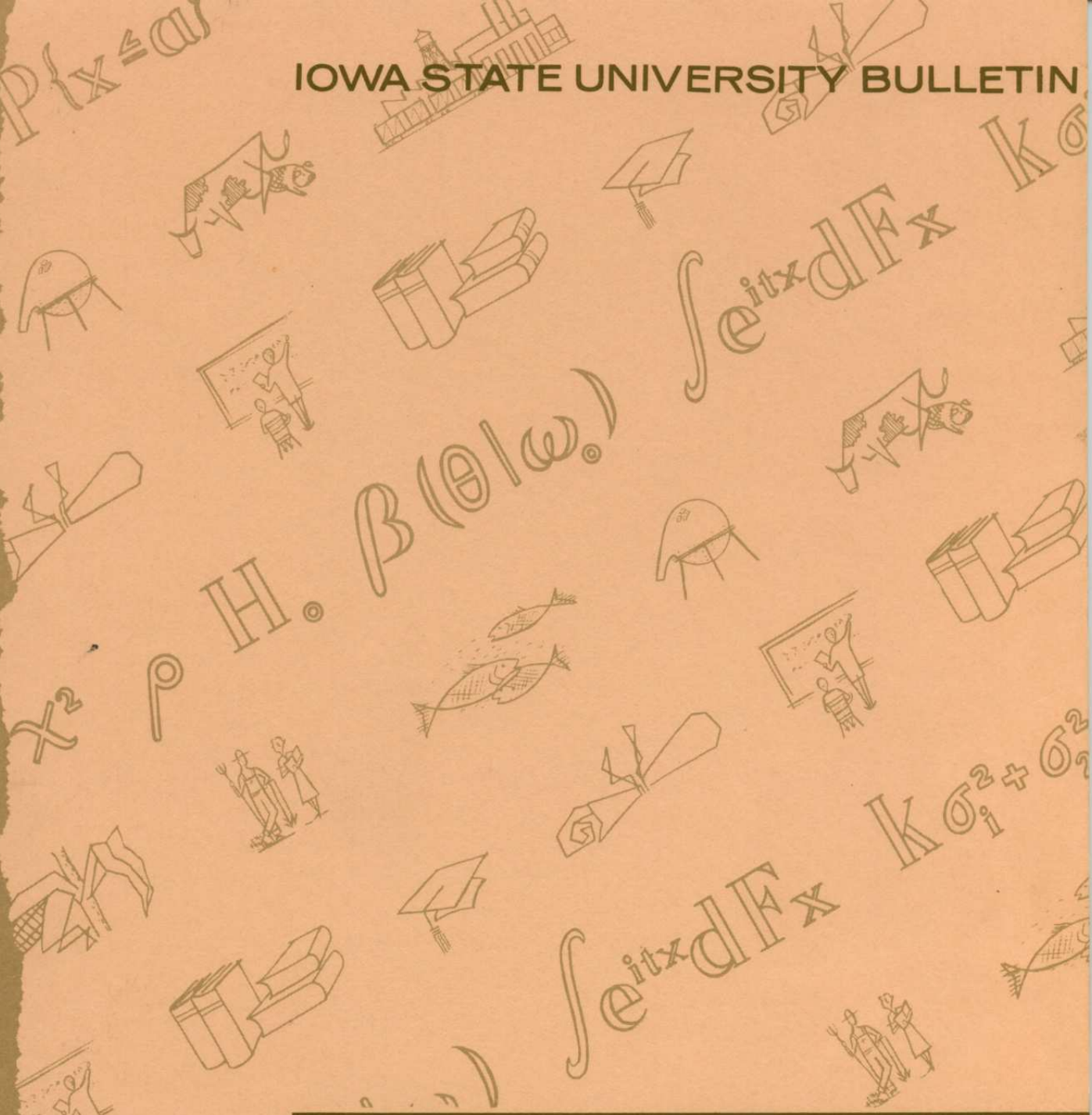
The Statistical Laboratory Established 1933 Iowa State University

IOWA STATE UNIVERSITY BULLETIN



ANNUAL REPORT

July 1, 1963 to June 30, 1964

President James H. Hilton
Iowa State University of
Science and Technology
Ames, Iowa

Dear President Hilton:

This is the Annual Report of the Statistical Laboratory staff at Iowa State for the period July 1, 1963 through June 30, 1964. It reports on the research, consulting, teaching and operational work of members of the university statistical center as complementary activities of the center's five components: the Statistical Laboratory, established as a research and service institute under the President's Office; the teaching Department of Statistics of the College of Sciences and Humanities; the statistics department of the Agricultural and Home Economics Experiment Station; and the statistics participant unit of the Industrial Science Research Institute; together with the research field office of the Statistical Standards Division, Statistical Reporting Service, United States Department of Agriculture, which is located in the Statistical Laboratory. Inasmuch as the statistical endeavors of individuals are carried on through institutions and departments of Iowa State University, this constitutes an annual report from those organizations.

Respectfully submitted on behalf of
the Statistical Laboratory staff,

T. A. Bancroft

Director, Statistical Laboratory and
Head, Department of Statistics; head
statistics department, Agricultural and
Home Economics Experiment Station

THE STATISTICAL LABORATORY

Iowa State University

ANNUAL REPORT 1963-1964

IOWA STATE UNIVERSITY BULLETIN
Ames, Iowa

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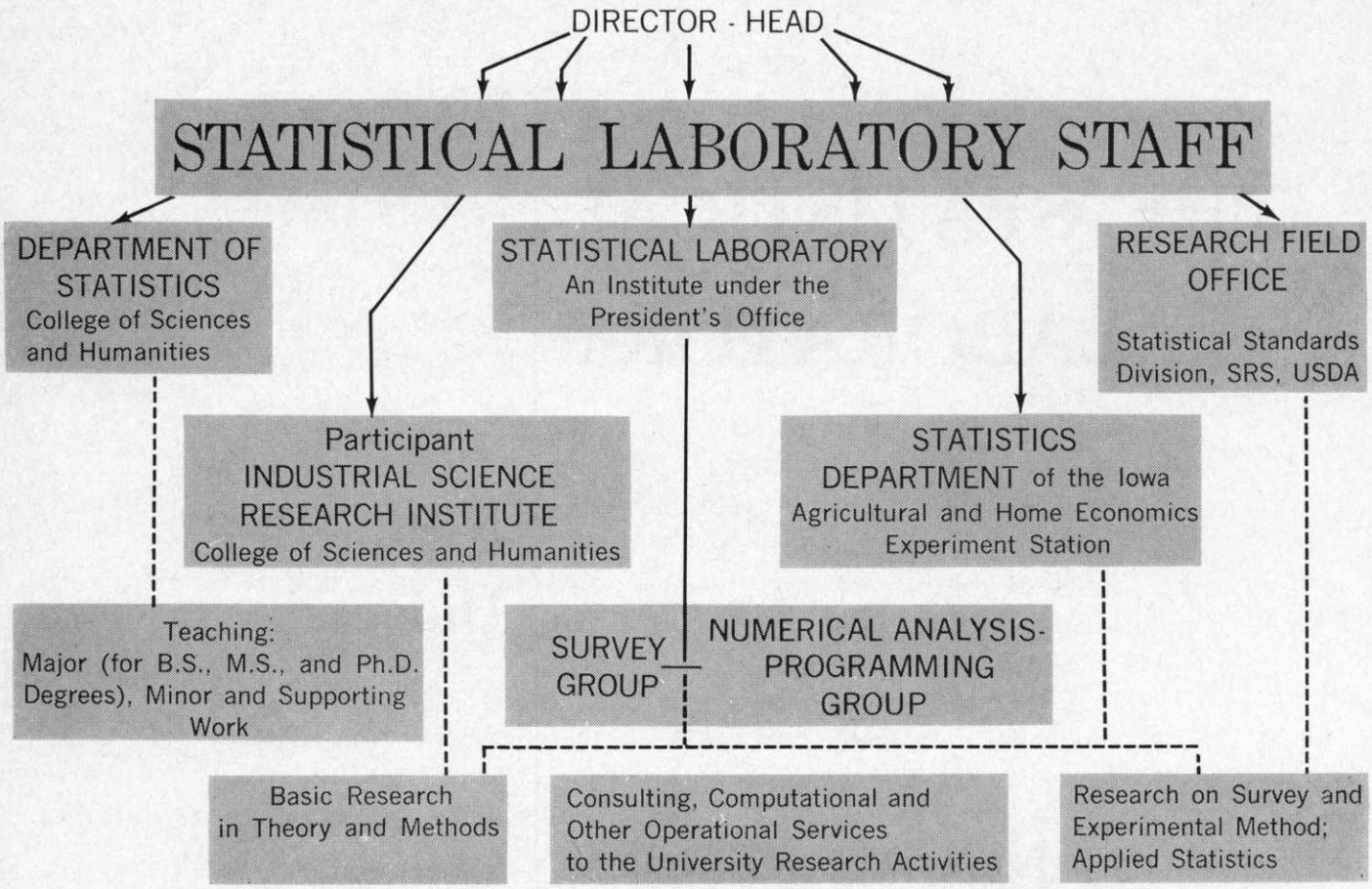
ORGANIZATION CHART



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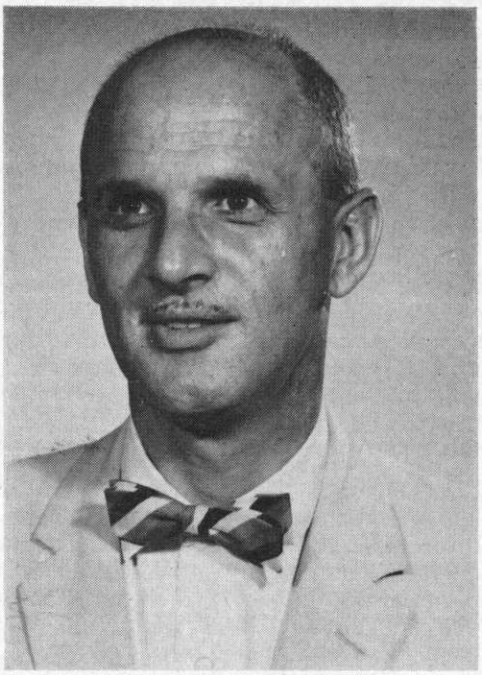
OSCAR KEMPTHORNE was named Distinguished Professor of Statistics in the College of Sciences and Humanities at Iowa State University on June 6, 1964. The presentation was made at the Honors and Awards Convocation. President James H. Hilton in reading the citation said in part:

> *Professor Kempthorne has achieved national and international recognition as a statistician and scientist through his research, teaching, publication of scientific papers and his guidance of graduate students. . . . From his creative thinking have come new and significant concepts, theories and methodologies in the design and analysis of experiments and genetic statistics.*

Iowa State instituted the Distinguished Professorships in 1956. Dr. Kempthorne, now one of four Distinguished Professors in the College of Sciences and Humanities, will carry the title throughout his academic career. An honorarium is made possible by contributions to the Alumni Achievement Fund.



OSCAR KEMPTHORNE
Distinguished Professor of Statistics

Personnel

The Statistical Laboratory is one of several independent research institutes on the campus of Iowa State University. The five components of the center have a single director and share personnel. In fiscal terms this means that a staff member's salary may be provided from several sources – e.g., Department of Statistics, the Statistical Laboratory budget set up by the President's Office, a statistical project of the Iowa Agricultural and Home Economics Experiment Station or the Engineering Experiment Station, or a research contract by the Statistical Laboratory and the Industrial Science Research Institute. The Laboratory also has a number of research grants and contracts with federal agencies which provide funds for research for both staff and graduate students at all levels.

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

THE STATISTICAL LABORATORY STAFF FOR THE YEAR 1963-64

Under the administrative direction of

James H. Hilton, D.Sc.....President of the University
Chalmer J. Roy, Ph.D.....Dean, College of Sciences and Humanities; Director, Industrial Science Research Institute
Floyd Andre, Ph.D.....Dean, College of Agriculture; Director, Iowa Agricultural and Home Economics Experiment Station
Theodore A. Bancroft, Ph.D.....Director, Statistical Laboratory; Head, Department of Statistics; Head, Statistics Department, Iowa Agricultural and Home Economics Experiment Station

Professors

T. A. Bancroft
C. Philip Cox
Herbert T. David
David V. Huntsberger
V. S. Huzurbazar (Visiting Professor)
Oscar Kempthorne
Norman V. Strand

Professor Emeritus

George W. Snedecor (in absentia)

Associate Professors

Om Aggarwal
Foster B. Cady
K. C. Chanda (Visiting Associate Professor)
Wayne A. Fuller
C. C. Mosier (Joint appointment with Computation Center)
Leroy Wolins (Joint appointment with the Department of Psychology)
George Zyskind

Assistant Professors

Carol Edwards Fuchs
Dale Grosvenor
Dewey L. Harris
William J. Hemmerle
Donald K. Hotchkiss
Howard W. Jespersen (Joint appointment with the Computation Center)
James R. Prescott (Joint appointment with the Department of Economics)
Joseph Sedransk

Post Doctoral Associate

A. W. Qureshi

Instructors and Associates

Harold Baker
Rodney Basson
Edward J. Carney
Robert Cochran
Charles Cress
Eugene Dayhoff
Thomas E. Doerfler
Francis Giesbrecht
Klaus Hinkelmann
Thomas C. Jetton
William D. Lawing
Florence Tetreault
Richard D. Warren

Graduate Assistants*

James Blinn
Leon Burmeister
Ahmed El Mawaziny
Jan Feller
Raymond Ferris
Edmund Fuller
William Hill
Louis W. Johnson
Shu-Wen Ke
Frank B. Martin
Richard Mensing
Martin Rosenzweig
John Schlater
Chang-sheng Shih
Richard R. Smith
Jarilaos Stavrou
Gary Spencer (Deceased)
Richard Swanson

Graduate Students

Aaron Booker (in absentia)
Robert Cochran
James Gebert
Burwell Gooch
Lee W. Jones
Shan Jong Lee
Michael H. Miller (in absentia)
Phrensi Svasti-Salee

NIH Trainees

Patricia Conn
Fred L. Ramsey
Thomas E. Roseberry
Donna J. Ruhl
James R. Veale

General Electric Fellows

John Peter Johnson
Henry Walter

NASA Fellow

David R. Thomas

*The status of graduate students often changes during the year. Students are listed here according to their appointment at the end of the academic year.

Affiliated Fellows

Aurelio Chavez	Government of Peru
James M. Condie	USDA Trainee
Betty Eberle	NIH–Western Reserve U.
José Gutierrez	FAO Philippines
Galen Hart	USDA Trainee
Lois Hendges	NIH–Western Reserve U.
Retno W. Kanujoso	AID–Gadja Mada–California Project
Angel Martinez	Institute for Improvement of Sugar Production–Mexico
Esmat Nouri	Government of UAR
Susumu Shiseki	Government of Japan
Nangnoi Suwanphant	Asian Foundation–Thailand
James Wahrenbrock	Operations Analysis Unit
Milton Weiss	Government of Canada
Ing-tzer Wey	National Council on Scientific Development–Taiwan
Herman Weidenhofer	Government of Venezuela
Mia Mohammed Yusuf	AID–Census Bureau–Pakistan

Student Assistants (Undergraduate)

Ronnie Mead
Leroy Snyder
Paul Stachour
Robert V. Wruck
Dennis Zweifel

General Office Staff

Administrative Assistant, Margaret G. Kirwin
Mabel M. Peterson, Accountant until June 1, 1964
Kathleen Ringgenberg, Accountant after June 1, 1964
Eleanor F. Bolton, Technical Writer-Editor
Glenda Sampson, Secretary
Iveta Zeliadt, Secretary, Experimental Design
Avonelle Jacobson, Secretary, Dept. of Instruction

Numerical Analysis-Programming Group

Shirley Saveraid, Secretary
Mary Ann Carney, Programmer

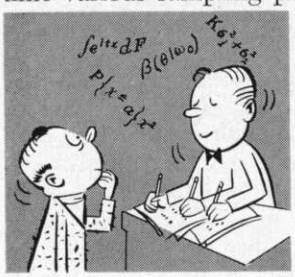
Survey Group

Anne Leicht, Secretary
Helen Ayres, Survey Supervisor
Marjorie Mason, Clerical Supervisor
Clerks:

Hazel Cook (Interviewer)	Marie Ostermann
Ava Klopf	Lucile White
Mabel Matthews	Anna B. Woodrow

Consulting and Joint Research

In addition, numerous field interviewers are temporarily employed by the Survey Group during the time various sampling projects are being carried out.



The members of the staff of the Statistical Laboratory, through their consulting activities on campus, come in contact with research work being carried on in many departments of the university. The Statistical Laboratory budget, provided by the President's Office, supports consultation in mathematical statistics and computational methodology, as well as general statistical consultation in areas where no other specific funds have been provided for advisory work. The Agricultural Experiment Station provides financial support to permit certain members of the Laboratory staff to engage in consulting on problems in the biological and agricultural sciences. The Engineering Experiment Station has also provided financial support for certain members of the Statistical Laboratory staff to assist on statistical problems in engineering. Recent problems in research with staff and students in agriculture, engineering, the biological and social sciences, home economics and veterinary medicine are exemplified in the reports which follow.

In general statistical consulting

T. A. Bancroft, under AES project 169, consulted a number of times with George R. Pescho, W. G. Lovely, Gene E. Scott, Lowell H. Penny, and Tom A. Brindley regarding the design of experiments on corn borer research. He also worked with Robert D. Jackson on the arrangement of plots. This work was done on a continuing basis with the Agricultural Experiment Station.

In the fall Bancroft consulted with Mr. W. K. Gamble of the Ford Foundation on the continuance of assistance to the Statistical Center at Chapingo, Mexico. This resulted in W. J. Hemmerle's work with the center as reported on page 15.

Bancroft and O. Kempthorne worked with Mrs. Mary Lum on the extension of the Wright Air Systems Development contract with the Statistical Laboratory.

In 1962 members of the administrative staff from the University of Missouri visited the Statistical Laboratory at Iowa State to consult with Bancroft with reference to establishing a statistical center at that university. Such a center was established there in the fall of 1963. Bancroft was invited to present a paper on December 9, 1963, on "The Role of a Statistical Center at a University," as part of the program for Arts and Sciences Week at the University of Missouri. He also spoke at a statistics seminar at that time and consulted with officials and staff of the University concerning their newly-established statistical center.

Mr. J. M. Bechtel, biostatistician with Veterans Hospital, Hines, Illinois, was in Ames in February to plan with Bancroft for the annual meetings of Biometric Society (ENAR) and (WNAR) to be held in Chicago December 27-30, 1964. Bechtel is a member of the local Committee on Arrangements for the meetings.

On March 16 Bancroft worked with Dr. Glen Bartsch of Western Reserve University regarding the joint training program for NIH trainees between the Statistical Laboratory and the Department of Statistics at Iowa State and the Department of Biostatistics, School of Medicine, at Western Reserve University. They planned programs for graduate students sponsored by NIH.

T. A. Bancroft, N. V. Strand and Om P. Aggarwal consulted with personnel in the Office of the International Statistical Programs, Bureau of the Census, Washington, D. C., as well as on the campus, concerning plans for a 1964 Special Summer Institute on Survey Techniques in Research for foreign students.

Bancroft, W. J. Hemmerle and J. Sedransk consulted with Robert Clyde and James Davis of WOI-TV on plans for continuing research on election forecasting in 1964.

Dr. Henri Theil, director of Econometric Institute, The Netherlands School of Economics, Rotterdam, visited the Statistical Laboratory on May 26. Bancroft, H. T. David and George Zyskind consulted with him on research problems in econometrics.

Bancroft has been appointed to a committee to review the final publication of the Iowa Corn Yield Test Bulletin.

D. V. Huntsberger consulted with staff and graduate students from various departments of the University on the statistical aspects of their research. A few examples of his work are described here.

With a graduate student in forestry he helped analyze data concerning the effects of various soil conditions on wood production with respect to a certain specie of tree of interest to the lumbering industry in Indonesia. Data for this study came from Indonesia.

With a chemical engineer Huntsberger helped design and analyze an experiment for investigating a response surface involving five independent variables and two dependent variables. The object of the study was to determine operating conditions which would give a maximum yield for one independent variable and minimum yield for the other. A central composite rotatable second order design using a half replicate of a 2^5 factorial was used. In order to investigate the surface, equal yield contours were plotted on the IBM 7074 computer for each pair of dependent variables. A program for this purpose was prepared by Howard Jespersen.

Huntsberger helped to analyze data concerning parasitism in mayfly larvae for a student in Fish and Wildlife Management. Examples had been taken at various dates and from various locations along the

Mississippi River. The objectives of the study were to determine whether or not the degree of parasitism changed from location to location and to determine the effects of emergence, size of larvae and abundance of larvae on the degree of parasitism. Various quantitative measures of the degree of parasitism were investigated.

Cox consulted with staff and graduate students in the Department of Animal Science on the technique and analysis for assays of pituitary L. H., using the ovarian ascorbic acid depletion method, and on some procedures in the pigeon crop weight assay of lactogenic hormone.

He consulted with a graduate student in agricultural engineering on the relations between temperature, soil strength, and the growth of alfalfa.

Cox assisted a bacteriologist with the analysis of data on the effects of kinetin on bacteria growth as measured by acid production with particular reference to a consistently observed wavelike but irregular pattern. A specific experiment was suggested to examine the possibility that the pattern was an artifact of the experimental procedure.

With Donna Jean Ruhl, Cox consulted with a graduate student in the Department of Child Development in the planning of experiments on the effects of visual and auditory training on learning a tactile task with particular attention to intrasensory transfer.

Cox worked with a graduate student in the Foods and Nutrition Department on the analysis of experiments for the biological evaluation of rice and peanut proteins by determinations on nitrogen in the liver of rats. Betty Eberle, who has been at Iowa State as an affiliated fellow from Western Reserve University, worked on particular details of this application. It was found possible to apply statistical procedures for the analysis of slope-ratio assays, and a general analysis has been developed to deal with the case when rats are fed ad libitum instead of having their intakes controlled.

David assisted a graduate student in economics with the application of the duality theorems of linear programming to the study of economic equilibrium.

With a staff member and a graduate student in sociology, David consulted concerning some game-theoretic aspects of bargaining.

W. J. Hemmerle served as a member of the Computation Center Advisory Committee at Iowa State and as a member of the Ad Hoc Computer Science Committee to establish a program in computer science at the graduate level.

In engineering

H. T. David consulted with staff and graduate students in engineering and the physical sciences on a number of projects, examples of which are described here.

He assisted a chemical engineer with the design and analysis of a split plot experiment testing the effect on specific resistance and permeability of certain characteristics of a compression-permeability test cell. A covariance adjustment was used to adjust experimental yields to target values of the cell characteristics. With two graduate students in chemical engineering, David consulted on the statistical aspects of flows through condensation trays and related flow structures. Of special interest were the theoretical bases of various lag time distributions proposed in the literature. David discussed with another graduate student in chemical engineering the construction of a three-factor systematic factorial design restricting to three the number of interactions confounded with linear time trend.

David consulted with a number of graduate students in agricultural engineering. With one he assisted with the empirical determination of the absorption coefficient for gamma radiation of corn in both granular and powdered form. The experiment was validated by a covariance analysis comparing the average variation about regression for several runs with theoretically similar absoption coefficients against variation among the several absorption coefficients computed for each of these runs. Another agricultural engineering graduate student was helped with a regression problem concerning the effects of terrain slope and contour on plowing efficiency and other cultivating activities. With another, David studied autocorrelation homogeneity and variance-stabilizing transformation for weather series. With two graduate students in agricultural engineering, he studied problems of discriminating between extreme-value, Weibull and log-normal distribution for calibrating the distribution of maxima.

With a staff member of the Department of Mechanical Engineering and industrial personnel, David discussed the estimation of order statistics of the lower tail of machinery life distributions.

He discussed, with an electrical engineering graduate student, optimal regression smoothing of observational series for various models.

David helped a graduate student in civil engineering to conduct an investigation into the accuracy of a new method of assessing the specific gravity of asphalt components. The precision was assessed in two different ways, one using the triplicate outlier paper designed by Davidson, David and O'Flaherty [Proceedings of the Am. Soc. for Testing Materials 62: 1297-1312. 1962] and the other using replicated measurements on a control.

An industrial engineering graduate student requested assistance in the design of an investigation into the variability and bias of cost benefit ratios for major federal and state projects. With an industrial engineering staff member, David discussed the mathematical-programming formulation of a plant location problem.

David and W. D. Lawing designed the experiment for a comparison of the bacteria-killing ability of three different types of electronic ranges with a standard non-electronic range for a member of the staff of the

Department of Household Equipment and three of her graduate students.

Engineering Extension and the Department of Industrial Engineering, with the cooperation of the Statistical Laboratory, conducted an Engineering and Management Institute on Quality Control in Perspective, April 15-16, 1964. This was the fourth cooperative effort in this area, the major emphasis of this year's conference being an overall look at quality control, its organization and relation to other functions. E. J. Carney and William D. Lawing were co-chairmen of the conference with H. T. David assisting. On the program were Dale O. Richards, formerly a member of the staff in Industrial Engineering and Statistics at Iowa State, now at Brigham Young University, Provo, Utah, who spoke on "Quality Control Organization"; and H. T. David, who spoke on "A Catalog of Statistical Tools." The conference concluded with a panel discussion by David, Carney, Lawing and Richards, all of whom have held joint appointments in Industrial Engineering and Statistics.

In the behavioral sciences

Leroy Wolins, who holds a joint appointment in statistics and psychology, is involved in much of the research in the behavioral sciences. He consults with all graduate students in psychology, with about half of those taking their graduate degrees in child development, sociology, and home economics education, as well as with a number of graduate students in other fields of home economics and in education. The examples which follow are representative of his consulting services.

A Ph.D. candidate conducted research concerning creative and technical competence of young art students five to eighteen years of age. Two samples of the art work of each student were judged by competent art critics. There was notable agreement among the judges on the degree of creativity and technical competence of the students in the study, but there was little correlation between their judgments of creativity and technical competence. The relationship between creativity and age was found to be non-monotonic; there was a "dip" in the curve at about age 13. The relationship between technical competence and age was monotonic.

Wolins conducted factor analysis of a 350-item inventory for the authors of the Minnesota Counseling Inventory Test. The items tended to cluster into about twenty major factors. Two of the more interesting factors suggest that emotional problems in young people may exhibit themselves as hostility to oneself or toward society. Since these factors are ostensibly orthogonal, these two ways of exhibiting hostility apparently occur independently.

A graduate student in psychology with whom Wolins consulted was interested in exploring learning in the following situation: On a cathode ray tube is a fixed point. Another point on this tube is controlled by the subject. This latter point is moved off of the fixed point and the subject's task is to compensate for this movement in order to keep the controlled point as close as possible to the fixed point. Change in performance as a function of trials was explored under six treatment conditions: three levels of visual feed-back, 100 percent, 50 percent, and 10 percent, coupled with the presence or absence of auditory feed-back, so that the closer the control point was to the target, the louder was the auditory stimulus. The major conclusion was that auditory feed-back tended to facilitate performance much the same for all levels of visual feed-back.

Another graduate student in psychology administered to 500 freshmen a new format of a well-known multiple choice intelligence test which is routinely administered at Iowa State University. This new format consisted of rearranging the alternatives so that the first alternative was the correct one about half of the time. For the readministration, the subjects were instructed to indicate how certain they were that the first alternative was the correct one by using numbers from 1 to 99, 1 indicating that they were sure the first alternative was incorrect and 99 indicating that they were certain it was correct. These "proportions" were transformed to normal deviates, the standard deviation for each person was computed, and the transformed response to each item was divided by this standard deviation. The items from both administrations were intercorrelated and also correlated with grades. The new test was substantially better than the old one in both validity and reliability. The average intercorrelation among items using the original format was .09, and by the new procedure it was .21. The average correlation of the original items with grades was .16, and the average correlation of the items in the new test was .23.

In the College of Home Economics certain members of the staff in the Home Management and Food and Nutrition departments were interested in measuring attitudes held by the general public toward various aspects of behavior with respect to foods. They were also interested in measuring knowledge of nutrition in the general public. With respect to the former, several internally consistent scales were developed. One of particular interest appears to measure laissez faire vs. disciplinarian attitudes toward the development of eating habits in children. The development of a scale to measure knowledge of nutrition was less successful. Responses to factual questions about foods correlate nearly zero in most cases. It was hypothesized that this occurs because this subject matter is not usually taught in an integrated fashion, but such knowledge accrues through diverse sources.

Carol E. Fuchs and Leroy Wolins consulted on a master's degree thesis in textiles and clothing which investigated preferences for children's clothing as a function of type of garment, design, and self-help features. Members of three occupational groups were questioned. For each question the degree of certainty a subject had in his answer was recorded, so that, upon transformation to normalized ranks, the data could be analyzed by the usual procedures, the scales approximating the property of additivity.

Richard Warren holds a joint appointment in sta-

tistics and sociology and has consulted with graduate students on problems involving design and analysis of investigations in sociology and other social sciences. The consulting with graduate students in sociology included assistance with their research designs and surveys, analysis of data, and the statistical aspects of their theses.

The Iowa Agricultural and Home Economics Experiment Station

The IAHEES provides financial support to permit certain members of the Statistical Laboratory staff to consult in statistical problems in the biological and agricultural sciences. Foster Cady and Donald K. Hotchkiss, under Agricultural Experiment Station Project 101, consulted with a large number of research workers and faculty members on designs, techniques, and analyses of investigations in the areas of soils, field crops, animal nutrition and management, veterinary medicine and food technology. Hotchkiss also worked with students and staff members in Home Economics in various areas. Oscar Kempthorne and Dewey L. Harris, under AES Project 1448, assisted with problems involving genetics. N. V. Strand and Wayne A. Fuller performed statistical consulting services for sampling investigations under AES Project 113. The examples which follow are representative of the consulting services of the staff in these areas.

Statistical services in the plant sciences

Foster Cady, under Project 101 with the Agricultural Experiment Station, continued his consulting activities in the plant sciences. Consulting problems vary, not only in the technical nature of the problem, but also in the amount of assistance needed by the investigator. Some problems may be fairly routine while others need a minor modification in existing statistical methods. Occasionally the consulting statistician will need to involve another member of the department and a substantive interplay between methods and theory may result. This interplay is evidenced at Iowa State by the number of statistical theses that have their origin in problems encountered during consulting. Often the service performed by the consulting statistician is to encourage a research worker to examine his objectives carefully in view of his proposed experiment to ensure its answering his questions.

One specific question encountered was the identification and separation of experimental unit error from sampling error and the ramification of using sampling error as the denominator in an F test. An example was a project in agricultural engineering which attempted to construct a field machine to strip alfalfa leaves from a standing crop.

The overall F test for treatments usually does not present difficulties, but then the need exists to provide a meaningful breakdown of the treatment degrees of freedom. Questions arise, as they did in one experiment comparing herbicides with more than one check plot per block, or as in a seed germination study

Foster B. Cady, associate professor, joined the staff of the Statistical Laboratory and the Department of Statistics on July 1, 1960. He received a B.S. degree from Cornell University in 1953, a master's degree in agronomy from the University of Illinois in 1956, and a doctorate from North Carolina State in 1960 with a major in soil science and a minor in experimental statistics.

At Iowa State he has been teaching methods and theory sequences for graduate minors in statistics, consulting, and carrying on joint research with staff and graduate students primarily in the plant sciences. He has been elected to the Faculty Council for a three-year term.

Cady is secretary of the Biometric Section of the American Statistical Association and a member of the Regional Committee of Biometric Society (ENAR). He is a member of Sigma Xi, the American Association for the Advancement of Science, and the American Society of Agronomy.

where the breakdown did not result in exact F tests for the single degree of freedom comparisons. Another example was a study where the treatments were designed to investigate the effect of the type of diluent, diluent size, and rate of application for controlling the European corn borer when larvae were present at the time of application of insecticide. Another experiment studied the effect of additions of various crop residues and potassium fertilizer on the potassium uptake by rye grass.

Experimenters are continually faced with deciding the optimum number of samples or observations per replication and the number of replications per experiment, or the optimum number of replications within a location and number of locations. This was the case in a study on red pine sapwood to determine if springwood cell lumens respond differently than summerwood cell lumens to changes in atmospheric humidity. This same general problem was of concern in a sorghum breeding experiment and in a corn breeding study comparing seed sources from various foundation seed stocks in the midwest.

With high speed computers available, increased interest exists in multiple regression studies and consequently more consulting problems arise. These

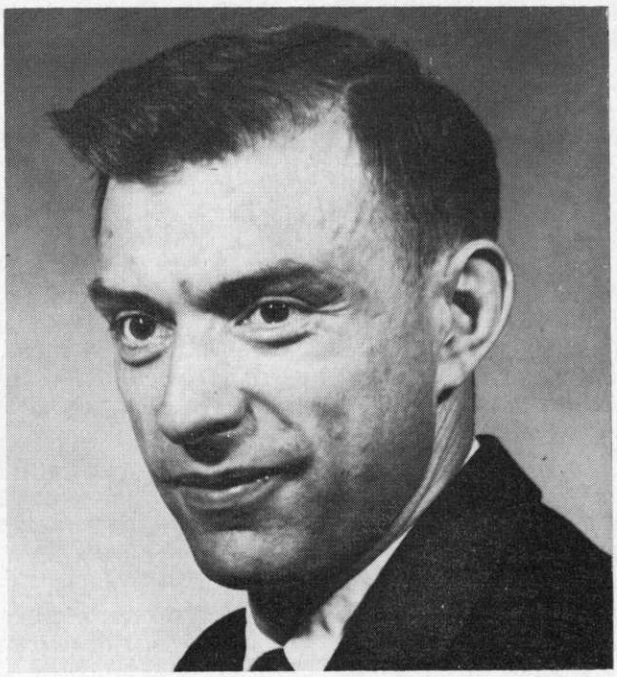
problems range from interpretation of a multiple regression study where the independent variables are correlated to using the general linear model in analysis of variance situations where unequal and disproportionate numbers in the subcells exist. Specific problems included a forestry experiment relating tree survival and growth to coal-spoil characteristics which were mainly chemical properties. An agricultural engineering study on energy demand was concerned with heterogeneous errors. Dummy variables were used in several studies to remove extraneous but known variation in the estimation of the regression coefficients. These studies included a soil fertility experiment with soybeans and a botany study investigating diffusion though small pores. A forestry research worker, in studying changes in specific gravity with distance from the pith, wanted to know if the first unit of distance from the pith was on the same linear regression line as the other distances. Again in this study dummy variables were used.

The coefficients needed for calculating orthogonal polynomials are available in the literature, but assistance was given in several studies where equal number of replications existed, but there were unequal intervals among the levels of the input variable. The most common examples were soil fertility experiments where each level of fertilizer was twice the previous level. Another interesting regression problem encountered during the year involved inverse regression estimation. An agronomist could estimate the relation between root carbohydrate reserves, the dependent variable, and leaf area index in Vernal alfalfa and Empire trefoil. After finding this quadratic relationship, he wanted to predict the leaf area index where the root carbohydrate reserves were at a minimum.

Problems occasionally arise in the use of covariance as exemplified by a study involving crib construction for grain drying where the rate of drying in the various bins had to be adjusted for different ambient temperatures.

In a physiological experiment studying the relationship between radiant light energy and leaf area index, biological theory would argue against using a polynomial for representing the relation. A form of the exponential seemed more appropriate, and an iterative method of estimation, modified by Wayne Fuller, was used. In another nonlinear regression estimation study, careful examination of the random error component in the model was made when a log-log transformation of the data was desired in order to estimate the relationship by linear regression.

In plant science work, the use of a split plot design is often necessitated by the nature of the soil condition or by the nature of the treatment imposed. This was the case in two horticulture experiments. In the first, a problem in gladiolus production existed because of a very real possibility of the spreading of a pathogen from one plot to another. The other study was concerned with the effect of irrigation levels on soil temperature and related quality features of Irish potatoes. Split plot considerations were made because of restrictions arising from applying the irrigation treatments and the location of early and late maturing varieties. Experimental design considerations were also made in a corn breeding experiment investigating the hypothesis of no difference between phenotypic selection and tester selection. An 8 x 8 simple lattice using two randomly selected replications at each location was used in this experiment.



Donald K. Hotchkiss, associate professor (July 1, 1964), joined the staff of the Statistical Laboratory and the Department of Statistics on September 1, 1961. He is a specialist in animal nutrition and management and consults and conducts statistical research with the staff of the Iowa Agricultural and Home Economics Experiment Station. He teaches courses in methods and special problems in statistics.

He received his B.S. degree from Iowa State in 1950 and was a County Extension Youth Assistant for a year. From 1951 to 1955 he was a commissioned officer serving as a pilot with the U. S. Air Force. In 1956 he returned to Iowa State to work for his doctorate in animal nutrition. After receiving his Ph.D. in 1960, he was reseach statistician for Ralston-Purina Company in St. Louis.

Hotchkiss is a member of Alpha Zeta, Gamma Sigma Delta and Sigma Xi. He also is a member of the American Statistical Association, Biometric Society (ENAR), American Dairy Science Association and the American Society of Animal Production.

Statistical services in animal science and veterinary medicine

Donald K. Hotchkiss also continued his consulting activities this year with the Iowa Agricultural and Home Economics Experiment Station Project 101. Interesting consulting in this area has dealt with the design of experiments in which high precision is desired, a regression relationship is desired, and those in which the analysis of data is complicated by missing observations or unequal subclass numbers.

In cooperation with the swine nutrition staff, an experiment was designed to demonstrate the appropriateness of the among pen mean square as the proper error term for testing treatment effects. This

study showed the among pen mean square, $M.S._E$, to be larger than the pigs within the pen mean square, $M.S._S$. A survey of previous Iowa State University pig growing experiments found 60 percent of the trials showed the same trend, $M.S._E > M.S._S$. In 40 percent of the trials $M.S._E$ was less than $M.S._S$, and it was proposed that a negative intra-pen correlation among pigs tends to inflate $M.S._S$ and to deflate $M.S._E$. The expected mean squares for the basic designs were determined and these gave further support to the importance of using $M.S._E$ to accomplish a valid test for treatment effects.

A second year of data was collected on blood fatty acid levels as they are affected by dietary additions of relatively pure fatty acid derivatives. These data were combined with the study reported last year. A partially balanced incomplete block design was utilized in which the fatty acid treatments were the whole plot factor arranged as an incomplete block and observations made over time were the split plot factor. The magnitude of the two error terms was obtained by using a least squares analysis. A significant time by treatment interaction necessitated the plotting of the response surface for each treatment adjusted for calf and year differences.

A crossover design was utilized to evaluate the effects of varying "concentration" ratios, hay-concentrate ratios, on the performance of dairy cows. Carry-over effect was removed in the subsequent analyses.

Two new assay techniques for the presence of salmonella in chicken feces and in eggs were compared to the standard technique by recording their presence or absence in a sample. A χ^2 test was proposed to evaluate the results.

Use was made of the *Aardvark* (analysis of variance) program to evaluate data which followed a split lot design having unequal numbers in the subplot. Whole plot totals were analyzed separately to divide the overall errors into fractions (a) and (b). This approach was used on lamb data in which the presence of a feed additive and the type of rumen fauna were combined in a 2 x 2 factorial as the main plot treatment, and the physiological responses measured over time as the subplot treatment, for each lamb. Loss of lambs during the study caused unequal numbers of whole plots.

Hotchkiss and C. P. Cox assisted a staff member of the Department of Veterinary Physiology with the analysis of an extensive experiment investigating the effects of zylocaine and epinephrine on uterine contractions. The Aardvark program was used since the data had unequal frequency of observations on each animal. Two runs of the program were required to obtain estimates of both error (a) and error (b) in the split plot analysis.

The effect of dust from rare earth compounds on the health of dogs was determined. A pre-dust exposure period was used as the control response and contrasted with the trend over time that occurred during dust exposure. An additional factor of exercise stress, confounded with blocks, was added following an evaluation of the first experiment replication.

A least squares analysis was used on renal clearance data from dogs which either had a kidney removed or a sham operation performed. Since interest was in the response immediately following the operation and during the recovery phase, the time trend was incorporated in the design as a split plot treatment.

Statistical services in food technology and home economics

Through a series of experiments, a long range study of turkey packaging materials was designed to evaluate the type of wrap, the length and temperature of storage, and the destruction of packaging material on the quality of the meat. The assignment of experimental units to the various treatment combinations was not on an equal basis, since most emphasis was placed on the comparative response of the treatment to the control. "Nonsense" treatment combinations also tended to destroy the balance of a complete factorial. Therefore a special set of comparisons was prepared to meet the objectives of each experiment.

Organoleptic properties of cooked turkey meat were examined to determine the effect of length of refrigerated storage. The design was set up to compensate for the influences on dark and light meat and the order of sample presentation. Correlations were made between panel scores and mechanical measurements for tenderness and juiciness, in addition to the routine analysis of variance.

A split plot analysis was used in several turkey studies in which dark and light meat and treatments applied to turkey halves were used as the subplot treatment. Storage of partially cooked and uncooked birds, injection of chemical preservatives, the type of cooking container, oven temperature and serving temperature were used as treatments. The occurrence of interactions between the several factors in each experiment usually required calculation of combined error terms to determine if taste preferences or differences in chemical constituents existed.

In a pork study, preferences for pork cooked at four different oven temperatures to different internal temperatures were evaluated. Two experiments were performed. In one, six-pound roasts were used, two from each animal. These roasts were cooked at the same oven temperature, but each roast was cooked to a different internal temperature. This experiment was analyzed as a split plot design. In the second experiment, four-and-one-half-pound roasts were used, four from each animal. Again the two internal temperatures were used as a subplot treatment, while four oven temperatures, which were the whole plot treatments, were allotted to pairs of roasts in the form of a balanced incomplete block design.

To determine the effect of adding lactone products to cheddar cheese, three treatment groups and a control were used. The resulting cheeses were tasted in all possible combinations using a block size of 2 in an attempt to insure discrimination by the judges. The scores were evaluated using a balanced incomplete block design analysis.

Statistical services in genetics

The genetic statistics group continued to consult with the Agricultural Experiment Station personnel in the Department of Animal Science, Poultry Science, Agronomy, Entomology and Horticulture on the statistical aspects of their genetic research. Many challenging and interesting problems were encountered and those discussed here exemplify their nature. Dewey Harris worked with members of the poultry breeding group on the analysis and interpretation of their studies on the direct and correlated responses to selection for single traits in Leghorn and Fayoumi chickens. Another problem in poultry was the estimation of variance components from multiple unit test data.

Harris and Kempthorne consulted with members of the corn breeding group on the estimation of genetic components of variance from an elaborate experiment with a random mating population of corn. Harris also aided in the design of a genetic experiment in sorghum. Harris was also involved in consultation on the analysis of two studies with alfalfa. One was concerned with fertility as influenced by various genetic and environmental influences. The other study involved seed weight in a replicated diallel cross experiment with considerable missing observations so that a least squares procedure for fitting constants had to be used.

Four of the interesting studies from the Department of Animal Science on which Harris assisted were: (1) a study of the influence of certain management factors on feedlot performance of beef cattle, (2) a study of genotype-environmental interactions in dairy cattle using identical twins as experimental material, (3) a study of the influence of genetic and environmental factors upon weaning weight and feedlot gain in beef cattle, and (4) a study of selection for various characteristics in sheep under semi-arid conditions over a period of several years.

Harris also consulted with a student from the Department of Horticulture on the analyses of an experiment concerning genetic aspects to bulb shape in onions and on the design of a future study.

These consulting activities are supported by AES Project 1448. For a discussion of the research activities under this project, see page 24.

Kempthorne, in addition to consultation mentioned above, did some consulting with members of the staff of the animal breeding group, poultry breeding group and plant breeders in connection with analysis of data having genetic structure.

Statistical services for sampling investigations

Statistical Services for Sampling Investigations, Project 113, is a consulting project with the Iowa Agricultural and Home Economics Experiment Station under N. V. Strand, Wayne A. Fuller and Harold Baker. Statistical services were provided within the areas of economics and sociology, agricultural engineering, animal and poultry science, rural sociology, forestry, agronomy, textiles and clothing, nutrition and education. Consultation and advice have been given on design of surveys and experiments, collection of data, outling appropriate analyses of data collected, supervising required computations, and assisting in the interpretation of results.

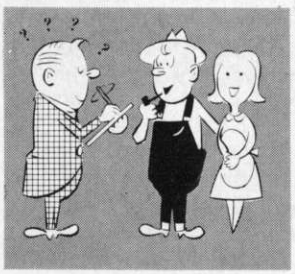
Much of Strand's work on Project 113 was done in connection with the work of the Survey Group on such projects as those discussed in the next section of this report. Other projects representative of Strand's consulting activities follow.

For the Household Equipment Department, Strand assisted in the design of a survey of the needs for and adequacy of kitchen equipment and appliances for older women. For the Department of Economics, Strand and Baker worked on a sample design and questionnaire to be used to ascertain the practices of farmers selling wool to private and cooperative buyers in Iowa. Also for the Department of Agricultural Economics, Strand advised on survey matters in connection with a taxation study. For a cooperative study of the USDA and the ISU Agricultural Economics Department, Strand assisted in the sampling and planning for a survey designed to evaluate a pilot crop conversion program for the USDA. For the Foods and Nutrition Department, Strand advised on the sample design to be used in a study of nutritional status of children and adults in Monroe County, Iowa. With sociologists in the Department of Agricultural Economics and Rural Sociology, a sample design and study plan were evolved for a study of anticipated occupational changes and retirement plans for specified occupational classes in towns with a population of 2,500 to 10,000 in Iowa.

Fuller consulted with a Ph.D. candidate in education on a study of male high school graduates who took vocational agriculture in high school or had a farm background. The purpose of the study was to learn the present activities of these students and their attitudes and their evaluation of their high school education. Schedules were collected by mail. A post-stratification estimation procedure was employed where IQ and the type of school were used as strata.

For a graduate student in forestry who was interested in recreation, Fuller aided in questionnaire construction and sampling procedures for a study of the uses people were making of a forested area in north central Iowa. Fuller consulted with an economics major on price combinations to use in a study employing multiple linear programs to determine quantity supplied at various price combinations. He assisted a state Conservation Commission officer in the analysis of a roadside survey to determine the influence of time of day, snow cover, light and temperature on rabbit counts. A least squares procedure was utilized. He helped economists in the Agricultural Extension Service design trade area surveys. He advised on questionnaire construction and drawing a sample of households and businesses. Three surveys were conducted in New Hampton, Albia and Naiad areas.

The Survey Group



The Survey Group of the Statistical Laboratory provides direct operational services to the rest of the campus on all aspects of 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 Industrial Science Research Institute. Professional staff members of the Survey Group for 1963-64 were Norman V. Strand, Om P. Aggarwal, Wayne A. Fuller, Leroy Wolins, and Joseph Sedransk; associates, Harold Baker and Thomas C. Jetton; and graduate assistants, Martin Rosenzweig and Louis W. Johnson. Helen Ayres and Marjorie Mason have supervised field interviewers and clerical personnel.

A number of foreign students have pursued their studies in sampling techniques with Survey Group personnel. Among these have been people supported by AID, FAO, and by the governments of Peru, the Philippines, Thailand, and Taiwan. USDA has supported two trainees.

The Survey Group participated in a number of studies during the year which were administered jointly by the Statistical Laboratory and some other university, institute, state, or federal agency, such as the Iowa Agricultural Experiment Station, Center for Agricultural and Economic Development, Industrial Science Research Institute, USDA, USDC-Bureau of the Census, Iowa Conservation Commission, and the Ohio Division of Wildlife.

Some projects which have been reported in previous annual reports were completed, others were continued, and still others were started in 1963-64. Progress is reported here on representative studies carried on by the Survey Group.

A three-year study of the Effects of Product Development, Merchandising, and Promotion, AES Project 1404, was continued through its second year, the Survey Group collaborating with research workers in agricultural economics, food technology, and the animal and poultry sciences. The study is concerned with tracing the effects of product development, merchandising and promotion from the consumer through the retailer and wholesaler to the producer to find out what effect these activities have on the decisions of the producer. A Ph.D. thesis in agricultural economics will be written on the findings of the study. A master's thesis will be written by another graduate student in agricultural economics on consumer decision making, and a master's thesis in statistics will be written on the statistical phases of the study.

The staff of the Survey Group collaborated in the preparation of the questionnaires, recruited the field staff and supervised the field work on the project. Approximately 650 householders in Webster County, Iowa, were interviewed four times each. The project leader for the Department of Agricultural Economics, Dr. Wilbur Maki, has completed work on the analytical procedures for use in analyzing data on the preferences of consumers for various kinds of meats. The data gathered is now being processed. Some work has been done on description of the general characteristics of the sampled population, but this has not been completed. Work on the project will continue through 1964-65.

Two studies which were reported in the 1962-63 Annual Report have now been completed. In 1963-64 data were coded for the survey of the shopping habits of householders in West Des Moines, and all information was turned over to Prof. Bob R. Holdren of the Department of Economics and Sociology, for whom the survey was made. Additional tabulations and analysis of data on the Business Impact project were completed.

Work was continued on the Farming Opportunities in Iowa project with D. R. Kaldor of the Department of Economics and Sociology and N. V. Strand, Department of Statistics, as co-leaders. Thomas Jetton of the Statistical Laboratory directed the field work and the tabulation.

The purpose of this study was to estimate (1) how many farmers entered farming in 1959-60; (2) how many left farming; and (3) the size, quality, and other characteristics of the farms given up. Emphasis this year has been on completing the analysis and preparing manuscripts for publication. Also, further work was done with two of the groups of operators who left farming, those who quit to take non-farm jobs and those who quit to retire. The objectives of these studies were to determine the causes for leaving an operatorship status and also to find out how well the ex-operators were satisfied with the results of their decision to quit farming for non-farm work or to retire. Little analysis has as yet been done on these two groups; however, the field work is completed for both, and much of the coding is completed.

Manuscripts for bulletins reporting the findings on the study of the conditions of entry of beginning farm operators, their initial year's financial experience and on the findings of the components of change in the number of farm operators in Iowa are in the final stages of preparation. These bulletins are expected to be available through the IAHEES Publications Office during the year 1964-65.

After coding, punching and tabulating all material relating to the Senior High School Boys' Career Plans project, which was reported in the 1962-63 Annual Report, all material was turned over to D. R. Kaldor for analysis. The findings will be used in a master's thesis by a student in the Department of Agricultural Economics.

In cooperation with the USDA and under the direction of Earl O. Heady and N. V. Strand, John T. Scott, Jr. began a study of the Demand for Farm Buildings in North Central Iowa. A farm survey questionnaire was developed in the fall and winter of 1963, was pretested, and operators and landlords of approximately 280 farms were interviewed in the late spring

of 1964. Coding and analysis will continue through the summer and fall of 1964. The purpose of the study was to make a physical inventory of farm buildings, their current and past use, and the extent of new building construction and remodeling. Another purpose was to investigate the many factors affecting the use of present farm buildings and the construction of new ones. Some indication of consolidation of farms and building abandonment are expected to be important results of the study. Results and analysis of the survey will be included in Scott's Ph.D. thesis in economics.

A five-year study of the Nutritional Characteristics of High School Students in Iowa was begun in January 1964 to be continued on an annual basis through 1968. The study being done with members of the Department of Internal Medicine, State University of Iowa, in cooperation with the Survey Group. Norman V. Strand of the Statistical Laboratory is coordinating the work with Thomas C. Jetton acting as project supervisor. The study this year involved nearly 2,900 students in grades 9 through 12 in 60 high school districts in the state. Sampling is being done on a rotational scheme in which any one student will be observed for only two consecutive years while in school and will be dropped from the study and will not be allowed to participate again. Sample size will be maintained by drawing an additional group each year, equal in size to the original group, to replace those dropped. The Statistical Laboratory will perform all coding, punching and tabulation for the study. Analysis will be done by physicians at the State University of Iowa.

A Child Care Study was conducted in Cedar Rapids, Iowa, in cooperation with Dr. Damaris Pease and a graduate student in the Department of Child Development. The purpose of the study was to find out what arrangements were made for children when working mothers were away from home during the day and how much need there is for day care facilities in Cedar Rapids. Mothers with children under thirteen years of age were included in the sample, which was drawn by the Survey Group. The Survey Group supervised the interviewing. The field work was finished by June 30, 1964. The coding and analysis remain to be done.

An Iowa Wool Marketing Study was begun in 1964 for Prof. Wilbur Maki and a graduate student in the Department of Agricultural Economics. The purpose of the project was to study the marketing practices of wool sellers and buyers, (1) whether the sellers sell through cooperative or private channels, and (2) what are the purchasing practices of the buyers regarding grading, price, and resale. A random sample of producers known to have sold wool in 1963 was drawn in eighteen randomly selected counties in Iowa. A training school for interviewers was held, and field work was finished by June 30, 1964.

A sample was drawn for a study of the attitudes of farmers toward hunting for the Division of Wildlife of the Department of Natural Resources of Ohio. This agency collected the questionnaires. The Survey Group edited, coded, and tabulated the data. The report will be prepared by personnel of the Ohio Wildlife Division. Phrensi Svasti Salee will summarize and prepare a description of the design of this survey which will also serve as her master's thesis in statistics.

In the spring of 1964 the Survey Group, under the supervision of N. V. Strand and Helen Ayres, conducted a School Census for the Ames Community School District for the fourth time. The main objectives of the study were to enumerate (1) all persons under 21 years of age who reside in the district, (2) people with certain physical and mental handicaps, and (3) blind people over 21 years of age. The census identified 9,952 persons under 21 in the district.

The Survey Group gave operational assistance to other departments on campus on a number of studies. Samples were drawn for studies on agricultural occupation skills, soybean seed quality, market facts, land tenure. Coding and analysis assistance was given on a survey for a Greek post-doctoral student. Further operational assistance was also given on studies which were reported more fully in the 1962-63 Annual Report and have now been completed.

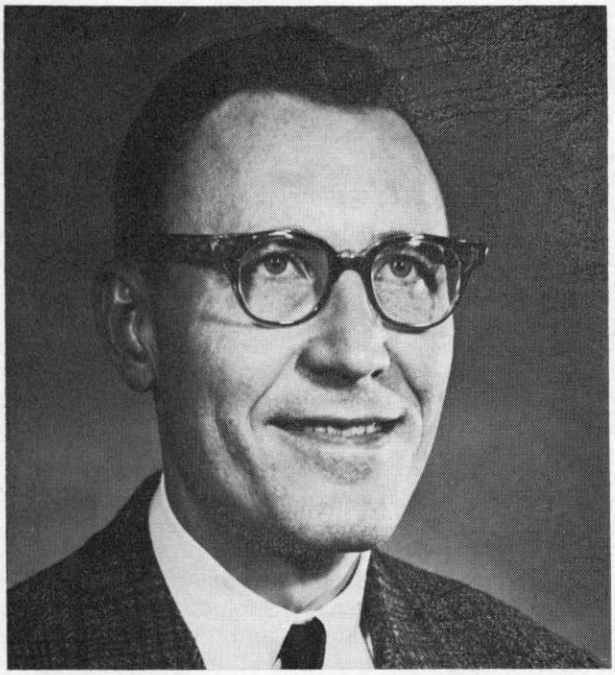
The Cropland Conversion Program is part of a long-range land use adjustment program authorized by Congress. The purpose of the program is to test, in selected states and counties, new methods of improving family farm income through conservation and better economic use of farm land. A survey was made in cooperation with the Agricultural Experiment Station of a sampling of 95 program participants and 106 non-participants in a pilot program. Five enumerators collected data from these operators during March and April, 1964. The data were coded and tabulated by the Survey Group.

Tabulations for the Soil Conservation Service, USDA, were continued under the direction of N. V. Strand, assisted by Marjorie Mason. Work performed in the year was largely in connection with river basin analyses conducted by the Economic Research Service, USDA. Tabulations of the SCS data were for states of the upper Mississippi and Missouri River basins.

During the year the procedures of processing SCS data were changed. To a great extent the conventional card tabulating equipment was dropped in favor of electronic equipment. Programs to update and otherwise change and revise SCS data were written and put into effect. These new ways of handling large masses of data (up to 100,000 cards or records per state) will greatly speed up the elapsed time the data are actually on machines. Tabulations can be made to disclose inconsistencies and errors in a short time. Corrective procedures may then be put into effect, making the records on the final, corrected tapes tight and consistent with respect to the fields for which corrective action was taken. In the updating process the entire file may be sorted and listed as many as five or six times, a prohibitive amount of work on conventional machines.

Numerical Analysis-Programming Group

The staff of the Numerical Analysis-Programming Group for 1963-64 consisted of W. J. Hemmerle, in charge, Dale Grosvenor, Edward J. Carney, James R. Prescott, a programmer, three graduate assistants, and two undergraduate assistants.



William J. Hemmerle, associate professor of statistics (July 1, 1964), was appointed to the staff of the Statistical Laboratory and the Department of Statistics in 1962. He earned his bachelor's degree at the University of Colorado in 1950 and his master's degree in mathematics at the University of Wisconsin in 1951. He spent four years with the National Security Agency in Washington, D. C., both as a civilian and as a Naval officer. Then for five years he was with IBM and its subsidiary SBC. During this period he managed a scientific computing center with an IMB 650 and was assistant manager of a data processing center with an IBM 604.

Hemmerle received his Ph.D. from Iowa State under H. O. Hartley in the spring of 1963. He is in charge of the Numerical Analysis-Programming Group of the Laboratory, teaches courses in Scientific Application of Digital Computers, and conducts research with graduate students in the area of computing. He has designed a number of computer programs for use by the Numerical Analysis-Programming Group and has published papers in professional journals. Hemmerle is a member of Beta Gamma Sigma and Phi Kappa Phi, honorary fraternities, the American Statistical Association and the Association for Computing Machinery.

This group continued its efforts in the preparation of general purpose programs for the IBM 7074-1401, as well as handling a diversity of specific research and consulting problems. Research which was conducted in 1963-64 is reported on page 18 of this report. The AARDVARK system was placed on the ISU library tape and made available for operational use through the Computation Center. Personnel in the center now handle the majority of problems processed on AARDVARK; however, the Numerical Analysis-Programming Group continues to maintain the system and consult on its use. Activity Analysis, also on the library tape, is used for production problems and for teaching, to illustrate the application of linear programming. The Lattice Analysis of Variance program ABIYOYO was completed by E. L. Fuller, graduate assistant, and used extensively in the fall of 1963 in processing last year's experimental crop data.

During the year several new general purpose programs were prepared, which are described on page 18 of this report. APTERYX was designed by W. J. Hemmerle to compute maximum likelihood estimates of factor loadings, communalities, and specific variances for a factor analytic model. Hemmerle developed an efficient iterative procedure to solve the relevant maximum likelihood equations. The procedure is also adaptable to obtaining least squares estimates. A large number of variance-covariance matrices of different order with varying numbers of factors extracted were processed for the departments of economics and psychology. Fuller and James C. Blinn, graduate assistant, helped prepare the program. Hemmerle and Fuller consulted with a staff member and a graduate student in economics and with Leroy Wolins in the departments of Statistics and Psychology on numerical or statistical evaluation of results produced by APTERYX for their research problems.

ADJUTANT, a convex programming system, is one which minimizes a convex function of several variables subject to convex restraints on these same variables. Dale Grosvenor consulted with an associate in the Department of Economics and Sociology on the optimization of some nonlinear economics models. The program was also used for a staff member in Statistics to establish minimum cost sample sizes consistent with limitations on variances in analytic sample survey design.

E. J. Carney consulted with a staff member in Industrial Engineering on a plant layout analysis to determine optimum location of work stations. A suitable algorithm for the solution was programmed for the computer. The program AOUDAD will take a random starting pattern and successively move stations to improve it, or starting patterns may be supplied. Funds for this work were provided under contract No. AF 49(638)702.

Staff and graduate students from the departments of Agricultural Engineering, Agronomy, Animal Science, Economics and Sociology, Poultry Science, Psychology, and Statistics were assisted with their programming problems. Some further examples of the consulting activities of the group follow.

Fuller assisted in processing data for members of the Agronomy staff associated with the Iowa Crop Improvement Association.

E. J. Carney consulted with a graduate student in Statistics on an Analysis of Variance problem. Programs were written to enumerate all possible generalized symmetric means of degree four of a three-way crossed population, and to obtain expression of generalized polykays in terms of these means. The latter program was prepared by James Blinn.

Carney consulted with O. Kempthorne on the effects of selection on a normally distributed attribute determined by one genetic locus. The problem in-

volved applying techniques of numerical integration, completing parameters for successive populations, and graphing gene frequencies. Programs were prepared and assistance was given with programming.

Mary Ann Carney and Blinn continued work on the analysis of farming costs and income for USDA for selected participants and non-participants in the 1963 Feed Grain Program. James Prescott also worked on the USDA Feed Grain Program, developing routines to compute Linear Discriminant Function to distinguish between participants and non-participants in the feed grain program. Mary Ann Carney worked with a staff member in Poultry Science on computation of binomial type confidence intervals for reagent groups and enumeration of disjoint intervals within groups.

AGOUTI, written by Mary Ann Carney, was employed to conduct a Wherry Winer item analysis involving 521 people, 100 items, and 12 clusters for staff and graduate students in the departments of Home Economics Education and Psychology.

Production functions for pigs were estimated in quadratic and exponential (Cobb-Douglas) forms by Prescott for a staff member in Economics and Sociology.

John Schlater, under the direction of Dale Grosvenor, developed a linear programming code which was used by three agricultural economists. Because of the very large number of individual solutions required, a program was written to fit the specific needs of the research problem.

One case involved a regional USDA study in which 67 Iowa farms were analyzed. For each farm optimal plans were derived for all combinations of three assumed price levels for hogs, beef and corn. Thus 1,809 solutions were obtained using this program.

In another case the problem was to compare optimal solution for various combinations of assumed prices for six different products. Approximately 400 individual solutions were obtained on this project. Certain of these variables were used in later stages of the research for regression analysis.

The other case involved the solution of 1,020 different linear programming models. This was a comparative study of corporate vs. non-corporate farm business organizations. It involved a simulator program to be used alternately with a linear programming program.

Paul Stachour and Robert Wruck, undergraduate assistants, worked on a number of research and consulting problems. In the course of their work they prepared a number of computer programs and assisted members of the Numerical Analysis-Programming Group in various ways.

Off campus advisory assignments

Staff members, in addition to their regular consulting duties on campus, are often called upon to serve in an advisory capacity to professional groups elsewhere.

In September 1963, T. A. Bancroft was in Rome, Italy, to study the possibilities of research in agricultural statistics involving chemical fertilizer experiments in the Middle and Far East. He consulted with Dr. P. V. Sukhatme, Director of the Statistics Division, FAO of the United Nations in Rome.

Bancroft attended a meeting on January 8, 1964, of a National Institutes of Health Projects Site Committee at the Harvard University School of Public Health in Boston.

Bancroft and C. P. Cox took an active part in the work of the Biostatistics Training Program Directors Meeting, National Institutes of Health, in Bethesda, Maryland, on January 29. Bancroft was a member of the committee on Curricula for Masters and Doctoral Degree Programs in Biostatistics. Cox was on a similar committee for Programs in Biomathematics.

H. T. David is a member of the Standby Unit of Operations Research and in that capacity attended the annual meeting of Air Force Analysts in San Francisco in March and the Military Operations Research Symposium in Washington, D. C., in April.

Om P. Aggarwal, at the request of Dr. John F. Timmons of the Department of Economics, consulted by correspondence with Mr. Enrique Vigues of The Instituto de Reforma Agraria y Colonizacion, Tarma, Peru, concerning work for the Projecto Sierra Central. Mr. Vigues was interested in having the Statistical Laboratory provide certain statistical services of importance to his project.

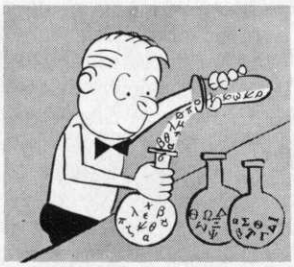
In November, Aggarwal consulted with the Peruvian government on final phases of the work he performed for FAO of the U. N. in Peru, prior to his coming to Iowa State.

O. Kempthorne spent Spring Quarter as Visiting Professor of Statistics and Genetics at Stanford University where he conducted research and taught a course in Mathematical and Statistical Theory of Quantitative Inheritance.

C. P. Cox consulted with former colleagues at the National Institute for Research in Dairying at Shinfield, Berkshire, England, on a series of collaborative experiments studying the hormonal induction of mammary glands and lactation in the goat. This study is to be reported in three joint papers.

W. J. Hemmerle gave a seminar talk and consulted with the staff of the Computation Center and the Department of Psychology at Northwestern University in February 1964.

Hemmerle spent two weeks in April, on a Ford Foundation assignment, assisting the post-graduate college of the National School of Agriculture at Chapingo, Mexico, with problems related to its newly-established Statistics and Computing Center. He worked with the staff and graduate students in the areas of statistical computing problems, programming techniques, the use of available programming systems, and the requisition and implementation of library routines. He delivered a series of lectures on scientific computing slanted toward Chapingo's problems. He assisted in evaluating the present staff of the center, considering future staff requirements, and determining an effective organizational structure for the center.



In the research program of the Laboratory, both the development and extension of basic theory and its application to new statistical methods and techniques are emphasized. The Laboratory cooperates with other research institutes and experiment stations on the campus in arranging programs of statistical research and in obtaining support through joint grants and projects. Many studies of a fundamental nature are supported by such grants and contracts with off-campus agencies. In most instances they provide for supervised graduate research on topics proposed by the staff. The Statistical Laboratory budget, however, supports only projects which are of specific interest to regular university research programs.

Statistical Laboratory Research Projects

In general methodology and theory

Leroy Wolins is exploring methods for analyzing multimethod-multitrait matrices. He has formulated this as a problem in factor analysis, but the solutions that result are not unique. He is attempting to find some reasonable restrictions which will make them unique. At this point it seems likely that the restriction that will provide a unique solution will minimize some function of the distances of groups of points from each other. The factor loadings determine the positions of points, which in turn represent the original variables in a cartesian space. Points in a group represent either measures of the same trait or involve the same method of measurement.

Raymond Ferris worked with Herbert T. David on a problem in life-testing. This involved parameter estimation and the study of the asymptotic behavior of such estimates when the sample of times of failure consists both of genuine and erroneous failure times. It is hoped to apply the resulting methodology to an actual problem in the wear-out of aircraft parts.

David R. Thomas has worked with Dale Grosvenor of the Numerical Analysis-Programming Group on an Activity Analysis linear programming system for the IBM 7074. A reference manual was prepared in September. During the year Thomas has worked with numerous graduate students and staff from the Department of Economics on the use of this program. He is working on his doctorate under H. T. David.

Joseph Sedransk conducted research in analytical studies with particular application to survey data. These were extensions of his study for his doctorate at Harvard on "Sample Size Determination in Analytical Surveys." He worked on three phases of the study: (i) a double sampling scheme for analytical surveys, including a large scale numerical evaluation of an approximate procedure to determine the optimum sample sizes; (ii) a sequential sampling scheme for analytical surveys, including a numerical evaluation of the properties of this procedure; and (iii) optimum sample size allocation when common fixed analysis of variance models can be used to analyze survey data.

NIH Research

During the academic year 1963-64 the National Institutes of Health Training Grant Program has provided traineeships for six degree candidates of whom five were working for their doctorates and one for his master's degree: Patricia Conn, John Peter Johnson, Fred L. Ramsey, Thomas Roseberry, Donna Jean Ruhl and James R. Veale.

Patricia Conn carried on her research under H. T. David on an NSF project in random walk which is reported on page 19. Fred L. Ramsey, working under K. C. Chanda, has completed his research and expects to receive his Ph.D. in August 1964. His research is reported under an NSF project in theoretical statistics on page 20.

John Peter Johnson began his NIH program under T. A. Bancroft in June 1964. He has been reviewing the consecutive decision part of the multiple decision theory discussed in a paper by E. L. Lehmann with the intention of comparing this approach with alternative ones.

Thomas D. Roseberry, under C. P. Cox, is proceeding with his research on the incorporation of concomitant information to increase the efficiency of discriminating between two treatments in sequential experiments. Particular applications to sequential and clinical traits are envisaged.

With Donna Jean Ruhl, Cox found that, with minor changes in notation, the procedure for fitting orthogonal polynomials (Journal of the Royal Statistical Society, B, 20: 406-7, 1958) can be easily generalized to cover the case of unequal replication at unequally spaced values of the abscissa.

James R. Veale, who expects to finish his work for his master's degree in the fall of 1964, has carried on research under D. V. Huntsberger in the area of statistical tests for outliers and the estimation of parameters of interest after making the test. This approach makes use of a preliminary test of hypothesis procedure developed by Huntsberger.

Four other trainees were supported on the NIH program during a summer quarter only. Ross Adams continued his research during the summer of 1963 before transferring to another department. Michael Billings did not return to Iowa State after the summer of 1963. Paul Leaverton was under the NIH program until he received his doctorate in November 1963. His research was reported in the 1962-63 Annual Report, and an abstract of his thesis appears on page 33 of this issue.

WASD project on analysis of variance procedures

Research under the contract with the Wright Air Systems Development, AF 33(616)8269, and the In-

dustrial Science Research Institute was completed in 1964, a new contract having been drawn up to continue research in the areas of analysis of variance and design of experiments. During 1963-64 Oscar Kempthorne was chief investigator and George Zyskind, project leader, with Eugene Dayhoff, Rodney Basson, and Thomas E. Doerfler working on the research.

The final report relating to the overall work was written and submitted to the Wright Air Systems Development Center. The research described in this report was directed toward understanding of linear models and the analysis of variance with regard to experimentation. The first chapter of the report is devoted to the study of the structure and analysis of a generalization of the balanced incomplete block design. An abstract of a paper on this work by George Zyskind is given on page 31. The report continues with a statement on a general formulation and analysis of experimental structures which was based on the Ph.D. thesis of Robert F. White. An abstract of White's thesis was published in the 1962-63 Annual Report of the Statistical Laboratory. Research was conducted on generalized polykays and their application to obtaining variances and covariances of components of variation. Eugene Dayhoff wrote his doctoral thesis on this phase of the research, the abstract of which is on page 32 of this report. Dayhoff's paper on the equivalence of second degree generalized polykays and of Cap Σ's will be published in the December 1964 issue of the Annals of Mathematical Statistics.

The final report to WASD also contains an extensive chapter by George Zyskind on topics in linear models theory. The account attempts to relate and synthesize the different possible approaches. Thus at various points in the study geometrical intuition and the suggested corresponding analytical developments are combined to give greater breadth and increased power to the development of the subject. Some standard results on best linear unbiased estimation are presented. Presented also is a statement on linear reparametrizations. Attention is given to complex error structures. Some of such error structures are induced, in particular, by the act of randomization in designed experiments. Conditions are stated for which best linear estimators of estimable parametric functions under complex error structures are identical with simple least square estimators. A general account is given of partitioned models, covariance analysis and of the connection among the augmentation and deletion procedures of parameters. The connection between covariance analysis and general elimination procedures is made explicit, as is also the formal relation of covariance analysis and analysis of data with missing observations. The analysis of models involving the fitting of additional parameters by a method called residual analysis is briefly presented and commented upon. It is shown explicitly how in the cases of parameter augmentation, deletion, restriction, and of hypothesis testing part of the matter reduces itself to solving an auxiliary set of normal-type equations.

Kempthorne and Doerfler have completed an initial study of the size and power of the F test, and three non-parametric tests, the Fisher randomization test, the Wilcoxon test and the sign test. The aim was to obtain a more complete understanding of the consequences of experiment randomization, which is almost uniformly used as part of the design. In particular the consequences with regard to tests of significance were examined in the population of repetitions induced by physical randomization. So the size and power are "under experiment randomization." The work involved considerable computing and to keep this within reasonable bounds for an initial study, the paired design was examined. With n pairs, there are of course 2^n possible plans for the experiment, one of which is chosen at random by the experimenter. The values of n considered were n equals 3, 4, 5, 6 and 8. The size and power of a test may be examined for any particular set of basal yields, because with a given set of basal yields and an assumed true treatment difference Δ, say, one can generate all the possible 2^n experiments with their results. The behavior of any of the tests depends on the particular pattern of basal yields. Samples of basal yields were drawn from 8 mathematical populations: normal, uniform, three based on triangles, truncated normal distributions with two levels of contamination by a uniform distribution and a strongly bimodal population.

Choice of test would of course be based on the whole of the operating characteristics of the competitors. The non-parametric tests have the property that the probability of achieving significance at the level α is α under the null hypothesis, if α is an achievable size, for any set of basal yields. They are different with regard to the achievable sizes, unless one introduces test randomization which seems reasonable from the point of view of testing hypotheses, but appears misleading if one is making an evaluation of significance.

The non-parametric tests would appear to be superior to the F test if their power were not inferior. The power under experiment randomization for any particular set of basal yields does not behave in a highly regular way, so the comparison of tests was made on the basis of average power curves for 50 samples, for $n = 3, 4, 5, 6$ and 10 samples for $n = 8$, this being a reasonable number in the light of the resources available. The general conclusion is that with samples from any distribution the average power of the Fisher randomization test and the Wilcoxon paired test are essentially identical. The power curve of the sign test is very close to that of the other two tests for sizes of test which are achievable with all three tests. The relative behavior of the F test and the nonparametric tests is somewhat peculiar. For the following cases: $n = 4$, and $\alpha = 12.5\%$, $n = 5$, and $\alpha = 6.25\%$, $n = 6$, and $\alpha = 6.25\%$, and samples from the normal population, the power is essentially the same. In the case $n = 8$ and tests of size 1.5625% the F test had slightly superior power for the smaller true Δ's, and in the case of size 0.78125%, the F test is somewhat superior at intermediate levels of Δ. It appears then that a comparison of tests on the basis of power curves does not give an unambiguous answer, but that the superiority of the F test to the non-parametric tests occurs with tests of very small size.

This is an indication that the comparison of tests on the basis of asymptotic relative efficiency may be somewhat misleading.

It was rather remarkable to the authors that the average size of the F test with the smaller experiments was quite close to the nominal normal distribution of 12.5%, 6.25%, 3.125%, even when the distributions were markedly non-normal, for example, the distribution

$$f(x) = \frac{2}{a^2}(x - a), \quad 0 \leq x \leq a.$$

It was also remarkable that the F test at sizes which are achievable by the non-parametric tests had a higher average power curve for intermediate values of Δ, for many of the distributions and sizes examined.

The general conclusion appears to be that except for their inability to achieve any prechosen size, the non-parametric tests have average power very similar to the F test. It will be interesting to examine whether this remains true for larger experiments. As regards implications for data evaluation, it seems that the non-parametric tests are to be preferred, because their behavior under the null hypothesis is known a priori and is the same regardless of the pattern of basal yields encountered (but, of course, unknown to the experimenter).

Three separate technical reports have been prepared for WASD: R. F. White's report on the general experiment; Eugene Dayhoff's separate report on general polykays and variances of variance components; and a monograph by Rodney Basson and George Zyskind on missing value procedures.

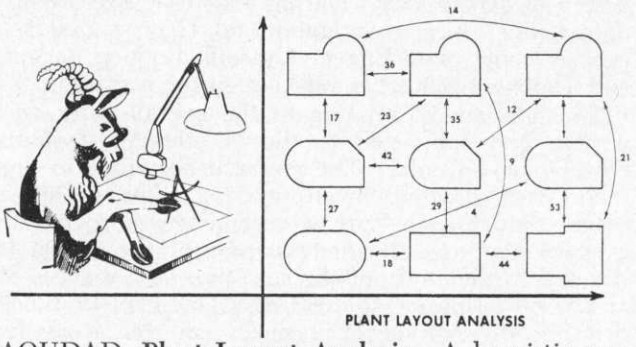
In Computational Methodology

During the year the Numerical Analysis-Programming Group continued to develop general purpose research programs for the IBM 7074-1401 as well as to carry on a diversity of specific research problems. Given here is a description of the programs which have been written to date in the "program zoo of ISU."

AARDVARK, **Analysis of Variance** – A general system for all balanced-complete structures and certain non-orthogonal cases. Algebraic problem specifications include the statistical model and provide for: covariates; transformations; selected means, estimates or residuals; secondary error terms; varying form and format of data; and annotation of results. Work on AARDVARK was described in the 1962-63 Annual Report.

APTERYX, **Factor Analysis** – A general program to compute maximum likelihood estimates or least squares estimates of factor loadings, communalities, and specific variances for a factor analytic model. Principal component analysis or principal axis factor analysis is also handled as a special case.

ADJUTANT, **Convex Programming** – A program to minimize a convex function of several variables subject to convex restraints on these same variables. This program is based on an algorithm developed by Hartley and Hocking [Management Science 9:4, July 1963]. It uses tangential approximation of the non-linear functions in order to adapt the model to the modified simplex method of linear programming.



AOUDAD, **Plant Layout Analysis** – A heuristic program to minimize the sum of products of the load times the distance between work stations arranged in a rectangular array, with the distance measured along "aisles" parallel to the coordinate axes.

ABIYOYO, **Lattice Analysis of Variance** – A general program designed to give a complete analysis of variance for either a balanced or partially balanced square lattice experimental design or a rectangular lattice design. Output includes an A.O.V. table for each variable, F ratios, efficiencies, and tables of adjusted and unadjusted treatment means.

AGOUTI, **Item Analysis** – A program which generates linear combinations of M initial variables and correlates these M variables with the N variables generated. Correlation coefficients are computed for each N variable with every other N variable, but correlation coefficients are not computed between the M variables.

Problems on which these programs were used are described in the consulting section of this report (see page 15).

NSF project in the properties of sufficient statistics

The National Science Foundation extended for a second year its grant (GP-1155) to Iowa State University for support of V. S. Huzurbazar's research in sufficient statistics. The concept of a sufficient statistic plays an important role in statistical inference. Huzurbazar obtained several interesting properties of sufficient statistics. The results of his research have been incorporated in three papers which are now in course of publication, or are under consideration for publication, in scientific periodicals.

In Huzurbazar's work are presented some new invariants of some well-known discrete distributions for parameters where sufficient statistics exist, e.g., the Bernoulli, Binomial, Poisson and multinomial distributions. Applications of invariants in statements of prior probability of parameters in estimation are indicated. The results obtained may also be regarded as a study of some interesting mathematical properties of the class of distributions admitting sufficient statistics for parameters.

Working in the general forms of distributions admitting sufficient statistics for parameters in non-regular cases, Huzurbazar found rigorous proofs, under

fairly general conditions, of the general forms of univariate distributions possessing probability density functions, which admit sufficient statistics for parameters in non-regular cases, i.e., when the ranges of the distributions depend on the unknown parameters to be estimated. In the non-regular case with a single sufficient statistic for a single unknown parameter, the exact sampling distribution of the single sufficient statistic has been obtained incidentally. A proof of Pitman's conjecture has also been given. The non-regular cases may be divided into two categories: pure and mixed types. It is shown that the pure type non-regular cases can be treated on their own merits, and the results in such cases follow directly from the basic definitions of sufficient statistics; and that the results do not require assumptions of the factorability criterion or the Koopman regularity conditions. In mixed type non-regular cases, the Koopman regularity conditions for the general forms of distributions admitting sufficient statistics in regular cases, are assumed, but their use is minimized. It is shown that if in the pure non-regular cases the Koopman regularity conditions are assumed in addition, the general forms are obtained with considerable ease. Somewhat simple alternative derivations of the general forms in mixed type non-regular cases are also given, assuming in full the Koopman regularity conditions.

Some properties of univariate distributions depending on location or scale parameters, or on both parameters of location and scale, are obtained, both for regular (i.e., when the range of a distribution does not depend on the parameters) and non-regular types. It is then shown under fairly general conditions that all the well-known location-parameter, or scale-parameter, or location-scale-parameter families of univariate distributions are characterized by combinations of the properties of location or/and scale, and sufficiency. Thus the family of normal distributions (with known scale parameter) and the family of generalized iterated exponential distributions (with known scale and numerical parameters) are the only location-parameter families of distributions of the regular type admitting a single sufficient statistic for the location parameter. The scale-parameter families of distributions of the regular type admitting a single sufficient statistic for the scale parameter, include also the family of normal distributions (with known location) as a special case. The two-parameter family of univariate normal distributions is characterized as the only location-scale-parameter family of distributions of the regular type admitting a minimal pair of jointly sufficient statistics for the parameters of location and scale. The exponential family of distributions (with known scale parameter) is the only location-parameter family of distributions of the non-regular type admitting a single sufficient statistic for the location parameter. The scale-parameter families of distributions of the non-regular type admitting a single sufficient statistic for the scale parameter, include also the family of rectangular distributions as a special case. The two-parameter family of rectangular distributions is characterized as the only location-scale-parameter family of distributors of the non-regular type with ranges depending on both location and scale parameters, and admitting a minimal pair of jointly sufficient statistics for location and scale parameters. Finally, the two-parameter family of exponential distributions is characterized as the only location-scale-parameter family distributions of the non-regular type with ranges depending on a single parameter, and admitting a minimal pair of jointly sufficient statistics for location and scale parameters.

NSF project in random walk

Research on National Science Foundation project (GP-1801), "Problems in Random Walk and Statistical Applications," began in August 1963 with Herbert T. David as principal investigator. Three graduate students have worked on this project under David's direction.

Patricia Conn, who is trainee under NIH support, has been extending previous work on asymptotically exact truncation to non-binomial cases. This has led to some subsidiary work, such as the study of the interrelation between moment properties of the sequence of probabilities of absorption and of the sequence of probabilities attached to a given location by the unabsorbed sample paths. Mrs. Conn is working on her doctorate.

William D. Lawing, Jr., who is also studying for his Ph.D., carried on research on multi-decision extensions of the Wald sequential probability ratio test. Part of this work involved studying how far OC computations, based entirely on terminal probability ratio properties, can be carried in the case of a sequential two-decision region in the shape of a wedge. One finds that the OC can be computed exactly on an equally spaced grid when the origin lies in the center of the base of the wedge and the sample paths are generated by the Wiener process. In binomial and Poisson cases, approximate computations of high accuracy can be performed. Wedge OC computations and the simple Waldian computations for SPRT bands are then combined to yield OC functions for the multi-decision procedures generalizing a three-decision procedure originally proposed by Sobel and Wald in 1949. A substantial simplification obtains for a fairly large class of such multi-decision procedures where the OC functions are simple linear combinations of the two-decision OC's mentioned above. In the case of the Wiener process, some optimization computations have been carried out, based on simple asymptotic OC and ASN expressions valid for extreme μ.

Richard Mensing, who is studying for his master's degree, has been supported by the project. He has studied a general reflection principle for grids in the plane and has characterized situations where the principle applies; his work contains several illustrations. Asymptotic computations have been carried out in one set of cases, and it has been possible to apply the principle to counting paths with specified numbers of boundary contact points.

NSF project on methods of finding optimum operating conditions

Research on this project (Grant No. 19940) was

completed and reported in 1962-63 by O. Kempthorne, chief investigator, Robert E. Buehler, B. V. Shah and Thomas E. Doerfler. A report of the research was published in March 1964 in the Journal of the Society of Industrial and Applied Mathematics. An abstract of the publication appears on page 30 of this report. "The Method of Parallel Tangents," an invited paper presented by Buehler at the annual meeting of the American Institute of Chemical Engineers in New Orleans in March 1963, is being published in the Optimization volume of the Symposium Series of the Institute.

NSF project for research in theoretical statistics

Under NSF grant (GP-274) research in theoretical statistics was carried on by T. A. Bancroft, chief investigator, K. C. Chanda, co-investigator, and Florence Tetreault, Ahmed El Mawaziny, Richard Swanson and Fred L. Ramsey, NIH trainee.

K. C. Chanda with Fred L. Ramsey, NIH trainee, investigated a particular type of non-stationarity in stochastic processes. The non-stationary process is assumed to be the sum of a regression function, linear in form, and a stationary residual which forms a linear autoregressive scheme. Three procedures are available for estimating the regression and the autoregressive parameters: (i) the two-stage least squares procedure of estimating the regression parameters, ignoring the autocorrelation of the residuals, and then using estimated residuals to estimate the autoregressive parameters, (ii) Durbin's procedure, and (iii) the non-linear "full information" procedure of simultaneous estimation.

For the particular cases when the regression is polynomial or trigonometric, each of these three methods yields estimators which are asymptotically efficient. It is therefore desirable, and perhaps necessary too, to consider the sampling properties of these estimators when the sample size is "small." One expects that the sampling properties would then be different for different estimation procedures, and as a result an effective basis for comparing the methods would obtain. With this in mind, asymptotic expansions for the estimators have been derived, and expressions for the bias and covariances have been obtained to order n^{-1} from the appropriate terms in the expansions.

Sampling properties of the "goodness-of-fit" tests for linear autoregressive schemes due to Bartlett and Diananda and to Quenouille have next been investigated in the case when a trend is present. The first two moments of the test criteria were calculated to order k/n, where k is the number of degrees of freedom associated with the asymptotic chi-square distribution of the test statistics. A part of this research was presented by Chanda and Ramsey at the spring meetings of the Institute of Mathematical Statistics at Manhattan, Kansas, in a paper on "Sampling Properties of Estimators in Linear Autoregressive Schemes When Trend Is Present." This material is part of Ramsey's Ph.D. thesis.

Miss Florence Tetreault, who has worked on her Ph.D. thesis problem under Bancroft, has obtained some results on statistical outlier methodology for observed points and lines. The objectives of an outlier test for observed points are (i) to identify aberrant observations, and (ii) to permit subsequent valid inferences based on the data as determined by the outlier test. Previously no work, involving explicit derivations of bias and mean square errors in the case of estimation after an outlier test or power and size in the case of a subsequent test after an outlier test, has been done on the second of these two objectives. An attempt is being made to consider the second of the two objectives by developing a theory based on inferences for incompletely specified models. An attempt also is being made to extend this theory to include the case of observed lines.

Ahmed El Mawaziny has prepared a report on "Distribution of Weighted Sums of Chi-Square Variates." This material is part of the research for a proposed Ph.D. thesis problem being prepared under the direction of Dr. Robert Buehler, formerly of the statistics staff at Iowa State, but now at the University of Minnesota. The paper is concerned with attempts to obtain the sampling distribution of a linear function of several Chi-square variates. Three aspects of this problem are considered in detail: (i) the distribution of a quadratic form which can be transformed to a linear function of Chi-square variates, (ii) a review of early work concerning the distribution of a linear function of Chi-square variates presenting exact as well as approximate results, and (iii) the derivation of a new closed finite expression for the density function of the positively weighted Chi-square variates with even number of degrees of freedom.

Richard Swanson investigated the problem of finding a suitable approximation for the null distribution of F_0, the ratio of the within samples mean square and the between samples mean square, for k samples drawn independently from k binomial populations. Two different types of approximations were used for this purpose. The first involved the Standard Edgeworth expansion, although it was pointed out that an account of the discrete nature of the population an expansion due to Esseen would possibly be more appropriate. The second approximation was also based on the Standard Edgeworth expansion with the difference that each one of the binomial variates was first randomized by using a suitable chance mechanism and the statistic F_0 was then defined in terms of these randomized observations. The results for both the approximations were similar in form.

NSF project on incompletely specified models useful in life testing

Work has continued on this project (GP-1855) during 1963-64 with T. A. Bancroft as chief investigator. A paper was prepared by Bancroft, "A Statistical Inference Theory for Incompletely Specified Models," which will be presented as an invited paper at the annual meetings of the Institute of Mathematical Statistics at Amherst, Massachusetts, in August 1964. A second paper was prepared by Dale O. Richards, who is now Associate Professor of Statistics at Brigham Young University, on "Inference for Incompletely Specified Models in Life Testing," based in part on his Ph.D. thesis, an abstract of which was included in the 1962-63 Annual Report of the Statistical Labora-

tory. This paper will also be presented as an invited paper at the Amherst meetings of the IMS.

In the first paper an attempt was made to initiate the formulation of a common basic theory for consecutive inference problems involving a preliminary test of significance to determine an appropriate model for subsequent inferences. In consecutive inference theory, a single sample is available for investigating two or more questions that are potentially of interest and are taken up one by one. Procedures based on the concept of an incompletely specified model are considered for such problems, rather than a consecutive decision theory approach based on conditional procedures. An evaluation of the effectiveness of inference procedures based on incompletely specified models is made by consideration of bias and mean square error in the case of estimation after a preliminary test and of power and size in the case of a test after a preliminary test.

The second paper provides an illustration of the use of the general theory described in the first paper. In particular, estimation and test of one particular parameter, after a preliminary test on the other parameter, for the two parameter exponential distribution used in life testing were discussed in great detail. For certain values of the parameters involved, estimation and test of one particular parameter using the incompletely specified model were found to be more effective than that based on the completely specified model of either one or two parameters.

NSF project on residuals in randomized experiments

The National Science Foundation Grant (No. 14237) for research on the Properties of Computed Residuals in Randomized Experiments has been administered by the Statistical Laboratory and the Industrial Science Research Institute under the direction of O. Kempthorne. During 1963-64 Francis Giesbrecht has carried on his research on the project.

The properties of the residuals obtained after fitting a model of the type $y_{ij} = \mu + a_i + b_j + e_{ij}$ to an r by c array of numbers, i.e., $z_{ij} = y_{ij} - y_{i.} - y_{.j} + y_{..}$ were examined under two different models. Under the randomization model the means, variances and covariances of the residuals are identical with those obtained if the e_{ij} are independent $N(0, \sigma^2)$. The third moment is zero only if the sum of the third power of the errors is zero. The third moment tends to zero as the number of treatments per block is increased. The fourth moment of the residuals under the finite error model is smaller than the corresponding term under the assumption of independent normal errors.

If it is assumed that one observes $x_{ij} = K_1 y_{ij} + K_2 y_{ij}^2$ where the y_{ij} are defined as above and the errors are assumed to be independent $N(0, \sigma^2)$, the expected value of the residuals depends on both the main effects and σ^2. The third moment of the residuals is not equal to zero, indicating a skew distribution. The direction depends on the main effects. The analysis of variance of the squared residuals was examined under the model $y_{ij} = \mu + a_i + b_j + \gamma_{ij} + e_{ij}$ where $\Sigma a_i = \Sigma b_j = \Sigma_i \gamma_{ij} = \Sigma_j \gamma_{ij} = 0$ and the e_{ij} are independent $N(0, \sigma^2)$. The expected values of the sums of squares due to rows, columns and error indicate that some information can be obtained by comparing the estimates of these quantities.

If the sum of squares with one d.f. for Tukey's test of non-additivity is written as A/B, where B is the product of row sum of squares and column sum of squares, then the expected value of A under the randomization model is

$$\sum_{ij} \sigma^2 \, b_{ij}^2 \left[a_i^2 + \left(\frac{c-2}{c^2}\right) \left(\frac{r-1}{r}\right) \sigma^2 \right].$$

Attempts were made to examine the properties of A/B under randomization.

Several modifications of Tukey's test for non-additivity have been examined. These can be motivated by the fact that the sum of squares due to non-additivity is the sum of squares due to the regression of the residuals on the product of corresponding marginal means. A method has been obtained whereby it is possible to compute the power of the test obtained if the estimated marginal effects are replaced by their ranks. This has also been extended to the case of a sum of squares for non-additivity with several degrees of freedom by computing the sum of squares due to the regression of the residuals on the products of powers of the row ranks and powers of the column ranks simultaneously.

NSF project on Monte Carlo studies in genetic selection

The National Science Foundation (G-19218) and the Agricultural Experiment Station (Project 1508) jointly supported studies in genetic selection under the supervision of O. Kempthorne, D. L. Harris and L. N. Hazel of the Department of Animal Science. Esmat S. Nouri, A. W. Qureshi, Klaus Hinkelmann and W. G. Hill assisted with the research.

E. S. Nouri did a Monte Carlo study of the effectiveness of selection for a quantitative attribute in finite populations which reproduce by full-sib mating, that is, the most intensive regular inbreeding system other than selfing. Offspring population sizes of 4, 8, 12 and 16 were considered. The general form of this study and the main results are given elsewhere. The main purpose was to obtain some idea of the main effects of population size, amount of environmental variance and degree of linkage in a polygenic situation (40 loci) with several different models of gene action, and to investigate the extent to which these factors interact. The general conclusion was that the effect of selection intensity was predominantly related linearly to the usual quantity z/b, and linkage appeared to have linear and quadratic effects over the range investigated (recombination rates of 0.5, 0.2, 0.05 and 0.005 between successive loci). Environmental variance behaved similarly. There were, of course, tremendous differences between models. In general the evidence for interaction of the factors that were studied was only moderate. Attempts to represent the effects of selection by some sort of prediction equation were basically unsuccessful.

Kempthorne and Hinkelmann made initial attempt to refine the infinitesimal theory of quantitative selection, which effectively gives only the short-term effect

for very slow selection and does not take account of the changes in the statistical parameters of a population which are brought about by selection.

Kempthorne has done initial work on the theory of truncation selection for situations involving one or two loci, with and without environmental variability for infinite populations. The selection theory in the literature deals with the case in which genotypes express themselves as unvarying phenotypes, and there are fixed rates of selection on these phenotypes. The level of selection intensity, therefore, depends on gene frequency. The alternative approach is to examine what happens if one takes the best S (a fixed fraction) of the population as the basis, under random mating, of the next population. Even in the absence of linkage, selection will give the appearance of linkage in the successive infinite populations that are generated. This effect, which may be termed selection-induced apparent linkage, seems to be of some relevance to the theory of polygenic selection. Some rather crude approximative formulae for the progress of infinite populations have been developed for some of the simpler situations. The need for development of such formulae is clear from the various Monte Carlo studies that have been done under the project.

The work of A. W. Qureshi on this project was aimed at developing an empirical polygenic theory of the consequences of truncation selection in small populations when possible linkages between loci are considered. Attempts were made to relate the intensity of selection, parental population size, and certain systematic linkage patterns with the rate of change in the genotypic mean and variance, with the total change when all loci are fixed, and with the number of generations required to attain fixation. A 3^4 factorial experiment was set up to explore such relationships. Also, sampling distributions of the genotypic mean and variance in each generation and the limiting distribution of the genotypic mean were studied in relation to the above factors.

Programs for the IBM 7074 were developed to simulate the basic Mendelian processes in the case of one locus, two linked loci, and a multiple of 10 loci with symmetric linkage patterns. The logic and procedure for programming is described in a mimeograph report No. MC-8.

Quadratic functions of t and exponential functions of the form $y_t = \sum_{i=0}^{2} \beta_i e^{-a_i t}$ appeared to describe adequately y_t, the observed genotypic mean in t-th generation. From the estimated values of the parameters with a quadratic fitting, it appeared that the effect of linkage with respect to the rate of response to selection is considerable only when population size is very small and linkages between certain loci are very close. The number of generations to fixation was shown to increase due to linkage, and in small populations this delayed response was associated with a depression of the total response because of increased level of inbreeding. These results and the observations on the role of linkage in bringing about operational plateaus in the case of dominance are given in the mimeographed technical reports MC-6 and MC-9.

A study was made of the distribution of total response with 50 replications of different combinations of selection intensity, linkage and population size for the additive model. The variability between replicates is a function of population size and linkage. Some of the effect of the inbreeding resulting from the finite population size can be overcome by crossing replicates, but such crossing does not overcome the depressing effect of linkage, which can be offset only by large population size.

W. G. Hill worked on properties of mathematical models of gene action with reference to the possible utility in Monte Carlo studies of genetic selection. The models considered were symmetric in the loci and involved the same gene frequency at all loci. The motivation was to obtain ideas of simple models in which epistacy accounted for an appreciable portion of the variance over a large part of the possible range in gene frequency so as to investigate the role of epistacy in selection. This turns out to be rather difficult.

Hill, Hinkelmann and Kempthorne examined the situation in which the overall genotype is composed of several subgenotypes, and the overall genotypic value is a function of the value in each subgenotype. Also the properties of some symmetric models were examined when gene frequency is not the same at all loci, but the frequencies at the separate loci are independent random variables from a Beta distribution. Hill also examined the partition of genotypic variance into the usual components when there are threshold effects.

The following mimeographed reports have been prepared on the Monte Carlo project:

MC-1 "Effect of Population Size, Selection Intensity Linkage and Non-additive Variability upon Genetic Change in Simulated Populations"—John L. Gill

MC-2 "Covariances of Relatives in Random Mating Populations with Linkage" — Mauritz van Aarde

MC-3 "Properties of Simple Models of Quantitative Gene Action for Monte Carlo Studies"—William G. Hill

MC-4 "Components of Variance for Theoretical Models of Quantitative Gene Action"—W. G. Hill, K. Hinkelmann and O. Kempthorne

MC-5 "The Partition of Phenotypic Variances for Threshold Traits"—W. G. Hill and O. Kempthorne

MC-6 "A Monte Carlo Evaluation of the Role of Finite Population Size and Linkage in Response to Continuous Mass Selection. I."—A. W. Qureshi

MC-7 "The Role of Monte Carlo Studies in Genetic Research"—Dewey L. Harris

MC-8 "Computer Programs for the Simulation of Genetic Processes"—A. W. Qureshi

MC-9 "A Monte Carlo Evaluation of the Role of Finite Population Size and Linkage in the Response to Continuous Mass Selection. II. Dominance and Overdominance" — A. W. Qureshi

Dewey L. Harris, assistant professor of statistics, was born in Texas. He received his B.S. degree from Texas A and M University in 1954 and worked as an assistant county agent with the Texas Agricultural Extension Service for a year. He served as lieutenant in the U. S. Army for two years. In 1958 he received his master's degree in animal breeding from Texas A and M, continued work toward his doctorate at Iowa State, and was awarded his Ph.D. degree in May 1961 with a major in animal breeding and with minors in statistics and genetics.

Harris became an instructor in statistics in December 1960 and in March 1961, upon completion of his doctorate requirements, was promoted to assistant professor in the Statistical Laboratory and the Department of Statistics. He has taught courses in genetic statistics, mathematical statistics, and statistical methods and theory, and conducts research under the Iowa Agricultural and Home Economics Experiment Station and National Science Foundation projects in genetic statistics and Monte Carlo studies in genetic selection.

Harris is the author of several publications. He is a member of Alpha Zeta, Phi Kappa Phi, Gamma Sigma Delta and Sigma Xi honorary fraternities, the American Statistical Association, Biometric Society, the American Genetic Association and the American Association for the Advancement of Science. He was president of the Iowa Chapter of the American Statistical Association in 1962-63.

NSF project in genetic statistics

The basic genetic structure of the covariance between genotypic values of related individuals was investigated by Dewey L. Harris under a project financially supported by the National Science Foundation (G-18093) through the Agricultural Experiment Station (Project 1505). In this study, quantitative traits in inbred populations derived with no selection from populations with Hardy-Weinberg structure are considered. A general formula is developed for the genetic covariance between pairs of relatives with a certain relationship and with certain degrees of inbreeding. When there is no epistasis, this general formula involves five (or six) parameters and eight measures of the degree of relationship and inbreeding. These parameters are functions of the additive effects and dominance effects of the genes for the original random mating population. The measures of relationship and inbreeding involve Malécot's concept of identity by descent. In fact, these measures of relationship are probabilities of identity by descent of various sub-sets of the four genes occurring in the genotype of the two individuals. Many more parameters, but the same measures of relationship, are involved when there is epistasis with no linkage.

This work will be reported on at the AIBS meetings in August.

NSF project on distributed lags

The National Science Foundation (G-10926) supported a 3½-year study of distributed lags in econometric analysis with George W. Ladd of the Department of Economics and Sociology and Wayne A. Fuller as co-leaders of the project. The work was completed in August 1963 when a final report was written. Some of the results have also been reported in publications, in a Ph.D. thesis and in papers given at professional meetings.

An estimation procedure was devised for least squares estimation of linear models from time series data when successive disturbances are correlated. The procedure was programmed for the current IBM equipment and used to study consumer demand for food and durable goods and in a variety of other analyses. A second estimation procedure was devised for the analysis of experimental data when successive errors are autocorrelated and errors at the same point in time are also correlated. An IBM program was also prepared to perform these computations.

Distributed lag concepts are used to incorporate dynamic economic considerations into economic models, to describe the way in which expectations are generated, and to incorporate technological, institutional and uncertainty frictions into models. Distributed lag models proved useful in the analysis of short-term business behavior, for example, in monthly and quarterly inventory analyses and in short-term pricing behavior.

Distributed lag models were utilized in studies of monthly, quarterly and annual consumer demand and in studies of demand for producers' or consumers' durable goods.

NSF Grant for remodeling

A grant from the National Science Foundation to be matched by equal funds from the State of Iowa was made for the remodeling and renovation of the third floor of the Service Building for the use of the Statistical Laboratory and the Department of Statistics. The objective is to provide more adequate physical housing for research and research-related activities and thus to strengthen the research potential of the university. The NIH Group, the Industrial Statistics Group and the staff in general statistical theory will be housed on the third floor. The plan calls for offices for the professional staff and for graduate students in each area. Provision is also made for a machine laboratory for graduate students and for two seminar rooms. The area should be ready for use by January 1, 1965.

AES Research on design of experiments and analysis of data

Project 890 is a continuing project supported by on-campus funds of the Agricultural Experiment Station and directed by O. Kempthorne.

Research activities have been associated almost entirely with specific projects reported on elsewhere in this report.

Properties of mean squares in the analysis of variance under random sampling of factor levels and randomization of association of treatments and experimental units have been investigated and progress is reported under the WASD contract report on page 16.

Study of residuals in the analysis of variance has been made jointly with F. Giesbrecht, partially supported by an NSF grant. This is reported on page 21.

Research on quantitative genetics and the theory of selection for quantitative attributes has been done jointly with A. W. Qureshi on the NSF supported project on Monte Carlo studies of genetics, and with K. Hinkelmann on the NSF supported project for study of the use of genetic crosses in quantitative genetic research. (See pages 22 and 29.)

Some consulting with research workers on quantitative genetics in the departments of Agronomy, Animal Science and Poultry Science has also been done.

Research on mathematical genetics and genetic statistics

AES Project 1448, which is a continuing project supported by funds of the Agricultural Experiment Station, provides for consultation and research in mathematical genetics and genetic statistics under Dewey L. Harris. A major portion of the research activities of Harris on this project was concerned with the development of a basic set of parameters involved in generation means and covariances between means of related groups in individuals in populations where all reproduction is by self-fertilization. These results seem quite informative in showing how the basic genetic mechanism is manifested in the parameters descriptive of such populations. This work was reported on at the XI International Congress of Genetics in The Hague, The Netherlands, in September 1963, and has formed the basis for a technical paper submitted to Genetics for publication.

Also, a paper entitled "Biometrical Genetics in Man" was prepared for publication. This paper was presented at the Conference on Methods and Goals in Human Behavior Genetics Research at University of Louisville, April 1963, and will be published in the proceedings of that conference.

AES Research on design of surveys and analysis of data

Wayne A. Fuller continued his research under Project 1005, a continuing project supported by on-campus funds of the Agricultural Experiment Station. Research on regression and unbiased regression estimation was conducted. An unbiased regression estimator was developed for those situations where the variance of the control variable is known. Unlike most regression estimators, an exact variance was derived for the estimator.

Work on the relationship between county population and the cost of county government was carried out in cooperation with members of the Department of Government.

Research on estimates for extremely skewed populations was also conducted. Carlos Cavallini wrote his master's degree thesis on "Estimation of Population Totals Given Samples from Similar Populations." The thesis abstract appears on page 32.

A paper by Fuller and others on "Effect of Age on the Growth of Porcine Muscle," reporting research carried on last year, was published in the Journal of Animal Science in November 1963. (Abstract on page 27.)

AES Research on agronomic experiments

Research was initiated under Project 1578 on the statistical and economic analysis for long-term, rotational agronomic experiments. Foster B. Cady and Wayne A. Fuller were co-leaders in charge of the project, together with two leaders from the Department of Agronomy.

Some preliminary work involving rotation experiments had been done under projects 101 and 1005 prior to this fiscal year. Model construction and consequent statistical analyses are now underway, using data from the rotation experiment on Kenyon silt loam at the Carrington-Clyde Experiment Station. The hypothesized model considers the structure of a rotation experiment, i.e., that the time series of yields for a particular rotation may be broken into cycles. It has also been hypothesized that the trend in yields is an exponential function. The resulting model is non-linear in the parameters and thus special estimation techniques are required. Preliminary results were presented in a paper by Cady and Fuller, "Estimation of Asymptotic Rotation and Nitrogen Effects," which was given at the annual meeting of the American Society of Agronomy in November 1963.

Investigations of modifications of the present hypothesized model are continuing. Special emphasis is being placed on testing the hypothesis that rotation effects are in essence nitrogen effects, and that, by a suitable scale transformation, the yields from rotation experiments may be expressed as a simple response function of nitrogen.

USDC, Bureau of the Census, Research in sample census methods in agriculture

The 1962-63 contractual research project in statistics supported by the USDC, Bureau of the Census, and administered jointly by the Statistical Laboratory and the Agricultural Experiment Station, was continued. Wayne A. Fuller, as project leader, and Harold Baker, Thomas Jetton and Helen Ayres worked on the study. The purpose of the study was to develop and test methods for the evaluation of data to be collected in the 1964 Census of Agriculture.

A panel operation was reported last year in which information was collected on certain farm transac-

tions. Two runs were conducted. A third run was made in July 1963, and a smaller one in September 1963 was concerned primarily with on-farm stocks of corn produced in 1962. The Bureau of the Census is now conducting an evaluation operation using procedures developed in cooperation with the Survey Group. The Survey Group is currently participating in the operation of the program in parts of the midwest.

A new research project for the Bureau of the Census was begun in January 1964. Present plans call for this to be a continuing program of cooperation. The first contract provides for the study of alternative procedures for constructing estimates utilizing outside information with the purpose of characterizing them from the point of view of statistical efficiency and the control of sampling biases. Estimation techniques utilizing outside information such as census data include regression estimation, ratio estimation, and post-stratification. Work on estimation for rotating designs is also contemplated. Martin Rosenzweig will report this research in his master's degree thesis.

SRS, USDA research

The Laboratory's research in sample census methods in agriculture was continued by agreement with the Agricultural Estimates Division of the USDA. A joint project of the Statistical Laboratory and the Iowa Agricultural and Home Economics Experiment Station, the work on this Project 1207 is supported mainly by funds from the Statistical Reporting Service. Norman V. Strand, Wayne A. Fuller, Robert Cochran and Harold Baker worked on the project. The object of this work is to improve the accuracy of yield estimates and forecasts which serves to improve the efficiency of administration of government programs as well as aiding farmers and feeders in planning their operations.

Cochran and Baker worked on the grain sorghum study. Observations on plant and head characteristics and number of plants were obtained from plots located on a sample of 50 farms in nine counties in southwestern Iowa. Each plot was visited three times between August 5 and October 15. In addition, a gleaning operation was carried out on ten of those farms. The data was used to provide an early season forecast of yield, a harvest time estimate of yield, and an estimate of the amount left in the field after harvest.

Harold Baker also worked on the development of objective methods for determining pasture production. A total of 56 plots were laid out in four university pastures. Observations were taken from late April until the middle of October. Twelve of the plots were clipped and relocated at one-week intervals, twelve at two-weeks intervals, and sixteen at four-week intervals. The data was used to estimate pasture production and to compare estimates computed using different cutting intervals.

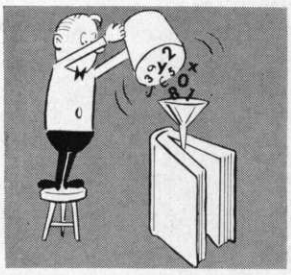
SCS, USDA Special survey projects involving applied research

Sampling in Soils Surveys, Project 1312, under the cooperation of the Statistical Laboratory and the Soil Conservation Service, USDA, and the Agricultural Experiment Station, was continued under the direction of N. V. Strand.

USDA Branch Field Office

A research field office of the United States Department of Agriculture is located within the Statistical Laboratory. This field office is a part of the Statistical Standards Division of the Statistical Reporting Service established by the federal government. Its general function is to conduct research in connection with sampling problems, survey procedures, and theory of mutual interest to the Statistical Standards Division and the Statistical Laboratory. The field office is staffed on a part-time basis by N. V. Strand and M. Kirwin. Its work during 1963-64 was again connected mainly with the Sorghum and Pasture Study already described.

Publications



The members of the Statistical Laboratory staff have written numerous articles describing their research, many of which have been published in professional journals. Staff members have also served in editorial positions or as referees for these journals. Foster B. Cady has been in charge of abstracting articles for the International Journal of Abstracts, Statistical Theory and Methods. Herbert T. David and George Zyskind have served as referees for the Annals of Mathematical Statistics during 1963-64.

Record of Published Research

Publications dealing with the research of the Laboratory are listed in the following pages, with a brief summary of each. Some of these publications are included in the Reprint Series of the Laboratory and copies are available upon request. These are indicated by an asterisk.*

Om P. Aggarwal, "First National Agricultural Census in Peru. Principal Results Obtained by Sampling." National Bureau of Statistics and Census, Lima, Peru. 62 pp. + xiv. November 1963.

The sample used for obtaining principal results of the agricultural census in Peru was a stratified systematic list sample of the census schedules. The primary strata were the districts, the smallest geo-

graphical and political subdivisions of the country, and within districts there were three strata, (i) all agricultural holdings considered as "more important" (M.I.) on the basis of the total area, area under temporary or permanent crops or cultivated meadows, or the number of animals, usually cattle or sheep, (ii) all holdings which did not qualify as M.I., but had a total area of 5 hectares or more, and (iii) all holdings with a total area of less than 5 hectares. The criteria for designating a holding as M.I. were established for each department in accordance with the agricultural conditions and the need for obtaining reliable departmental estimates. The M.I. holdings were included on a 100 percent basis and the sampling fraction for (ii) and (iii) varied with individual departments. The sample, apart from the M.I. holdings, was divided into 5 independent subsamples. The first preliminary results were based on the M.I. holdings and only one subsample. Later the area figures were obtained on the basis of 3 subsamples and the production figures utilized all the 5 subsamples. The sampling scheme was successful in obtaining results with an increasing degree of precision with checks built in against gross nonsampling errors.

*__Harold J. Larson__ (U. S. Naval Postgraduate School, Monterey, California†) and **T. A. Bancroft,** "Biases in Prediction by Regression for Certain Incomplete Specified Models." Biometrika 50: Parts 3 and 4, 391-402. December 1963. (Jour. Paper No. J-4660, Iowa Agri. and Home Ec. Exp. Sta., Ames, Iowa. Project 169) Reprint Series No. 139, Statistical Laboratory, Iowa State University.

This publication is concerned with the consequences of an experimenter separating the independent variables in a multiple regression model into two classes: (1) those the experimenter is sure are necessary for accurate predictions, and (2) those 'doubtful' variables which will be included in the model if the joint preliminary hypothesis (that the 'doubtful' coefficients are simultaneously zero) is accepted. Designating the predictand finally adopted as y^*, then y^* is dependent on either k predictors (keep all independent variables) or on m predictors (accept the hypothesis that k-m of the coefficients are jointly zero and delete the corresponding k-m independent variables from the model).

The expected value (thus exhibiting an explicit evaluation of the bias) and the mean square error of y^* were derived. Some tabular values were obtained to illustrate the numerical size of the bias in certain situations. An example was constructed to illustrate the use of those tabular values and the mean square error was numerically evaluated and discussed for the example.

The inference procedures used in this paper, incorporating a preliminary test of significance, belong to a general class of such procedures relating to the analysis of incompletely specified models. Some general comments on inference for incompletely specified models are presented and references are made to other papers in this general area.

T. A. Bancroft, "The Role of a Statistical Center in a University." Mimeo-Multilith Series No. 6, Statistical Laboratory, Iowa State University. March 1964.

The methodology of statistics, as part of scientific method in acquiring new knowledge, has proved useful in many scientific fields. In view of this it seems highly desirable that graduate students, in substantive fields using this methodology, should have the opportunity to study statistics at least as a research tool. The program in statistics should be determined by the size and particular requirements of the university. A complete statistical center should provide (i) a research and teaching program as a discipline in its own right; (ii) an undergraduate and graduate service teaching program to provide basic courses in theory and methods and specialized courses in statistics for students majoring in some substantive subject matter area; (iii) a consulting program; and (iv) a computer oriented numerical analysis and programming service for the analyses of data of a statistical nature resulting from research investigations.

Problems of staffing a center, sources of financial support, the relation of the center to other departments and institutes of the university, and administration problems are discussed.

T. A. Bancroft, with **W. J. Hemmerle** and Robert W. Clyde (See Hemmerle, Fall 1963).

*__Robert J. Buehler__ (University of Minnesota) and **Alan P. Feddersen** (N. Amer. Aviation, Anaheim, Calif.), "Note on a Conditional Property of Student's t." Annals of Mathematical Statistics 34: 3, 1098-1100. September 1963. Reprint Series No. 132, Statistical Laboratory, Iowa State University.

For one degree of freedom the 50 percent fiducial interval based on Student's t is $x_{min} \leq \mu \leq x_{max}$. In the subset $3 \mid x_1 - x_2 \mid \geq 2 \mid x_1 + x_2 \mid$ it is shown that for all (μ, σ), $x_{min} \leq \mu \leq x_{max}$ occurs with probability exceeding 51.8 percent. The choice of subset is based on Stein's 1961 Wald Lectures.

R. J. Buehler, with M. M. Lentner (See Lentner, September 1963)

F. B. Cady and W. V. Bartholomew, "Investigations of Nitric Oxide Reactions in Soils." Soil Science Society of America Proceedings 27: 5, 546-549. September-October 1963.

The equilibrium reaction between NO (nitric oxide) and nongaseous compounds in the denitrification process was studied. Increments of NO were added to or removed from denitrification systems during the course of incubation.

Nitric oxide rapidly equilibrates isotopically with nongaseous products during the early stages of denitrification. Under acid soil conditions NO appeared in the gaseous phase. Under basic soil conditions NO did not appear from denitrification reactions but

*Indicates reprints are available.

†When research was carried on by a staff member who has gone on to another position, the institution with which he is now connected is given in parentheses.

added NO persisted in the system and isotopically equilibrated with the nongaseous products in the soil. The equilibrium reactions between NO and the nongaseous compounds in the denitrification system could not be adequately explained by the conventional equation $3NO_2^- + 3H^+ \rightleftarrows NO_3^- + H^+ + 2NO + H_20$. The hypothesis is advanced that other reactions and products are involved.

*K. C. Chanda, "Asymptotic Expansions for a Class of Distribution Functions." Annals of Mathematical Statistics 34:4, 1302-1307. December 1963. Reprint Series No. 138, Statistical Laboratory, Iowa State University.

Investigations have been made in the past by several authors on the possibility of extending the content of the classical central limit theorem when the basic random variables are not mutually independent. Mention may be made in this connection of the work done by Hoeffding and Robbins, Diananda, and Walker. However, no attempt has been made so far to investigate whether the type of asymptotic expansions as discussed by Cramer, Berry, Hsu and others for the distributions of means of independent random variables could as well be extended to apply to situations where the random variables are not independent. An attempt has been made in this paper to investigate this problem somewhat systematically. The main results are the following: (i) Let $X_1, \ldots X_n$ be a sequence of stationary m-dependent random variables with $\Sigma(X_1) = 0$. If $F_n(x)$ denotes the distribution function of $\Sigma_{t=1}^n X_t/s_n$ where $s_n^2 = V(\Sigma_{t=1}^n X_t)$ and $F(x)$ is the standardized normal distribution function, then under usual regularity conditions $\text{Sup}_{-\infty < x < \infty} | F_n(x) - F(x) | \leq M/n^{1/2}$ where M is a finite positive constant. (ii) If $\{X_t\}$ is a linear process with $\Sigma(X_t) = 0$, $\Sigma | X_t |^r < \infty$ for some $r \geq 3$, then $\text{Sup}_{-\infty < x < \infty} | F_n(x) - F(x) \leq M/n^{r-2/2}$.

*C. Philip Cox, "Statistical Principles for the Line of Best Fit." Laboratory Practice 12: 8, 733-740. August 1963. Reprint Series No. 133, Statistical Laboratory, Iowa State University.

In discussing some principles of statistical estimation and inference, showing how they enter and assist in the problem of fitting a line to a set of data, the author divides his paper into a number of sections. These cover the mathematical model, estimating the line of best fit, calculating and fitting the sample regression line, the significance of the regression coefficient, determining the limits for significance, the t-test for significance, and numerical example.

L. J. Circeo, D. T. Davidson and **Herbert T. David,** "Relationship Between Cement Content and Freeze-Thaw Loss of Soil-Cement Mixtures." Highway Research Record, No. 36, Highway Research Board Publication 1156: 133-149. 1963.

Although the freeze-thaw test was originally devised to measure the hardening effect of Portland cement on soils, it has become useful as a reliable criterion for the determination of the durability of a soil-cement mixture. One great disadvantage of this test is the large amount of labor necessary to complete the freeze-thaw test. This paper attempts, by correlation analysis, to reduce the amount of testing required to conduct a reliable freeze-thaw evaluation of a soil-cement mixture.

A strong logarithmic relationship was found to exist between the cement content and the freeze-thaw loss of a soil-cement mixtures. Two freeze-thaw tests will establish the logarithmic relationship for any soil type. From this relationship the cement content that will produce a satisfactory freeze-thaw loss can be determined.

Thomas E. Doerfler and **O. Kempthorne,** "The Compounding of Gradient Error in the Method of Parallel Tangents." Interim Technical Report on Air Force Project AF 33(616)8269, published by Aeronautical Research Laboratory, Office of Aerospace Research, U. S. Air Force, Wright-Patterson Air Force Base, Ohio. August 1963.

This report considers the problem of determining by successive experiments the input conditions which optimize a response. An investigation is made of the role of observational error on the performance of two competing iterative methods. Chapter I gives a general description of the contents of the report. Chapter II contains terminology used and describes the two-path methods considered, steepest descent and steepest descent partan. In Chapter III a gradient error is introduced. Certain restrictive assumptions are made, and equations are developed which represent a response in terms of a surface, contour, starting point, and error. A criterion which measures performance is developed and then averaged over a collection of starting points and errors for each competing method. Chapter IV gives the numerical results of representative inputs considered, and Chapter V contains a summary and conclusions.

C. E. Elson, **Wayne A. Fuller,** E. A. Kline and L. N. Hazel, "Effect of Age on Growth of Porcine Muscle." Journal of Animal Science 22: 4, 946-952. November 1963. (Jour. Paper J-4565, Iowa. Agri. and Home Ec. Exp. Sta. Project No. 1239.)

Muscle determinations were obtained from five litters of crossbred barrows. The determinations were made at 45-day intervals commencing at 45 days of age with the final determination at 180 days. The muscle fiber area, percent fat, percent water and iodine number of the *longissium dorsi, psoas major, semi-membranosus* and *semitendinosus* muscles were determined. Growth curves of the form $y = K + be^{at}$ and of the form $y = \frac{A}{1 + be^{at}}$ were fitted to the determinations on the four muscles. Growth rates varied by muscles and in certain cases by litters. It was inferred that increasing age caused a decrease in the muscular water content and iodine number and an increase in fiber size and fat content. Using the given form, $y = K + be^{at}$ and with a limited number of observations, it was estimated that the *longissimus dorsi* fibers had completed 70 percent of their growth at 180 days whereas the *psoas major* fibers had completed 50 percent of their growth and the *semiten-*

dinosus fibers, 99 percent. At 135 days, the percent of fat was apparently no longer increasing in the *psoas major* whereas in the *semimembranosus* and *semitendinosus* the percent of fat was increasing at an increasing rate.

E. O. Heady, G. P. Poehrkasse, Walter Woods, J. M. Scholl and **Wayne A. Fuller**: "Experimental Production and Profit Functions for Beef Steers." Canadian Journal of Agricultural Economics XI: 2. 1963.

Estimates of functions relating gain of feedlot time and grade to corn and soilage consumption are presented. Estimates of the production function were derived under the assumption of first order autocorrelation in the errors. These functions are then used to indicate optimum feeding patterns.

***Dewey L. Harris,** "Expected and Predicted Progress from Index Selection Involving Estimates of Population Parameters." Biometrics, 20:1, 46-72. March 1964. (Jour. Paper No. J-4591, Iowa Agri. and Home Ec. Exp. Sta. Project 1055.) Reprint Series No. 145, Statistical Laboratory, Iowa State University.

The nature of the index selection procedure when sample estimates are used in place of the true parameter values is considered. Approximate equations are developed for the low order moments of the joint distribution of the expected progress from selection for a particular calculated index and the predicted progress from this index. These equations involve the variances and covariances among the estimates used for index construction. Formulae are developed for these variances and covariances for paternal half-sib estimation. This joint distribution is also studied by a simulated sampling procedure. Numerical results for the two phases of the study are tabulated and studied for verification of the validity of the approximate equations and for assessment of the influence of the errors of estimation upon index selection procedures when estimates are obtained from paternal half-sib analyses of variance and covariance.

***H. O. Hartley** (Texas A and M University, College Station, Texas) and **Ronald Hocking** (Texas A and M University): "Convex Programming by Tangential Approximation," in Management Science 9: 4, 600-612. July 1963. Reprint Series No. 129, Statistical Laboratory, Iowa State University.

This paper describes an algorithm for the solution of the convex programming problem using the simplex method. The algorithm is computationally very simple, requiring the solution of a single linear programming problem which can be accomplished with only slight modification of existing computer codes for the modified simplex method.

***H. O. Hartley** (Texas A and M University, College Station, Texas) and **Dewey L. Harris**: "Monte Carlo Computations in Normal Correlation Problems," in the Journal of the Association for Computing Machinery 10: 3, 302-306. July 1963. (Jour. Paper No. J-4545 of the Iowa Agri. and Home Ec. Exp. Sta. Project 1505.) Reprint Series No. 131, Statictical Laboratory, Iowa State University.

A procedure is developed for the Monte Carlo generation of the two sample variances and the sample covariance for a sample of n paired observations from a bivariate normal distribution with arbitrary parameters. This procedure utilizes as a basis three generated standardized normal deviates and uses the Wilson-Hilferty approximation for generating the necessary chi-square variables. A numerical example is given for the generation of the values in the analyses of variance and covariance table for two attributes with a one-way classification model.

*Robert W. Clyde, **W. J. Hemmerle** and **T. A. Bancroft**: "An Application of 'Post Stratification' Technique in Local TV Election Predictions." The Public Opinion Quarterly 27: 467-472. Fall 1963. Reprint Series No. 134, Statistical Laboratory, Iowa State University.

The 1962 off-year election provided an opportunity for the Iowa State Statistical Laboratory to develop and test a design for local prediction of the upset in the Iowa gubernatorial contest. County-by-county vote returns were transmitted by telephone from the Des Moines Bureau of the Associated Press on a regulated frequency throughout the evening. Cumulative vote totals were keypunched into IBM cards and verified. Computations for the analysis were made on an IBM computer.

Counties were stratified in a two-way stratification based on population and voting behavior. From the design established, it was possible to use two stratified ratio estimators with predictive capabilities superior to an "uncorrected observed percentage." One difficult problem is that partial vote returns must be used in the order received. Consequently the sample is not a random sample, and the uncorrected observed percentage is biased. To reduce the bias in the estimator, stratified ratio estimators were used. The combined ratio estimator, which employs precinct information to a limited degree, was found to yield a high degree of accuracy. When the combined ratio estimator is compared with the separate ratio estimator, the combined ratio estimator seems to yield a more accurate prediction. The separate ratio estimator, although it yields smaller variance, permits a larger bias and hence less accurate estimation of final percentages.

It is tentatively concluded that the combined ratio estimator provides a reasonably accurate method of election analysis and prediction for television reporting at the local level.

***W. J. Hemmerle,** "Algebraic Specification of Statistical Models for Analysis of Variance Computations." Journal of the Association for Computing Machinery 11: 2, 234-239. April 1964. Reprint Series No. 144, Statistical Laboratory, Iowa State University.

A method for computing an analysis of variance from an algebraic specification of the statistical model

is described. The model is written in a form consistent with usual statistical notation, but also suitable for computer input and logical manipulation. Calculations necessary to obtain the analysis of variance are then determined by the model. An outline of the computational procedures is given.

*K. Hinkelmann and O. Kempthorne, "Two Classes of Group Divisible Partial Diallel Crosses." Biometrika 50: 281-291. 1963. Reprint Series No. 140, Statistical Laboratory, Iowa State University.

The diallel crosses of n lines or individuals requires the development of $n(n-1)/2$ crosses and is often unfeasible because of the large amount of work involved. Partial diallel crosses (PDC) have therefore been developed. Such PDC's are necessarily related structurally to incomplete block designs with blocks of two units. In this paper, two classes of PDC are developed, based on a generalized group divisible and an extended group divisible partially balanced incomplete block (PBIB) designs with m associate classes. The treatments are represented by $(i_1, i_2, \ldots, i_m)$ where $i_j = 1, 2, \ldots N_j$, and the total number of treatments is $N = N_1, N_2, \ldots, N_m$. Association schemes are based on the likeness of components of the m-ple representation. The properties of the PBIB designs are developed. Possible PDC's based on these designs are described, and the analysis of the PDC's given. A selection of possible PDC plans is given.

*Klaus Hinkelmann: "Extended Group Divisible Partially Balanced Incomplete Block Designs." Annals of Mathematical Statistics 35:2, 681-695. June 1964. (Jour. Paper No. J-4754 of the Iowa Agri. and Home Ec. Exp. Sta. Project 1508.) Reprint Series No. 147, Statistical Laboratory, Iowa State University.

This paper deals with a particular class of partially balanced incomplete block designs for which the number of associate classes may be greater than 2. The number of treatments N is factorized as $N_1N_2, \ldots, N_v$, and a treatment denoted by $(i_1, i_2, \ldots, i_v)$. The associate classes are defined by ordered v-plets $\gamma = (\gamma_1, \gamma_2, \ldots, \gamma_v)$ where each γ_i is 0 or 1, and the v-plet $(0, 0, \ldots, 0)$ correspondends to the 0-th associate class. Hence, there are $(2^v - 1)$ associate classes. The association scheme is that two treatments $(i_1, i_2, \ldots, i_v)$ and $(j_1, j_2, \ldots, j_v)$ are γ-th associates, if they differ only in the components that correspond to unit components of γ. The uniqueness of the association scheme is established. Properties of the matrix NN', where N is the incidence matrix, and non-existence theorems based on the Hasse-Minkowski invariant of NN' are established.

O. Kempthorne, with K. Hinkelmann (See Hinkelmann, 1963.)

O. Kempthorne, with Thomas E. Doerfler (See Doerfler, August 1963.)

*M. M. Lentner (University of Maine) and R. J. Buehler: "Some Inferences about Gamma Parameters with an Application to a Reliability Problem." Journal of the American Statistical Association 58: 670-677. September 1963. Reprint Series No. 135, Statistical Laboratory, Iowa State University.

If z_1 and z_2 are gamma variates with scale parameters θ_1 and θ_2, then a UMPU similar region test can be found for the hypothesis $\gamma = \gamma_0$ where $\gamma = C_1/\theta_1 + C_2/\theta_2$ (Lehmann and Scheffe). Appropriate conditional distributions are given for $(C_1, C_2) = (1, 1)$ and $(1, -1)$. Application: A series system has two dissimilar components whose expected lives are θ_1 and θ_2. When component failures are exponentially distributed, so are system failures, the mean being $\theta = (\theta_1^{-1} + \theta_2^{-1})^{-1}$. From separate estimates of θ_1 and θ_2 one can obtain confidence limits for θ.

*J. N. K. Rao (National Council of Applied Economic Research, New Delhi, India) and Gerhard Tintner (University of Southern California, Los Angeles): "On the Variate Difference Method." The Australian Journal of Statistics 5: 3, 106-116. November 1963. Reprint Series No. 142, Statistical Laboratory, Iowa State University.

The variate difference method is often used as a quick and approximate method to find the order of the finite difference at which the systematic part (assumed to be smooth) of the time series, x_t, is eliminated, and then estimate σ^2. Here we confine ourselves to polynomial systematic parts only. The usual test procedure is to test for the significance of V_1/V_0, V_2/V_1, . . . in a sequence until a non-significant value is obtained, where V_0 is the variance of $x_t (t = 1, 2, \ldots N)$ and $V_k (k \geq 1)$ is the variance of the k-th differences (under a circular universe). However, the conditional nature of the test procedure is not taken into account in finding the percentage points. The conditional distributions in the usual procedure involve the unknown parameters of the systematic part.

Therefore, a modified test procedure is suggested that overcomes this difficulty. It consists in specifying the highest order of the difference at which to start the test procedure, say q+1, and then test for the significance of V_{q+1}/V_q, V_q/V_{q-1}, . . . in a sequence until a significant value is obtained. Since the exact joint distributions of these ratios are very complicated, asymptotic joint distributions of the ratios are obtained which are shown to be multi-variate normal. Due to the non-availability of tables for incomplete probability integrals of multi-variate normal, an approximation is suggested which uses only the bivariate normal tables, to find the conditional percentage points. Finally, we tabulate certain lower 5 percent and 1 percent conditional points for selected values of N and give an example to illustrate the use of the tables.

*J. N. K. Rao (National Council of Applied Economic Research, New Delhi, India): "On Two Systems of Unequal Sampling Without Replacement." Annals of the Institute of Statistical Mathematics (Tokyo) XV: 1, 67-72. 1963. Reprint Series No. 141, Statistical Laboratory, Iowa State University.

All systems of unequal probability sampling without replacement need not necessarily lead to estimators with variance always smaller than the variance in sampling with replacement. It is therefore useful to identify sampling systems for which the variance is always smaller than the variance with replacement sampling. In this note two such sampling systems are identified. It is also shown that the Yates and Grundy estimator of variance is always positive for the two systems.

*J. N. K. Rao (National Council of Applied Research, New Delhi) and **Jack E. Graham** (Dominion Bureau of Statistics, Ottawa, Ontario): "Rotation Designs for Sampling on Repeated Occasions." Journal of the American Statistical Association 59: 306, 492-509. June 1964. Reprint Series No. 148, Statistical Laboratory, Iowa State University.

When the same population is sampled on repeated occasions, it is well known that the use of rotation sampling may increase the precision of the estimators on the current occasion and of the change. Hansen et al. (J. Amer. Statist. Assoc., 1955) have developed composite estimators of the population total on the current occasion and of the change (e.g., quarter-to-quarter change in a quarterly survey). However, the variance of these estimators was not investigated in detail and, moreover, the population size N on each occasion was assumed infinite. The purpose of the present paper is to develop a unified finite population theory for the composite estimators. This is accomplished by considering that the finite population is the N′. possible rotation patterns (assuming that N is constant from occasion to occasion) and the sample consists of one random rotation pattern from this population. The rotation pattern of the sample is formulated as follows: n_2 units stay for r occasions ($n_2 r = n$ where n is the number of units in the sample on any occasion) and leave the sample for m occasions and then come back where m is seen to be equal to $r(N/n - 1)$. Then the general variance formulae for the composite estimators are developed and the optimum values of Q, the weight factor in the composite estimator, and the optimum values of r are determined for certain special correlation patterns of the characteristics in different occasions.

*Thomas D. Roseberry and Edmund A. Gehan: "Operating Characteristic Curves and Accept-Reject Rules for Two and Three Stage Screening Procedures." Biometrics 20:1, 73-84. March 1964. Reprint Series No. 143, Statistical Laboratory, Iowa State University.

A method for constructing operating characteristic curves and accept-reject rules for two and three stage screening procedures is given. These procedures allow rejection at any stage, but acceptance only at the final stage. The variable of interest, X, is assumed to be normally distributed with known test-to-test variance σ^2. If a value of γ is specified ($\gamma = .50, .95,$ or $.99$) and a value of the mean of X, $\mu = \mu_o$, such that Prod. (Acceptance $\mid \mu_o, \sigma$) $= \gamma$, a set of tables are provided which give simple formulae for calculating c_i, the accept-reject cut-off points for the i^{th} stage, and for obtaining probability points on the operating characteristic curve (Probabilities $= .01, .05, .10$ $(.10)$ $.90, .95, .99$). The procedures given by the tables are found to be very nearly optimum in a certain sense. An example illustrates the simplicity of the computations.

J. K. Sengupta and G. Tintner (University of Southern California, Los Angeles): "Stochastic Programming Interpretation of the Domartype Growth Models." Arthaniti 6: 1, 1-11. January 1963.

A stochastic generalization of the well known Domar Growth Model is applied to planning in India. Minimization of the variance and of a linear combination of the mathematical expectation and standard deviation are considered.

J. K. Sengupta, G. Tintner (University of Southern California, Los Angeles) and C. Millham: "On Some Theorems of Stochastic Linear Programming with Applications." Management Science 10:1, 143-149. October 1963. (Jour. Paper No. J-4583 of the Iowa Agr. and Home Ec. Exp. Stat., Project 1200.)

Chance constrained programming, two stage programming under uncertainty, and stochastic linear programming are compared. Some theorems about the passive and the active approach in stochastic linear programming are developed, also bounds and inequalities for the objective function. Application is made to a two-sector model of planning in India.

J. K. Sengupta, Gerhard Tintner (University of Southern California, Los Angeles) and Brenda Morrison: "Stochastic Linear Programming with Applications to Economic Models." Economica 30: 119, 262-276. August 1963. (Jour. Paper No. J-4471, Iowa Agr. and Home Ec. Exp. Sta., Project 1200.)

Some theorems on the active and passive approach in stochastic linear programming are applied to a static and a dynamic model of planning in India.

*B. V. Shah, R. J. Buehler (University of Minnesota) and O. Kempthorne: "Some Algorithms for Minimizing a Function of Several Variables," in Journal of the Society of Industrial and Applied Mathematics 12:1, 74-92. March 1964. Reprint Series No. 146, Statistical Laboratory, Iowa State University.

The general problem of determining the values $x_1, x_2, \ldots, x_n$ for which a function ϕ $(x_1, x_2 \ldots, x_n)$ takes its optimum (maximum minimum) value is examined. The function ϕ may be specified mathematically and not amenable to purely analytic solution, or may be unknown, as, for example, when it is the yield of a chemical process. The paper describes a class of algorithms based on quadratic approximation to the function ϕ. These algorithms require the determination of the optimum on successive straight lines in the $(x_1, x_2 \ldots x_n)$ space, which are determined by the information that is accumulated. Each straight line is called a step, and in the ideal case of a quadratic function, with no errors of determination of the optimum on any line, the optimum of the function is reached in at most $(2n - 1)$ steps. The main

theorems are results in the geometry of hyperellipsoids. The general algorithm is based on the fact that parallelism of lines is retained under a general affine transformation.

The procedures based on the algorithms are called general partan, steepest descent partan, scale invariant partan. Some generalizations of the theorems and modifications of the procedures are described. The applicability of the procedures to the non-ideal case is discussed and illustrated by a numerical example which exhibits the difficulty of the general problem. Two possible procedures called iterated partan and continued partan are examined for the numerical case.

*George Zyskind, "Some Consequences of Randomization in a Generalization of the Balanced Incomplete Block Design." Annals of Mathematical Statistics 34: 4, 1569-1581. December 1963. Reprint Series No. 137, Statistical Laboratory, Iowa State University.

This paper envisages a generalized situation of the balanced incomplete block design in the sense of allowing for the sampling of sources of experimental material, of blocks within sources, of experimental units within blocks, and of treatments under consideration. A model for an arbitrary observation of a generalized balanced incomplete block design is derived explicitly from the physical way in which the experiment is performed, i.e., from the way in which the sampling and randomization procedures are carried out. The correlation structure of the observations is therefore implicit in the model. The model initially uses no assumption of additivity of treatments with experimental material. It is shown that expected values of squares of partial observational means, as well as the expected values of products of individual observations, admit simple and easily specifiable expressions in terms of quantities called cap sigmas and denoted by Σ's. The expected values of mean squares in the analysis of variance table are then derived. Consequences of the presence of various types of nonadditivity on the usual test of no treatment effects are discussed for fixed, mixed and random situations. For example, when the blocks actually used in the experiment form a random sample from an infinite population of blocks, then the presence of interactions of blocks with treatments produces no bias in the comparison of the error and adjusted treatment mean squares. The correlational structure of the observations under the simplifying additivity assumption is examined for the standard balanced incomplete block design. It is shown that the usual forms of estimators of treatment comparisons are appropriate and that the Σ's play the roles which the block and plot variances have in the corresponding assumed infinite model.

*George Zyskind, "A Note an Residual Analysis," Journal of the American Statistical Association 58: 1125-1132. December 1963. Reprint Series No. 136, Statistical Laboratory, Iowa State University.

In this note some aspects of residual analysis are considered critically. The relation between residual analysis in the sense of Freund, Vail, and Cluniess-Ross and the analysis of covariance is clearly exhibited. The note establishes exact expressions for the difference between the "true" additional regression sum of squares obtained by simultaneous regression analysis and the regression sum of squares due to additional variables by residual analysis. The difference is given some simple interpretations. It is shown that a residual analysis test statistic considered by Freund, et al. ["Residual Analysis," JASA 56, 98-104. 1961.] is subject to certain serious defects.

Book Reviews

An Introduction to Linear Statistical Models, Vol. I: Franklin A. Graybill, New York, McGraw-Hill, Inc. 1961. Pp. 463 + xiii. $12.50. Reviewed by Technometrics 6:1, 107-111, February 1964, by George Zyskind.

Field Plot Technique, Second Ed. by Erwin L. LeClerg, Warren H. Leonard and Andrew G. Clark. Burgess Publishing Co. 1962. Pp. 373 + iii. $7.75. Reviewed in the Journal of the American Statistical Association 58: 303, p. 865, September 1963, by Foster B. Cady.

Introduction to the Mathematical Theory of Genetic Linkage, Norman T. J. Bailey. New York, Oxford University Press. 1961. Pp. x + 298. $8.80. Reviewed in the Journal of the American Statistical Association 59: 305, p. 285, March 1964, by Oscar Kempthorne.

ABSTRACTS OF THESES

Harold D. Baker: "The Evaluation Program for the 1959 Census of Agriculture; A General Review of the Procedure and a Discussion of Some of the Problems." M.S. thesis. Iowa State University Library. August 1963.

The evaluation program for the 1959 Census of Agriculture is one of a continuing series of quality checks being conducted by the Bureau of the Census. In this thesis the procedures employed are described in detail with special emphasis on those features designed to insure maximum accuracy of the quality check data. Some of the more difficult problems encountered are discussed and, where possible, tentative solutions suggested. An alternative estimator intended to take advantage of suspected correlation between the amount of the reporting error for an item and the amount of the item to be reported is investigated, but exhibits no clear superiority over the estimator used by the Bureau of the Census. The sources of error which together comprise the net error are examined individually to see if some pattern exists which can be capitalized on in future programs of this sort by improved stratification techniques — in particular, by stratification of primary sampling units on the basis of average farm size instead of, or in addition to, the present stratification scheme, which is primarily geographic. No strong pattern is revealed on which concrete suggestions for improving future evaluation programs could be based.

Aaron Hicks Booker: "Nonlinear Estimation." Ph.D. thesis. Iowa State University Library. November 1963.

In this thesis a method of point estimation for a general nonlinear model is developed which produces a consistent, asymptotically efficient estimate. First the method consists of grouping the observations so that the number of groups equals the number of unknown parameters. The solution of simultaneous non-linear equations, resulting from setting the mean observation equal to the mean expectation for each group, provides a consistent estimate. If one uses the consistent estimate as a starting value for the modified Gauss-Newton method, the result of one further iterative step is asymptotically efficient.

Several ways of determining exact nonlinear confidence regions are given and criteria for evaluating these various regions are developed. The methods for point and region estimation are also illustrated by a numerical example.

Carlos Manuel Cavallini: "Estimation of Population Totals Given Samples from Similar Population." M.S. thesis. Iowa State University Library. July 1963.

This work is an attempt to improve the estimates for individual cells of one- and two-way classifications. The estimators studied were of the adjustment type, that is, certain sample marginal totals are accepted and these totals are then distributed to the individual cells.

In each individual cell the sample may contain extreme observations to the right of the mean. Therefore the available data were divided into two groups by an arbitrary boundary. One group contains all those values less than or equal to the arbitrary boundary. The other group, "extreme observations," consists of all values greater than the arbitrary boundary.

Three possible estimators of the individual cell totals were considered:

i) a ratio estimator, defined as the ratio of the estimated row total to the estimated row total for the small group multiplied by the estimate of the small group of the cell under consideration;

ii) an estimator based on an additive model, defined as the sum of the row and column marginal means of the large part of the corresponding cell minus the grand mean of the large part plus the estimated total of the small part of that particular cell; and

iii) an estimator based on a multiplicative model, defined as the product of the row and column marginal totals of the large part of the corresponding cell divided by the total sum of the large part plus the estimated total of the small part of that particular cell.

These estimators may be biased for any particular cell but the biases sum to zero in every row and/or every column if the original marginal totals are unbiased.

Estimates were constructed for estimating the total number of chickens, hogs, and sheep on farms for twelve southern states for the three years, 1958-1960. The mean square error of the estimators was estimated to be less than the variance of the unbiased estimator in 4/5 of the cases.

The sum of the estimated mean square errors over states and years for each of the estimators was lower than the sum of the estimated variances of the unbiased estimator for all items.

Investigation of the M.S.E. for the additive model indicated that the best boundary for the particular problem, given the boundaries for the other cells, is twice the mean of the small group minus twice the product of the sampling fraction and the bias.

Eldred Eugene Dayhoff: "Generalized Polykays and Application to Obtaining Variances and Covariances of Components of Variation." Ph.D. thesis. Iowa State University Library. May 1964.

This thesis is concerned with the extension of polykays and bipolykays to completely generalized polykays for all balanced population and sample structures in pure random sampling situations, and with the application of certain of these results to obtaining the variances and covariances of estimates of components of variation in the analysis of variance under very general conditions.

After the polykays are extended, the generalized polykays of degree two are shown to be equivalent to a set of functions developed in prior work, which are linear functions of components of variation. The inverse relation is easily obtained and thus the problem of obtaining variances and covariances of estimates of components of variation resolves to that of obtaining the variances and covariances of sample generalized polykays.

The generalized polykays of degree two, three and four are exhibited for two two-factor structures and five three-factor structures. The variances and covariances of the estimates of the components of variation in the sample analysis of variance of these structures are obtained and exhibited either explicitly or in abbreviated form.

The development was based on a concept of random cross labeling of the subscripts of observations from crossed structures which was used to extend the definition of the polykays and to obtain the desired variances and covariances in the arbitrary structures from the results already obtained for the crossed structures.

It was also found that a sample mean from certain balanced structures raised to a given power can be expressed as a linear sum of generalized polykays with coefficients depending only on a sample size.

Dale Grosvenor: "Uses of Integer Programming in Problems of Optimization and Their Computational Aspects." Ph.D. thesis. Iowa State University Library. August 1963.

This study is concerned with those models of linear programming in which some or all of the variables

are restricted to be integer-valued in the final solution.

The computational aspects of integer programming were considered from the standpoint of computing efficiency and size of model limitations. A new computational method is presented for the full integer and partial integer algorithms. This new method permits the use of the product form of the inverse in its calculations. The published computer programs which are available to date use an 'in-core' type of procedure which limits the size of the input model to those which can be stored in the immediate-access storage of the computer. The use of the so-called 'product-form-of-inverse' method relaxes size limitations considerably. The integer algorithm involves, in addition to the original restrictions, a set of restrictions which are computed from intermediate results during the calculations. This new method uses the original data in column-order form and the new data is row-order form.

In addition to the computational aspects of integer programming, certain formulations of integer models were investigated. For purposes of exposition, a particular physical problem is chosen as an example. This involves a decision-making problem common to the metal-frabrication industry. Any mass-production industrial plant which manufactures many different detail parts, perhaps as components which will later be assembled into finished machines, has a problem of standardization of raw material. The exemplary problem used here (the bar-length problem) is one of minimizing the cost of storage of the inventory of steels bars used in production. The same problem is used to show how special techniques might be substituted for the classical integer programming. A brief description is given of a method which utilizes the fact that the integer variables are allowed to be only zero or one. A more extensive description is given of a combinatorial method of solving the bar length problem.

Klaus Heinrich Hinkelmann: "Design and Analysis of Multi-Way Genetic Cross Experiments." Ph.D. thesis. Iowa State University Library. November 1963.

For studying quantitative inheritance and developing hybrid breeding programs it is useful to examine two-way or three-way or four-way crosses among a set of n lines. The numbers of these crosses are $n(n-1)/2$, $n(n-1)(n-2)/2$ and $n(n-1)(n-2)(n-3)/8$, respectively, and under most circumstances it would be impossible to examine the totalities. This study is directed toward developing procedures for sampling these sets of crosses. The samples are given the names partial diallel cross (PDC), partial triallel cross (PTC) and partial tetra-allel cross (PTAC) respectively for the three cases.

A correspondence between PDC's and m-associate class PBIB's is set up which allows the construction of a wide class of PDC's. Two particular types of PDC's, derived from the Generalized Group Divisible PBIB and the Extended Group Divisible PBIB, are considered in some detail, especially with regard to analysis. The mathematical properties of the Extended Group Divisible PBIB design are discussed with special reference to non-existence theorems.

Next the PDC is considered from the point of view of sampling from a finite population. Using different reference sets the results are compared with those obtained from infinite population theory. It is shown that for a finite population the usual test of significance for general combining ability variance is slightly biased negatively.

A general development of PTC's is given by deriving a correspondence between PTC's and generalized PBIB designs with blocks of size three. PTC's can then be constructed by means of appropriate association schemes. The analysis is closely related to that of PBIB designs.

A special class of PTC's, called circulant PTC's, is considered in some detail. Their construction is facilitated by introducing the concept of elementary PTC's. It is shown how these can be combined to give connected and, under certain conditions, completely balanced PTC's.

PTAC's can be obtained by means of PBIB association schemes. Among these the circulant PTAC's are of some interest, since they can be constructed and analyzed very easily.

The analysis of PDC's, PTC's and PTAC's is considered from a statistical as well as from a genetic point of view. The models for two-way, three-way and four-way crosses are simplified models, derived on the basis of general genetic considerations. Goodness-of-fit criteria for these models are provided by an appropriate analysis of variance. Under certain assumptions hypotheses about different types of gene action can be tested.

Paul Leaverton: "Statistical Procedures Applicable in the Analysis of Bioassays When the Usual Assumptions Are Not Fulfilled." Ph.D. thesis. Iowa State University Library. August 1963.

The standard statistical methods for the analysis and interpretation of bioassays are based on a number of assumptions concerning the relevance of the mathematical model to the behavior of the experimental material. Situations arise in bioassay studies where some of the usual assumptions are not justified so that the standard statistical methods are inappropriate. This dissertation is concerned with the investigation of some of the basic assumptions used in bioassays and the development of procedures applicable when they are not fulfilled.

One basic assumption, which must be considered in the statistical analysis of all bioassays, is that the dose-response function, $F(z)$, is monotonic. General tests for monotonicity, when the parametric form of $F(z)$ is not specified, are developed for both the quantal and quantitative response cases.

Another assumption which is frequently made is that the response function is or can be made essentially linear, with respect to dose or log dose, by an appropriate transformation of the response variable. The estimation of relative potency (under the hy-

pothesis of similarity) in quantal response bioassays, when no exact parametric form (such as a linear model) for F (z) is assumed, is also investigated.

For the relative potency of one preparation with respect to another to be a constant value, the assumption of similarity must be valid. General methods for investigating similarity, without assuming an exact form for F (z), are presented. Although the standard statistical procedures available for the analysis of bioassays are based on the assumption of similarity, many cases arise in practice in which this convenient assumption is violated, and by the usual statistical procedures an assay is considered "invalid" if the hypothesis of similarity is rejected. Efficient alternative procedures for analysis in such cases are not generally available. Methods are developed for the analysis and presentation of bioassay results when the assumption of similarity is not necessarily appropriate.

William Thomas Lewish: "Linear Estimation in Convex Parameter Spaces." Ph.D. thesis. Iowa State University Library. July 1963.

The classical Least Squares estimation of the parameter vector β of a linear model considers both the case when β is "free" and the case when β is known to satisfy several linear equations. This study is concerned with the Least Squares estimation of β, where β is known to lie in a convex space. The minimization of the residual sums of squares in the convex region is identical with determining the point $\tilde{\beta}$ on the boundary which is "nearest" to the unrestrained Least Squares estimator $\hat{\beta}$. The concept of "nearest" refers to the metric in which the elements of $\hat{\beta}$ are independently distributed with unit variance. In this metric, the biased restrained estimator $\tilde{\beta}$ is nearer the population mean β than the unrestrained estimator $\hat{\beta}$. Because of this property it is shown that

$$\sum_{i=1}^{p} \text{MSE } (\tilde{\beta}_i) \leq \sum_{i=1}^{p} \text{VAR } (\hat{\beta}_i)$$

The estimator $\tilde{\beta}$ is consistent and asymptotically normal if the population mean lies inside the region. The bias, variance and mean square error is obtained when the convex region is specified by two parallel and two non-parallel planes.

The fitting of polynomials with non-negative derivatives is considered in detail. For a third degree polynomial, the discriminant must be negative. This is shown to be a convex constraint. An approximate method of estimation is given for determining the coefficient for any polynomial over a finite interval of the argument. The method has certain desirable limiting properties. Two examples are given. One example is concerned with estimating the coefficients of a cubic equation that was used in a variate transformation. The second example is concerned with the estimation of the coefficients of the Gram-Charlier series such that the graduation is positive.

The general numerical procedure of estimation is identical with solving a quadratic programming problem. In the examples considered it was also possible to use the minimum distance property to project directly to the boundary of the convex region.

Rudolfo Mengido: "Random Walk in Sequential Analysis." M.S. thesis. Iowa State University Library. July 1963.

For suitable parametric values, binomial sequential probability ratio tests constitute Markoff chains with two absorbing states, or, more precisely, random walks with two absorbing barriers; indeed this fact has been used in the development of exact OC and ASN functions for such parametric cases.

This thesis attacks the problem of truncation through the convergence properties, under iteration, of the transition matrices associated with these random walks; such properties have been exploited before, in other areas – for example, in general operator theory, in numerical analysis, and in genetics.

It is first pointed out that, when the characteristic vectors of a matrix A span a subspace of maximum dimension, then operating on an arbitrary vector with an iterate of A yields a simple expression involving these characteristic vectors and the corresponding characteristic roots. A counter-example is also given which illustrates that the condition that the dimension of the subspace spanned by the characteristic vectors be maximal cannot in general be dispensed with. Next, the transition matrices for a particular class of random walks are examined in some detail, and it is shown, at least in certain special cases, that the condition of maximum dimensionality is met by the relevant transition matrices so that "asymptotically exact" truncation rules can be constructed.

Michael Holmes Miller: "Estimates for the Mean of a Discrete Variable Obtained from Transformed Data." M.S. thesis. Iowa State University Library. February 1964.

The estimation of treatment means on the original scale after the data have been transformed by the square root transformation, $y = \sqrt{x+A}$, was considered. The analysis of variance for y provides estimates for group or treatment means on the y-scale, and an estimate for the variance of y, S_y^2 with ν degrees of freedom. Each treatment mean is based on n observations.

An unbiased estimate for the i^{th} mean on the original or x-scale is given by Neyman and Scott as

$$X_i' = \bar{y}_i^2 - A + \left(\frac{n-1}{n}\right) S_y^2.$$

The probability density function of X_i' was derived, as was an unbiased estimate for the variance on X_i'.

The complexity of the p.d.f. for X_i' precluded finding exact confidence intervals for a treatment mean on the x-scale in terms of statistics based on the analysis of the y's. Three approximate methods for calculating confidence intervals were proposed: one based on a convergence theorem by Anderson; one on the fact that reduced random variables are frequently asymptotically normal; and a third consisting of applying a correction for the bias that occurs when the confidence limits for the mean on the

y-scale are transformed by means of the inverse transformation.

All three approximate confidence intervals were evaluated using the results of three experiments where the square root transformation was employed. In all, nine means were estimated. The three methods were in reasonably close agreement, but the third method gave uniformly shorter intervals than either of the others.

Esmat M. Nouri: "A Monte Carlo Study of Selection for a Quantitative Genetic Trait in Full-Sibbing Populations." M.S. thesis. Iowa State University Library. May 1964.

This thesis describes an investigation by simulation on a computer of the basic Mendelian processes, of the role of finiteness of population, linkage environmental variation and genetic model on the progress of a genetic population with truncation selection. The parent population size was two, and different sizes of offspring population were generated. A 4^3 factorial experiment on population size, linkage between successive loci and environmental variance was made for each of 9 genetic models, 6 of which involved various types of epistacy. The effects and interactions of the experimental factors were examined. An examination was made of a prediction formula obtained by modifying Griffing's formula by including a term depending on the amount of inbreeding. The resulting predictor was fairly good for the first 5 or 10 generations, but not thereafter, this being one of the considerable changes in genetic components of variance resulting from the selection.

Dale O. Richards: "Incompletely Specified Models in Life Testing." Ph.D. thesis. Iowa State University Library. August 1963.

This study considers the effects of preliminary tests of hypotheses involving the location parameter of a two parameter exponential distribution on subsequent inferences about the scale parameter of this distribution. Comparisons are made among inferences based on three possible ways of model specification. These ways are (1) always assume the location parameter to be zero; (2) always assume the full two parameter exponential distribution; and (3) perform a preliminary test of the hypothesis: location parameter equals zero, and use the model of (1) if the hypothesis is accepted, but use the model of (2) if the hypothesis is rejected.

Use of (1) and (2) means the use of completely specified models. Use of (3) is referred to as an incompletely specified model.

It is assumed that truncation of the life test occurs after r failures without replacement have been observed. Calculations were done for values of r from two through fifteen, since it was felt that this was the range of r where use of procedure (3) could be quite advantageous.

Inferences both in estimation and testing of hypotheses were considered. For comparative purposes in estimation, the bias and the mean square error of the estimators arising from the above three ways of model specification were calculated. Three different levels of significance of the preliminary test, 0.10, 0.25 and 0.50, were used for estimators based on the incompletely specified model. For comparative purposes in testing of hypotheses, the size and power of upper and lower one-sided 5 percent tests based on all three ways of model specification were used. The same three levels of significance for preliminary tests in the incompletely specified model as used in estimation were studied. Consideration was given the problem of how the bias, mean square error, size and power were each affected by various values of the location parameter.

Recommendations are made for use of specific levels of significance of the preliminary test for certain known a priori information about the location parameter for each of the situations of estimation and testing of hypotheses. Assuming no known a priori information, tables and figures are provided to show how the characteristics examined vary for different values of the location parameter.

PARTICIPATION IN PROFESSIONAL SOCIETIES

Members of the staff of the Statistical Laboratory have made significant contributions to various professional societies during the year as part of their off-campus activities.

T. A. Bancroft became president of the Biometric Society (ENAR) on January 1, 1964, and in that capacity also became a member of the Committee of Presidents of Statistical Societies (COPSS). He is a member of the Board of Directors of the American Statistical Association. He will serve on the Program Committee for the annual meeting of the Institute of Mathematical Statistics at Amherst, Massachusetts, on August 30 - September 4, 1964.

Oscar Kempthorne has served on the Editorial Board of Biometrics.

Foster B. Cady was reelected secretary of the Biometrics Section of the American Statistical Association for a one-year term beginning January 1, 1964. He was also appointed to the Regional Committee of the Biometric Society (ENAR).

Leroy Wolins is president of the Central Iowa Psychological Association.

George Zyskind is a member of the Council of the American Statistical Association.

T. A. Bancroft, as president-elect of the Biometric Society (ENAR), attended the meeting of the Fifth International Biometrics Conference in Cambridge, England, September 9-14, 1963. O. Kempthorne, C. P. Cox and Dewey L. Harris also attended the meetings. Bancroft, Cox and Harris served as leaders of discussion groups at the two-day Study Conference which followed the International meetings.

V. S. Huzurbazar was invited to attend the Fulbright Visiting Professors Conference on Higher Education in the United States at the University of Wisconsin, Madison, June 17-19, 1963. He was sponsored by the Conference Board of Associated Research Councils, Committee on International Exchange of

Persons, Washington, D. C. Huzurbazar also attended the International Symposium on the Classical and Contagious Discrete Distributions at McGill University, Montreal, on August 15-20, and served as chairman of a session.

T. A. Bancroft, Oscar Kempthorne and Herbert T. David were elected to membership in the International Association for Statistics in the Physical Sciences Section of the International Statistical Institute.

David was appointed Visiting Lecturer in Statistics by the American Statistical Association, the Biometric Society, and the Institute of Mathematical Statistics, under the support of the National Science Foundation. He was one of two professors of statistics appointed to the program in the Westcentral Region. He lectured and consulted with staff and graduate students in seven colleges and universities requesting a visiting lecturer in statistics.

O. Kempthorne and George Zyskind served as chairmen of sessions, and Kempthorne was a member of the Committee for Program Arrangements, at the 123rd annual meetings of the American Statistical Association held jointly with the Biometric Society (ENAR) and the Econometric Society at Cleveland.

T. A. Bancroft, as president of Biometric Society (ENAR), presided at the meeting of the society at Kansas State University May 7-9, 1964.

C. P. Cox and W. J. Hemmerle served as members of the Regional Advisory Board of Biometric Society (ENAR). Foster Cady was a member of the Regional Committee on program arrangements for the meetings at Kansas State, and Om P. Aggarwal was chairman of a joint session of IMS and Biometric Society (ENAR).

Papers presented at scientific and professional meetings

Papers presented at professional meetings reflect the work that has been done in the Statistical Laboratory. Many of these papers will appear later in publications. Abstracts of papers are often published, and in such cases references are given.

Ross Adams and **T. A. Bancroft**: "Estimating Missing Values by a Regression Method in Time-Trend Experiments," a paper presented at the 123rd annual meetings of the American Statistical Association at Cleveland, September 4-7, 1963. Biometrics 19:4, 656. December 1963. Abstract No. 911.

T. A. Bancroft: "Analysis and Inference for Incompletely Specified Models Involving the Use of Preliminary Tests of Significance," an invited paper presented at the Fifth International Biometrics Conference in Cambridge, England, September 9-14.

R. J. Buehler and **Fred L. Ramsey**: "Fiducial Prediction and Fiducial Consistency," a paper presented at the Institute of Mathematical Statistics held in Ottawa, Ontario, on August 27-29.

D. W. Stanforth and **Foster B. Cady**: "Nodulating and Non-Nodulating Soybeans as Simulated Weed Infestations in Corn," a paper given at the Weed Society of America meeting in Chicago, February 10-13.

K. C. Chanda: "Sampling Properties of Tests for Categorical Data," a paper presented at the Institute of Mathematical Statistics, Ottawa, August 27-29. Annals of Math. Stat. 34:4, 1617. December 1963. Abstract No. 31.

K. C. Chanda and **Fred L. Ramsey**: "Sampling Properties of Estimators in Linear Autoregression Schemes When Trend Is Present," a paper given at the joint meetings of the Institute of Mathematical Statistics, Biometric Society (ENAR), and Section on Physical and Engineering Sciences of the American Statistical Association at Kansas State University, Manhattan, Kansas, May 7-9, 1964.

C. Philip Cox: "Statistical Principles for the Line of Best Fit," at the joint meeting of the Canadian and Midwestern Regions of the 1620 USERS Group in Des Plaines, Illinois, on February 19-21.

H. T. David and **R. M. Mengido**: "Asymptotically Exact Truncation in Binomial Sequential Analysis," a paper presented at the meetings of the Institute of Mathematical Statistics held in Ottawa, Ontario, on August 27-29. Annals of Math. Stat. 34:4, 1617. December 1963. Abstract No. 32.

Wayne A. Fuller and **F. B. Cady**: "Estimation of Asymptotic Rotation and Nitrogen Effects," a paper presented at the 55th annual meeting of the American Society of Agronomy at Denver, Colorado, November 18-21.

Dewey L. Harris: "The Role of Monte Carlo Studies in Genetic Research," a paper presented at the annual meeting of the American Institute of Biological Sciences held in Amherst, Massachusetts, August 28-29. Biometrics 19:4, 654. December 1963. Abstract No. 906.

Dewey L. Harris: "Biometrical Parameters of Self-Fertilizing Diploid Populations," a paper presented at the International Congress of Genetics at The Hague, Netherlands, September 2-10, 1963.

William J. Hemmerle: "Aardvark – A Compiler-Monitor System for Analysis of Variance," a paper given at the annual meetings of American Statistical Association in Cleveland, September 4-7. Biometrics 19:4, 655. December 1963. Abstract No. 908.

V. S. Huzurbazar: "Some Invariants of Some Discrete Distributions Admitting Sufficient Statistics for Parameters," a paper given at the International Symposium on Discrete Distributions at McGill University, Montreal, August 15-20.

V. S. Huzurbazar: "Location and Scale Parameters and Sufficient Statistics," a paper given at the joint meetings of IMS, Biometric Society (ENAR), at Kansas State University, May 7-9, 1964.

Oscar Kempthorne: "Monte Carlo Investigations of Genetic Selection," a paper given at the Fifth International Biometrics Conference at Cambridge, England, September 9-14.

Joseph Sedransk: "Designing Analytical Surveys," a paper given at the joint meetings of IMS and Biometric Society (ENAR) at Kansas State University, May 7-9.

Donald V. Sisson (Utah State University, Logan): "Combining Data Over Years," a paper presented at the Biometric Society (ENAR) meeting at Cleveland, Ohio, September 4-7. Biometrics 19:4, 655. Abstract No. 932.

Leroy Wolins: "The Measurement of Different Traits by Means of a Common Psychological Scale," a paper given at the annual meeting of the Psychonomic Society at Philadelphia, August 30.

Seminar talks

T. A. Bancroft: "The Role of a Statistical Center in a University," a lecture given as part of the program for Arts and Sciences Week at the University of Missouri, and "On the Theory of Incompletely Specified Models in Statistical Inference," a talk at the Statistics Seminar at the University of Missouri, Columbia, on December 9-10, 1963.

K. C. Chanda: "Asymptotic Expansions for a Class of Distribution Functions," at the University of Minnesota, Minneapolis, on November 15.

Herbert T. David: "A Sampling from Current Statistical Practice and Thought," "What Is Statistics?", Reflection Principles and Their Statistical Applications," "Asymptotically Exact Truncations in Sequential Analysis," "Asymptotic Run Theory," lectures given as Visiting Lecturer in Statistics at the following colleges and universities: Cardinal Stritch College, Milwaukee, Wisconsin, on November 19; College of St. Catherine, College of St. Thomas, Hamline University, Macalester College, and the University of Minnesota, at St. Paul-Minneapolis, on January 9-10; Kent University, Kent, Ohio, on January 28-29.

W. J. Hemmerle: "A Computer Technique to Obtain Maximum Likelihood Estimators of Factor Loadings, Communalities, and Specific Variances for Factor Analysis," at Northwestern University in February.

David V. Huntsberger: "Statistics, Its Applications and Opportunities," at Simpson College, Indianola, Iowa, on December 10.

V. S. Huzurbazar: "Sufficient Statistics and Parameters of Location and Scale," a seminar at Princeton University on March 3; and "The General Forms of Distributions Admitting Sufficient Statistics for Parameters in Non-Regular Cases," a seminar at Harvard University of March 4.

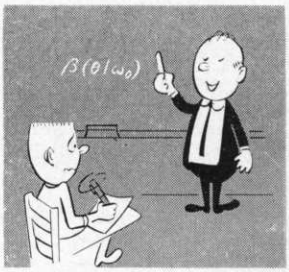
George Zyskind: "Some Views and Connections in Least Squares Linear Models Theory," seminar talk at the Statistical Laboratory, Virginia Polytechnic Institute, on March 5.

George Zyskind: "Conditional and Generalized Inverses and Their Relevance to Problems in Least Squares Theory," seminar talk to the Applied Mathematics Group at the Wright Patterson Air Force Base, Ohio, on March 9.

George Zyskind: "Randomization Theory and a Structural Approach to the General Balanced Experiment," seminar talk to the Mathematical Statistics Group, Wright Patterson Air Force Base, Ohio, on March 10.

George Zyskind: "On Structures, Relation, and Σ in Experimental Design," at a University of Wisconsin, Statistics Department, seminar on April 27.

Teaching



The Department of Statistics in the College of Sciences and Humanities at Iowa State offers work leading to the degrees of Bachelor of Science, Master of Science, and Doctor of Philosophy with majors in statistics. Each major is built around a common core of courses in theory and methods, with other courses being chosen to fit the individual student's background and interests. At all levels, the program in statistics is designed to emphasize the close relationship between sound application and modern statistical theory. The Department also offers minor and supporting work in statistics. When desired, a joint major program may be arranged between statistics and a substantive field of application for the Ph.D. degree.

Training facilities include two student laboratories equipped with 75 electric calculating machines for course instruction and for student use during non-class hours. Use is also made of the IBM 7074-1401 high speed computer and electrical equipment for punch card analysis of data which are located in the Computation Center of the University. The Statistical Laboratory Library includes reprints of articles considered important in theoretical and applied statistics, reprints of staff publications, graduate theses, various statistical journals, reference books and other publications obtained on an exchange, gift or loan basis.

The Department of Statistics continues to grow as the use of statistics increases in all branches of learning, and changes made in the curriculum as necessary to keep pace with the needs of the students.

H. T. David has taught courses in Sampling Inspection (531) and Operations Research (539) and in Decision Theory (642). The course in Operations Research will be taught annually instead of in alternate years only. The increased demand for this course is due to the recent growth in the area of Industrial Statistics.

K. C. Chanda has taught Stochastic Processes (649) and a new course in Time Series (646). The latter course has been taught at two levels, both at an intermediate level and as a more advanced course.

The 201 courses now include Stat. 201A, a service course in statistics now required in several curricula in agriculture, taught this year by D. V. Huntsberger and D. K. Hotchkiss. Stat. 201B, a service course for engineers, was taught by William D. Lawing.

Psychometrics (505) and Factor Analysis (506), taught by Leroy Wolins, are gaining in importance now that a Ph.D. in Psychology is offered at Iowa State.

Om P. Aggarwal taught Theory of Probability and Statistics (542-543). More emphasis than previously was placed on statistical decision theory in the development of the material covered in these courses.

The courses offered by the Department of Statistics during the academic year 1963-64 follow:

COURSE OFFERINGS IN STATISTICS

Courses for undergraduate students only

201	Principles of Statistics	5	FWS*	Conn, Fuchs, Huntsberger, Martin, Tetreault
201A		3	WS	Hotchkiss, Huntsberger
201B		3	S	Lawing
327	Elementary Business Statistics	3	F	Fuchs
341, 342	Introduction to Theory of Probability Statistics	3	FW	Tetreault
380	Introduction to High Speed Computing	3	FWS	Jespersen, Grosvenor

*FWS—Taught Fall, Winter and Spring Quarters.
†SS_2, 1—Taught Summer Session 2 (1963), Summer Session 1 (1964).
Note: The summer quarter is divided into two 5½-week periods. Since the fiscal year began on July 1, 1963, and ended on June 30, 1964, only the courses offered during the second period of 1963 and the first period of 1964 are shown in this report.

Courses for graduate minors and undergraduates

401, 402	Statistical Methods for Research	4	FWS SS†$_{2,1}$	
	A. Animal Sciences			Fuchs, Hotchkiss
	B. Plant Sciences			Cady, Cox, Hotchkiss, Huntsberger, Wolins
	C. Physical Sciences			Lawing
	D. Economics			Warren
	E. Undergraduate			Tetreault
	F. Social Sciences			Wolins
411	Experimental Design for Research Workers	3	S, SS$_1$	Hotchkiss, Huntsberger
421	Survey Designs for Research Workers	3	S, SS$_2$	Fuller
431	Elementary Statistical Quality Control	3	S	Carney
446, 447, 448	Statistical Theory for Research Workers	3	FWS SS$_{2,1}$	Cady, Harris, Huntsberger
480, 481, 482	Processing of Data	2	FWS	Mosier
499	Special Problems	Arr.	FWS SS$_{2,1}$	Fuller, Hemmerle

Courses primarily for graduate students, major and minor

501	Intermediate Statistical Methods	3	F	Bancroft
505	Psychometrics	3	S	Wolins
506	Factor Analysis	3		
511, 512	Design of Experiments	3	WS	Kempthorne, Zyskind
521, 522	Design of Surveys	3	WS	Sedransk
531	Industrial Statistics: Sampling Inspection	3	F	David
532	Industrial Statistics: Design of Experiments	3		
535	Biological Statistics	3	S	Cox
536, 537	Genetic Statistics	3	FW	Harris
538	Elementary Econometric Statistics	3	F	Fuller
539	Operational Research Methods	3	W	David
541, 542, 543	Theory of Probability and Statistics	3	FWS	Aggarwal, Sedransk
554, 555	Probability	3		
580, 581	Scientific Applications of Digital Computers	3	WS	Hemmerle
599	Special Topics	Arr.	FWS SS$_{2,1}$	
	A. Theory			Chanda
	B. Methods			Aggarwal, Cox, Hotchkiss, Huntsberger, Grosvenor
	C. Design of Experiments			
	D. Design of Surveys			Fuller

Courses for graduate students, major and minor

601	Advanced Statistical Methods	3	F	Cox
621	Advanced Design of Surveys	3	W	Aggarwal
622	Seminar on Design of Surveys	Arr.		
638	Advanced Econometric Statistics	3		
641	General Theory of Linear Hypothesis	3	F	Zyskind
642	Probability and Distribution Theory	3	F	Huzurbazar
643	Theory of Estimation and Testing of Hypotheses	3	W	Huzurbazar
646	Time Series	3	S	Chanda
647	Multivariate Analysis	3	S	Huzurbazar
649	Recent Developments in Statistics and Probability	3	F SS$_1$	Chanda
680	Seminar on Advanced Computer Techniques	Arr.		
688	Seminar on the Theory of Statistics and Probability	3	FS SS$_2$	Chanda, David
699	Research	Arr.	FWS SS$_{2,1}$	Aggarwal, Bancroft, Chanda, Cox, David, Fuller, Harris, Hemmerle, Huntsberger, Kempthorne

Roster of Graduate Majors and Special Students

Ph.D. Candidates

Rodney Basson
Edward J. Carney
Patricia Conn
Charles E. Cress
Eugene Dayhoff
Thomas E. Doerfler
Ahmed ElMawaziny
Francis Giesbrecht
Burwell Gooch
Jose S. Gutierrez
John P. Johnson
Louis W. Johnson
William D. Lawing
Frank B. Martin
Esmat Nouri
Fred L. Ramsey
Thomas D. Roseberry
Donna Jean Ruhl
Chang-sheng Shih
Richard R. Smith
Gary S. Spencer (deceased)
Florence G. Tetreault
David R. Thomas
Henry F. Walter
George M. Weiss

M.S. Candidates

James Blinn
Aurelio Chavez
Jan Feller
Raymond M. Ferris
Edmund Fuller
James R. Gebert
Retno Kanujoso
Shu-wen Ke
Shun-jong H. Lee
Angel Martinez
Richard W. Mensing
Michael H. Miller
Martin S. Rosenzweig
John E. Schlater
Susumu Shiseki
Jarilaos Stavrou
Nangnoi Suwanphant
Phrensi Svasti-Salee
Richard W. Swanson
James R. Veale
James Wahrenbrock
Ing-tzer Wey

Special Students

Ewald S. Ombre
Beryl Reckord
Fazil Momand Rahim
Bekele Teguegne

Degrees granted and positions taken

During the academic year 1963-64, seven candidates were awarded doctorate degrees and five were awarded master's degrees in statistics. Titles and abstracts written as part of the requirements for advanced degrees are given on pages 31 to 35 of this report.

Recipients of the Ph.D. degree

William Lewish (July 1963, under H. O. Hartley) returned to his position as Special Service Engineer with E. I. DuPont de Nemours, Wilmington, Delaware.

Dale Grosvenor (July 1963, under H. O. Hartley) remained on the staff of the Statistical Laboratory and Department of Statistics at Iowa State University as assistant professor.

Paul Leaverton (August 1963, under C. Philip Cox) took a position as consultant and research worker and assistant professor of statistics at the University of Colorado Medical Center in Denver, Colorado.

Dale O. Richards (August 1963, joint major in statistics and industrial engineering, under T. A. Bancroft and J. K. Walkup) on September 1 became associate professor of statistics at Brigham Young University, Provo, Utah.

Aaron Booker (November 1963, under H. O. Hartley) continued with his work with United Electro Dynamics in Alexandria, Virginia.

Klaus Hinkelmann (November 1963, under O. Kempthorne) became a research associate at the Institut für Forstgenetic, Germany.

Eugene Dayhoff (May 1964, under O. Kempthorne) is assistant professor of statistics at Texas A and M University, College Station, Texas.

Recipients of the master's degree

Carlos M. Cavallini (July 1963, under Wayne A. Fuller) took a position with IBM World Trade Corp., System Engineering Department, in Buenos Aires, Argentina.

Rudolfo Mengido (July 1963, under H. T. David) returned to Buenos Aires.

Harold Baker (August 1963, under H. O. Hartley) continued as an associate with the Survey Group of the Statistical Laboratory at Iowa State.

Michael Miller (February 1964, under David H. Huntsberger) is assistant professor of statistics at Kansas State University, Manhattan, Kansas.

Esmat Nouri (May 1964, under Dewey L. Harris) is continuing his work for his doctorate at Iowa State.

Recipients of the bachelor's degree

Robert J. Cochran (August 1963) works as field secretary for Delta Chi fraternity, Iowa City, Iowa.

Steven Edgar Ryan (February 1964).

Leon Burmeister (May 1964) will continue study toward an advanced degree.

Glen E. Mackie (May 1964) went into service with the U. S. Air Force.

Fazil Rahim (May 1964) returned to Afghanistan.

Dennis Zweifel (May 1964) will be in service for six months, then plans to start his graduate work in statistics.

The George W. Snedecor Award in Statistics for 1964 was granted by the Graduate Faculty of the Statistical Laboratory to Fred L. Ramsey. The award, established in 1954 to honor Professor Snedecor, is given annually to the graduate student judged to be the most outstanding among those candidates for the Ph.D. degree in statistics at Iowa State who have successfully completed doctoral preliminary examinations within the preceding calendar year. This year a plaque naming award winners since 1954 was hung in the main office of the Statistical Laboratory. A brass plate carries the inscription:

> IOWA STATE UNIVERSITY
>
> THE GEORGE W. SNEDECOR AWARD IN STATISTICS
>
> presented annually
>
> To honor the most outstanding Ph.D. candidate in statistics
> Established in 1954 to honor Professor George Snedecor
> Founder and Director, Statistical Laboratory, 1933-1947

Eleven names are now engraved on brass name plates, and space is provided for listing award winners through 1975.

Iowa State University Stat Club

Under the leadership of Leon Burmeister and Dorothy Rustag, undergraduate statistics majors, and Mrs. Carol Fuchs and D. K. Hotchkiss, faculty advisors, the ISU Stat Club was reorganized. Effective undergraduate leadership was sought and a constitution was adopted. The following officers were elected:

President – Leon Burmeister
Vice President – John Allen
Secretary – Dennis Zweifel
Treasurer – John Hunt

At a fall picnic held to recognize those who took an active part in the 1963 Veishea Open House and to acquaint new students with upperclassmen and the faculty, interest in a club was aroused.

At the first regular meeting Dr. T. A. Bancroft discussed "Careers in Statistics," that having been chosen the subject of interest for the year. Subsequent speakers included two representatives from IBM, who discussed careers in computing, a representative of Collins Radio who talked on the statistician's role in quality control, and a vice president of Bankers Life Insurance Co. who spoke on actuarial statistics.

The Stat Club submitted a petition to the Board of Directors of the American Statistical Association for a special affiliate membership status. It was proposed that undergraduates become affiliate members upon obtaining membership in a recognized undergraduate statistics club. The petition is now being considered.

John Hunt served as chairman of the 1964 Veishea Statistics Open House. Other members of the club assisted. The display exhibited an actual experiment in progress, employing a χ^2 test to evaluate random mating of chickens.

Officers elected for 1964-65 are:

President – Terry Jenkins
Vice President – John DeMarle
Secretary – Ronald Mead
Treasurer – James Destival

Student interest and cooperation in the Stat Club activities have been high, and faculty advisors hopefully anticipate that the club will create interest in the field of statistics among qualified students on campus.

Seminars

Statistical Laboratory—Department of Statistics Series

Each year the Statistical Laboratory and the Department of Statistics sponsor weekly seminars which are offered on a non-credit basis and are open to students and faculty from other departments on the campus as well as those of the statistical center. Talks on current research projects of the staff and graduate students as well as in more general areas of statistics precede informal discussion. The seminar committee was composed of C. P. Cox, Dewey L. Harris and Om P. Aggarwal. The 1963-64 program included the following topics and speakers.

Fall Quarter 1963

September	18	Introduction of New Staff Members. D. V. Huntsberger
September	25	Digital Computer Techniques for Analysis of Variance. William J. Hemmerle
October	2	Mathematical Programming with Integer Requirements. Dale Grosvenor
October	9	Impressions of the Fifth International Biometrics Conference, Cambridge University. C. P. Cox
October	15	Joint meeting with Central Iowa Chapter of ASA at Ames. Applications of Linear, Nonlinear and Integer Programming. Dr. H. O. Hartley, Texas A and M University
October	23	Generalized Concentration Fluctuation under Diffusion Equilibrium. Dr. Harold Ruben, University of Sheffield, England
October	30	Asymptotically Exact Truncation in Binomial Sequential Analysis. H. T. David and R. M. Mengido
November	6	Confidence Bounds of Regression Lines. K. C. Chanda
November	13	Research for Action Programs. Richard Warren

Winter Quarter 1963-64

December	11	Estimation of Asymptotic Rotational and Nitrogen Effects. Foster B. Cady
December	18	The Analysis of Covariance as a Test of Sub-Hypothesis and Missing Value Technique. Rodney Basson
January	8	Regression Estimation for Sample Surveys. Wayne A. Fuller
January	15	Non-Parametric Least Squares. Dr. H. D. Brunk, Chairman, Department of Statistics, University of Missouri
January	22	Residuals in Planned Experiments. Francis Giesbrecht
January	29	Problems in Analysis of Numbers Assigned to Stimuli by Judges. Leroy Wolins
February	5	Optimization Procedures. Thomas Doerfler
February	12	Size and Power of Tests Under Experiment Randomization. Oscar Kempthorne
February	19	Combinatorial Problems and Integer Programming. Ellis L. Johnson, Operations Research Center, University of California, Berkeley

Spring Quarter 1964

March	11	Iowa Chapter, American Statistical Association. Problems in Sequential Design of Experiments. Dr. Judah Rosenblatt, Associate Professor of Mathematics and Statistics, University of New Mexico
March	18	A Multidimensional Branching Process as Motivated by a Class of Problems in Mathematical Genetics. Dr. Charles J. Mode, Professor of Mathematics, Montana State College, Bozeman, Montana
March	25	Asymptotic Behavior of Posterior Distributions. Dr. Robert H. Berk, Harvard University
April	1	Location and Scale Parameters and Sufficient Statistics. Dr. V. S. Huzurbazar
April	7	Topics in Programming under Uncertainty. Roger Wets, Operations Research Center, Richmond Field, California
April	8	Central Iowa Chapter, American Statistical Association, at Iowa City. Estimating Common Parameters from Several Responses. Dr. Norman Draper, Professor of Statistics, University of Wisconsin, Madison, Wisconsin
April	15	On Certain Connections in Linear Models Least Squares Methodology. George Zyskind
April	22	Asymptotic Expansions for Distribution Functions. Dr. K. C. Chanda
April	29	Designing Analytical Surveys. Joseph Sedransk
May	13	Sampling Properties of Estimators in Linear Autoregression Schemes When Trend Is Present. Fred L. Ramsey

Quantitative Genetics Series

Seminars are held regularly on topics in quantitative genetics, participated in by staff members and graduate students in Statistics, Genetics, Animal and Poultry Science, Agronomy, and Horticulture. Dewey L. Harris was in charge of the series. The following seminars were held:

October	1	Biometrical Parameters of Self-Fertilizing Diploid Populations. Dewey L. Harris
October	15	A Monte Carlo Study of Genetic Selection in Full-Sibbing Populations. Esmat Nouri
October	29	Estimation of Sex-Linkage and Maternal Effects in Single-Cross Data. Rolf G. Beilharz (Antigenics Lab.)
November	12	Partial Triallel Crosses. Klaus Hinkelmann
December	3	A Monte Carlo Evaluation of the Role of Finite Population Size and Linkage in Response in Continuous Mass Selection. A. W. Qureshi
December	17	Genetic Loads and Genetic Deaths. Dr. J. L. Lush, Department of Animal Science
January	7	Genetics of Reproduction and Growth in Species of Lepidoptera. Dr. Ian M. Campbell, Department of Entomology
January	21	Genotypic Covariances Between Inbred Relatives. Dewey L. Harris
February	4	Relaxed Selection Experiment with Chickens. Dr. Arne W. Nordskog, Department of Poultry Science
March	10	Pleitrophy of Genes in Developmental Instability of Quantitative Characters. Dr. K. Sakai, National Institute of Genetics, Mishima, Japan
March	17	Some Observations on the Schnell Linkage Parameters with Applications to Problems of Inbreeding. Dr. Charles J. Mode, Professor of Mathematics, Montana State College, Bozeman, Montana
March	24	Genetic Loads. Dr. James F. Crow, University of Wisconsin, Madison, Wisconsin
April	7	Genetics of Gestation. Dr. D. F. Cox, Department of Animal Science
April	14	The Effect of Linkage on Average Degree of Dominance of Genes Determining Quantitative Traits in Corn. Dr. C. O. Gardner, University of Nebraska
April	28	Estimation of Genetic Effects from Variety Cross Performance. Dr. Steve Eberhart, USDA Collaborator
May	12	A Monte Carlo Study of Some Sampling Distribution Problems in Genetics. A. W. Qureshi
May	19	Covariances Among Relatives in a Random Mating Population in Corn. Ruey K. Chi, Graduate Student, Department of Agronomy

Miscellaneous seminars

Members of the staff of the Statistical Laboratory occasionally participate in seminar programs sponsored by other departments of the university. The following are representative of such seminars.

March	19	Animal Breeding Seminar – A Critical Look at Animal Breeding. Dewey L. Harris
May	13	Agricultural Engineering Seminar – Misuses of Statistics. Herbert T. David
June	29	NSF Research Participation Program for High School and College Teachers – Statistics As a Tool in Scientific Research. T. A. Bancroft

A publication of the Statistical Laboratory
Iowa State University
Eleanor F. Bolton, editor