa taxes for the Agricultural Extension Service were in the area of changes caused by adjustments in both personal and real estate property taxes. Coding and machine tabulations have been completed. A thesis on the results of this part of the study is in preparation.

In cooperation with the State Conservation Commission and the Department of Agricultural Economics, a survey was made of visitors to Iowa parks. The main purpose was to learn something about expenditures made by park visitors, and their opinions about parks both inside and outside Iowa. During the past year the information on this project has been coded and machine tabulations have been completed.

Sampling in Soil Surveys

Professor Norman Strand has continued as director of Agricultural Experiment Station Project 1312, a cooperative agreement between the Survey Group and the Soil Conservation Service. Work is performed incident to the SCS contract on the National Soil and Water Conservation Inventory.

This work includes statistical consulting on procedures and editing, coding, machine computation and listing of tables for each of 2,032 counties in the United

States, an area which includes all but the south central and southeastern states. These tables show land use and land treatment needs by land capability units. Work has continued on updating and improving the inventory.

The preparation of land resource areas, river basin and state tables continues, and tabulations are completed as needed by various research workers.

CURRENT RESEARCH

Both the development and extension of basic theory and its application to new statistical methods and techniques are emphasized in the Statistical Laboratory's research program. The Laboratory's budget supports only projects which are of specific interest to regular university research programs; cooperation with other research institutes and experiment stations on campus obtains support through joint grants and projects for other programs of statistical research. Many studies of a fundamental nature which are supported by off-campus agencies provide for supervised graduate research on topics proposed by the staff.

Dr. B. V. Sukhatme has been supervising the masters' research of graduate students Mallika Mokkhaves and Sorachai Bhisalbutra. One area of study involves the problem of optimum allocation in stratified sampling using ratio and regression methods of estimation when the strata residual variances are not known. The other investigation is concerned with the efficiency of two-way systematic sampling designs in agricultural surveys.

Further work on developing methods of controlled selection resulted in two papers co-authored by Dr. Sukhatme and M. S. Avadhani which are abstracted in the publications section of this report. Research continued on developing finite population models for comparison of different probability sampling schemes and a paper presented at the statistical society meetings in December is listed in the Papers and Speeches column.

Dr. Richard D. Warren, who holds a joint appointment in statistics and sociology and anthropology, continued as co-leader, with Dr. George M. Beal and Dr. Joe M. Bohlen from sociology, of Agricultural Experiment Station Projects 1469 and 1626, administered through the Department of Sociology and Anthropology. Project 1469 was designed to determine the effect of an experimental training program conducted for general managers of retail farm supply firms. An abstract of "Changes in Knowledge, Attitudes and Performance of Farm Supply Dealers and Changes in Business Firms," published this year, appears in the publications section of this report. Two papers based on this project were presented at the Rural Sociological Society and American Sociological Association meetings and are listed in the Papers and Speeches column.

This year's work on Project 1626, dealing with managers and local agribusiness firms, included the continued development of scales and indexes, examination of single variable relationships to success, examination of interrelationships of independent variables and multiple independent variable relationships to success.

Dr. Warren also continued as co-leader of Agricultural Experiment Station Project 1640, concerning the purchases and uses of chemical pesticides by farmers and in urban area homes. Publications have been prepared using information which has been obtained, including: types of chemicals being sold and used; perceptions regarding possible consequences of use or misuse of chemical pesticides in terms of danger to plants, animals and humans; knowledge and opinions about chemical pesticides and their use; decision-making regarding the purchase and use of these pesticides; and sources of information used.

NIH Training Grant

The Statistical Laboratory's second five-year National Institutes of Health graduate training grant program was completed in June, and word has been received that a third grant has been approved to permit its continuation. Dr. T. A. Bancroft directs the program, which supports up to six graduate students who plan careers in biometry or medical statistics.

During the year two doctoral candidates received their degrees and two more were added to the program. John Johnson completed his research on pooling regressions and an outlier methodology for regression lines, under Dr. Bancroft's direction. Professor C. Philip Cox directed Charles Sampson's research on developing sequential procedures for the comparison of two treatments utilizing concomitant information. Abstracts of both theses appear in the publications section of this report.

Predoctoral students Tom Fears and Ronald Jacobson joined the program during the year. Fears is working on preliminary research concerning robustness properties of certain nonparametric procedures: estimation and testing, under the supervision of Dr. K. L. Mehra.

Jacobson, working under Professor Cox, assisted with the analysis of data from a bacteriology research project concerned with the development of an *in vitro* method for the detection and assay of Type A botulinum toxin. This approach has far-reaching practical implications by giving earlier detection than previous standard methods; early detection is of paramount importance because of the severity and possibly terminal effects of the toxin. A slope response was found which could be linearly related to the logarithm of the toxin concentration and the LD50 estimated for the new procedure, which com-

pared well with that obtained in mouse protection tests. A method for fitting the general polynomial regression equation by orthogonal polynomials was programmed to assist this investigation.

Roland Loup has completed course work for his Ph.D. and will spend the summer working at the Mayo Clinic in Rochester, Minnesota, as part of his training. He has been working under the supervision of Professor Cox on a consulting problem with Dr. Emerson Bird, dairy and food industry, involving an improved method for the estimation of sulfur recovered from organic compounds. An appropriate mathematical model was defined for evaluation in terms of bias and precision. Analyses of variance were constructed and their interpretations were discussed.

Peter O'Brien completed his masters' thesis and has since been working with Dr. David Thomas, who directed his research, to extend and make more rigorous the results, in which selection procedures relating to gamma and Weibull populations were developed. A paper has been prepared for the August American Statistical Association meetings and an abstract of his thesis appears in the publications section of this report. O'Brien is now working toward his doctorate under the supervision of Dr. Wayne Fuller.

Research in Mathematical and Statistical Genetics

This research is jointly sponsored by the National Institutes of Health, Grant GM 13827, and the Agricultural Experiment Station, Project 1669. Dr. Oscar Kempthorne and Dr. Edward Pollak continued as principal investigators.

During the year the study has been completed of the fate of a mutant gene if the mean number of mutant genes passed to the next generation by an individual carrying one such gene is less than one. An approximation is obtained to the distribution of the number of descendents in generation n, where n is large, of a single gene in generation 0. It is shown that this approximation is good if the mean number of mutant genes among the offspring of an individual carrying one such gene is near one.

Also essentially completed is the study of the influence of varying selective advantages of a gene on random genetic drift in a finite population. The usual continuous approximation to the problem of varying selective advantages has been found misleading, because certain terms, which may be of importance, are neglected. These have been included in the analysis. Qualitatively speaking, the approximate differential equation solution to the finite population problem indicates that fixation or loss of an allele tends to occur faster than it would if there were only random drift with no variation in the selective advantage of one of the two alleles. A simple special case can be solved exactly by computer, and the results compared to those obtained by solving the differential equation derived from the continuous approximation.

Study shows that the genetic load theory is based on the assumptions of constant selective coefficients, no linkage between loci, multiplicative gene action between loci, infinite population size, non-overlapping generations, small effects of individual loci, Hardy-Weinberg equilibrium frequencies at all loci, and that no selection takes place during the inbreeding done to estimate loads. Work has been completed on the conditions necessary for Hardy-Weinberg frequencies and the effect of deviations from these frequencies.

Results for the case in which reproduction occurs solely by self-fertilization have been obtained from work on the deterministic theory of selection in diploid populations with overlapping generations. Assume reproduction can occur at $s + 1$ stages of life; between these times there may be death. Once reproduction occurs, the proportions of the various types of progeny are those predicted by Mendelian genetics. If there are three genotypes, AA, Aa and aa, and the probability of survival and mean number of offspring of an individual of a particular genotype and age do not depend on time, then in the long run, the numbers of individuals of the genotypes increase exponentially. A more complete stochastic analysis has been done for the case of a haploid population, consisting of m genotypes, for each of which the distributions of number of offspring and of length of life are known. Papers detailing this research have been accepted for publication.

In one project on the theory of selection by culling, it has been assumed that there are two alleles (and three genotypes) at a locus, and that the values on some scale of merit for genotype A_iA_j are normally distributed with mean μ_{ij} and variance σ^2. In each generation the fraction S of the population, which scores highest with reference to this scale of merit, is saved for reproduction. These saved individuals are mated at random. Particular attention is paid to the case where there are two alleles A_1 and A_0. Under the assumption that μ_{11}, μ_{10} and μ_{00} do not differ much, an approximate formula has been derived for the relationship between the frequency of gene A_1 and the number of generations that have elapsed since selection began. To determine the reliability of the approximate formula, special cases were programmed for the computer. This approach now is being generalized to the case in which there are several linked loci.

In a study of selection in finite populations, a generation is considered as arising in two stages. In the first, M individuals are obtained at random from reproduction among their parents and then ranked on their phenotypes. The top ranking N are selected as parents of the next generation. It is assumed that the species under consideration is monoecious and one locus influences the character. Particular attention is devoted to the case where there are two alleles at the locus and the distribution of phenotypes associated with the three genotypes are normal with the same variance, but different means. Computations for the case in which the allele is dominant indicate that a well-known approx-

imate formula for the probability of fixation of one of the alleles gives satisfactory results, provided selection is not intense.

Computer simulation studies have been made of truncation selection in finite populations, when there is a polygenic system determining the character that is being selected. A ten locus system of additive or dominant genes was specified with linkage varying from free recombination to gene clusters on a chromosome. Results obtained on frequencies of fixation of desirable genes indicate that the effect of selection intensity in small populations of freely recombining loci is greater for high initial gene frequency and less for low initial gene frequency than that obtained from the diffusion approximation of Kimura for a single locus or from the qualitative selection theory of Robertson. The effects of linkages between loci in lowering this probability of fixation and in causing rapid fixation are demonstrated for various situations of parental population size. In a study of the effects of gametic equilibria on the additive and dominance components of the genetic variance, it was possible to derive algebraic results for a two-locus and a three-locus case. Complexity necessitated simulating the problem for more than three loci. The build-up of gametic disequilibria resulted in an increase in the dominance variance and a decrease in the additive variance between and within sub-populations.

A total of ten papers on this research have been submitted for publication.

Design and Analysis of Sample Surveys

Research directed by Dr. J. H. Sedransk continued under the support of the U. S. Office of Education, Contract OEC-3-6-002041-2041.

In the design of several factor analytical surveys, a double sampling scheme has been developed for use when independent sampling is not feasible. A large (first phase) simple random sample is selected, and a subsample then selected from each identified subpopulation. The "sampling rule" (S. R.), which specifies how to subsample, is developed so that for any given division of the first phase sample among the subpopulations, the ultimate sample is selected to maximize a specified precision statement. Finally, a procedure to determine the optimal choice of the first phase, and ultimate sample sizes, has been suggested. Since this procedure requires one to use an electronic computer, an alternative, approximate, method has been developed. The two methods have been compared using a sequence of numerical examples.

This research resulted in Gordon Booth's masters' thesis, which is abstracted in the publications section of this report. The salient features of the thesis are summarized in a paper "Designing Several Factor Analytical Surveys," by Booth and Dr. Sedransk, listed in the Papers and Speeches column, which has been published and also is abstracted in the publications section.

In another area of research, computer programs for evaluating the properties of the various ratio, ratio-type and regression estimators have been refined to make them more efficient. For any given (finite) population and any sample size, the properties of the estimators can be ascertained by complete enumeration or by utilization of Monte Carlo Sampling.

Six actual finite populations were used to compare eleven ratio, ratio-type and regression estimators. For each population, the values of Y (the variable of interest) and X (a related "concomitant" variable) are known for all units in the population. For the six finite populations, the relationship between X and Y is either linear or quadratic, and the (linear) correlation coefficients range from $\rho = .50$ to $\rho = .98$. These forestry populations are typical of those where ratio, ratio-type or regression estimators would be employed.

In general, it appears that among the ratio and ratio-type estimators, the ordinary ratio estimator ($\hat{R} = \bar{y}/\bar{x}$ where $\bar{y}$, $\bar{x}$ are the sample means) almost always has the smallest mean square error. The bias of $\hat{R}$ may not be negligible if sample sizes as small as 2 are used, but the numerical evidence indicates that, in most cases, the bias in $\hat{R}$ is tolerable. Situations in which one might prefer a ratio-type or regression estimator to $\hat{R}$ are indicated in Richard Frauendorfer's M. S. thesis. An abstract appears in the publications section.

Research has been conducted on some elementary properties of systematic sampling, which is often used in lieu of simple random sampling. Therefore, it is of interest to ascertain the relative merits of the two sampling procedures.

First, it is considered to be easier to draw a systematic sample, and to execute it without errors. Most comparisons of the sampling properties of the two procedures have involved specifying the form of the finite population. For example, one may assume that the finite population is arrayed so that the values of the variable under study form a linear trend as one proceeds from y_1 to y_N. However, some very simple assumptions about the "randomness" of the order of the entire finite population (and various subsets of it) can be utilized to compare systematic, simple random, and stratified random sampling. Moreover, these assumptions, which may closely approximate "real" situations, suggest appropriate variance estimators. A further extension to single-phase cluster sampling is also possible.

James Veale, a graduate student partially supported by the contract, has completed research relating to the estimation of a mean when one observation may be spurious. The objective is to provide a better estimator (in terms of reduced mean square error) of a population mean when one observation may be an "outlier." In particular, estimation on the basis of a random sample of size n, of the mean, μ, of a normal distribution with known variance σ^2, is considered. It is intended that the n observations constitute a random

sample from the population of interest, but one observation may be an "outlier" (i.e., an observation from a normal population with mean $\mu + b\sigma$ and known variance σ^2). Two estimators have been proposed by Veale and Dr. D. V. Huntsberger, and their mean square errors determined. Using numerical examples, these two estimators are compared with several other estimators which have been suggested in the literature. While the problem treated is an "elementary" one, the approach may be useful in providing better estimators in some sample survey applications.

Analysis of Variance Procedures and Related Topics

One general purpose of this research, supported by the Aerospace Research Laboratories, has been the development and integration of linear models and analysis of variance procedures, when these are approached from a finite randomization viewpoint according to which experiments are generally performed. This contract ended in December, under the direction of Dr. Oscar Kempthorne and Dr. George Zyskind.

Research reported upon includes: a formulation of aspects of best and simple least squares linear estimation in linear models with arbitrary, possibly singular, covariance structure; a generalization of the famed Gauss-Markoff theorem, applying to situations including a singular variance-covariance structure of the observations; simple combinations of information in linear models originating from uncorrelated distinct sources of information; some formulations of sampling from balanced complete experimental structures, and with theoretical and computational aspects arising in the calculation of variances of variance components; results of a Monte Carlo investigation of significance levels generated by the Behrens-Fisher fiducial procedure and by the Welch Aspin procedure; and a brief discussion of certain nonparametric test procedures based upon ranks which, in particular, points up the problems arising from the inevitable grouping error of measurement.

The complete details of this work will appear in a Technical Report published by the Aerospace Research Laboratories.

Analysis of Variance and Experimental Design Research Procedures

January 1 marked the beginning of a new contract with the Aerospace Research Laboratories, Office of Aerospace Research, United States Air Force, which will continue research conducted under the last ARL contract. Dr. Oscar Kempthorne and Dr. George Zyskind will direct the project.

Dr. Kempthorne has been working with a graduate student, S. T. M. Naqvi, on the problem of "estimation of components of variance." The ideas being explored are (a) the likelihood function, (b) so-called Bayesian approach, (c) goodness of fit procedures, and (d) decision-theory approaches. A computer program, which consisted of the evaluation of a two variable function and the graphing of contour curves using the plotter, was developed for this research.

The research activities of graduate student Leon Jordan-Filho, which have been supported by this contract, were directed toward the problem of optimal allocation of the observations in response surface studies in its multiple aspects like model discrimination and estimation.

In the area of sequential model discrimination, initial steps of a sequential procedure were developed for the assessment of the form and degree of an unknown polynomial response curve, and a study of its optimal properties was started. Research in the area of deterministic model discrimination may be divided into two parts. The first was concerned with the development of a procedure for better approximation of the unknown underlying response curve than the standard least square method. The general conclusion was that spline approximation may be preferable to polynomial ones, especially in situations where no previous information about the true model is available. This study was discontinued because any meaningful comparison will require a large amount of data which will be impossible to accumulate in the time available. Current research is concerned with a search for a method that will not only take care of the model discriminative aspect of the problem but will also have other properties that may be considered desirable.

The research of another graduate student, P. Papaioannou, is aimed at developing methodology with regard to optimization strategy, with particular attention to fitting of nonlinear models and experimental optimization research by the steepest descent PARTAN algorithm.

One of the critical points of the PARTAN algorithm or any other "path" method of optimization is the problem of line minimization. The idea of cubic interpolation (suggested by Davidon) along any arbitrary direction was examined and several conditions for the application of the method were obtained. Cubic interpolation seems to provide an efficient way of line minimization for the case of analytically known objective functions whose partial derivatives of first order are also analytically known and, moreover, are easily and inexpensively computable. However, when derivatives are difficult to obtain, an algorithm based only on function evaluations should be used. A general computation program using functional evaluation and a PARTAN algorithm has been developed.

Dr. Zyskind has been working on linear model theory. In particular, conditions on the covariance structure were obtained under which all parametric augmentations of a particular model form result in all simple least squares estimators being also best linear unbiased. If the common part of the model is $y = X\beta + e$ then one necessary and sufficient form of the condition is that the covariance matrix of y be of the form

aI + XGX', where G is arbitrary. It is shown that such a covariance matrix can be envisaged as having essentially just one error term, and thus is inadequate for the representation of most complex randomized experimental schemes, such as illustrated, for instance, by the ordinary split plot design. Conditions on covariance structures for such complex but useful experimental schemes are now being developed.

Singular covariance matrices are of particular interest in the consideration of finite randomized experiments. In the case of a possibly singular multivariate normal variate $Y \sim N(\mu, V)$, a recently obtained result is that a positive semi-definite quadratic form Y'AY obeys a χ'^2 distribution if and only if the matrix AV is non-zero and idempotent. An extension of a known result on independence of two quadratic forms has also been obtained.

Graduate student Justus Seely, working under Dr. Zyskind, has been searching for unified approaches to problems of the general mixed linear model. Results will appear in his doctoral dissertation.

USDC, Bureau of the Census Research Project

Dr. Wayne Fuller remained director of Project Cco-9165, the continuing cooperative program between the Statistical Laboratory and the U. S. Bureau of the Census, which supports basic research in sampling, response errors and other fields of joint interest.

A paper containing the results of a Monte Carlo study of alternative ratio and regression estimates has been prepared. Part of this work is contained in the M.S. thesis of Nancy Johnson, who was graduated in August.

Alternative estimators of the mean were investigated under the assumption of partial response. Bounds on the bias were derived. Part of this work is reported in Cary Isaki's M.S. thesis. Abstracts of both theses appear in the publications section of this report.

Investigation of methods of selecting samples continues with programs being developed to automate certain selection schemes. Sampling procedures which have efficiency exceeding one per stratum in the presence of linear trend, and for which unbiased estimators of the variance are available, have been developed.

Problems in Random Walk and Sequential Decision-Making

Dr. Herbert T. David continued as director of this National Science Foundation project, Grant GP-6013, which terminated at the end of June. During the year the doctoral research of Joseph L. Abbey, Patricia S. Conn, Richard W. Mensing and Donald J. Soults was partially supported by this grant.

Abbey's research has led to a.e.—convergent expansions for UMVUE estimators of arbitrary estimable functions of the parameters of certain exponential families. Extensions have been made to the sequential case, where known variance bounds have been sharpened and mean square-convergent expansions derived.

Mrs. Conn's research continued in the area of the asymptotic behavior of unabsorbed sample paths of non-homogeneous random walks within absorbing barriers. Tractable "ergodicity" conditions have been provided. The work has applications for generalized SPRT's with initially curved but asymptotically straight parallel decision boundaries; here one can now determine the asymptotic behavior of the sequence of distributions of unabsorbed path end-points, conditional on no prior absorption.

Mensing's research was concerned with planar versions of the invariance principle applied to three problems in planar random walk. In one problem the process computations are simple, so that the invariance principle provides asymptotic results for a certain class of random walks with drift. On the other hand, in the other two problems asymptotic computations are simple for a particular one of a class of random walks, so that the invariance principle provides absorption results for tied and untied Wiener processes, as well as asymptotic results for the rest of the class in either problem.

Research conducted by Soults is on the asymptotic value distributions of k x n matrix games. One conclusion has been that, in the normal case, as contrasted to the uniform case, the norming constants do not depend on k. The study has also brought out that, for certain other cases, the geometry associated with player I's programming problem, which is in a sense the dual (intersecting lines replacing joined points) of the S-game geometry previously used, is better suited to distributional considerations than is the S-game geometry.

Some Problems in Multivariate Analysis; Symmetric Multiple Decision Problems

Dr. T. A. Bancroft remained as administrative director of this National Science Foundation Grant GP-6149, which was originally granted to visiting professor Dr. Akio Kudô who has since returned to Japan. Work on the project was terminated during the year.

A paper, "Modified and Partially Truncated Poisson Distribution," by graduate student Munir Ahmad and Dr. Kudô, has been published and an abstract appears in the publications section of this report. These co-authors have also written a paper on "The Maximum Likelihood Estimation of Right Hand Truncated Poisson Distributions," which has been submitted for publication.

Dr. Kudô has also completed a preliminary report on his research conducted under this project, in the area of a bivariate t-test with two-sided alternative.

Inference Theory for Certain Incompletely Specified Models

This National Science Foundation project, Grant GP-5688, was terminated January 15. It has been reinstated as of July 1, for approximately a year. Dr. T.

A. Bancroft served as principal investigator and Dr. Chien-pai Han conducted research supported by the grant during the year.

Investigations of the properties of inference procedures incorporating preliminary test(s) of significance, conducted under this grant, include evaluation of the bias, mean-square error, and relative efficiencies in the case of estimation after preliminary test(s) of significance, and size and power in the case of test of a main hypothesis after preliminary test(s) of significance.

Studies were also made leading to recommendations for a proper choice of a probability level for the preliminary test of significance to control bias and mean square error for the estimation problems; and size and power for those problems involving a test of a main hypothesis.

The doctoral research of John P. Johnson on pooling regressions and a statistical outlier methodology for lines has been completed, and an abstract of his thesis appears in the publications section of this report.

Graduate student Ronald Mead is completing research on pooling regressions and a statistical outlier methodology for line, for his masters' degree.

Papers prepared for possible publication, not previously reported, include "Applications of Pooling and Outlier Methodology for Regressions," by Dr. Johnson and Dr. Bancroft; and "On Pooling Means When Variance Is Unknown," by Dr. Han and Dr. Bancroft. The latter paper has been accepted for publication by the Journal of the American Statistical Association.

Goodness of Fit Procedures

This National Science Foundation Grant GP-5997, concerned with research on the general problem of testing goodness of fit of distributions in one or more dimensions, continued under the direction of Dr. Oscar Kempthorne.

Goodness of fit of a class of negative binomial distributions has been examined. Initial work has been done on goodness of fit of the general linear model $y = X\beta + e$.

Design of Experiments and Analysis of Data

Dr. Oscar Kempthorne has continued to direct research on the logic of uncertain inference, particularly in experimental and sampling situations; the testing of goodness of fit of models; and the study of modes of data analysis, including dissection, condensation and transformation of data. The work is supported by the Agricultural Experiment Station, Project 890.

Consultation and Research in Mathematical and Genetic Statistics

Dr. Edward Pollak continued research in this area, supported by Agricultural Experiment Station Project 1448.

A mathematical problem with the following genetic interpretation was considered: It is assumed that there is a large population that is approximately fixed in size and that there is initially one gene that is dominant and disadvantageous in comparison to the other genes in the population. The question posed was to calculate the distribution of descendents in generation n of the one heterozygote originally present in generation 0. There is no exact solution known, but it was possible to obtain a good approximation, at least when n is large.

Design of Surveys and Analysis of Data

Dr. Wayne Fuller continued as director of Agricultural Experiment Station Project 1005. Research was conducted on response surface estimation when the factors are measured with error. Special attention was focused upon animal feeding experiments.

A paper was prepared on ratio and regression estimation. It reports research which demonstrates that ratio estimation may result in a loss of efficiency for the cell totals of tables typically computed from survey data.

The approximate variance and bias are derived for the regression estimator constructed from grouped data. The grouped regression estimator may be used to ensure positive weights for all observations or to reduce the bias associated with a nonlinear regression of y on x.

Agricultural Estimates

Agricultural Experiment Station Project 1207, Research in Sample Census Methods in Agriculture, is designed to develop improved techniques, procedures and theory in sample surveys related for the most part to agricultural problems. The project has been supported largely by the Statistical Reporting Service, United States Department of Agriculture, with additional financial assistance from the Bureau of the Census. Professor Norman Strand is project director.

Work has continued and first reports have been made on the sampling frame studies for small and scattered populations for which lists are not readily available. The initial work, for the populations of beekeepers, turkey raisers and sorghum growers was discussed in last year's annual report.

Also supported by this project is work on improving and updating the 1945 Master Sample of Agriculture.

Statistical and Economic Analysis for Long-Term (Rotational) Agronomic Experiments

Work has progressed in the area of rotation fertilization practices, under the auspices of Agricultural Experiment Station Project 1578 with Dr. Wayne Fuller as director for statistics. This is a cooperative project with the Department of Agronomy.

Response functions for hay, oats and corn have been estimated, using recent data. These results substantiate the earlier conclusions that the rotation effects could be explained in terms of nutrient effects. Estimation of income variability associated with different rotations is planned.

PUBLICATIONS and PROFESSIONAL ACTIVITIES

Papers presented at professional meetings and articles published in professional journals report most of the research conducted by the Statistical Laboratory staff. Staff members also take an active role in their professional societies and affiliated journals.

Editorial collaborators for the Journal of the American Statistical Association this year included: H. T. David, Wayne Fuller, Oscar Kempthorne, K. L. Mehra, J. H. Sedransk, Justus Seely and George Zyskind. C. Philip Cox and Dr. Zyskind served as referees for the Biometric Society, and Dr. Sedransk was a reviewer for Mathematical Reviews. Dr. James Walsh serves as editor of Iowa Psychologist, and continues on the editorial boards of Perceptual and Motor Skills and Psychological Reports.

RECORD OF PUBLISHED RESEARCH

This is a record of articles published by staff members and graduate students during the past fiscal year. When the research was conducted at Iowa State but the author has since accepted a new position, his current location is listed in parenthesis after his name. Some of these publications are included in the Statistical Laboratory's Reprint Series and copies are available upon request. These are indicated by an asterisk (*).

*Munir Ahmad: "Truncated Logarithmic Distribution." Bulletin of the Institute of Statistical Research and Training, 2:1, 40-45. December 1967. Reprint Series No. 221, Statistical Laboratory, Iowa State University.

In this paper logarithmic distribution has been truncated at right. Parameters have been estimated by the method of maximum likelihood estimation. A general formula for j-th moment about origin has been found. An example is given to illustrate the method.

*Munir Ahmad and Akio Kudô (Kyushu University, Japan): "Modified and Partially Truncated Poisson Distribution." Bulletin of the Institute of Statistical Research and Training, 1:2, 82-90. 1967. Reprint Series No. 211, Statistical Laboratory, Iowa State University.

In this paper modified and partially truncated poisson distributions have been obtained and their parameters estimated by the method of maximum likelihood. The asymptotic variances and covariances of the maximum likelihood estimates have been derived. Some salient properties of these estimates have been discussed.

*Barry C. Arnold: "A Generalized Urn Scheme for Simple Learning with a Continuum of Responses." Journal of Mathematical Psychology, 4:2, 301-315. 1967. Reprint Series No. 203, Statistical Laboratory, Iowa State University.

A generalization of the classical urn scheme is suggested for the case of simple learning with a continuum of responses. The behavior of the new model under simple noncontingent and simple contingent reinforcement is analyzed. Sufficient conditions for ergodic behavior in the case of contingent reinforcement are developed. The paper concludes with an empirical comparison of the linear model and the correlated urn scheme.

*Barry C. Arnold: "Response Distribution for the Continuous-Time *N*-Element Pattern Model." Journal of Mathematical Psychology, 4:3, 489-500. October 1967. Reprint Series No. 209, Statistical Laboratory, Iowa State University.

Stimulus sampling theory is extended to cover the case of a continuum of responses in which the response is given continuously in time. The case of noncontingent Poisson-type reinforcement is studied in detail, and some attention is given to contingent schedules. Two axiom systems suggested by Suppes and Donio are examined, together with a third possible axiomitization.

Throughout the paper, nonuniform sampling probabilities for the stimuli are considered.

*Barry C. Arnold: "A Note on Multivariate Distributions with Specified Marginals." Journal of the American Statistical Association, 62:320, 1460-1461. December 1967. Reprint Series, Statistical Laboratory, Iowa State University.

A method for generating multivariate distributions with marginals in a prescribed family is introduced. It is a straightforward generalization of a method due to Marshall and Olkin.

*Barry C. Arnold: "A Modification of a Result Due to Moran." Journal of Applied Probability, 1968. Reprint Series, Statistical Laboratory, Iowa State University.

Let $\{X(n)\}$ be a Markov chain with state space $\{0, 1, 2, \ldots, N\}$ and transition probability matrix $P = (p_{ij})$ where $p_{ij} = \binom{N}{j} \left[\frac{(1+s)i}{N+si}\right]^j \left[\frac{N-i}{N+si}\right]^{N-j}$, in which $s > 0$. For $i = 1, 2, \ldots, N-1$, let a_i be the probability of absorption in state N given that the chain starts in state i. It is shown that

$$\frac{1 - z_L^i}{1 - z_L^N} \leq \frac{1 - \underline{z}^i}{1 - \underline{z}^N} \leq a_i \leq \frac{1 - \bar{z}^i}{1 - \bar{z}^N} \leq \frac{1 - z_U^i}{1 - z_U^N}$$

where

$$z_L = \max \{w^{*N}_{N-1}, \exp(-2s/[1 + s(\frac{N-1}{N})])\} ,$$

$$\underline{z} = \max \{w^{*N}_1, w^{*N}_2, \ldots, w^{*N}_{N-1}\} ,$$

$$\bar{z} = \min \{w^{*N}_1, w^{*N}_2, \ldots, w^{*N}_{N-1}\} ,$$

$$z_U = \min \{w^{*N}_1, \exp(-2s/[1 + \frac{s}{N}])\} ,$$

in which, for each i, w_i^* is the unique root of the polynomial $w^N - [\frac{N+is}{(1+s)i}]w^i + \frac{N-1}{(1+s)i}$ in the interval (0, 1).

The argument follows Moran (1960) and the resulting bounds are the best possible using his procedure.

***T. A. Bancroft:** "Statistical Laboratory of the Iowa State University." The Bulletin of the Institute of Statistical Research and Training, 1:1, 14-21. December 1966. Reprint Series No. 216, Statistical Laboratory, Iowa State University.

This paper sketches the history of the Statistical Laboratory, explains its establishment in 1933 as the first statistical center of its kind in the United States, and traces its development.

***S. R. Srivastava** (Vikram University, Ujjain, India) and **T. A. Bancroft:** "Inferences Concerning a Population Correlation Coefficient from One or Possibly Two Samples Subsequent to a Preliminary Test of Significance." Journal of the Royal Statistical Society, Series B (Methodological), 29:2, 282-291. 1967. Reprint Series No. 207, Statistical Laboratory, Iowa State University.

It is shown in this paper that under certain restrictions on population parameters, estimates formulated on the basis of a preliminary test of significance concerning inferences for a population correlation coefficient are better than the usual unbiased estimators.

Gordon Booth and **J. H. Sedransk:** "Designing Several Factor Analytical Surveys." Proceedings of the Social Statistics Section, American Statistical Association, 344-353. 1967.

This investigation considers analytical surveys dealing with comparison of only two levels of each factor. Initial problems are to suggest comparisons of interest and appropriate estimators, and to plan the survey to attain, at minimum cost, specified precision for the estimates of the comparisons. Assuming independent sampling, optimal sample size allocations are obtained and approximate solutions, shown to be quite adequate, are suggested. If independent sampling is not feasible, a double sampling procedure is provided.

***F. B. Cady** and **W. A. Fuller:** "Use of Regression Residuals in the Calculation of Orthogonal Polynomial Coefficients." Agronomy Journal, 60, 195-197. March-April 1968. Journal Paper No. J-5847 of the Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1578. Reprint Series No. 220, Statistical Laboratory, Iowa State University.

A method is presented for calculating orthogonal polynomial coefficients when the levels of the independent variable are not equally spaced and(or) replicated. The coefficients may be found by using a standard regression computer program or by means of a hand calculator. The method is based on the orthogonality between the computed residuals and the independent variables in a regression analysis.

***Edward J. Carney** (University of Rhode Island, Kingston): "Relationship of Generalized Polykays to Unrestricted Sums for Balanced Complete Finite Populations." Annals of Mathematical Statistics, 39:2, 643-656. April 1968. Reprint Series No. 218, Statistical Laboratory, Iowa State University.

In order to make computations of the variance-covariance matrix for estimated variance components economically feasible, several requirements must be met. First the variance-covariance formulas in terms of the generalized symmetric functions must be generated by computer algorithms. Secondly, a way of computing the generalized symmetric means must be developed which significantly reduces the number of additions and multiplications. Thirdly, the algorithms must be made general enough for application to the many possible balanced complete response structures which may be encountered as the relationship of nesting among the factors varies.

In meeting these requirements it is necessary to determine a logical system of relationships which allows the development of a few relatively simple algorithms to perform the various tasks on the computer, and which may be applied generally to the many different structures possible. The present paper results from an attempt to find such logical relationships among the various quantities which may be used in programs for digital computation of the variance-covariance matrix of estimated variance components.

Study of the patterns of subscript restrictions which specify the generalized symmetric means leads to the development of algebraic relationships between the generalized polykays and the generalized symmetric means, which may be formulated in terms of a lattice of ordered partitions. Similar relationships exist between the numerators of the generalized symmetric means and quantities called unrestricted sums. These latter quantities may be computed much more efficiently than the generalized symmetric means themselves. The various relationships, in addition to their intrinsic theoretical interest, provide the necessary logical basis for the development of digital computer algorithms for performance of the algebraic and numerical computations

for estimation of the variances and covariances of the variance component estimates.

*C. Philip Cox: "A Statistical Application of Euler's Theorem." The American Statistician, 22:2, 29. April 1968. Reprint Series, Statistical Laboratory, Iowa State University.

Using Euler's theorem on homogeneous functions, a very simple proof is given for the standard result that the minimum sum of squares when the linear model $y_i = \sum_j x_{ij} \beta_j + \epsilon_i$, $i = 1, 2, \ldots, n$; $j = 0, 1, \ldots, p$, is fitted to a sample of n observations, can be calculated as,

$$S_{min} = \sum_i y_i^2 - \sum_j b_j \sum_i x_{ij} y_i \quad , \qquad (1)$$

where $\Sigma x_{ij} y_i$ is the right hand side of the normal equation for b_j, the least squares estimate of β_j.

*C. E. Cress (Michigan State University, East Lansing): "Reciprocal Recurrent Selection and Modifications in Simulated Populations." Crop Science, 7, 561-567. November-December 1967. Journal Paper No. J-5513, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1193. Reprint Series No. 212, Statistical Laboratory, Iowa State University.

Computer simulation was conducted by the Monte Carlo method for a bisexual organism with two alleles at each of 40 independently segregating loci. Reciprocal recurrent selection and two modifications were performed for the completely dominant and purely overdominant models at a number of starting gene frequencies. Genetic divergence is an unsound basis for selecting starting populations when the goals of selection are long term. A short term increase in the means of the recurrent populations cannot be used as evidence for a predominance of partially or completely dominant gene effects.

Two modifications are important for the improvement of genetic potential and rate of progress for types of recurrent selection using progeny testing. (1) A synthetic variety should be made from all material entered into a moderate to long term recurrent selection program. (2) One generation of selfing (or other inbreeding) should precede the test crosses in each cycle.

H. T. David: "Goodness of Fit." Pp. 199-207 in Volume 6, *International Encyclopedia of the Social Sciences*. The Macmillan Co. and The Free Press. 1968.

This article explains and describes the use of goodness of fit procedures. Topics covered include: Types of hypotheses - simple, composite and approximate; Conducting a test of goodness of fit; Choosing a test of goodness of fit; Tests of simple hypotheses - the chi-square test, modifications of the chi-square test, other procedures; Tests of Composite Hypotheses - the chi-square test, composite analogues of other tests, tests based on special characteristics, transforming into simple hypotheses, conditioning, tests related to probability plots; and Approximate Hypotheses.

*A. H. El Mawaziny (Central Agency for Public Mobilization and Statistics, Cairo, U.A.R.) and R. J. Buehler: "Confidence Limits for the Reliability of Series Systems." Journal of the American Statistical Association, 62:320, 1452-1459. December 1967. Reprint Series No. 213, Statistical Laboratory, Iowa State University.

It is desired to set confidence limits for the probability of successful operation at least until time x_0 of a series system of k dissimilar components. The components follow exponential failure laws, and data are available on failure times of components of each type. Exact confidence limits for $k = 2$ have previously been given by Lentner and Buehler. The present paper deals with a large-sample approximation to the exact solution for arbitrary k.

*Takeshi Amemiya and Wayne A. Fuller: "A Comparative Study of Alternative Estimators in a Distributed Lag Model." Econometrica, 35:3, 509-529. July 1967. Reprint Series No. 219, Statistical Laboratory, Iowa State University.

Hannan, in "Regression for Time Series", proposed a method of estimating regression coefficients using spectral techniques, and later in "The Estimation of Relationships Involving Distributed Lags" applied the method to the estimation of parameters in a distributed lag model. This paper first illustrates that Hannan's method in his former article is asymptotically equal to Aitken's least-squares estimation in which the covariance matrix of the regression residual is estimated in a certain consistent manner from the calculated residuals. Next it proves that Hannan's method in his latter article is asymptotically equal to a maximum likelihood estimation of the distributed lag model.

Hannan's method is useful when the investigator's *a priori* knowledge about the stochastic process of the residual is minimal. But if the process can be specified to be, say, a first order or second order autoregressive system, it is desirable to use such a knowledge in estimation. For such a case, the paper proposes an estimator of the distributed lag model based on the Gauss-Newton iterative method and proves it to be asymptotically equal to the maximum likelihood.

The paper evaluates the asymptotic distribution of two other estimators of the distributed lag model, including the one proposed by Klein.

*Klaus Hinkelmann (Virginia Polytechnic Institute, Blacksburg): "Circulant Partial Triallel Crosses." Biometrische Zeitschrift, 9:1, 22-33. 1967. Journal Paper No. J-5558, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 890. Reprint Series No. 205, Statistical Laboratory, Iowa State University.

In order to investigate three-way crosses on a large scale, one is forced for practical reasons to consider only a sample of all possible three-way crosses. Such a sample is provided by plans which are called partial triallel crosses.

In this paper a particular class of partial triallel crosses, which are named circulant partial triallel crosses, is investigated. The construction of these plans is based on an analogy to circulant partially balanced incomplete block designs. Necessary and sufficient conditions for their existence are given. It is shown how these plans can be constructed appropriately and how they can be analyzed from the point of view of estimating the parameters of the underlying model. Some attention is given to balanced designs. All procedures are illustrated by examples.

E. O. Wright, W. S. LaGrange, Connie Dennis, E. W. Bird and **D. K. Hotchkiss:** "Protein 'Solubilization' and Calcium and Magnesium Precipitation by 'Chlorinated Cleaners'." Journal of Milk and Food Technology, 30:10, 310-316. October 1967. Journal Paper No. J-5666, Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa, Project 1298.

This investigation reports the degree of protein solubilization resulting from changes in available chlorine and changes in the active alkalinity of cleanser solutions. Two sources of milk were used. One source was used more frequently than the second, resulting in unequal number of observations in the whole plot of a split plot analysis. The data were analyzed using a least squares regression analysis. The technical results of this study are summarized in the article.

Earle S. Ruan, L. C. Lewis, J. C. Picken, Jr. and **D. K. Hotchkiss:** "Gamma Irradiation of European Corn Borer Larvae." Journal of Economic Entomology, 60:6, 1724-1730. December 1967. Journal Paper No. J-5563, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1193.

Actively growing nondiapausing 3rd, 4th or 5th-instar laboratory-reared larvae of the European corn borer, *Ostrinia nubilalis,* were irradiated with gamma rays. Diapausing larvae collected in the field were irradiated after either three or five and a half months of refrigeration. The nondiapausing larvae had too much somatic damage from the irradiation to make this a practical method of borer control, however, the diapausing larvae showed little evidence of somatic damage.

Considerable disproportionality was experienced in the various classifications of the data. Consequently, a general least squares analysis was completed. The resulting analysis indicated an interaction ($P < .05$) between time to pupation and dose level when diapausing larvae were irradiated and divided into three groups based on length of time to pupation. Egg hatch was affected ($P < .05$) by the irradiation treatment.

Irradiation of diapausing larvae appeared to affect the motility or viability, or both, of sperm instead of inducing lethal gene mutations.

D. L. Hamm, E. G. Hammond and **D. K. Hotchkiss:** "Effect of Temperature on Rate of Autoxidation of Milk Fat." Journal of Dairy Science, 51:4, 483-491. 1968. Journal Paper No. J-5699, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1517.

Milk fat was autoxidized at 50, 35, 21, 4, -10 and -27C, and the reaction monitored by peroxide and thiobarbituric acid (TBA) values and organoleptic examination. The season of production and addition of 0.1 ppm of copper as copper palmitate had little effect on the flavor response, and the same character and sequence of flavors were observed at all temperatures. Equations were fitted statistically to the pooled organoleptic data to predict the effect of time and temperature on the flavor responses. Peroxide and TBA values showed significant correlation with the flavors at higher temperatures, but at lower temperatures no increases in peroxide and TBA values could be observed. Autoxidation flavors were observed at all temperatures and were actually more intense at -27 than at -10 C. Apparent heats of activations were calculated for the peroxide, TBA, and flavor reactions. The heat of activation of the TBA reaction was significantly higher than the others. The TBA and peroxide values were significantly stimulated by addition of copper, but copper did not affect the apparent heats of activation of the reactions.

***B. K. Kale** (University of Manitoba, Canada) and V. P. Godambe: "A Test of Goodness of Fit." Statistische Hefte, 8:3, 165-172. 1967. Reprint Series No. 208, Statistical Laboratory, Iowa State University.

The authors propose a new test of goodness of fit for the simple null hypothesis that the actual distribution is equal to a given, everywhere continuous distribution function. Under the Neyman-Pearson setup they obtain a test which (a) is meaningful without reference to any specific set of alternatives, and (b) is based on the fact that there is a tendency to disbelieve tall scores for improbable events.

They also show that their test is connected with a pseudo distance between two distribution functions defined in terms of the Kullback-Leiber mean information index. Finally, they compare their test with the standard procedures: the chi-square test, Kolmogorov's test and two modifications of the latter, applying all of them to data published by Durbin.

***Oscar Kempthorne:** "The Classical Problem of Inference-Goodness of Fit." Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability. Pp. 235-249 in Volume I-Theory of Statistics. University of California Press. 1968. Journal Paper No. J-5461, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 890. Reprint Series No. 215, Statistical Laboratory, Iowa State University.

The purpose of this paper is to describe and evaluate partially a completely objective simple rule, namely, divide the distribution, fitted on the basis of N ob-

servations, into N equal parts with probability 1/N. This gives N cells each with expectation equal to unity. Count the number x_i in each cell. Then the chi-square criterion

$$K = \sum_i \frac{(x_i - e_i)^2}{e_i}$$

becomes

$$K = \sum_i (x_i - 1)^2 = \sum_i x_i^2 - 2\sum_i x_i + N$$
$$= \sum_i x_i^2 - N$$
$$= \sum_i x_i(x_i - 1).$$

The evaluation of the criterion is then made by reference to the chi-square distribution with degrees of freedom equal to (N - 1 - p), where p is the number of parameters fitted. In evaluating the criterion, however, it is to be noted that K can take only even integral values, so that one obtains the probability of exceeding (K - 1) for the mathematical chi-square distribution.

It is to be noted that in the case of continuous data this rule is objective, and there is no room for personal choice on number and location of cells. It is assumed that the resulting classes are still wide relative to the grouping interval of observations, though clearly this will not be true with very large samples. In very large samples the grouping error of observations would have to be considered.

The present paper gives some preliminary results on this procedure. It contains a discussion of the distribution of the Pearsonian criterion with k equally likely classes in the case when no parameters are estimated, this discussion being relevant and appropriate to the case of any continuous distribution. Then some Monte Carlo results are given on the distribution of K for the case of the normal distribution, in which the mean and variance are estimated. Finally a few power comparisons are made, and some discussion on the relevance of power is presented.

***Oscar Kempthorne:** "The Concept of Identity of Genes by Descent." Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability. Pp. 333-348 in Volume IV-Biology and Health. University of California Press. 1968. Journal Paper No. J-5618, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 890. Reprint Series No. 217, Statistical Laboratory, Iowa State University.

The aim of this paper is to present some basic ideas of the application to the progress of finite populations, and to describe some extensions of the basic idea to the status of more than two genes.

The concept is used first to describe the probability status of a random individual in a finite population, each member of which has a coefficient of inbreeding equal to F. A simplified argument for the progress of the inbreeding coefficient in a finite dioecious population is given. The case of a finite haploid population with variability of viability is shown to be easy to examine from the viewpoint of the inbreeding coefficient, as is a fairly elementary two-niche model.

The paper then deals with probabilities of likeness of triples, quadruples and k-plets of genes, given the details of the algebra for a finite monoecious population. The case of random viabilities in a haploid population is also worked out, noting that it would be easy also to include mutation.

The paper concludes with the view that many interesting aspects of genetic populations can be worked out early using the concept of "identity by descent" *if* the population processes do *not* depend on the actual genes involved.

Richard E. Lund, Lawrence A. Duewer, Wilbur R. Maki and **Norman V. Strand:** *Characteristics of Demand for Meat by Consumers in Webster County, Iowa.* Iowa Agricultural Experiment Station Special Report No. 56. February 1968.

Data regarding meat purchases of 642 households in Webster County, Iowa, were collected in order to investigate consumer preference regarding quality and type of meat consumed. These data were related to socioeconomic characteristics of the household and to data on marketing activities by retailers. Opinion data were also collected on the importance of various attributes of meat quality, and on consumer satisfaction at time of preparation and eating. A model representing the response of households to changes in prices, advertising and in-store promotion on the part of the retailer was developed.

Floyd K. Harmston and **Richard E. Lund:** *Application of an Input-Output Framework to a Community Economic System.* University of Missouri Studies Volume XLII. 124 pp. University of Missouri Press, Columbia. 1967.

This treatise, based on research conducted at the University of Wyoming, deals with community economic systems. Special emphasis is given to developing some concepts concerning what a community economic system is and why it exists. Of special importance is the concept of an economic base. The problem of constancy in basic and nonbasic relationships is given attention from both a theoretical and an empirical basis.

Upon this background a framework for analysis is constructed in Chapter III. Initial attention is given to possible measurement units and advantages and disadvantages of each. An input-output framework is then described and a working example provided. While not all possible frameworks of economic base analysis are examined, a few popular techniques are compared to the input-output framework proposed.

Some progress into applying the input-output framework to any community economic system is made in Chapter IV, which concerns definitional problems and industry and sector delineations. In Chapter V problems

of data collection are discussed. In Chapter VI, the many practical uses of the framework proposed are discussed in detail. Attention is turned to measuring the current economy, possible changes, and forecasting. The many places in which an input-output type analysis would fit in general purpose surveys are covered.

***Masashi Okamoto** and Mitsuyo Kanazawa: "Minimization of Eigenvalues of a Matrix and Optimality of Principal Components." Annals of Mathematical Statistics, 39:3. June 1968. Reprint Series, Statistical Laboratory, Iowa State University.

Let x be a random p x 1 vector with mean zero and variance matrix $E(xx') = \Sigma$. Let $\lambda_1 \geq \ldots \geq \lambda_p$ be the eigenvalues of Σ and $v_1, \ldots, v_p$ be the corresponding orthonormal eigenvectors. The linear combination $\xi_i = v_i'x$ is called by Hotelling the ith principal component of x. Principal components have several optimal properties due to Hotelling, Rao, Darroch, etc. The main result of this paper, which includes some of them as special cases, is as follows: Let A be any p x k ($k \leq p$) matrix and y be any random k x 1 vector, then the eigenvalues of the matrix E (x-Ay) (x-Ay)' are minimized simultaneously when and only when $Ay = v_1 \xi_1 + \ldots + v_k \xi_k$. This theorem is based on the following algebraic lemma: For any real symmetric matrix A let $\lambda_i(A)$ denote the ith largest eigenvalue of A. If B and A-B are non-negative definite and if B is at most of rank k, then λ_i (A-B) $\geq \lambda_{k+1}(A)$ for each i. A necessary and sufficient condition that all equality signs hold simultaneously is that $B = \lambda_1 (A)v_1 v_1' + \ldots + \lambda_k(A)v_k v_k'$, where $v_1, \ldots, v_k$ are orthonormal eigenvectors of A corresponding to $\lambda_1(A), \ldots, \lambda_k(A)$.

***J. H. Sedransk:** "Designing Some Multi-Factor Analytical Studies." Journal of the American Statistical Association, 62:320, 1121-1139. December 1967. Reprint Series No. 214, Statistical Laboratory, Iowa State University.

The designing of some multi-factor "analytical" studies of survey data is considered in this paper. It is assumed that, for each factor, there are two categories of interest and these are to be compared. The main objective is to allocate the sample so that the desired precision for the specified contrasts is obtained at minimum cost. It is assumed that one may sample independently in each of the sub-populations under investigation.

A model is employed to facilitate designing and analyzing such a survey. The relevance of this model for "analytical studies" is discussed and a few examples are presented.

Several survey objectives are explored, and an optimal allocation is obtained for each. Two-, three- and four-factor studies are considered explicitly.

George W. Snedecor (Emeritus, San Diego, California) and William G. Cochran: *Statistical Methods,* Sixth Edition. 398 pp. Iowa State University Press, Ames. 1967.

Combining the best and most workable features of the earlier, highly regarded editions with the most recent changes in statistical method and theory, this new 6th edition continues to be an outstanding text for introductory statistics courses as well as a reference source for research workers in the interpretation of their data.

As in past editions the mathematical level required involves little more than elementary algebra and dependence on mathematical symbols has been kept to a minimum. The new edition also retains one of the characteristic features of the past one-the extensive use of experimental sampling to familiarize the reader with the basic sampling distributions that underlie modern statistical practice.

Suggestions from teachers who have used past editions have resulted in several structural changes. Two related topics, the analysis of two-way classifications with observations in the sub-classes and the analysis of proportions in two-way classifications, have been combined in one chapter. The second topic is new to this edition.

The material on large sample methods is now presented earlier and an introduction to probability is followed by the binomial and Poisson distributions. The discussion of multiple regression precedes the presentation of covariance and multiple covariance. All statistical tables have been placed in an Appendix.

Also new in the edition are: analysis of data recorded in scales having only a small number of distinct values, prediction of the independent variable X from the dependent variable Y, linear regression when X is subject to error, comparison of two correlated estimates of variance, analysis of proportions in ordered classifications, testing a linear trend in proportions, analysis of a set of 2 x 2 contingency tables, remedial measures for the effects of failures in the assumptions of the analysis of variance, selection of variates for prediction in multiple regression, the discriminant function, a general method of fitting nonlinear regression equations and its applications to asymptotic regression, and analysis of proportions in two-way tables with unequal numbers of observations.

While the book supplies material for a year's course in statistical methods, a suggested list of subjects to be covered in a short course is also included.

M. S. Avadhani and **B. V. Sukhatme:** "Controlled Selection in Sampling with Varying Probabilities with and without Replacement." Australian Journal of Statistics, 9:1, 8-15. 1967.

The authors have previously (1965) evolved certain techniques of controlled selection which eliminate altogether some non-preferred combinations and reduce the probability of selection of the remaining combinations, if any, to the minimum possible extent without deviating from the fundamental principles of random sampling. Although it is often considered convenient, in practice, to draw sampling units one after another from the population rather than to draw combinations of units, no technique for doing this and at the same time reducing the probability of selection of non-preferred units is currently available in literature.

In this paper, the authors have suggested a solution to this problem which not only minimizes the selection probability of non-preferred units (and of samples containing predominately large numbers of non-preferred units), but also provides more efficient estimates than the usual probability proportional to size sampling scheme.

*M. S. Avadhani and **B. V. Sukhatme:** "Simplified Procedures for Designing Controlled Simple Random Sampling." Australian Journal of Statistics, 10:1. 1968. Reprint Series, Statistical Laboratory, Iowa State University.

The authors have introduced controlled simple random sampling designs with a view to reducing, to the minimum possible extent without affecting the precision of the estimate of the parameter under study, the risk of getting a non-preferred sample from the population. The method presumes the listing of all points of the sample space in order to write down the system of equations which defines the designs. When the sample size and the population size are considerably large, this listing becomes laborious. Further, solving the system of equations to get a design under consideration appears to be somewhat unmanageable since the number of unknowns would be quite large. Therefore, to ensure wider applicability to these designs, it would be worthwhile to remove these drawbacks.

This paper presents a simple mechanism by which one can easily get a controlled simple random sampling design to draw a sample of size n from a population of size N whatever the values of n and N.

Henry Tucker: "Statistical Techniques and Computation." Chapter 3.2, 3-18 to 3-52, in *Digital Computer Users Handbook*. McGraw-Hill Publishing Company, New York. 1967.

This chapter focuses on basic statistical methods in analysis of a single sample, two samples, multiple samples, regression analysis and transformation of variables, with short programs or references to existing programs for digital computers.

Donald G. Zytowski and **James A. Walsh:** "Response Tendencies in the SVIB: The Popular, the Rare and the Socially Desirable." Journal of Applied Psychology, 51:6, 491-496. December 1967.

A number of response sets: popular, rare, socially desirable, liking, and indifference, were examined for their correlations with each other and personality social desirability (SD), and for their influence on the scales of the SVIB-M.

It was found that the scale of SD formed from personality items is independent of socially desirable interest scales, and that the latter vary more freely from item probability of endorsement. Certain of the scales for which the SVIB is scored vary directly with one or more response tendencies. The significance of these findings for interpretation of the profile sheet is discussed.

Richard D. Warren, George M. Beal and Joe M. Bohlen: "Changes in Knowledge, Attitudes and Performance of Farm Supply Dealers and Changes in Business Firms." Rural Sociology Report No. 55, Department of Sociology and Anthropology, Iowa State University. 1967. Iowa Agricultural and Home Economics Experiment Station (in cooperation with TVA), Project 1469.

This report is based on an experimental research project designed to determine the effect of an experimental training program conducted for ten retail farm supply dealers who sold fertilizer and agriculture chemicals as two of their product lines. The educational phase consisted of planning, organizing and implementing an intensive training program. The research phase included setting up the experimental design, designating the participating and control dealers, measuring the influence of this training upon the manager and his business firm and data analysis.

The problem setting, discussion of training program, situational setting of the retail dealer, theoretical orientations and hypotheses, empirical measures and findings of this study are presented in this monograph.

Edwin C. Lewis, **Leroy Wolins** and Julie Johnson Yelsma: "The Academic Interests of College Women: A Factorial Study." Personnel and Guidance Journal, 46:3, 258-262. November 1967.

The extent to which college programs meet the needs and goals of women students has not been established. In this study, a sample of students and alumnae of the College of Home Economics, Iowa State University, responded to a set of attitude scales concerning their reactions to courses in their core curriculum. Factor analysis of the person-course interactions revealed six factors which were tentatively defined in terms of the courses loading most heavily on each. Implications for improved educational planning of women are discussed.

***Leroy Wolins:** "The Use of Multiple Regression Procedures when the Predictor Variables are Psychological Tests." Educational and Psychological Measurement, 27:4, 821-827. Winter 1967. Reprint Series No. 210, Statistical Laboratory, Iowa State University.

Typically when the psychologists use multiple regression, their results are subject to error due to both sampling and measurement. Statisticians have not developed procedures through which this situation can be dealt with precisely. However, perusal of such theory that does exist strongly suggests certain procedures commonly used are not justified, others are not optimum, and still others have not been fully exploited.

The purpose of this paper is to expound these principles, alerting the quantitatively sophisticated reader to them and providing the less quantitatively sophisticated reader with statistical tools more appropriate for psychological prediction than those offered in textbooks.

***George Zyskind:** "On Canonical Forms, Non-Negative Covariance Matrices and Best and Simple Least Squares Linear Estimators in Linear Models." Annals of Mathematical Statistics, 38:4, 1092-1109. August 1967. Reprint Series No. 206, Statistical Laboratory, Iowa State University.

This paper discusses best linear estimation in linear models with arbitrary covariance structure. Conditions are first considered under which all the simple least squares linear estimators are also best, then a general characterization of the best linear estimators is given, and then conditions for the equality of subsets of best and simple least squares estimators are obtained. Finally, the linear model involving parametric restrictions as an example of a model with a special singular covariance matrix is discussed. In dealing with these problems it has been found to be both clarifying and fruitful to employ a canonical form of the general linear model.

When the covariance matrix of the observation vector y is $\sigma^2 I$ then it is well known that a linear function w'y is the best linear estimator (b. l. u. e.) of its expectation E(w'y) if and only if w is a vector belonging to $\mathcal{C}(X)$, the column space of the design matrix X. It is demonstrated that in the general case where the covariance matrix of y is $\sigma^2 V$, with V possibly singular, the function w'y is b. l. u. e. for E(w'y) if and only if the vector Vw belongs to $\mathcal{C}(X)$. Further, it follows that an estimator w'y is both a simple least squares estimator and a b. l. u. e. if and only if w is a vector in $\mathcal{C}(X)$ which remains in $\mathcal{C}(X)$ when operated upon by the matrix V. A corollary of the last fact is that *all* the usual simple least squares estimators of estimable functions are also corresponding b. l. u. e.'s under an arbitrary covariance matrix $\sigma^2 V$ if and only if the column space of the design matrix X is an invariant subspace of the matrix V, i.e., if and only if for every vector x belonging to $\mathcal{C}(X)$ the vector Vx belongs also to $\mathcal{C}(X)$.

***George Zyskind:** "Topics in General Linear Models Theory." Bulletin of the Institute of Statistical Research and Training, 2:1, 1-35. December 1967. Reprint Series No. 222, Statistical Laboratory, Iowa State University.

In this paper the usual general model is described and the minimization of a sum of squares is used to arrive at the normal equations. Then the normal equations are investigated and it is shown how they can be made relevant in developing certain mathematical constructs useful in the study of linear models; constructs such as projection, matrix projection operator, and certain generalizations of a matrix inverse. Some of the standard linear model developments are presented briefly and the vital role played in them by normal-type equations is exhibited.

A brief formulation of equivalent linear reparametrizations is included. Here heavy emphasis is laid on the necessity of assuring that the unknown expected vector of the observations is allowed to range over the identical vector space in the different parametric representations of the linear model. Then follows a consideration of complex error structures and a statement of a number of equivalent necessary and sufficient conditions for the equality of best and simple least squares estimators of estimable functions.

Book Reviews

D V. Huntsberger: Review of *Mathematics and Statistics for Students of Chemistry, Chemical Engineering, Chemical Technology and Allied Subjects,* by C. J. Brookes, I. G. Betteley and S. M. Loxton. International Statistical Institute Review, 35:2, 193-194. 1967.

James A. Walsh: Review of *Elementary Statistics* by Hoel. Educational and Psychological Measurement, 27, 532-533. 1967.

James A. Walsh: Review of *Probability and Statistics in Psychological Research and Theory* by Stilson. Educational and Psychological Measurement, 27, 887-890. 1967.

ABSTRACTS OF THESES

Munir Ahmad: "Truncated Multivariate Poisson Distributions." Ph.D. thesis. Iowa State University Library. May 1968.

This thesis considers first the problems of estimating the parameters of univariate Poisson and Hyper-Poisson distributions under various types of truncation.

For the case of multivariate Poisson distributions, new types of truncation are introduced, namely, left corner, right corner and cell truncation. In the case of bivariate Poisson distributions, this thesis considers the estimation problems for the left hand and right hand truncation as well as for the left corner, right corner and cell truncation. In the multivariate case, only left hand truncation is studied.

An attempt has also been made to derive a general class of bivariate correlated Hyper-Poisson distributions of which the bivariate Poisson is a special case. Explicit forms of asymptotic variances and covariances of various types of estimators have been given. It is shown that in the bivariate case the truncated marginal distributions are equivalent to marginal truncated distributions if and only if the variates are independently distributed.

This research has also derived some general recursion relations of derivatives of generating functions which can be of great use for computational purposes.

Joseph Leo Abbey: "Series Representation of Uniformly Minimum Variance Unbiased Estimators." M.S. thesis. Iowa State University Library. August 1967.

For the exponential class of distributions, with a scalar parameter Θ, it is well known that any estimable parametric function $g(\Theta)$ has a unique uniformly minimum variance unbiased estimator (UMVUE). Provided an unbiased estimator is available, the UMVUE is obtainable in integral form by a method due to Rao and Blackwell and known by their names.

In this thesis a series converging to the UMVUE in mean square is given, provided certain assumptions

Cary T. Isaki: "Non-Response Bias in Estimators of the Mean from Sample Surveys." M.S. thesis. Iowa State University Library. May 1968.

In most survey studies some units selected for the sample are never observed and hence the common estimators for the population mean are subject to bias. The extent of the bias depends on the mean of the non-respondents in comparison to the mean of the respondents and on the degree of non-response.

It is assumed in the analysis that non-response arises as a result of a screening process which can be represented by response probabilities, R_i. That is, the probability that population unit i selected in a sample of size n will respond is given by R_i.

In general, given non-response, nothing can be said with respect to the relative bias of the post-stratification estimator and the simple mean as estimators of $\overline{Y}$. Even when a simple two-way linear model $y_{ijk} = \mu + \alpha_i + \beta_j + \epsilon_{ijk}$ is assumed, the relative bias depends on the signs and magnitudes of the α_i and β_j components of the bias. Post-stratification eliminates the portion of bias associated with the characteristic stratified upon, but the estimator may still have a larger bias than the simple mean.

Only under strict model assumptions is the regression estimator unbiased in the presence of non-response. Given the regression estimator

$$\overline{y}_{1.r.} = \overline{y}_t + \hat{\gamma}\,(x_t - \overline{X}_1) \text{ where } \hat{\gamma} = \frac{\sum_{i=1}^{t} (x_i - \overline{X}_1)\, y_i}{\sum_{i=1}^{t} (x_i - \overline{X}_1)^2},$$

a bound on the absolute bias is derived for large n and N. This bound is

$$\frac{\sigma_u}{\overline{R}_N} \sqrt{\sum_{i=1} \frac{N\,(R_i - \overline{R}_N)^2}{N}} \quad \text{where } u_i = y_i - \gamma x_i$$

and R_i is the response probability for unit i. An estimate for this bound, from the sample, is

$$\frac{\hat{\sigma}_u}{\overline{W}_n} \sqrt{\frac{N-1}{N} \sum_{i=1} \frac{n\,(w_i - \overline{w}_n)^2}{n}}$$

where w_i takes on the value 1 if unit i is in the sample, and zero otherwise. Since u_i is not observed for the non-respondents, $\hat{\sigma}_u$ may be obtained from past experience or on the basis of a distributional assumption and the non-response rate. A table is constructed for the minimum and maximum variance and mean associated with various non-response rates for the normal and exponential distributions.

Louis Jensen: "Some Effects of Random Selective Advantages of a Gene in a Finite Population." M.S. thesis. Iowa State University Library. November 1967.

This thesis considers the change in the genetic structure of a haploid population, using a single locus model. The genetic change was described in terms of the frequency of a gene. The method used to describe the change in a gene frequency involved the assumption that the gene frequency is a discrete parameter Markov chain. This Markov chain was approximated by a continuous parameter Markov process, and the forward Kolmogorov partial differential equation was derived for this process. The solution of the Kolmogorov forward equation gives an approximation to the probabilities in the original discrete parameter Markov chain.

The forward Kolmogorov equation was solved for three different processes of change in a gene frequency. The first process of change to be considered was when a gene frequency changes from generation to generation due to random sampling of the infants produced in each generation. The method of solution used on the partial differential equation, which described this change, was separation of variables. The Gegenbauer polynomials, a complete orthogonal set of polynomials, were used to facilitate the solution. It was also shown that if the change in a gene frequency was due to random sampling of the infants then the assumptions made in deriving the forward Kolmogorov equation were satisfied.

The second process of change to be considered was when the frequency of a gene changes due to random fluctuations of the selective intensities. For this process of change it was shown that the first and second moments of change in the gene frequency during one generation were

$$M_{\Delta x} = \bar{s}x(1\text{-}x) + V_s x(1\text{-}x)^2 \text{ and } V_{\Delta x} = V_s x^2(1\text{-}x)^2.$$

In these expressions $\bar{s}$ and V_s are respectively the first and second moments of the random variable which describes selection. Previous authors have incorrectly stated that these expressions were

$$M_{\Delta x} = \bar{s}x(1\text{-}x) \text{ and } V_{\Delta x} = V_s x^2(1\text{-}x)^2.$$

The final forms of the solution of the first two processes considered were due to Kimura.

The final problem to be considered was when a gene frequency changes from generation to generation due to random sampling of the infants and to random fluctuations of the selective intensities. The method used to solve the partial differential equation again involved separation of variables and the introduction of the Gegenbauer polynomials. Several relationships involving the Gegenbauer polynomials were used to reduce the second order differential equation, obtained after applying the method of separation of variables, to an algebraic equation. The final form of the solution was a linear combination of Gegenbauer polynomials.

John Peter Johnson: "Pooling Regressions and a Statistical Outlier Methodology for Lines." Ph.D. thesis. Iowa State University Library. November 1967.

This investigation presents a study of the effects that a preliminary test for the possible pooling of regression line, or an outlier test for a possible aberrant line, has on subsequent inferences about the population regression model of interest. Preliminary test procedures are given for testing if two linear regression coefficients are equal, if N linear regression coefficients are equal, if two linear regression lines considered in their entirety are equal, if N linear regression lines considered in their entirety are equal, if two multiple regression lines are equal, if there exists a slope outlier, and if there exists a line outlier when there is *a priori* information sufficient to identify a suspected line outlier.

The biases and mean square errors of estimation procedures subsequent to these preliminary tests are derived for the cases of pooling two linear regression coefficients, pooling N linear regression coefficients, pooling two linear regression lines, pooling N linear regression lines, pooling two multiple regression lines, and the possible rejection of a slope outlier.

The power functions for test procedures subsequent to these preliminary tests are presented for the cases of pooling two regression coefficients, the pooling of two regression lines, and the possible rejection of a slope outlier.

An attempt was made to obtain a preliminary test criterion for the possible rejection of a line as an outlier, but the distribution of the test statistic is not parameter free and hence is of limited usefulness.

Nancy Rowe Johnson: "A Monte Carlo Investigtion of Some Regression and Ratio Estimators." M.S. thesis. Iowa State University Library. August 1967.

A Monte Carlo procedure was used to obtain 500 samples in each of the sizes: 5, 10, 15, 25 and 40, from the normal and exponential distribution to estimate the bias and MSE for each of three regression and two ratio estimators. These Monte Carlo results were then compared with approximation formulae.

The estimators investigated were the usual regression estimator, two "approximately unbiased" regression-type estimators, the usual ratio estimator, and an "approximately unbiased" ratio estimator.

The model for this study was

$$y_i = \alpha + Bx_i + \delta x_i^2 + dw_i + u_i$$

where $E(u_i|x) = 0$

$E(u_i^2|x) = \sigma_u^2$

$E(x_i) = \mu$

and $w_i = 0$ if $x_i < \mu + 0.5$

$= x_i$ if $x_i > \mu + 0.5$.

The x_i and u_i are assumed to be independent.

From the results of this study, the biases of the "approximately unbiased" regression and ratio estimators were found to be smaller than the biases of the usual regression and ratio estimators. The MSE of the approximately unbiased estimators and the common estimators differed very little.

The approximate formula for the bias of the usual regression estimator, to order $1/n^2$, for the normal distribution approximated well the Monte Carlo results. The ratio approximation to the bias to order $1/n$ of the usual ratio estimator, appears in general to do better than the regression approximations to the biases for the normal Monte Carlo results.

Comparing the ratio and regression Monte Carlo MSE's for the normal distribution, the components of the ratio estimators are slightly larger than the comparable components of the regression estimators with the exception of the multiplier for σ_u^2.

For the exponential distribution, an "approximately unbiased" regression estimator has smaller Monte Carlo bias components than the common regression estimator. All the Monte Carlo components for the bias of the "approximately unbiased" ratio estimator are smaller than those of the regular estimator. The usual bias approximation for the common ratio estimator is the best approximation to the Monte Carlo results for the exponential distribution.

As with the normal distribution, the components of the Monte Carlo MSE's for the ratio estimators are larger than the comparable components of the regression estimators with the exception of the multiplier for σ_u^2. Of the MSE approximations for the exponential distribution, the approximation to order $1/n^2$ for the usual regression estimator most closely approximates the Monte Carlo results for any of the regression estimators. The MSE approximation for the usual ratio estimator closely approximates the Monte Carlo results. In general, the ratio approximations are better than the regression approximations for the exponential distribution.

The approximate formulae for the biases worked better for the normal distribution than for the exponential distribution. The MSE approximations for the regression estimators perform better for the normal distribution than for the exponential while the converse is true for the ratio approximations.

Richard Edgar Lund: "Factors Affecting Consumer Demand for Meat, Webster County, Iowa." Ph.D. thesis. Iowa State University Library. August 1967.

Factors affecting consumer demand for several classes of meat items were investigated. Consideration was given to socio-economic characteristics of individual households as well as to factors associated with the retail market. Factors having a significant effect on demand were isolated and elasticity coefficients for their quantitative effect on demand were estimated.

Data on which the investigation was based were collected by use of a consumer panel of 642 households in Webster County, Iowa in June-July, 1963. A system of panel rotation produced a collection period of seven weeks for the data used. Thus, the data possessed a time series as well as a cross-sectional character. Time

series data were also collected on several aspects of the retail market.

A model relating consumer demand to the general factors of interest was developed upon traditional Paretoan consumer demand theory. Various linear models were developed to approximate the theoretical model. Classical regression methods were applied to estimate coefficients.

Several socio-economic attributes of the households were examined with respect to their effect on demand for meat. Among the attributes examined, it was determined that purchasing behavior could be most satisfactorily explained by (a) household income, (b) household composition (presence of children), (c) size of household, and (d) age of household head. A significant correlation between education of the household head and purchasing was found for only two kinds of meat.

A linear model was used to relate independent variables based on the above four attributes to demand for meat. Demand was defined in terms of both quantity purchased and size of expenditure per person for twelve classes of meat items and four aggregations of these twelve. The variation explained by the four independent variables was significant at the .05 level for all meat classes.

Factors affecting consumer demand associated with the retail market were summarized by the variables (a) retail price, (b) an index of newspaper advertising, and (c) an index of in-store promotion. These three variables were quantified in the form of data series pertaining to thirteen meat classes, five store groups, and seven weekly time periods.

A linear model was formulated to relate the above data series as explanatory variables to a corresponding quantity of purchases series. When explaining the quantity purchased of a particular meat at a particular store group, the model took into account not only the level of price, advertising, and in-store promotion of that meat at that store, but also the level of these variables for other meats and for other stores. Components were included in the model to estimate interactions of price, advertising, and in-store promotion with both the classes of meat and the socio-economic characteristics of the households.

Statistically significant estimates of elasticities of quantity demanded with respect to price, advertising, and in-store promotion were obtained. But a variation in these elasticities among individual classes of meat (i.e. interaction) was not supported by the data. A clear interaction with socio-economic characteristics was determined only for the price elasticity. The relationship of price elasticity to socio-economic characteristics was reduced to one involving only income and household composition.

Mark John Malone: "Algorithms for Analysis of Experiments with Incomplete Structures." M.S. thesis. Iowa State University Library. August 1967.

A computer program for the analysis of a large class of designs with balanced incomplete structures is described. The analysis of variance follows the method proposed by B. V. Shah which is suitable for designs which are partially balanced incomplete block designs, or can be analyzed as partially balanced incomplete block designs. The literature review includes a discussion of the types of designs which satisfy Shah's criterion. Shah's method of analysis is extended to the combined intra- and inter-block analysis of variance, and an analysis of covariance is added.

The problem of determining the association scheme of a design from the incidence of treatments in blocks is also discussed. Two methods of solving this problem are proposed, one based on Shah's criterion, and the other based on graph theory. Examples are included to illustrate each approach.

James Issac Mellon: "A Power Comparison of the Hodges-Lehmann Conditional Rank Test and the F Test for Homogeneity of Means." M.S. thesis. Iowa State University Library. May 1968.

This thesis is concerned with the empirical evaluation of the power curves of both the conditional rank test as described by Mehra and Sarangi (1967) and the F test. Eight experimental conditions were simulated and reproduced fifty times for various treatment differences. Imposed on the model $Y_{ij} = \mu + \alpha_i + \beta_j + \epsilon_{ij}$, the conditions were:

1) ϵ_{ij} were i.i.d. $N(0, \sigma^2)$,

2) ϵ_{ij} were i.i.d. $N(0, \sigma^2)$ but a block by treatment interaction existed,

3) ϵ_{ij} were i.i.d. $N(0, \sigma_1^2)$ with probability p and $N(0, \sigma_2^2)$ with probability 1-p,

4) ϵ_{ij} were i.i.d. $N(0, \sigma_i^2)$ where $\sigma_i^2 = c\alpha_i^2$,

5) ϵ_{ij} were i.i.d. Logistic r.v.,

6) ϵ_{ij} were i.i.d. from a right triangular density,

7) ϵ_{ij} were i.i.d. from a parabolic density, and

8) ϵ_{ij} were i.i.d. $U(a, b)$.

The results suggest that, for sample sizes as small as seven for $\alpha = 0.01$, four for $\alpha = 0.05$, and three for $\alpha = 0.10$, the exact probability levels of the permutation test should be tabulated. In general the results of the asymptotic theory seem to be confirmed for finite sample sizes. That is, for a given number of blocks, N, the efficiency relative to the F test is at maximum when the number of treatments, K, is three, and decreases monotonically as K increases. The efficiency when N equals 11 and 12 is very comparable to the asymptotic efficiency, given a normal distribution.

The efficiency increased as the type I error increased. This seems to be because the test statistic is only asymptotically distributed as chi-square. The approximation to the exact permutation test would seem to be weakest in the tails. In all eight situations the F test was uniformly more powerful than the conditional rank test.

Ahmed Zogo Memon: "Z Statistic in Discriminant Analysis." Ph.D. thesis. Iowa State University Library. May 1968.

The statstic $Z = \frac{N_1}{N_1 + 1} (x-\bar{x}_1)' S^{-1}(x-\bar{x}_1) - \frac{N_2}{N_2 + 1} (x-\bar{x}_2)' S^{-1}(x-\bar{x}_2)$ is one of the criteria proposed in discriminant analysis for classification of a vector observation x into its correct population when the observation is known to have come from either of the two multivariate normal populations π_1:N(μ_1, Σ) and π_2:N (μ_2, Σ). The samples $x_{11}, \ldots, x_{1N_1}$ and $x_{21}, \ldots, x_{2N_2}$ drawn from π_1 and π_2 respectively, are assumed to be independent of each other. $\bar{x}_1$, $\bar{x}_2$ and S are the best estimates of the unknown parameters μ_1, μ_2 and Σ. The sampling distribution of Z for small samples appears to be extremely complicated for the purpose of numerical use. A large sample approach therefore has been employed in determining its approximate characteristic function and consequently its distribution function. These expressions are given in the form of asymptotic expansions with respect to N_1^{-1}, N_2^{-1} and n^{-1} where n is the total number of degrees of freedom used in estimating the covariance matrix Σ.

The procedure of classification according to the criterion under consideration is to assign the observation x to π_1 if $Z \leq 0$ and to π_2 if $Z > 0$. However, there are chances of misclassifying the observation into one population while it comes, in fact, from the other population. The resulting probabilities of misclassification, which are of two kinds, are derived as functions of N_1, N_2, n and D where D is the Mahalanobis distance between π_1 and π_2. It is discovered that the interchange of N_1 and N_2 in the probability of misclassification of one kind gives the probability of misclassification of the other kind. The two kinds of probabilities are equal when the sample sizes are the same.

Another situation considered with $N_1 = N_2$ is when the discriminators in the Z statistic are correlated with other normally distributed characters y having unspecified parameters and the regression matrix of x on y is unknown. The probabilities of misclassification which arise due to the use of the modified Z criterion are derived for the purpose of investigating the effects of covariates on discrimination of the observation x.

Several mathematical lemmas, which may also be useful for other multivariate studies, are established in building up various theorems related to the investigation.

Abel Geber Mexas: "Algorithms for Computer Analysis of Variance of Balanced Complete Structures." M.S. thesis. Iowa State University Library. November 1967.

Analysis of general purpose computer algorithms for computations in the analysis of variance of designs in the class of balanced complete structures is discussed in this thesis, with particular emphasis on the impact of recent developments in computer hardware and software on statistical programs. In particular, the role of an operating system as an aid in handling intermediate results for very large experiments and the feasibility of the new PL-1 language for general purpose statistical programs is evaluated and developed.

Algorithms for the computations of admissible means and components are defined in terms of logical and set theoretical operations programmable with PL-1 bit functions. The system as designed yields the components entering the Analysis of Variance table for factors crossed or nested with or without concomitant variables and with or without missing observations. Minimum problem specification and varied entry points to the system are provided. Through the use of PL-1, significant improvements are achieved over existing systems such as AARDVARK.

Peter Charles O'Brien: "Selection Procedures Relating to Gamma and Weibull Populations." M.S. thesis. Iowa State University Library. May 1968.

A single sample procedure and two sequential procedures are developed for selecting the gamma population with the largest scale parameter (largest mean). These procedures are developed using an indifference region formulation and are all invariant under a common change of scale of the data.

Procedures for discriminating between two Weibull populations also are studied. A question is raised regarding the validity of two existing procedures, and four alternative procedures are developed.

Monte Carlo studies of the average sample number, average sample time, and probability of correct selection of the procedures are presented.

Donna Jean Brogan Ruhl: "Preliminary Test Procedures and Bayesian Procedures for Pooling Correlated Data." Ph.D. thesis. Iowa State University Library. November 1967.

This dissertation discusses several methods of pooling correlated data when observations are available on the random variable $(\tilde{x}, \tilde{y})$ and it is desired to estimate $E(\tilde{y}) = \mu_y$. $(\tilde{x}, \tilde{y})$ is assumed to follow a bivariate normal distribution with parameters $(\mu_x, \mu_y, \rho, \sigma_x^2, \sigma_y^2)$. The sampling scheme allows for $n \geq 0$ independent observations on $(\tilde{x}, \tilde{y})$, $n_x \geq 0$ additional independent observations on $\tilde{x}$ alone, and $n_y \geq 0$ additional independent observations on $\tilde{y}$ alone.

The bias and mean square error of the estimators PT and PTR are derived under the assumption of known ρ, σ_x^2, σ_y^2. These two estimators are based on a preliminary test. If H_o:$\mu_y = \mu_x$ is accepted by a preliminary test of significance, then both PT and PTR are a weighted average of the respective means of the observations on $\tilde{x}$ and $\tilde{y}$. If H_A:$\mu_y \neq \mu_x$ is accepted by the preliminary test, then the estimator PT is simply

the mean of the observations of $\tilde{y}$, whereas PTR is a classical regression estimator of $\bar{y}_n$ upon $\bar{x}_n$ with μ_x estimated from the sample. PTR is seen to have a smaller mean square error since it makes more efficient use of the available data. The two estimators PT and PTR are also compared to the estimation scheme: "use a regression estimator all the time."

Also derived under the assumption of known ρ, σ_y^2, σ_x^2 are several Bayesian point estimators of μ_y. For *comparison* with the preceding classical estimators, the priors on $\tilde{\mu}_y$ and $\tilde{\Delta} = \tilde{\mu}_y - \tilde{\mu}_x$ are assumed to be bivariate normal. The method of "precise measurement" and a variant of this approach are also considered. The Bayesian point estimators, in general, are weighted averages of means and various "regression-type estimators," and some interpretation of the weights is given. For some cases, optimal sample size allocations are obtained.

Under the assumption of unknown ρ, σ_y^2, σ_x^2 the difficulties in the preliminary test approach and Bayesian approach are pointed out. A preliminary Monte Carlo study was carried out to investigate the bias and mean square error of PT and PTR when the quantities ρ, σ_y^2, σ_x^2 are estimated from the sample.

In the last chapter, pooling observations from two binomial distributions is discussed from a Bayesian viewpoint. A joint prior on $\tilde{p}_1$ and $\tilde{\Delta} = \tilde{p}_2 - \tilde{p}_1$ is suggested, and several desirable properties of the prior are demonstrated.

Charles Berlin Sampson: "Contributions to the Study of Sequential Covariance Analysis." Ph.D. thesis. Iowa State University Library. February 1968.

Wald's Sequential Probability Ratio Test is known to be optimal in certain senses when both the null and alternative hypotheses are simple. In practical hypothesis testing situations, however, such hypothesis formulations are often unrealistic because of unspecified nuisance parameters and the possibility that the region of interest for the parameter under investigation contains more than two points. More realistic formulations are admitted in this study, which is primarily aimed at the development of sequential procedures for discrimination between two treatments when concomitant information is utilized.

The design where the subjects are paired and receive one of two treatments at random is considered first. Two types of situations are envisaged. In the first, each observation is taken to be a $p + 1$ vector consisting of the variate of interest plus p covariates, and these are assumed to be multivariate normally distributed. In the second situation considered, the covariates are assumed to be controlled.

Using a weight function approach, sequential tests are derived for each of several hypothesis formulations. The location and scale invariance characteristics of these tests are examined and some termination proofs are presented. An alternative approach, in conjunction with the assumption of controlled variates, is based on fixed sample size sufficiency and invariance properties.

In the second design case, the restriction requiring pairing of the subjects is removed and, again employing the methods of weight functions, a sequential two-sample t-test utilizing controlled concomitant variates is constructed. It is demonstrated that this test is, in fact, a type of sequential t-test as put forward by Hajnal.

A Monte Carlo study is presented and the results indicate that the test statistics derived do permit advantages of practical importance to be obtained by the use of concomitant information in sequential trials.

Douglas Elwin Splitstone: "Estimation of the Weibull Shape and Scale Parameters." M.S. thesis. Iowa State University Library. August 1967.

This thesis is a Monte Carlo investigation of some distributional properties of selected methods of estimating the scale and shape parameters of the Weibull distribution.

The two parameter family of Weibull probability densities was considered. The methods of estimation investigated were maximum likelihood, Weibull probability plots or graphical estimation, best linear unbiased estimation (BLUE) and the nearly best linear unbiased estimation (NBLUE) derived by Blom (ca. 1958). The method of maximum likelihood uses the original Weibull variates and requires the numerical solution of the likelihood equations. The latter three methods employ linear combinations of the logs of the Weibull variates.

The correspondence between the extreme-value distribution,

$$h(y;\gamma,\beta) = \frac{1}{\gamma} e^{\frac{y-\beta}{\gamma} - e^{\frac{y-\beta}{\gamma}}},$$

and the Weibull distribution is given simply by the transformation

$$y = \ln x,$$
$$\beta = \ln b,$$
and $$\gamma = 1/c,$$

where b and c represent, respectively, the scale and shape parameters of the Weibull distribution. Since this transformation is one-to-one, estimates of the extreme-value parameters provide estimates of the corresponding Weibull parameters.

The maxiumum likelihood, graphical, BLUE and NBLUE methods of estimation were employed for samples of sizes 5, 15 and 25. These estimators were compared on the basis of bias, variance and mean square error. The maximum likelihood, graphical and NBLUE methods were considered for samples of size 35, and the same comparisons made. Also considered were samples of size 5 and 25, censored from above after 2, 3 and 4, and 15 and 20 observations respectively.

The BLUE and NBLUE estimates were found to

possess very similar biases and mean square errors for all sample sizes. The method of maximum likelihood and the graphical method show large biases for γ. The method of maximum likelihood also yields estimates for c showing a large bias. Correlations between the estimators are also given. The approximate asymptotic normality of the BLUE and maximum likelihood estimators is illustrated through normal probability plots.

Vincent A. Sposito: "Variables Acceptance Sampling Plans for Non-Normal Distributions." M.S. thesis. Iowa State University Library. February 1968.

This study presents possible approaches to the problem of designing variables acceptance sampling plans when normality cannot be assumed.

The first approach considered is that the underlying population is known or believed to be non-normal, but the exact form of the distribution is unknown. The approach here is an attempt to develop a sampling plan through the use of Tchebycheff-type inequalities and order statistics.

The second approach considered is that the probability distribution of the quality characteristic is known to belong to a certain family with the values of one or more parameters unknown. Several distributions are considered and methods of designing a variables sampling plan for certain families are presented.

When the coefficients of skewness and kurtosis for a non-normal distribution are known, then the underlying population can be approximated by one of Burr's distributions. Zimmer and Burr have developed a procedure to approximate many distributions when the first four central moments are known. Therefore, the underlying distribution can be scaled and relocated to a known distribution so that a variables sampling plan can be designed.

An evaluation of the procedures under this study showed that no use can be made of the sample variables unless something is known concerning the distribution of the random variables. In the absence of such information, the decision to reject or accept the lot can only be based on the number of defectives in the sample. When the underlying distribution can be classified as a member of a known family of distributions, an appropriate sampling plan can be designed by assuming the normality of $\bar{x}$. Zimmer and Burr's procedure yields fairly good results when the distribution can be fit by one of Burr's distributions. However, due to the lack of extensiveness of their tables, it becomes quite difficult to fit many distributions and hence this is a major drawback to their procedure.

Eric Neil West: "Monte Carlo Investigation of the Behrens-Fisher Problem." M.S. thesis. Iowa State University Library. November 1967.

This study investigates the performance of the Behrens-Fisher test as a solution to the problem of comparing two normal population means without assuming equality of variance. The Behrens-Fisher test is compared with the Aspin-Welch solution on the bases of distribution of significance levels generated under null and alternative hypotheses for a large variety of true variance ratios and sample sizes.

The results suggest that for degrees of freedom greater than four, the significance levels generated by the two tests are nearly uniformly distributed when the null hypothesis of equality of means is true. It is also suggested that even for small degrees of freedom the Behrens-Fisher test is usable as long as the size of the test does not exceed 0.20; also, that both tests give nearly the same level of significance for a given observed difference between the two means. Finally, it is suggested that the two tests have almost identical power characteristics for the range of data situations studied.

PAPERS AND SPEECHES

Papers presented at scientific and professional meetings reflect the research and activities of the Statistical Laboratory staff. Many of these papers will appear later in publications. Abstracts of papers often are published, and in such cases references are given.

Barry Arnold: "Multivariate Distributions with Prescribed Marginal Distributions," a seminar at the Statistics Center of the Graduate College of the National School of Agriculture, Chapingo, Mexico, March 1.

Gordon Booth and **J. H. Sedransk:** "Designing Several Factor Analytical Surveys," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economic Association and other allied societies, Washington, D.C., December 27-30.

F. B. Cady and R. J. Laird: "Bias Error in Yield Functions as Influenced by Treatment Design," and "Combined Analysis of Yield Data from Fertilizer Experiments" (R. J. Laird and **F. B. Cady**), at the American Society of Agronomy annual meeting, Washington, D.C., November 4-10.

F. B. Cady and **Henry Tucker:** "Teaching Graduate Courses in Statistics in Mexico," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economics Association and other allied societies, Washington, D.C., December 27-30.

Richard L. Chamberlain: "Implementation of OMNITAB on the IBM 360/50 at Iowa State University," at the OMNITAB-OMNITEXT Workshop, National Bureau of Standards, Washington, D.C., August 23-25.

C. Philip Cox: "An Introduction to the Design and Analysis of Continuous Response Assays," at the Workshop Conference on Statistics in Endocrine Research, Endicott House, Dedham, Massachusetts, December 4-7.

C. Philip Cox: "Some Observations on the Teaching of Statistical Consulting," at the eastern regional meeting of the Institute of Mathematical Statistics, Virginia Polytechnic Institute, Blacksburg, April 8-10.

H. T. David: "Information Reliability and Price," at a meeting of the Twin Cities Chapter, American Statistical Association, Minneapolis, Minnesota, October 24.

Chien-pai Han and **T. A. Bancroft:** "On Pooling Means when Variance Is Unknown," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economic Association and other allied societies, Washington, D.C., December 27-30. Abstract 14 in the Annals of Mathematical Statistics,38:6, 1933, December 1967.

Roy Hickman: "Demonstration Course in Survey Methods," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economic Association and other allied societies, Washington, D.C., December 27-30.

John P. Johnson and **T. A. Bancroft:** "Applications of Pooling and Outlier Methodology for Regressions," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economic Association and other allied societies, Washington, D.C., December 27-30.

Paul Johnson, Wayne A. Fuller and **Foster B. Cady:** "Designs to Discriminate Between Exponential and Quadratic Responses," at the 6th International Biometric Conference, Sydney, Australia, August 20-25. Abstract 1429 in Biometrics, 24:1, 222-223, March 1968.

Louis Jensen and **Edward Pollak:** "Some Effects of Random Selective Advantages of a Gene in a Finite Population," at the eastern regional meeting of the Institute of Mathematical Statistics, Virginia Polytechnic Institute, Blacksburg, April 8-10.

Oscar Kempthorne: "Aims and Methods of Studying Yield Response Relationships," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economic Association and other allied societies, Washington, D.C., December 27-30.

Oscar Kempthorne: "Some Remarks on Statistical Inference in Finite Sampling" at a symposium on Foundations of Survey Sampling, University of North Carolina, Chapel Hill, April 21-27.

W. D. Lawing, Jr.: "Sequential Methods in Process Control," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economic Association and other allied societies, Washington, D.C., December 27-30.

W. D. Lawing, Jr.: "Introduction to Statistical Quality Control" and "Control Chart Fundamentals" at the Engineering and Management Institute on Quality Control, Ames, May 15-16.

E. L. LeClerg: "Crop Losses in Agriculture," at a special plant pathology seminar, Iowa State University, Ames, May 17.

F. B. Martin and **George Zyskind:** "The Relative Efficiency of Simply Weighting Uncorrelated Linear Estimators," at the eastern regional meeting of the Institute of Mathematical Statistics, Virginia Polytechnic Institute, Blacksburg, April 8-10.

K. L. Mehra: "On Conditional Rank-Order Tests for Experimental Design," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economic Association and other allied societies, Washington, D.C., December 27-30. Abstract 91 in the Annals of Mathematical Statistics, 39:2, 688, April 1968.

Richard W. Mensing and **H. T. David:** "Method of Images in the Plane," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economic Association and other allied societies, Washington, D.C., December 27-30. Abstract 93 in the Annals of Mathematical Statistics, 39:2, 688, April 1968.

Peter C. O'Brien and **David R. Thomas:** "Procedures for Selecting the Best One of Several Gamma Populations," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economic Association and other allied societies, Washington, D.C., December 27-30.

M. Okamoto and M. Kanazawa: "Minimization of Eigenvalues of a Matrix and Optimality of Principal Components," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economic Association and other allied societies, Washington, D.C., December 27-30. Abstract 21 in the Annals of Mathematical Statistics, 38:6, 1935-1936, December 1967.

M. Okamoto: "Optimality of Principal Components," at the Second International Symposium on Multivariate Analysis, sponsored by Aerospace Research Laboratories, Wright State University, Dayton, Ohio, June 17-22.

Donna B. Ruhl: "Some Pooling Procedures for Two Correlated Means Based upon a Preliminary Test of Significance," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economic Association and other allied societies, Washington, D.C., December 27-30. Abstract 1349 in Biometrics, 23:3, 607, September 1967.

Charles Sampson and **C. Philip Cox:** "Some Sequential Hypothesis Tests Utilizing Concomitant Information," at the eastern regional meeting of the Institute of Mathematical Statistics, Virginia Polytechnic Institute, Blacksburg, April 8-10.

B. V. Sukhatme and M. S. Avadhani: "Comparison of the Rao-Hartley-Cochran Estimate in Unequal Probability Sampling with Ratio Estimate and its Application to Sampling on Successive Occasions," at meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics, American Economic Association and other allied societies, Washington, D.C., December 27-30. Abstract 123 in the Annals of Mathematical Statistics, 39:2, 697, April 1968.

P. V. Sukhatme and **B. V. Sukhatme:** "On Some Methodological Aspects of Sample Surveys of Agriculture in Developing Countries," at a symposium on Foundations of Survey Sampling, University of North Carolina, Chapel Hill, April 21-27.

Henry Tucker: "Computers in Graduate Studies," at the 6th International Biometric Conference, Sydney, Australia, August 20-25. Abstract 1409 in Biometrics, 24:1, 215, March 1968.

Henry Tucker: "The Statistician and the Computer," a lecture at the North Texas Chapter, American Statistical Association, Southern Methodist University, Dallas, December 8.

John J. Hartman and **James A. Walsh:** "Simulation of Newspaper Readership: An Experiment in Computer Analysis of Social Data," at the Rural Sociological Society annual meeting, San Francisco, California, August 25-28.

James A. Walsh: "Computer Simulation in Social Sciences," at the 4th annual research conference, New Directions in Social Research, North Dakota State University, Fargo, November 10-11.

James A. Walsh: "Computer Simulation of Personality: Design for a Robot Research Vehicle," at a psychology seminar, Iowa State University, Ames, March 19.

John J. Hartman and **James A. Walsh:** "Computer Simulation: Case for increased Rigor," at a Midwest Sociological Society meeting, Omaha, Nebraska, April 19-20.

Richard D. Warren and Roy Hougen: "Measuring the Influence of a Training Program: A Field Experiment," at the Rural Sociological Society annual meeting, San Francisco, California, August 25-28.

George M. Beal, Joe M. Bohlen and **Richard D. Warren:** "Influence of a Training Program for Managers," at the 62nd annual meeting of the American Sociological Association, San Francisco, California, August 28-31.

Robert Boruch and **Leroy Wolins:** "Procedure for Estimating the Proportion of Variance Attributable to Method, Theory and Error," at the Psychometric Society meeting, University of North Carolina, Chapel Hill, April 17-20.

PARTICIPATION IN PROFESSIONAL ACTIVITIES

Dr. T. A. Bancroft has been elected vice president of the American Statistical Association, to serve through December 1970. He has been appointed to the ASA Committee on the Preservation of Documents of Distinguished Statisticians, and continues to serve on the ASA Advisory Committee on Statistical Policy to the Bureau of the Budget.

Dr. Bancroft has been appointed a member of the council of the international Biometric Society, and serves as a member of the Regional Advisory Committee and the Regional Advisory Board of the Biometric Society, ENAR. He was reappointed for a three-year term

to the National Research Council, Division of Biology and Agriculture, as a representative of the Biometric Society, ENAR, and is a member of the Committee on Affiliations of the Biometric Society. Dr. Bancroft recently has been named to a committee organized by the Veterans' Administration to work on the establishment of a training grant program in biometry.

Dr. F. B. Cady served as secretary of the Biometric Section, American Statistical Association, and was elected Biometrics Section representative on the ASA National Council.

Dr. H. T. David, on leave during the year as visiting professor and acting director of the Statistics Center, Department of Statistics, University of Minnesota, continues on the organizing committee of the National Science Foundation Visiting Lecturer Program in Statistics. Dr. David chaired a session on "Sequential Methods" at the statistical society meetings December 27-30 in Washington, D.C., and a session on "Distribution Theory—II" at the Second International Symposium on Multivariate Analysis, sponsored by the Aerospace Research Laboratories, at Wright State University, Dayton, Ohio, June 17-22.

Dr. Wayne Fuller served as a discussant for a session on "Structural Systems and Causality" at a Conference on Causal Inference from Linear Models at the University of Minnesota, Minneapolis, May 13. He has been elected to a six-year term on the curriculum committee of Iowa State's College of Sciences and Humanities.

Dr. D. V. Huntsberger was made a Fellow of the American Statistical Association during statistical society meetings December 27-30 in Washington, D.C. He has been elected vice president and president-elect of the Iowa State chapter of Sigma Xi. Dr. Huntsberger continues to serve on a COPSS (Committee of Presidents of Statistical Societies) Career Brochure committee.

Dr. Oscar Kempthorne has been named chairman of a COPSS committee for the R. A. Fisher Memorial Lecture Series, and he continues to serve on an ASA committee for the S. S. Wilks memorial medal. He chaired a session on "Multivariate Analysis of Variance" at the Second International Symposium on Multivariate Analysis, sponsored by the Aerospace Research Laboratories, at Wright State University, Dayton, Ohio, June 17-22.

Dr. E. L. LeClerg continued as secretary and treasurer of the Biometric Society, ENAR, and is serving on three COPSS committees: Directory of Statisticians, News and Notes, and Student Membership.

C. C. Mosier moderated a panel discussion entitled "A Question Box and Panel Discussion Session Exploring New Areas Brought Out at the Conference," at the 13th annual College and University Machine Records Conference, University of Iowa, April 22-24.

Dr. Edward Pollak chaired a session on "Mathematics of Genetic Systems," at the eastern regional meeting of the Institute of Mathematical Statistics Virginia Polytechnic Institute, Blacksburg, April 8-10.

Dr. J. H. Sedransk served as president of the Iowa Chapter, American Statistical Association. He was a discussant at a symposium on Foundation of Survey Sampling at the University of North Carolina, Chapel Hill, April 21-27.

Dr. Henry Tucker continued as international treasurer of the Biometric Society. He chaired a session on "Unsolved Problems in Biometrics" at the 36th session of the International Statistical Institute, Sydney, Australia, August 28-September 8.

1968 initiates to Phi Kappa Phi, scholastic honorary, include Dr. Oscar Kempthorne; graduate students Joseph L. Abbey, Roy D. Hickman (now an assistant professor), Peter C. O'Brien, Justus F. Seely and Eric West; and undergraduate Dean E. Harvey.

Staff members and graduate students named to or promoted in Sigma Xi include: Dr. E. J. Carney, promoted; James R. Gebert, Dr. Roy D. Hickman and Dr. Richard E. Lund, full members; and associate members Gordon D. Booth, Alfonso F. Carrillo, James S. DeGracie, Louis Jensen, Paul A. Johnson, Abel G. Mexas, Peter C. O'Brien and Justus F. Seely.

TEACHING

Enrollment growth continues to be the keynote for the Department of Statistics. Enrollment this year in the Principles of Statistics courses increased nearly 25 percent. This was especially evident during spring quarter when one additional section of 201A and two additional sections of 201B had to be added.

Three new courses were offered during the year. A special problems course in socio-metrics offered for the first time fall quarter had an enrollment of 19. A new honors program special problems course had its first enrollee spring quarter, and Genetic Statistics for Research Workers also was new in the spring.

COURSE OFFERINGS IN STATISTICS

The courses offered by the Department of Statistics during the academic year 1967-68 were as follows:

Courses for Undergraduate Students Only

201, 201A,	Principles of Statistics	5 3	FWS* WS, SS_1	DeGracie Abbey, Fuchs, Huntsberger, S. Sukhatme, Tang
201B		3	FS	Mensing, S. Sukhatme, Tang
327	Elementary Business Statistics	3	F	Fuchs
341,	Introduction to Theory of	3	F	Huntsberger
342,	Probability and	3	W	Huntsberger
343	Statistics	3	S	Huntsberger
380	Statistical Applications of Digital Computers	3	FWS	Mexas, West

Courses for Graduate Minors and Undergraduates

401,	Statistical Methods for Research Workers	4	FW, SS_1	C. P. Cox, DeGracie, Hickman, Jowett, Mensing, S. Sukhatme, Walsh, Warren, Wolins
402		4	SS_2WS	D. Cox, DeGracie, Hickman, Jowett, Mensing, S. Sukhatme, Walsh, Warren, Wolins
411	Experimental Design for Research Workers	3	S, SS_1	D. Cox, Jowett, LeClerg
421	Survey Design for Research Workers	3	SS_2S	B. Sukhatme
431	Elementary Statistical Quality Control	3	S	Lawing
436	Genetic Statistics for Research Workers	3	S	Jowett
446,	Statistical Theory for	3	F	Han
447,	Research Workers	3	W, SS_1	Han
448		3	SS_2S	Han
481,	Processing of Statistical	2	W	Mosier
482	Data	2	S	Mosier
499	Special Problems	Arr.	FWS, SS_1	C. P. Cox, Hickman, Mensing, Mexas, Walsh, Warren, West, Wolins
499H	Special Problems, Honors Program	2	S	Wolins

Courses Primarily for Graduate Students, Major and Minor

501	Intermediate Statistical Methods	3	F	Bancroft
505	Psychometrics	3	S	Wolins
506	Factor Analysis	3	F	Wolins
511,	Design of Experiments	3	W	Zyskind
512		3	S	Zyskind
521,	Design of Surveys	3	W	B. Sukhatme
522		3	S	Sedransk
531	Industrial Statistics: Sampling Inspection	3	F	Lawing
535	Biological Statistics	3	S	C. P. Cox
536,	Genetic Statistics	3	F	Pollak
537		3	W	Pollak
538	Econometric Statistics	3	F	Fuller
539	Operations Research	3	W	Lawing
540	Operations Research Methods and Economic Analysis	3	S	Sengupta
541,	Theory of	3	F	Arnold
542,	Probability and Statistics	3	W	Mehra
543		3	S	Sedransk
544	Statistical Decision Theory	3	S	Mehra
580	Computational Techniques in Statistics: Methods	3	W	Kennedy
581	Computational Techniques in Statistics: Theory	3	S	Kennedy
599	Special Topics	Arr.	SS_2FWS, SS_1	
	A. Theory			Huntsberger, Kempthorne, Lawing, Sedransk
	B. Methods			Fuller, Jowett, Warren, Wolins
	C. Design of Experiments			Kempthorne, Zyskind
	D. Design of Surveys			Hickman, B. Sukhatme
	X. Socio-metrics			Warren

Courses for Graduate Students, Major and Minor

601	Advanced Statistical Methods	3	F	C. P. Cox
621	Advanced Design of Surveys	3	W	Sedransk
622	Seminar on Design of Surveys	3	S	B. Sukhatme
638	Advanced Econometric Statistics	3	W	Fuller
641	General Theory of Linear Hypothesis	3	F	Zyskind
642	Probability and Distribution Theory	3	W	Arnold
643	Theory of Estimation and Testing of Hypotheses	3	S	Okamoto
646	Time Series	3	S	Fuller
647	Multivariate Analysis	3	F	Okamoto
648	Seminar on the Theory of Statistics and Probability	3	SS_2S, SS_1	Arnold, Mehra, Okamoto
649	Recent Developments in Probability and Statistics	3	FW	Mehra, Okamoto
699	Research	Arr.	SS_2FW, SS_1	Arnold, Bancroft, C. P. Cox, David, Fuller, Han, Hickman, Jowett, Kempthorne, Lawing, Mehra, Okamoto, Pollak, Sedransk, B. Sukhatme, Walsh, Wolins, Zyskind

* Because the fiscal year began July 1, 1967, and ended June 30, 1968, the courses taught in the second summer session of 1967 through the first summer session of 1968 are reported here. Symbols indicate the quarter each course was taught: SS_2—Second Summer Session, F—Fall, W—Winter, S—Spring, SS_1—First Summer Session.

SUMMER INSTITUTE

The fourth annual summer institute on survey sampling techniques for international students was conducted by the Statistical Laboratory July 17 through August 24. The purpose of this demonstration survey course is to provide actual experience for participants in conducting a small-scale sample survey.

The institute, initially planned by the Statistical Laboratory and the U.S. Bureau of the Census, included 17 students representing nine different countries. Twelve were sponsored by the U.S. Bureau of the Census, three by the U.S. Department of Agriculture, and two by the Food and Agriculture Organization of the United Nations.

Most of the six-week session was devoted to the planning, execution and evaluation of a sample survey under the direction and supervision of Dr. Roy Hickman. Hazel Cook, Helen Ayres and other members of the Statistical Laboratory's Survey Group also assisted with the institute. A short course in sampling methods was presented by Dr. B. V. Sukhatme, and Dr. Norman Hutton of the Computation Center presented lectures on data processing techniques. Participants were awarded certificates of achievement at the completion of the course.

GRADUATE STUDENTS

As enrollment continues to rise, the Department of Statistics continues to train a great many international students. A directory prepared by Iowa State's Office of Foreign Student and Visitor Services, of persons on campus from outside the United States during spring quarter, indicates that the Departments of Statistics and Agronomy have the highest number of international graduate students enrolled as majors. Both departments have 36. They are followed by the Departments of Agricultural Economics, with 32, and Electrical Engineering, with 27. A total of 79 departments have foreign staff and students on campus.

Ph.D. Candidates

Joseph Abbey*
Munir Ahmad
George Battese
Gordon Booth*
Leon Burmeister
Alfonso Carrillo
Shang-Wang Chang
Isidoro David
James S. DeGracie
Thomas Fears
G. L. Ghai
Francis Giesbrecht
John W. Hazard
Muzammil Husain
Cary Isaki*
Ronald Jacobson
Louis Jensen*
John Johnson
Leon Jordan
William Kennedy
Roland Loup
Richard Lund
Angel Martinez
James Mellon*
Ahmed Memon
Richard Mensing
Abel Mexas*
Kenneth Mount
Syed T. M. Naqvi
Esmat Nouri
Peter O'Brien*
Panagiotis Papaioannou
Carl Z. Roux
Donna J. Ruhl
Ahmed Salem
Charles Sampson
Nell Sedransk
Justus Seely
Melvin Seibel
V. B. Solomon
Donald Soults
Vincent Sposito*
Richard Stein
Victor Tang
James Veale
Eric West*
Donald McElhone
Franklin Wolf

* received M.S. during the year

M.S. Candidates

Joseph Abbey
Farrukh Ahmad
Robert E. Albert
Forrest Aspengren
Sorachai Bhisalbutra
Gordon Booth
Richard Chamberlain
Godfrey Coker
Richard Darman
Sudha Desai
Sharon Earley
Gregory Fawcett
Richard Frauendorfer
A. Ronald Gallant
John Goebel
Omer Gucelioglu
Bonnie Hanson
Omar Henriquez
Y. Hongsakaphadana
James Immordino
Charles Ingwell
Cary Isaki
Louis Jensen
Nancy Rowe Johnson
Khadija Khatun
George Lauer
Arlette Machado
Leopoldo Machado
Mark Malone
James Mellon
Kenneth Merritt
Abel Mexas
Mallika Mokkhaves
Peter O'Brien
C. M. Patel
David Pyne
David Ray
Jan Shoemaker
Douglas Splitstone
Vincent Sposito
Malte Sund
Nantit Supamongkon
Jane Toben
Eric West
Tom Whitley
Terral Wittgow
Chartsee Xumsai

Degrees Granted and Positions Taken

Students who were graduated during the year and their location after graduation are listed here. Abstracts of their theses, written as partial fulfillment of the requirements for advanced degrees, appear in the publications section of this report.

Recipients of the Ph.D. Degree

Munir Ahmad (May 1968, under Masashi Okamoto) worked at Michigan Technological University, Houghton, during the summer before returning to his post as lecturer in statistics at the University of Karachi, West Pakistan.

Francis Giesbrecht (November 1967, under Oscar Kempthorne) returned to his position as statistician with the Statistics Research Division, Research Triangle Institute, North Carolina.

John Johnson (November 1967, under T. A. Bancroft) joined the technical staff of the Aerospace Corporation in San Bernardino, California, and has accepted an additional post as associate professor at the University of California, Riverside.

Richard Lund (August 1967, joint statistics-economics major under Wayne Fuller) became a visiting lecturer with the Statistical Laboratory, serving in Chapingo, Mexico, on the Ford Foundation cooperative project.

Ahmed Memon (May 1968, under Masashi Okamoto) remained at Iowa State during the summer before returning to his post with the Department of Mathematics and Statistics at West Pakistan Agricultural University, Lyallpur.

Donna J. Ruhl (November 1967, under J. H. Sedransk) accepted a position as assistant professor of biostatistics at the University of North Carolina School of Public Health, Chapel Hill.

Charles Sampson (February 1968, under C. Philip Cox) joined Eli Lilly and Co. in Indianapolis, Indiana, as a senior statistician.

Recipients of the M.S. Degree

Joseph Abbey (August 1967, under H. T. David) remains at Iowa State working toward his doctorate.

Gordon Booth (August 1967, under J. H. Sedransk) is employed as a consulting statistician with the National Animal Disease Laboratory, Ames, while completing requirements for his doctorate.

Richard Frauendorfer (November 1967, under J. H. Sedransk) accepted a position with Bell Aerosystems, New York, as a digital analyst.

Cary Isaki (May 1968, under Wayne Fuller) remains at Iowa State working toward his doctorate.

Louis Jensen (November 1967, under Edward Pollak) remains at Iowa State working toward his doctorate.

Nancy Rowe Johnson (August 1967, under Wayne Fuller) moved to California with her husband.

Mark Malone (August 1967, under E. J. Carney) is a civilian employee in operations analysis at Scott Air Force Base, Illinois.

James Mellon (May 1968, under David Jowett) remains at Iowa State working toward his doctorate.

Abel Mexas (November 1967, under E. J. Carney) remains at Iowa State working toward his doctorate.

Peter O'Brien (May 1968, under David Thomas) remains at Iowa State working toward his doctorate.

Douglas Splitstone (August 1967, under David Thomas) accepted a position with U.S. Steel, Monroeville, Pennsylvania, as an associate research engineer.

Vincent Sposito (February 1968, under W. D. Lawing) remains at Iowa State working toward his doctorate.

Eric West (November 1967, under Oscar Kempthorne) remains at Iowa State working toward his doctorate.

The George W. Snedecor Award in Statistics

Justus F. Seely received the George W. Snedecor Award for 1968. Established in 1954 by the Statistical Laboratory to honor its founder and first director, the award is given annually to the most outstanding candidate for the Ph.D. degree in statistics. Seely, who holds B.S. and M.S. degrees from Utah State University, Logan, is working toward his doctorate under a National Science Foundation traineeship.

UNDERGRADUATES

Dr. D. V. Huntsberger continued to serve as undergraduate advisor. During the year he advised from 40 to 51 students per quarter.

Recipients of the B.S. Degree

John Allen, July
Harry Alley, November
Sharon Burr, May
Thomas Davis, November
Gary DeSmidt, November
Douglas Keyes, May
Frank Kopish, May
Michael Mersch, May
Michael Milligan, May
Van Dee Nelson, May
Jacquelyn Ann Watts, May

Iowa State University Statistics Club

A proposal made to the IBM Corporation by the Statistics Club resulted in an undergraduate scholarship jointly sponsored by the two organizations. The award pays instate tuition costs for one year and is renewable for a second year if the recipient maintains satisfactory academic standards and continues to qualify. Sharon Burr was named first winner of the scholarship, for 1967-68, and Lawrence Kinyon has received the award for 1968-69.

During the year the club heard Dr. R. L. Willham, Department of Animal Science, and Dr. Oscar Kempthorne speak on areas of statistics; held a joint meeting with computer science majors featuring Dr. M. E. Terry of Bell Telephone Laboratories; sponsored field trips to the new animal science building, swine nutrition farm and the John Deere plant in Ankeny; and prepared the department's Veishea exhibit.

In December the club was one of three departmental clubs in the College of Sciences and Humanities asked by Science Council to participate in a panel discussion to exchange ideas on organizing a club, attracting members, planning programs and financing. Statistics Club secretary Sue Ritchie served as mathematical sciences representative to Science Council.

Miss Ritchie was elected president of the club for 1968-69. Other new officers are: Lawrence Kinyon, vice president; Beth VanSittert, secretary; and Bill Kruhm, treasurer.

Mu Sigma Rho

As an outgrowth of the Statistics Club, staff members and students joined to organize Mu Sigma Rho, a national statistical honor society, whose purpose is the promotion and encouragement of scholarly activity in statistics and the recognition of worthwhile achievement among the staff and students in eligible academic and nonacademic institutions.

The incorporators, T. A. Bancroft, who is the official registered agent, D. V. Huntsberger and Oscar Kempthorne, signed the Articles of Incorporation on May 29 and the document was filed at the Secretary of State's office in Des Moines and the Court House in Nevada.

First officers of the national society are D. K. Hotchkiss, president; Wayne Fuller, vice president; H. T. David, secretary-treasurer; and Drs. Bancroft, Huntsberger and Kempthorne, directors-at-large. Students organized an Iowa Alpha Chapter and elected Eric West, president; Lawrence Kinyon, vice president; and Sue Ritchie, secretary-treasurer. Panagiotis Papaioannou was named representative to the Executive Council.

SEMINARS

Statistical Laboratory–Department of Statistics Series

Non-credit seminars, open to all students and faculty members on campus, were sponsored weekly by the Statistical Laboratory and the Department of Statistics. Through these seminars the latest information on current statistics research is presented, explained and discussed. Special guest speakers from other institutions add to the range of topics covered.

The 1967-68 seminar committee included Dr. Chienpai Han, Dr. Dennis Lawing and Dr. Leroy Wolins,

chairman. Topics and speakers included during the year were:

Fall Quarter 1967

September 13 Current Status and Outlook. T. A. Bancroft.
September 20 Controlled Selection in Sampling. B. V. Sukhatme.
September 27 Stochastic Processes in Genetics. G. Malécot, University of Lyon, Lyon, France.
October 4 Algorithms for AOV of Balanced Incomplete Structures. E. J. Carney, University of Rhode Island.
October 11 A Power Comparison of Several Nonparametric Analogues to the One-Way Analysis of Variance. W. J. Conover, Kansas State University.
October 18 Ethical Considerations in Constructing Statistical Models. M. E. Terry, Bell Telephone Laboratories.
October 25 (joint Statistical Laboratory and Department of Economics) Bayes Tests of Regression Hypotheses when the Equations have Different Numbers of Parameters and Different, but Functionally Related, Dependent Variables. Hodson Thornber, University of Chicago.
November 8 Optimality of Principal Components. Masashi Okamoto.

Winter Quarter 1968

November 29 Data Analysis. Oscar Kempthorne.
December 6 The Limiting Behavior of a Branching Process. Edward Pollak.
December 13 Procedures for Selecting the Best One of Several Gamma Populations. Peter O'Brien.
December 18 Small Sample Distributions in the Variate Difference Method. Gerhard Tintner, University of Southern California.
January 3 A Survey of Some Sequential Methods Used in Process Control. Dennis Lawing.
January 10 A Monte Carlo Study of the Behrens-Fisher Problem. Eric West.
January 12 A Bayesian Approach to Analysis of Variance Components. David Culver, University of Michigan.
January 17 Some Applications of the Double Sampling Technique. Gordon Booth and J. H. Sedransk.
January 24 Estimators of Components of Variance with Small Mean Square Error. Jerome H. Klotz, University of Wisconsin.
February 2 Sequential Trial Selection (A Waldian Two-Armed Bandit). Herbert T. David.
February 7 Some Problems in Prediction Theory. Glen Meeden, University of Illinois.
February 13 (joint Statistical Laboratory and Agricultural Experiment Station) World's Hunger and Overnutrition. P. V. Sukhatme, Food and Agriculture Organization of the United Nations, Rome, Italy.

Spring Quarter 1968

March 6 Some Effects of Random Selective Advantages of a Gene in a Finite Population. Louis Jensen.
March 13 Factor Analysis with Constraints (or Analysis of Variance with Fewer Constraints). Robert F. Boruch.
March 20 Some Statistical Problems Met in the Practice of Consulting at the Mayo Clinic. William F. Taylor, Mayo Clinic.
March 28 (meeting at Drake University) Dynamic Programming. Leroy Folks, Oklahoma State University.
April 1 (meeting of the Iowa Chapter, American Statistical Association in Iowa City) Errors of Measurement in Statistics. William G. Cochran, Harvard University.
April 10 Nonparametric Inference for Linear Models. K. L. Mehra.
April 11 The Identification and Diagnostic Checking of Stochastic and Dynamic Time Series Models, with Particular Emphasis on the Distribution of Residual Autocorrelations. David A. Pierce, University of Wisconsin.
April 17 On the Truncated Poisson Distribution. Munir Ahmad.
April 24 Current Operations of the Survey Section of the Statistical Laboratory. Wayne Fuller and Harold Baker.
May 1 Six Unsolved Problems in Regression Analysis. Cuthbert Daniel, Statistical Consultant, New York City.
May 8 (joint Statistical Laboratory and Department of Mathematics) Stochastic Integrals and Derivatives. Dean Isaacson, University of Minnesota.
May 13 Minimax Linear Predictor Under Lipschitz Type Condition for the Regression Function. Kei Takeuchi, New York University.
May 15 The Incomplete Binomial Distribution in Human Genetics. C. C. Li, University of Pittsburgh.

Applied Statistics Series

In its second year, the applied statistics series of seminars sponsored by the Statistical Laboratory continued to serve research workers for all areas of the campus who use inferential statistics as a primary research tool. Dr. David Jowett served as chairman of the seminars. Programs during the year included:

October 17 General Linear Regression. Model I-Fixed Effects. George Zyskind.
October 31 Regression Analysis II. Inference for Some Incompletely Specified Regression Models. T. A. Bancroft.
November 7 Regression Analysis III. The Random Model and Generating Hypotheses. Richard D. Warren.
December 5 Regression when the Independent Variable is Subject to Error. Wayne Fuller.
January 16 Nonlinear Statistical Models. Oscar Kempthorne.
January 30 OMNITAB: A Computer Programming System Using Basic English Commands. Richard L. Chamberlain.
April 2 Some Factors of Importance to Field Experimentation and their Relation to Precision and Accuracy of Results. Erwin L. LeClerg.
April 16 Consumer Price Statistics. Joseph W. Hines, Bureau of Labor Statistics, Kansas City.
April 30 Selection of Data and Choice of Models in Multiple Regression. Cuthbert Daniel, Statistical Consultant, New York City.
May 14 Some Observations on the Teaching of Statistical Consulting. C. Philip Cox.

Quantitative Genetics Series

Dr. Oscar Kempthorne and Dr. Edward Pollak continued in charge of this series of seminars planned especially for staff members and graduate students in the departments of statistics, genetics, animal science, poultry science, agronomy and horticulture. Topics discussed during the year were:

September 26 Degrees of Relationship in Locally Panmictic Populations. G. Malécot, University of Lyon, Lyon, France.
October 17 The Effect of Inbreeding, Linkage and Continued Truncation Selection on the Genotypic Variances Within and Between Lines. A. W. Qureshi, Visitor, Lyallpur, West Pakistan.
December 12 Estimating Genetic Change in Progeny of Artificially Used Bulls. C. G. Hickman, Canada Department of Agriculture, Ottawa.

January	30	Monte Carlo Studies of Selection and Inbreeding in Swine. B. Bereskin, USDA.
February	13	Antagonistic Selection for Two Correlated Traits. A. W. Nordskog.
March	19	Is the Genome Really Made of Genes? R. C. Lewontin, University of Chicago.
April	2	The Genetic Structure of Populations Under a Mixture of Selfing and Random Mating. G. L. Ghai.
April	16	The Inheritance of Pupa Weight in Tribolium Castaneum. Ian Franklin, University of Chicago.

FORD FOUNDATION MEXICAN PROJECT

The Ford Foundation-sponsored project between the Statistical Center at the National School of Agriculture, Chapingo, Mexico, is beginning its third year. Dr. T. A. Bancroft, in charge of the project for statistics, and Dr. J. B. Page, ISU's vice president for research who is administrative coordinator, visited Mexico in May to check progress and make plans for the project's continuation.

Dr. Donald Hotchkiss and Dr. Richard Lund, who joined the project in June, 1967, replaced Dr. Foster Cady and Dr. Henry Tucker who left in December. Dr. Barry Arnold joined the visiting staff this June.

This visiting staff has continued to provide assistance through teaching, consulting and research to further the development of the graduate program in statistics at Chapingo. The availability of their services also has enabled the Mexican staff members to work toward advanced degrees. Alfonso Carrillo and Angel Martinez currently are enrolled in the Ph.D. program at Iowa State, where they will get their degrees through the support of the Ford Foundation. Ignacio Mendez is similarly enrolled at North Carolina.

Six students currently are enrolled full-time in the statistics core curriculum. Another three students are working actively on theses on a part-time basis. Two additional students are associated with the Center on a special-student basis in order to complete additional statistical training.

Four students completed their masters' degree requirements during the fall as a result of the visiting staff members directing their theses, bringing to 6 the total M.S. degrees already awarded in statistics through the joint program at Chapingo. Current progress indicates that three more should complete M.S. degrees during the summer.

Assistance also has been given to M.S. candidates from other departments, both in the development of theses topics and in data analysis problems. The provision of service-type courses to graduate students in other departments is an important function of the Center, which the visiting staff members also share.

Consulting services continued at Chapingo, not only for other departments of the Graduate School, but also for other departments of the Secretariat of Agriculture. The members of the Iowa State project were active in promoting initial contacts, carrying on detailed analysis, advising on experimental design, preparing surveys, and integrating the computational phases. The consulting activity has been extended into the animal science area on the campus through assistance in the design and analysis of experiments.

Work was completed on a survey to estimate current citrus production and future production potential in Mexico. A visiting staff member has been assisting in developing survey procedures for collecting production data on all basic Mexican crops. The anticipated use of multiple-frame sampling procedures in collecting data on some crops stimulated the development of a more efficient estimator for use in multiple-frame situations.

A detailed analysis was made on the effect of several environmental factors on the density of locust populations in the Yucatan area. Survey methods were developed for collecting data to evaluate the rate of acceptance of new agricultural techniques by Mexican farmers. Another survey planning project concerned the collection of data on the current condition of Mexico's wooden electric power poles. Consulting time continued to be given to the Ford Foundation-sponsored project to evaluate the Mexican extension service.

Whenever possible the responsibility for handling routine consulting has been shifted to Chapingo staff members in order to further their experiences. This has been possible in both the agronomic science areas and computational work.

Each of the major agronomic experimental stations in Mexico was visited in order to establish more effective lines of communication and compare the present status with a benchmark study made in 1955 by Dr. Bancroft and Paul Homeyer, under the sponsorship of FAO. A similar visitation program for the animal science and veterinary medicine experimental facilities was initiated in order to evaluate the use of statistical methods and experimental designs in these areas.

The computing center has become fully operational and a long-term extended program has been prepared. Complete services in programming, data preparation, and regularly organized computer runs are being provided. The capacity of the IBM 1620 computer was enlarged during the year. As computing projects increase, the center is gradually being shifted over to a self-supporting enterprise that will serve the campus and other outside agencies, particularly in the area of data processing with emphasis on statistical analysis.

During the year an increased interest in statistics has been exhibited in the type and quality of statistical methodology used in research, theses and study programs. While most departments on the campus had been users of statistics in the past, the role often was passive rather than active. It is expected that the use of valid statistical techniques by the Mexican research community will continue to grow as additional contacts are made with students through the classroom, and with students and staff through consulting activities and seminar programs.

A publication of the Statistical Laboratory
Iowa State University
Susan Alice Brown, editor