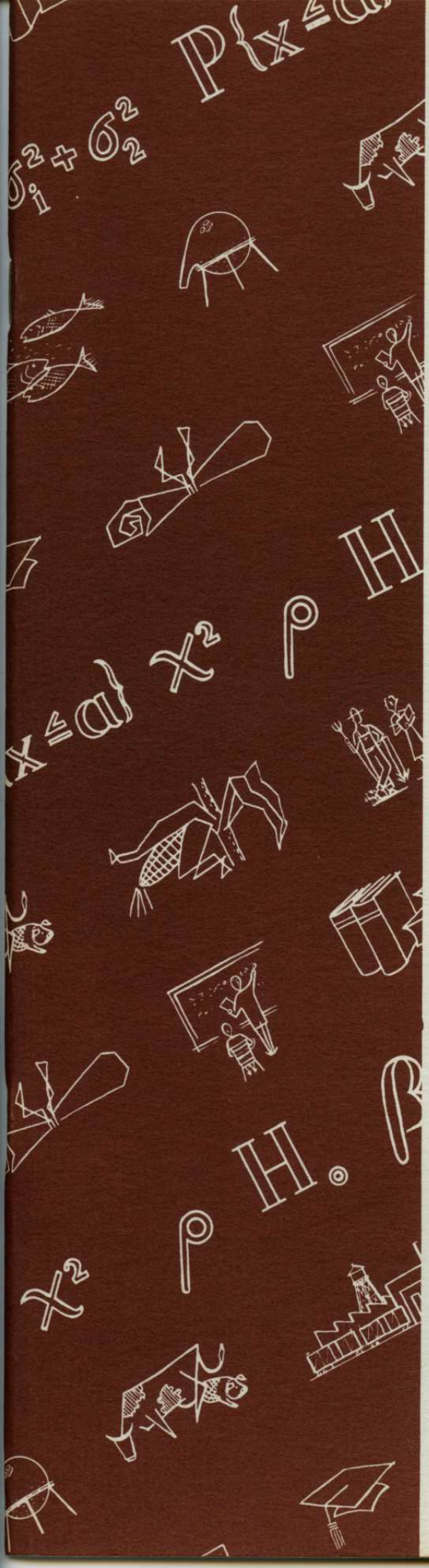

IOWA STATE UNIVERSITY BULLETIN

STATISTICAL LABORATORY

ESTABLISHED 1933

ANNUAL REPORT

July 1, 1968 to June 30, 1969

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

Dear President Parks:

This is the annual report of the Statistical Laboratory at Iowa State University for the fiscal year July 1, 1968, through June 30, 1969. It reports on the research, consulting, teaching and operational work of the staff of the university statistical center.

The statistical center is composed of:

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

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

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

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

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

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

Respectfully submitted on behalf
of the Statistical Laboratory staff,

T. A. Bancroft

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

THE STATISTICAL LABORATORY

Iowa State University

ANNUAL REPORT 1968-1969

IOWA STATE UNIVERSITY BULLETIN
Ames, Iowa

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Iowa State's statistical center includes the Statistical Laboratory, an institute under the president's office; the Department of Statistics in the College of Sciences and Humanities; the Statistics Department of the Agriculture and Home Economics Experiment Station; and the statistics participant in the Sciences and Humanities Research Institute and the Engineering Research Institute. The director of the Statistical Laboratory reports to the president of the university through the vice president for research. He also serves as head of the Department of Statistics and Statistics Department and in these capacities reports to the respective dean and director.

Personnel are shared by the various components of the statistical center, which means that a staff member's salary may be budgeted from several sources, depending on the emphasis of his work. In addition, a number of cooperative agreements with federal agencies provide research funds for both staff and graduate students.

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

THE STATISTICAL LABORATORY STAFF FOR THE FISCAL YEAR 1968-69

Under the administrative direction of

W. Robert Parks, Ph.D. . . . President of the University

J. Boyd Page, Ph.D. . . . Vice President for Research; Dean of the Graduate College

Chalmer J. Roy, Ph.D. . . . Dean, College of Sciences and Humanities; Director, Sciences and Humanities Research Institute

Floyd Andre, Ph.D. . . . Dean, College of Agriculture; Director, Iowa Agriculture and Home Economics Experiment Station

Theodore A. Bancroft, Ph.D. . . . Director, Statistical Laboratory; Head, Department of Statistics; Head, Statistics Department, Iowa Agriculture and Home Economics Experiment Station

Professors

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

PERSONNEL

Associate Professors

Barry Arnold—on assignment in Mexico
David F. Cox
Donald K. Hotchkiss—in Mexico through fall quarter
David Jowett
C. C. Mosier—joint appointment with Computation Center
Edward Pollak—joint appointment with Department of Genetics
J. H. Sedransk
James Walsh—joint appointment with Department of Psychology
Richard D. Warren—joint appointment with Department of Sociology and Anthropology

Assistant Professors

Harold Baker
Chien-pai Han
Roy Hickman
Paul Hinz
James L. Hutter—joint appointment with Department of History, Government and Philosophy
Dean Isaacson—joint appointment with Department of Mathematics
Glen Meeden
Richard Mensing
Shashikala Sukhatme

Instructors and Associates

Leon Burmeister
G. L. Ghai
Leon Jordan—through winter quarter
William Kennedy—in charge, Statistical Numerical Analysis and Data Processing Section
Barrie Latter
John Lin
Abel Mexas
P. Papaioannou
Carl Z. Roux
Vincent Sposito
Richard Stein
Victor Tang
James Veale
Eric West
Milton Winger

Statistical Data Processing Service

Bud Meador, Supervisor
Jill Batchelor Blaskovich—through spring quarter

Visiting Lecturer

Richard Lund—on assignment in Mexico

Visiting Scholars

Isabel Gravett—beginning spring quarter
Sundardi Wirjosudirdjo—beginning spring quarter

Graduate Assistants

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

George Battese
Richard Chamberlain
Eliahou Cohen
Jean Denis DesRosiers
John Goebel
Bonnie Hanson
Her Tzai Huang
Charles Ingwell
Louis Jensen
J. D. Jobson
Henry Kelker
Dennis Mar
James Mellon
Kenneth Merritt
Kenneth Mount
Martin J. O'Connell
C. M. Patel
David Pyne
J. R. Schmid
Justus Seely
Jan Shoemaker
Wendell Smith
Jane Toben
William Warde
Irene Yung

Other Graduate Students

NIH Trainees:

Pamela Doctor
Thomas Fears
Ronald Jacobson
Roland Loup
Peter O'Brien
Lonnie Vance

NDEA Fellows:

A. Ronald Gallant
Nancy Heath
G. N. Lauer

NSF Fellows:

John Kinney (Faculty Fellow)
Richard Madsen

IBM Fellow:

Cary Isaki

ISRF Fellow:

Kenneth Mount

Supported Students:

Guillermo Adames-Suari, Government of Mexico
Yahia Ahmed, Ford Foundation, UAR
Sirisin Assakul, Thailand
Sorachai Bhisalbutra, AID, Thailand
Alfonso Carrillo, Ford Foundation, Mexico
Shang-Wang Chang (joint statistics-mathematics), Department of Mathematics
Pathra Chatkeo, AID, Census Bureau, Thailand
Godfrey Coker, AID, Census Bureau, Sierra Leone
Isidoro David, Rockefeller Foundation, Philippines
K. T. deGraft-Johnson, Population Council
Amiri Gamshadzahi, USDA, Iran
Soner Gonen, Hacettepe University, Turkey
Charles Graham, NADL
Joseph E. Grimes, Department of Mathematics
Omer Gucelioglu, Census Bureau, Turkey
Omar Henriquez, Rockefeller Foundation, Chile
Muzammil Husain, AID, Census Bureau, West Pakistan
Jairof Jayavadhanangkur, AID, Census Bureau, Thailand
Khadija Khatun, AID, Pakistan
Brian D. Macpherson, University of Manitoba, Canada
Angel Martinez, Ford Foundation, Mexico
Nimmagadda Murthy, AID, India
Syed T. M. Naqvi, AID, Census Bureau, Pakistan
Vipanee Rojanavanich, Thailand
Ahmed Salem, Government of UAR
Ivan Sampaio, IRI
Choosak Udomsri, AID, Census Bureau, Thailand
Fredric A. Vogel, USDA Trainee
Sherman B. Winnings, USDA Trainee
Franklin Wolf (joint statistics-industrial engineering), Department of Industrial Engineering

Unsupported Students:

Hosni Abou-Seada
Robert E. Albert
Forrest Aspengren
Gordon Booth
Sudha Desai
Charles MacIsaac
Donald McElhone
Nell Sedransk
Terrance Svejda
Chartsee Xumsai

General Office Staff

Margaret G. Kirwin, Administrative Assistant
Kathleen Ringgenberg, Accountant
Susan Alice Brown, Technical Writer-Editor
Avonelle Jacobson, Supervisor, Teaching Section
Shirley Saveraid, Secretary, Statistical Numerical Analysis and Data Processing Section
Iveta Zeliadt, Secretary, Experimental Design-Genetic Statistics Section
Jan Bates, Secretary
Norma Christian, Secretary
Donna Cooper, Secretary—beginning spring quarter
Judy Donald, Secretary—through fall quarter
Carol Shafer, Secretary—beginning fall quarter
Marlene Sposito, Secretary—through spring quarter

Survey Section

Anne Leicht, Secretary—through fall quarter
Sandi Partlow, Secretary—beginning fall quarter
Marjorie Mason, Survey Supervisor
Betty Fell, Programmer

Clerks:

Helen Carney
Hazel Cook
Evelyn Green
Ava Klopf
Anna B. Woodrow

CONSULTING and JOINT RESEARCH

Consulting services are available for the statistical analysis and interpretation of data, statistical design of experiments and surveys, and the development and extension of new statistical methods and techniques.

The statistician is continually confronted with situations which require the modification of existing techniques and the development of new ones for the application of statistical methodology and theory to research problems. The consulting involves the discussion of the objectives of a research worker's investigation and setting up a suitable plan which will furnish answers to his questions.

All members of the Statistical Laboratory staff are available for consulting, although certain personnel devote a major proportion of their time to these services. This consulting service is made possible by the budgetary allowance of the Statistical Laboratory and the financial support provided to some staff members by the Agriculture and Home Economics Experiment Station and the Engineering Research Institute.

Although it isn't possible to give a complete report of all consulting activities, the following record indicates the type and scope of this service.

Consulting in the Animal Sciences

Consulting in the area of animal sciences is supported by Agriculture Experiment Station Project 101, Statistical Services in the Animal Sciences and Plant Sciences. Personnel working in this area during the year included Dr. D. F. Cox, Dr. D. K. Hotchkiss and graduate students Leon Burmeister and Dr. Eliahou Cohen.

The major part of this consulting involves examination of data by general least squares techniques. The models to be tested are developed in consultation with the research worker. One key to constructive and useful consulting is the ability to produce analyses of data based on the proposed models easily and efficiently. The best results have been obtained when the research workers themselves became involved in the analysis procedures.

Two tools are necessary to achieve such goals. First, powerful general purpose programs are required and must be designed to handle a broad range of problems without the necessity of detailed programming for each job. Second, a more flexible programming system should be available for examination of data in ways not covered by the general programs.

The second requirement has been met admirably by the OMNITAB system. The system has made the computer accessible to any research worker willing to make a very minimal effort to learn the basic principles. OMNITAB provides an array of very powerful and easily accessible tools. It has become indispensible to the consulting work in animal sciences and has opened the use of computers to workers with neither the time nor inclination to learn a symbolic language like FORTRAN.

General purpose programs for the animal sciences must allow for situations where substantial disproportionality in subclass numbers is the general rule. Less than ten percent of the problems examined can be handled with general programs for balanced designs such as the main AARDVARK program that is so useful in other areas. During the past year several programs have been maintained and used in conjunction with the IBM 360/65, including two general least squares programs. Additional programs for correlational analysis and nested analyses of variance are also widely utilized.

A partial list of the types of problems studied follows:

In animal science Dr. Cox assisted Dr. M. P. Hoffman in determining the effects of shelter and pen surface on the gain and feed utilization of beef cattle in Iowa feed lots. He worked with Dr. L. L. Anderson on a study of the prolactin content of pituitary extracts in swine following various surgical and hormonal treatments as assessed by a bioassay using pigeons.

Graduate students sought advice on isolating the differences in the characteristics of beef cattle with normal muscles and those carrying hereditary factors for "doubling muscle"; determining the influence of storage temperatures on the quality of beef carcasses as judged by taste panels and objective measures on the meat itself; studying the plasma flow rates in dairy calves following various treatments (the rates measured over a 17-hour period at two sites in the calves); judging the influence of growth hormone, insulin and protein-bound iodine on daily gain and body weight in beef cattle; comparing various methods of assessing body composition by visual, mechanical and chemical scores on lamb carcasses; and determining differences in growth and chemical characteristics between two strains of pigs, one termed "normal" and the other known to be susceptible to death from stress induced by handling.

In the area of poultry science, Dr. Cox was consulted by Dr. W. M. Marion on a study of factors influencing the percentage of turkeys that receive a USDA grade of "A" in processing plants. The work included investigation of models accounting for the hour the birds were loaded into delivery trucks, breed, season and plant differences. Dr. A. W. Nordskog sought advice on studying the influences of egg size, strain and level of inbreeding on hatchability in chickens.

Dr. Cox and Dr. Cohen helped a graduate student with a study of the factors influencing the production of secondary bone in chickens and the most suitable bone to use to evaluate secondary bone in the total skeleton. Dr. Cohen has worked closely with the analysis of this experiment. Using the OMNITAB system, he has examined many different models and prepared plots of the data that have been helpful in interpreting the results.

Dr. Cohen also analyzed some survey data on deaths of cattle during and immediately following trans-shipment. The data were collected by Dr. R. F. Bristol, veterinary clinic, using a postal questionnaire. The response was incomplete, which strictly speaking invalidated the analysis, but there were indications that vaccination and treatment with antibiotics had an adverse effect on survival, as Dr. Bristol expected. He was advised to pursue the subject obtaining complete data, and it was suggested he consult the Survey Section.

A graduate student in dairy industry consulted with Dr. Cox on a study to isolate characteristics of different types of Swiss cheese in an effort to improve the quality and especially the uniformity of the manufactured product.

In the area of veterinary medicine, Dr. R. H. Ingraham and Dr. D. D. Gillette consulted with Dr. Cox on studies of milk yields and fertility of cattle maintained in tropical conditions in Mexico. The purpose was to deliniate the climatological factors influencing productivity in order to devise management practices that will increase yield.

Dr. R. G. Huhn sought advice on the influence of new medicated feeds on the control and eradication of pneumonia in swine. A feeding trial used pigs from herds known to be infected as well as pigs raised in specific-pathogen-free environments.

Dr. Cox worked with a graduate student on an investigation of the distribution of particles between cell compartments (nucleous vs. cytoplasm) with the several viruses measured at various times after exposure. The counts were made using radioactive tracers.

Dr. Hotchkiss assisted personnel in veterinary anatomy to obtain a partial analysis of an exploratory type study on denervation of the heart in which a lack of replication necessitated the use of higher order interactions as the error estimate.

In other experiments with which Dr. Hotchkiss assisted, sets of data from observations of ground squirrels and white rats were combined in a study of the response of a 4x3x3 factorial experiment. The recovery of radioactive iodine was investigated.

Dr. Cox was consulted by staff members and graduate students on two studies in home economics. One was concerned with the influences of cooking temperature, kind of muscle and type of oven on cooking losses, measures of quality and taste of ham. The other investigated factors affecting the quality of turkey rolls stored for various lengths of time and prepared with different kinds of gravy.

Burmeister worked with an associate in dairy and food industry on a project for the Iowa Development Commission. The Commission was interested in determining the effects of various temperature levels and types of freezing on repressing the growth of several types of bacteria on meat products. The bacterial counts were transformed to the log scale and the factorial arrangement of treatments was analyzed using the AARDVARK program. The results will be used in making recommendations with respect to the conditions under which Iowa meat products are shipped to foreign countries.

A graduate student in zoology consulted with Burmeister on a study of the behavioral patterns of leaf hoppers. Whenever one of several leaf hoppers executed a distinct action, the immediate response of the other leaf hoppers was recorded. The intent of the experiment is to determine the actions and noises associated with courting with the eventual hope of curtailing reproduction.

Dr. Pilar Garcia, food and nutrition, was interested in the effect of the aging process on various physiological characteristics in women. Burmeister assisted with an analysis which utilized both the OMNITAB and AARDVARK programs, to discover such facts as whether protein intake changed significantly as women grew older and, if so, in which decade of age the change occurred. In another project in food and nutrition, for Dr. Lotte Arnwich and two graduate students, eight groups of rats were subjected to deprivation of food and water for a period of time. They were then fed various recovery diets. Dr. Arnwich was interested in determining how these recovery diets compared with respect to the amount of various fatty acids found in the liver.

Dr. Dwight Coulter, physiology and pharmacology, consulted with Burmeister on a study of the differences of anemic and non-anemic pigs with respect to certain blood characteristics and certain heart measurements. He also was interested in determining whether such differences were the same for both male and female animals.

Henry Kelker, a graduate student in statistics, has used the general least squares program to examine the relationships between measures of blood sugar and growth during the first two weeks of life in swine. The investigator has sought an understanding of the interrelationships among many variables measured on individual pigs, such as growth, levels of glucose, fructose,

lactic acid and total reducing sugars in the blood, lactic acid and the time and order of birth. Kelker has also generalized a computer plotting routine capable of displaying two and three dimensional plots using the Calcomp plotter with the IBM 360/65 computer.

A graduate student in zoology consulted with Dr. David Jowett on a study of the effect of steroids on mammary and uterine development in rats. Three factors were applied in a 2^3 configuration in ten replications, and the relative and absolute amounts of RNA and DNA in mammary glands and uterus were examined using standard analysis of variance techniques. An experiment similar in design but quite different in concept was brought for analysis by another graduate student in zoology. This was a single replicate of a 2^3 experiment infecting pigeons with *Ascaridia columbi*. The factors were age of eggs, age of pigeons, and single or multiple exposure, and the data included number of worms recovered. Probability plots were tried using several transformations, but no significant effects could be discerned.

Dr. Jowett worked with another graduate student in zoology on a problem which involved relating guesses of the size of bird flocks on water to the actual number of birds. In practice, it is not feasible to count the birds on the water, but using photographs the researcher hoped to relate his guesses to the actual numbers. The relationship was curvilinear and of course the variance of the guess was related to the size of the flock. However, the regression of log on log equalized the variance and produced a straight line relationship.

Professor C. Philip Cox worked with Charles Graham of the National Animal Disease Laboratory on a factorial chi-square analysis used in the quantal response assay of erysipilas bacteria. Ben Bereskin, geneticist in the Regional Swine Breeding Laboratory, consulted with Professor Cox on the analysis of piglet birthweight records. The problem was to assess evidence for and against a birthweight difference between piglets surviving and those not surviving to weaning.

Consulting in the Plant Sciences

Agriculture Experiment Station Project 101, Statistical Services in the Animal Sciences and Plant Sciences, has also supported the work of Dr. David Jowett and Dr. Paul Hinz, and graduate students Richard Chamberlain and James Mellon. Graduate student Roger Mrachek was supported during July and August.

A wide variety of experimental situations has been presented by research workers in all agriculture-related disciplines. Advice has been given on the design of investigations and on the feasibility of statistical analysis. Considerable bodies of data, again from all fields, have been analyzed on the electronic computer. Much progress has been made in the installation and full utilization of advanced general purpose computer programs of value to agricultural research workers on the available IBM 360/65.

Mrachek cooperated with personnel in earth science and botany on ordination and classification procedures for multivariate data. Fossil collections had been classified by frequency of species occurrence in sedimentary rocks, and diatom collections from a lake bottom core were classified by depth and frequency of species occurrence. Two procedures were programmed and successfully applied. The first was a chi-square contingency procedure, developed by Lambert and Williams, and the second an ordination procedure based upon generalized Euclidean distance described by Orlocci. Since Mrachek was drafted, this work is being continued by graduate student R. E. Albert, working with data on the vegetation, duck populations and water composition of prairie pot holes in North Dakota.

A related problem was approached by Dr. Jowett and Dr. James Walsh for Dr. J. H. Huddleston, agronomy. Data was available on physical and soil test properties of soil at 12 depths on a transect of an Iowa hillslope. Initially the data for each characteristic were mapped using the Calcomp plotter routine for drawing projections developed by Howard Jespersen of the Computation Center. Several interesting features were revealed. Subsequently several factor analyses were carried out on correlation matrices, and Dr. Huddleston was able to characterize the factors which emerged as reflecting pedological and geological processes.

Students of Dr. R. Q. Landers, botany, have been active in describing the ecology of a relict area of prairie near Fort Dodge, Iowa. One student investigated the effects of burning and mowing on the frequency of plant species occurrence. Dr. Jowett assisted by carrying out an analysis of variance. Another student was interested in applying polynomial models to frequency data of common species, and also in the application of ordination and classification techniques. Dr. Jowett also assisted with the design of a trapping study to investigate the small mammals of this area.

Chamberlain developed a program to assist a graduate student in agricultural engineering to characterize the rate of germination of corn and soybeans after exposure to electric fields. In was hypothesized that the distribution of number of seeds germinated over time, or some transformation of the time scale, would be approximately normal, and a maximum likelihood technique was devised to estimate means and variances of such a distribution. The estimates using maximum likelihood were found to be satisfactorily approximated by probability plotting and fitting a straight line by eye, which is an easier technique to apply.

Chamberlain also served as programming consultant for the Iowa Corn Yield Trials. Users wish to receive the report on these trials very soon after the end of the current season to place their seed orders. Chamberlain wrote a program to analyze the rather complex lattice designs used for these experiments and produce computer output suitable for direct printing, thus eliminating the time consuming steps of tabulation and typesetting.

Mellon assisted in the analysis of an interesting 2^5 experiment involving five mycorrhizal fungi on walnut in water culture with three levels of nutrient solution. The analysis revealed an abundance of interactions, which made the experiment difficult to interpret. Transformations were sought which might result in a fit to a simpler model, but without success. This data came from Dr. H. S. McNabb, botany, and a graduate student.

Mellon also continued to work on the development of quality criteria for chrysanthemums in cooperation with Dr. C. H. Sherwood, horticulture, and the fitting of logistic models to spore count data from artificially induced epiphytotics of *Puccinia coronata* on oats, in cooperation with Dr. J. A. Browning and a graduate student in botany.

Dr. Jowett developed and analyzed an experiment on the uptake of plastics by wood blocks in cooperation with Dr. J. D. Wellons, forestry. Three plastics and several pre-treatments of the wood blocks were involved, in factorial combination. Ultimately the problem became an exercise in curve fitting, relating the ratio of uptake to time, involving a logarithmic transformation of the dependent variable.

Dr. R. F. Finn and R. A. McQuilkin, forestry and USDA, are continuing their investigation of nutrient requirements of economic tree species using response surface designs and fitting second order polynomials. Dr. Jowett assisted with an extensive analysis on black walnut. The researchers now have decided to attempt to fit nonlinear models of the kind described by J. A. Nelder, Rothamsted Experiment Station, England, at a recent applied statistics seminar. This will involve a radical departure in the experimental design used.

Another problem in forestry has involved the analysis of data on the fine structure of wood obtained by sampling from entire trees. The wood can be characterized as to its age and the age of the cambium producing it, its height in the tree, its radial distance from the center and so forth. Interest resides in fitting functional models, but treating the two sides of the tree as replicates enables the fitting of a classification model; a measure of goodness of fit of the functional model can be obtained. In one study, two trees were involved, which introduced a second element of replication.

A graduate student in agronomy consulted with Dr. Jowett on the partition of genotype/environment interaction of oat lines grown from seed exposed to radiation. The analysis adopted involved the examination of the regression of the yields of individual lines upon environmental mean yields to obtain stability parameters for each line. These parameters were compared to ecovalence, a term defined by G. Wricke, which involves a simple partition of the genotype/environment interactions among lines.

A graduate student in agricultural engineering consulted on a problem of relating estimated erosion from watersheds based on hypothetical functional relationships of storm intensities, land use, slope etc., with observed data from the stream exiting from the watershed. A sampling system was set up for map sheets to obtain point estimates of expected run-off, and the calculations programmed in OMNITAB. Agreement between observation and expectation was not good.

Dr. Jowett performed a covariance analysis for Dr. W. F. Wedin and a graduate student in agronomy. The experiment consisted of two fields planted to two species of forage. Four cows were grazed on each field and data obtained on digestibility and faecal nitrogen. The purpose of the experiment was to relate these two characteristics along with several others, a process which was facilitated by the calculation of simple and multiple analyses of covariance.

Dr. Hinz assisted in the analysis of data on the strength of wood glues for Dr. D. W. Bensend, forestry. In particular, Dr. Bensend was interested in determining if the amount of time to assemble the glue joint could be increased without a strength decrease when blood was used as an additive to the glue. No such effect was noticed.

A graduate student working at the European Corn Borer Laboratory in Ankeny consulted with Dr. Hinz on a study to determine how the development and reproductive abilities of the borer were affected when the larvae were fed certain resistant varieties of corn. It was easily shown that survival, etc. were adversely affected by the resistant varieties.

Dr. Edward Pollak continued to provide consulting services in mathematical and statistical genetics, under the support of Agriculture Experiment Station Project 1448. Among the people consulted with were Dr. M. D. Simons, botany, a graduate student in animal science and Dr. A. R. Hallauer and a graduate student in agronomy. The advice given involved experimental design, the genetical interpretation of mean squares, and iteratively solving for regression coefficients when the variances and covariances of deviations from regression are not known.

Dr. Wayne A. Fuller was consulted by W. K. Turner, USDA collaborator in agricultural engineering. He assisted with the development of procedures utilizing time series analysis to isolate the effect of irradiation on insect activity.

Dr. Fuller also worked with members of the agronomy staff on the construction of designs and estimation procedures to measure the effect of environmental factors upon the yield of corn. In these studies experimental plots are placed at several locations throughout the state for several years. Estimation problems include the presence of errors of measurement and the necessity of screening a large number of environmental variables.

Consulting in Engineering and the Physical Sciences

Dr. H. T. David returned from his leave of absence as visiting professor and acting director of the Statistics Center, Department of Statistics, University of Minnesota, to resume his schedule of consulting in the area of engineering and the physical sciences. The projects listed are typical of the problems about which he is consulted.

A staff member in electrical engineering sought advice on the computation of the variance of a certain stochastic integral arising in network theory. Personnel in chemical engineering, electrical engineering and physics were assisted with the computation of the precision of estimators of parameters of nonlinear regression models.

Dr. David was consulted by a graduate student in agriculture economics on a study which involved the application of dynamic programming to optimal crop management problems. A staff member in agriculture engineering requested assistance in the application of extreme-value theory to flood prediction. Two graduate students in chemical engineering, and a staff member and graduate student in sanitary engineering, were advised on the design of filtration experiments.

Dr. B. V. Sukhatme was consulted by a graduate student in civil engineering on the statistical analysis of data, with special reference to preparing a report.

Dr. David Jowett and graduate student Richard Chamberlain consulted with Dr. F. D. Stevenson, chemical engineering, on techniques for the examination of residuals from linear and nonlinear models, particularly with reference to the detection of outliers and asymmetry. Normal plotting was also attempted on signal count data generated by neutron emission from a radioactive source. The expected distribution is Poisson, but the mean was so large in this case that the approach to normality was close, although demonstrably not close enough, being light in the tails.

Consulting in the Behavioral and Social Sciences

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

Several consulting requests have been in the area of evaluation and application of various alternative approaches for the analysis of complex relations in non-experimental research settings. Major interest has been in model building and testing with emphasis on regression, partial correlation approach and path analysis. Stepwise regression has been used in some theses to assist in the selection of variables for the regression equation.

Dr. Warren has worked with a graduate student in sociology who is comparing the partial correlation approach, stepwise regression and path analysis as model building techniques utilizing sociological data. In another study, a path analysis approach was used to determine the variables related to the transition from subsistence to commercial patterns of agricultural production among a sample of farmers in Guatemala. Variables included in the analysis were age, cosmopoliteness, farm size, orientation toward control-over-nature, market system orientation, credit system orientation, risk preference and information orientation. Farm size, information orientation score and risk preference each had a direct effect on the degree of commercialization.

Dr. Warren also assisted with a path analysis approach to examine variables related to managerial performance and economic returns to the business firm. The variables in the analysis included education, past experiences, knowledge, value orientations, role satisfactions, motivational orientations, role performance, return on fixed investments and net operating revenue.

With the assistance of Dr. Leroy Wolins, an approach was developed for the situation when some of the variables are subject to measurement error. Two measures were constructed for each of those variables which would be subject to measurement error. The first set of measures was used to empirically test and modify the models which were developed in the theoretical sections of the thesis which resulted from this research. The second set of measures was used to make additional modifications in the models and to estimate the contribution of the variables.

Since the independent variables were correlated and subject to measurement error, correction for attenuation was made. Path coefficients and residuals were computed utilizing the above approach. Formal education, a composite of knowledge and value orientation to economic ends and role satisfaction had a direct effect on the managers' role performance. A composite of knowledge and value orientation to economic ends and role satisfaction were included in the model when return on fixed investment was the dependent variable. When net operating revenue was the dependent variable, managerial role performance and past experiences were the variables remaining in the model.

In other consulting in the social sciences, Dr. Warren was asked to help in designing the investigation and developing appropriate hypotheses, developing questionnaires and schedules, constructing scales and indexes, coding the responses, analyzing and interpreting the data collected.

Some of the topics on which Dr. Warren was consulted regarding design and analysis of the studies included: influence of personal and mass communication on behavior, socio-economic factors related to the clothing behavior of urban families, adoption of new

rice varieties in developing countries, social and psychological factors related to orientation programs, factors related to marital adjustment of married college students, interaction of parent-child with varying levels of originality, relationship of college major and open- and closed-mindedness, social characteristics related to use of mass media by Iowa farm women, communication patterns of parent and child during adolescence, and factors influencing effectiveness of lighting in dormitory rooms.

Dr. Wolins, who has a joint appointment in statistics and psychology, has spent increasingly more of his consulting time with students in child development and psychology.

Among projects on which he was consulted, two of particular interest were studies of small group behavior where analysis of variance was performed on each group separately. The factors included categories of group behavior, time (each group was observed several times) and observer (each group was observed by several observers arranged in a PBIB design). Following these analyses, variance components were estimated and the square roots of these coefficients were analyzed across groups and treatments.

Dr. Wolins also assisted with series of studies conducted by Dr. Wayne Bartz and his students in psychology, designed to test the hypothesis that a single mechanism is sufficient to explain learning and storage of information. Although no definite answer has resulted, many interesting shortcomings in previously applied statistical models have come to light. For example, when judging the presence or absence of a particular stimulus in a previously presented list of stimuli, the variance of the responses is greatest when the stimulus is absent in the previously presented list. This does not appear to be a scale artifact since the mean and the variance are uncorrelated within stimulus present or absent.

Dr. Roy D. Hickman also has continued to consult with graduate students and staff members in the behavioral and social science areas. A graduate student in education sought help with a problem involving 3-group discrimination. Data on junior college students in three types of programs (college transfer, technical and vocational) indicated whether they had completed their course of study, dropped while doing satisfactory work, or dropped while failing. Using variables measuring prior achievement and ability, discriminant functions were developed to aid in correctly classifying a student at initial enrollment. On a similar study, another student consulted with Dr. Hickman regarding prediction of academic success in physics courses in the Iowa community colleges.

Dr. Hester Chadderdon of the College of Home Economics conducted a survey in Des Moines, Iowa, on attitudes regarding food service occupations. Dr. Hickman assisted with the analysis of the data to determine relationships of socio-economic characteristics with the degree of favor toward employment in the food service industry. He also continued to assist Dr. Geraldine Montag and Dr. Marjorie McKinley, College of Home Economics, with analysis of data from the experimental training program for public school food service workers.

Dr. Frank Haggard, Department of English, and advanced students in the department, conducted a survey of English majors in an attempt to obtain an evaluation of the curriculum. Dr. Hickman and Harold Baker assisted with questionnaire construction and layout, coding and analysis of the survey results.

Dr. Hickman continued to provide consulting assistance to the Department of Agricultural Education on the agricultural competency study. This project, directed by Professor C. E. Bundy, seeks to determine the degree of competency needed and possessed by farmers and agricultural workers in various technical areas in agriculture.

Dr. B. V. Sukhatme was consulted by a graduate student in economics. The project concerned designing a sample survey to collect data for model building purposes.

Dr. Paul Hinz worked with Rita Carey, an instructor in women's physical education, to set up an experiment to evaluate two exercise programs. Measured responses included gripping strength, skinfold thickness, standing heart rate, exercise heart rate, and heart rate at 1, 3, 5 and 10 minutes after exercise. Large variability in the data obscured possible differences among the programs and their interactions with the initial weights of the subjects.

Consulting in Numerical Analysis-Programming

The Numerical Analysis-Programming Section became the Statistical Numerical Analysis and Data Processing Section July 1 with the addition of a new Statistical Data Processing Service. William Kennedy remains in charge of the numerical analysis-programming work.

Staff members provide consultation in statistically-oriented computer techniques and computer programming. General purpose programs for which computer "languages" have been prepared handle entire classes of statistical problems, and manuals for them are available.

Graduate student Bonnie Hanson has developed a new computer program called "Mouflon." This program incorporates four different procedures for model building in regression. Any one or combination of the procedures can be applied to a given set of data.

Graduate student Kenneth Merritt completed work on a new analysis of variance system which performs the analysis for balanced incomplete block, partially balanced incomplete block, and a wide class of lattice designs. This new system, called "Gavial," is an interpretative system which utilizes a keyword set to achieve simplified user input.

"Zorilla," a program which may be used to solve quadratic programming problems on the IBM 360 system, was revised during the year. New features have been incorporated to minimize numerical problems and new keyword commands aid in finding invalid input data or an incorrectly specified model.

The AARDVARK analysis of variance system was maintained and improved by associates Abel Mexas and Richard Stein. It continues to be the workhorse for consulting with researchers in agriculture, education and psychology. The problems which have been analyzed using this program are far too numerous to mention individually. One particularly large analysis involving 1200 entries in a restricted randomization pattern grown at three locations in two years exemplified the versatility of the program. Mexas had to expand an array to accommodate such a large analysis, and clear the operating system from the machine, but once this was done the analysis proceeded without a hitch.

Kennedy assisted faculty members in botany with development of a classification program which utilizes a cluster analysis technique to divide plant species into ecological groups.

Associate Eric West worked with graduate students in statistics on the characterization of several populations of forestry data and the Monte Carlo examination of many types of estimators, and on graphical and other representation of various techniques of estimation of components of variation.

Associate Vincent Sposito, assisted by graduate student Wendell Smith, helped economists on applications of mathematical programming in economic forecasting. Sposito carried through the analysis of what is thought to be the largest linear programming problem, as well as the largest quadratic programming problem, ever solved on a digital computer. The restriction matrix for the linear programming problem contained 41,000 variables and some 7,000 rows. The restriction matrix for the quadratic programming problem contained 1750 restrictions and some 1750 variables.

Graduate student Richard Chamberlain has continued work on the development of OMNITAB. The addition of commands to generate random normal and random uniform numbers has considerably enhanced the usefulness of the program for teaching. The development of tape, disk and drum I/0 commands increases versatility, and for statistical usage the addition of matrix commands to extract eigenvalues and eigenvectors is most valuable. The program has attracted a great deal of interest, and tapes and copies of the manual have been sent all over the world.

The new Statistical Data Processing Service organized at the beginning of the fiscal year has Bud J. Meador as supervisor. It's coordinated with the consulting, numerical analysis and programming services already available through the Statistical Laboratory. The function of the new service is to provide researchers with the capability of using computer facilities more efficiently, through consultation on the proper preparation and processing of research data. The service can provide the most efficient and up-to-date processing techniques in the use of software and hardware facilities, and can solicit additional assistance from professional statisticians or computer science technicians as needed.

During the fiscal year Meador and one programmer provided programming, data handling and consultation regarding computer processing for some 80 research workers who used both the software services of the Statistical Laboratory's Statistical Data Processing Service and and the hardware facilities of the Computation Center. It is anticipated that additional staff will be added in the coming year as this statistical data processing work and technical assistance to research workers increases.

Off-Campus Consulting

Dr. Richard Warren continued as statistical-methodological consultant to members of the NC-90 committee, assisting with planning the design, selecting sampling procedures and developing a field instrument at their third annual meeting in October. This committee is working on the NC-90 project, "Factors affecting patterns of living in disadvantaged families." Dr. Warren also participated in the general coordinating committee meeting in March. This committee has prepared alternative plans for cooperation based on general characteristics of area, area of emphasis, population to be sampled and sampling procedure.

Dr. T. A. Bancroft participated in three program site visits for the National Cancer Institute. He served as one of a committee of three to review proposed health statistics and quantitative epidemiology research training programs at Harvard University, Yale University and San Fernando Valley State College.

Dr. Wayne Fuller continued as a consultant to the evaluation study sponsored by the Ford Foundation, of certain agricultural extension programs in Mexico. With the assistance of Dr. Richard Lund, on assignment in Mexico, the staff of the graduate school at Chapingo has prepared a report on the benchmark survey which was completed in two states in Mexico.

Dr. D. F. Cox was consulted by James Mayhew of the Iowa State Conservation Commission on problems of managing fish populations in Iowa. Mayhew has made extensive use of the OMNITAB programming system in his research effort.

Survey Section

The Survey Section of the Statistical Laboratory provides direct operational services on all aspects of sampling, surveys, and census-type studies. These serv-

ices include design of surveys, drawing of samples, contruction of questionnaires, training and supervising of field workers, collection of data by personal interview and mail questionnaires, coding of data for IBM processing, analysis of data, and maintaining liaison with programmers and the Computation Center on machine manipulation of data coded. The Laboratory has accumulated a sizable store of basic data and materials for sampling U.S. population and agricultural groups.

Consulting services are combined with operational work through the financing of the Statistical Laboratory, the Statistics Department, the Iowa Agriculture and Home Economics Experiment Station and the Sciences and Humanities Research Institute. In addition to projects for various Iowa State departments, work is done for other state schools and governmental agencies, off-campus civic and research groups, and federal agencies.

During the year the Survey Section has provided consultative advice for over 30 projects supported by Agriculture Experiment Station Project 113, Statistical Services for Sampling Investigations. Departments with which the Section cooperated included agricultural economics, agricultural education, agricultural engineering, agricultural extension, agronomy and soils, animal industry, family environment, farm operations, forestry, home economics administration, institution management, and the Crop Improvement Association.

The Survey Section assisted with a study of former patients of the Harrison Treatment and Rehabilitation Center for alcoholics in Des Moines, at the request of Dr. Keith Simpson, director of the Center.

Samples were drawn of people with Des Moines addresses who had undergone the full 10-day treatment since the Center opened. Survey personnel reviewed the questionnaire, helped train the interviewers, coded the replies and formulated the tables. The study focused on the habits of the patients, as nearly as could be determined, for the 12 months before and after their stay at the Center. Records were secured of the number of non-drinking days before and after treatment. Contacts were made with 175 patients. A report is being written.

The school census was finished in August for the Ames Community School District. This biennial census enumerates all persons under 21 years of age who live in the district.

Interviewing has been completed and data coded for the study of Iowa farmers discussed in last year's report. This survey of 191 farmers who had previously been identified as having entered farming during 1959-60 was planned to discover their present location and occupation and to obtain data on their financial progress and structural position. Tables are now being prepared and the findings will be evaluated as part of an M.S. thesis in economics, under the direction of Dr. Donald Kaldor. This study will compare the respondents who are still farming with those who are no longer farming.

Information for another M.S. thesis in economics resulted from a study of farm capital use. Dr. Gordon Ball was the major professor. The survey personnel drew the sample, advised on the preparation of the questionnaire, recruited and trained the interviewers and coded the data, which is now being tabulated. Approximately 620 households were contacted in 35 counties. Of these contacts, 177 Iowa farmers were interviewed. The study sought to determine how they used capital in their farm businesses, which included beef raising, farm grain, etc.

A teacher mobility study has been completed which will result in a thesis in economics, directed by Dr. Arnold Paulsen. Data was collected to discover why teachers move from one school system to another, and how these moves are affected by the policies of school boards and superintendents.

All work has been completed on the survey of factors relating to the diets of preschool children in the 12 north central states. The study was planned to obtain a picture of the dietary intakes and eating habits of the children in order to determine the type of nutrition education needed by those in charge of their feeding. Home economists of the nutrition research departments of Agriculture Experiment Stations at Iowa State University, the University of Illinois, Kansas State University, the University of Nebraska and Ohio State University conducted the study in cooperation with researchers from the Department of Agriculture. Some papers have been written on the findings and others are expected.

Survey personnel are working with Edward Sealine of ISU's CIRAS (Center for Industrial Research and Service) on a marketing management study. Sealine mailed questionnaires to Iowa manufacturers in several standard industrial classifications, to learn how decisions are made at their places of business. The Survey Section coded the data and is assisting with tabulations for the report.

The Survey Section has a four-part role in the third national cancer survey, under an agreement with the Department of Health, Education and Welfare. The work includes: preparation of manuals which will be used to train interviewers and supervisors; consultation with the project officer on the design of questionnaires and other field forms to be used by the interviewers; conducting three training sessions for interviewers and supervisors; and review of initial field work plus visits with interviewers and supervisors in the field to establish a high level of quality in the collection of data. The survey is being conducted in Atlanta, Birmingham, Dallas, Denver, Detroit, Minneapolis-St. Paul, Philadelphia, Pittsburgh and San Francisco.

Under a second agreement with the National Cancer Institute, the Survey Section will reinterview a subsample of persons contacted during the initial survey. Results will be studied to determine the economic effects of cancer on the individual, his family and the community.

CURRENT RESEARCH

In addition to promoting and fostering the use of sound statistical methods in university research, the Statistical Laboratory conducts research in statistical theory and methodology. Research projects which are of specific interest to regular university research programs are supported by the Laboratory's budget. Joint grants and contracts in cooperation with other campus research institutes and experiment stations provide for additional programs of statistical research. Also, contractural research projects set up with off-campus agencies make possible supervised graduate research on statistical problems of common interest. Statistical research has produced many fundamental techniques which can be used in the study and analysis of scientific and industrial problems.

During the year Dr. Leroy Wolins has considered appropriate methodology for analyzing interrupted time series when results are available for more than one observational unit. For example, if performance of animals was observed in a learning experience over several trials and in the middle of the process a drug was introduced, test the hypothesis that the interruption (the drug) altered the performance. The problem with the conventional methodology is that the coefficient associated with the linear trend is highly correlated across animals with the coefficient associated with the interruption. Thus the problem was defined to derive an index lowly correlated with other coefficients derived from the background trend that is reasonably sensitive to the immediate effects of the interruption. These results are published in a report submitted to D. T. Campbell, Northwestern University, for research supported by NSF Grant GS1309X.

Dr. Wolins has also worked on a longitudinal study of 183 managers located at 26 plants of Owens-Illinois Glass Company. These managers have responded to various questionnaires and have been assessed three times in the last three years. It is hoped that this research will help define managerial skills and provide information on how they are acquired. It is expected this information would be helpful in training managers.

The only longitudinal results analyzed indicate that foremen promoted to department heads change the way they respond toward the typical response of department heads. However, the promoted former foremen do not tend to emulate their previous department head.

Dr. B. V. Sukhatme continued directing the research work of M.S. graduate students Mallika Mokkhaves and Sorachai Bhisalbutra who were graduated in August. The abstracts of both theses appear in the publications section of this report. Further work was done on developing ratio-type estimators in the case of qualitative characteristics. Part of this work is reported in Miss Mokkhaves' thesis and a paper has been prepared for publication. Another paper resulted from further work with Ravindra Singh on developing optimum methods for construction of strata.

Dr. Richard Warren continued as co-leader of Agriculture Experiment Station Project 1626 with Drs. George M. Beal and Joe M. Bohlen, Department of Sociology and Anthropology. This project is an attempt to determine the characteristics of managers and local agribusiness firms that will permit prediction of their success and ability to adjust to innovation and change.

During previous years the theoretical model was constructed, empirical measures were developed, and a sample of managers was interviewed. The study includes: knowledge of manager, attitudes of manager, managerial performance, manager's background and experience, perceptions of factors relevant to business management, selected personality characteristics, available resources and economic returns. This year's activities included the continued development of scales and indexes, examination of single variable relationships to success, examination of interrelationships of independent variables and multiple independent variable relationships to success. During the year one M.S. and two Ph.D. theses in sociology resulted from this research. Reports, papers and publications are in process.

Visiting professor Masashi Okamoto, who left fall quarter after nearly a year and half on the staff, was working on research in discriminant analysis.

Two problems were solved in this research, both in collaboration with Dr. Ahmed Z. Memon, now a senior lecturer at the West Pakistan Agricultural University. The first problem was to find an asymptotic expansion of the distribution of the Z statistic. This resulted in Dr. Memon's Ph.D. thesis "Z Statistic in Discriminant Analysis," which was abstracted in the publications section of last year's Annual Report.

The second problem is related to covariate discriminant analysis. Consider the problem of classification of a multivariate observation into one of two normal populations, where in addition to the knowledge of discriminator x, information is available on covariate y whose mean is known to be the same in both populations. Although the covariate has no discriminating power by itself, it is still possible to utilize the additional information in using the residual $x^* = x - By$, where B denotes the regression matrix of x on y, in the linear discriminant function W in place of x (the discriminator itself) to obtain a new discriminant function W*.

In this research an asymptotic expansion of the statistic W* was obtained, as well as the associated probabilities of misclassification of two kinds, in an inverse power of three numbers which represent degrees of freedom of the estimators of $\mu^{(1)}$, $\mu^{(2)}$ and Σ. These expansions can be used to compare the performance of three kinds of classification procedures which are based on (1) discriminator x only, (2) whole variate (x, y), and

(3) residual x*. It was shown that the second, which involves the covariate y as a part of the discriminator (ignoring the information that y has the same mean in both populations), is indeed less efficient than the third, a covariate procedure. On the other hand, the superiority of the first or the third was ascertained to depend on the balance of dimensionality of the variate and Mahalanobis' distance between two populations.

NIH Research

Six doctoral candidates are supported by the current National Institutes of Health graduate training grant program—the third such grant awarded to the Statistical Laboratory, which continues the program originating in 1958. NIH trainees complete the balanced program of statistical theory and application, based on modern statistical methodology, which is required of all statistics graduate students at Iowa State. In addition, they take courses in biological statistics and in the biological sciences and participate in consulting in biological and medical applications of statistics, under senior supervision.

Two of the students, Pamela Doctor and Lonnie Vance, are new to the program this year. Both have been full-time students during the year and both will serve in summer intern programs. Mrs. Doctor, whose work has been directed by Dr. James Walsh, will participate in an ongoing cooperative arrangement with the Mayo Clinic in Rochester, Minnesota and Dr. William Taylor of that institution, which permits NIH trainees to obtain experience, under senior consultants in medical statistics, on problems which arise in experiments undertaken by this famous medical facility.

Vance, who has been advised this year by Dr. T. A. Bancroft, will spend most of the summer at the University of Iowa College of Medicine, working under Dr. Paul Leaverton. Dr. Leaverton, who received both M.S. and Ph.D. degrees as a former NIH trainee at Iowa State, is now head of biostatistics at the SUI Department of Preventive Medicine.

These off-campus intern programs have been developed to provide additional consulting experience for trainees. Roland Loup spent six weeks at the Mayo Clinic last summer, where he reviewed papers on the relationship of blood clotting diseases in women and the use of oral contraceptives, evaluated an upper motion function test, and analyzed data gathered in a study on the effect of antiemetic drugs given to patients after receiving radioactive treatments for cancer.

Currently, Loup is continuing research for his doctoral thesis, extending the Von Neumann mean square successive difference statistic used for testing the occurrence of monotone trend in means of sample normal populations. The extension he is working on involves devising a test for discerning which type (if any) of polynomial trend occurs in these means. He is also examining the possible adoption of several nonparametric tests to test for polynomial trend in the means of continuous populations which are being sampled. His research is directed by Professor C. P. Cox.

Peter O'Brien completed a two-month assignment at the Mayo Clinic in December. During his stay he prepared the analysis of two experiments designed to test the reliability of laboratory technicians and investigated a method for estimating renal plasma flow in humans.

His present research, which will be used in his thesis, is directed by Dr. Wayne Fuller. The problem under study is that of selecting the best of several populations belonging to a common known family while maintaining a specified level of probability of correct selection using a minimum number of observations. The multinomial, gamma, Poisson and Bernoulli families have been considered thus far.

Tom Fears will be with the Biometry Bureau of the National Cancer Institute in Washington, D.C. during June and July. Working under the supervision of Dr. K. L. Mehra, his research continued during the year on robustness properties of certain nonparametric procedures used in estimation and testing. Both Fears and Loup also taught at Iowa State during the year.

Ronald Jacobson continued his work under Professor Cox. One project he completed during the year involved consulting with a graduate student in bacteriology. The research study concerned thermophilic bacteria, and Jacobson assisted in the statistical analysis.

Some Problems Involving Inference After a Preliminary Test of Significance

The objective of National Science Foundation Project GP9046 is to extend the theory and methodology of inference after preliminary tests of significance to include new problems of considerable importance to statisticians and research workers. Dr. T. A. Bancroft is project leader with Dr. B. V. Sukhatme, Dr. Chien-pai Han and William J. Kennedy as co-investigators. Current research is being conducted in three areas:

1. Preliminary Test of Significance in Some Sample Survey Inference Problems.

Dr. Sukhatme has been working with Alfonso Carrillo, a graduate student, on the problem of estimating a parametric function of the form $\sum_{i=1}^{k} W_i \sigma_i^2$ based on preliminary test(s) of significance where σ_i^2 is the variance of the i-th population and W_i $i=1, 2, \ldots, k$ are known weights associated with the k populations. They have investigated the bias, the mean square error and the relative efficiency of the proposed estimation procedure with respect to the procedures currently in use for the case $k=2$. In the special case of two strata, certain conditions have been obtained under which the proposed estimation procedure based on a preliminary test of significance is more efficient than the usual estimation procedures. A paper containing these results with an application to estimating the variance in stratified sampling has been prepared for possible publication.

Using the multivariate F distribution, it is proposed to extend the results further and investigate in detail the efficiency of the proposed estimation procedure based on preliminary test of significance and the optimum choice of the level of significance of the preliminary test.

This research will result in Carrillo's Ph.D. thesis.

2. On Pooling Means in Normal Populations.

The problem considered involves an incompletely specified model as follows: the experimenter is interested in testing some hypothesis concerning the mean μ_1 of a normal population. A sample of size n_1 is taken from this population. However, a second sample of size n_2 is available which might be taken in a different time or place. The experimenter suspects that the second sample may have come from the same population. It is assumed that the populations are normal with the same variance which is unknown, but the means may be different. Whether to pool the second sample for testing some hypotheses about μ_1 is made to depend on the result of a preliminary test for $\mu_1 = \mu_2$. If it is rejected, only the first sample is used; if it is accepted, the two samples are pooled to test the hypothesis, say, $\mu_1 = \mu_0$.

It is found that the size for the overall testing procedure occurs at $\mu_1 = \mu_2 = \mu_0$. When $\mu_1 \neq \mu_2$ but $\mu_1 = \mu_0$, it is possible to commit an error in pooling the two samples under the null hypothesis H_0: $\mu_1 = \mu_0$. This error is called the "pooling error." Also when $\mu_1 \neq \mu_0$, the power has been computed. Computer programs have been written so that it is possible to evaluate the size, pooling error and power for all parameter values.

The object of evaluating the size, pooling error and power by computer is to select an α level of the preliminary test such that the test procedure is most efficient. In order to achieve this object, a measure of relative efficiency was defined, based on the powers of the sometimes pool procedure and the never pool procedure after adjusting the size and the pooling error. When the experimenter specifies a minimum relative efficiency he is willing to have, then he can select an α level from the computed table. Graduate student G. N. Lauer, working under Dr. Han, is using the computer to obtain such a table. Research results are included in his M.S. thesis.

3. Model Building for Prediction in Multiple Regression (σ^2 unknown), Sample Size and the Ordering of Independent Variates in Model Building for Prediction Procedures.

Within the class of procedures recommended for use in model building for prediction in multiple regression, two different procedures for obtaining a predictor have been considered in detail.

The first model building procedure under consideration is called the Sequential Deletion Procedure and is a procedure wherein the coefficients β_i of k-r "doubtful" independent variates are tested one at a time, beginning with β_k and proceeding in order k to r+1, the process being terminated when either all k-r "doubtful" variates are rejected or some one of the coefficients in the "doubtful" set is declared to be significantly different from zero at some selected significance level α. Upon termination of the testing process the model is taken to contain the r fixed variates and all other variates from the "doubtful" set except those variates whose coefficient was declared to be significantly different from zero. All tests are F tests, the F statistic in each case uses the residual mean square from the full fit in its denominator.

The second model building procedure is called the Forward Selection Procedure and is implemented by testing sequentially the coefficients of "doubtful" independent variates, one at a time, in order r+1 to k. The testing process terminates when a test indicates that the coefficient being tested is not significantly different from zero. All tests are F tests with test statistic using the residual mean square from the full fit in the denominator of the F ratio. Upon termination, the model is taken to contain all variates in the basic set of r plus all variates whose coefficient was declared significantly different from zero when tested at a selected level α. The bias and mean square error for Y*, the predictive model for each of the above procedures, has been obtained when σ^2 is unknown.

Further research is directed toward solving the following problems: If a research worker has no basis for stating in which order his doubtful variates should be tested, i.e., he cannot specify an order of importance, can a methodology be obtained for ordering the "doubtful" variates which allows one to make general recommendations as to the minimum sample size necessary in order that a required degree of precision in estimation is maintained under general classes of population configurations? Also, when using either of the two model building procedures, how large must the sample size be in order that the mean square error of the predicted y does not deviate more than a specified amount from the mean square error of predicted y when σ^2 is known?

Doctoral candidate Kennedy, working under the direction of Dr. Bancroft, has obtained results on the above problems which will be included in his Ph.D. thesis.

Analysis of Variance and Experimental Design Research Procedures

Research directed by Dr. Oscar Kempthorne and Dr. George Zyskind has continued for the Aerospace Research Laboratories, Office of Aerospace Research, United States Air Force.

In the area of linear model theory, Dr. Zyskind has done work in establishing further connections with frameworks relevant under induced error structures in randomized experiments, and in extensions to the general mixed linear model. A manuscript has been prepared. Progress in the area of the general mixed linear

model has been pursued by Justus Seely, working under Dr. Zyskind's direction. Results are reported in Seely's doctoral thesis; an abstract appears in the publications section of this report. In addition, a paper has been prepared and submitted for publication.

Dr. Zyskind's more recent research in linear model theory has been concerned with the notions of orthogonality and of partitioned linear models. Some aspects of conditional inverses have also been explored. In particular, relations between impositions of non-estimable parametric conditions and classes of conditional inverses reflecting those conditions are being investigated.

Methods of inference on values of components of variance have been examined by S. T. M. Naqvi, under the direction of Dr. Kempthorne. The simplest situation of components of variance was examined from three points of view: Bayesian analysis, likelihood inference, and goodness of fit testing. This research is summarized in the abstract of Dr. Naqvi's thesis, which appears in the publications section.

Dr. Kempthorne has also directed the work of graduate student Leon Jordan-Filho on the allocation of observations in response surface studies and in polynomial model discrimination. The work shows that a certain function of the residual sum of squares will be an unbiased estimator of the averaged squared bias, with respect to an assumed true polynomial response surface, if the design moments are made equal to the corresponding ones of a uniform distribution over the region of experimentation. This allocation also provides the extra property of minimum bias, and it is shown that in the case of more than one dimension, the designs must be complete factorial in structure.

General methods to obtain one-dimensional designs as well as theorems concerning the construction of designs for higher dimensions are derived, and some examples are given. The development also deals with comparisons of designs.

Mr. P. Papaioannou, working under Dr. Kempthorne, has continued his research on the statistical aspects of information theory. An attempt has been made to define the concept of information about a parameter contained in the sample. Twelve types of requirements have been used to characterize the general concept. The most important ones are:

(i) The extent to which the uncertainty about a parameter Θ is reduced as a consequence of the observations, is the information on Θ contained in the random variable or its distribution.

(ii) A sufficient statistic contains all the information about Θ supplied by the sample.

(iii) Statistical observations contain a fixed amount of information under a fixed statistical model.

These statements together with other intuitive considerations on the concept of information indicate the relevance of information with regard to statistical inference, data condensation, and data interpretation.

Graduate student Abel Mexas has been working under Dr. Zyskind's guidance on the analysis of variance of balanced complete experiment data on a digital computer. The structural formulation exploits many of the general randomization results developed in connection with the current and also previous WADC projects. In addition, concepts of Logical Boolean algebra are being found useful and are being exploited. A manuscript on the subject has been prepared.

Research in Mathematical and Statistical Genetics

Research has continued under the support of the National Institutes of Health, Grant GM 13827, and Agriculture Experiment Station Project 1669, with Dr. Oscar Kempthorne and Dr. Edward Pollak as principal investigators.

Work on the progress of an infinite Mendelain population with viability and fecundity differences resulted in the examination of several possible definitions of fitness. One aim is to determine to what extent a formulation in terms of Malthusian parameters can be useful. The equilibrium of Mendelain populations segregating for two loci has been investigated, using a model of two life stages, infant and adult, again with viability and fecundity differences. The results have been incorporated in an examination of the theory of genetic loads. It is concluded that there are major difficulties, perhaps insuperable ones, to a useful application of the theory.

Additional work has been done on the role of population size and linkage in the response to selection in polygenic systems. Several possible approaches to models of polygenic inheritance involving a large number of alleles or a large number of loci have been examined. The dynamics of the structure of populations under partial inbreeding and a mixture of mating systems have been investigated. Some initial work has been done on a theory of culling selection with finite populations.

A number of papers have been prepared on research supported by this grant. Those which have appeared during this fiscal year are abstracted in the publications section. They include: "On the Fixation of Genes of Large Effects Due to Continued Truncation Selection in Small Populations of Polygenic Systems with Linkage," "The Role of Finite Population Size and Linkage in Response to Continued Truncation Selection. I. Additive Gene Action and II. Dominance and Overdominance," and "A Multidimensional Age-Dependent Branching Process with Applications to Natural Selection. I."

Design of Experiments and Analysis of the Data

Agriculture Experiment Station Project 890 has supported continued research in the design of experiments and analysis of data. Dr. Oscar Kempthorne continued as project leader.

Work has progressed on the development of understanding of statistical methods. This has been directed to the roles of significance tests in general, of goodness of fit tests, and of likelihood tests, particularly with respect to data analysis.

Design of Surveys and Analysis of the Data

Work supported by Agriculture Experiment Station Project 1005 continued with Dr. Wayne Fuller as director.

The use of quadratic programming to construct regression weights meeting certain inequality constraints (e. g. non-negativity) was investigated. Since most quadratic programs handle easily only problems of modest size, the observations are grouped and weights computed for each group.

A modification of the common regression estimator to improve efficiency is being developed.

The results of the Monte Carlo study of alternative regression estimators were summarized.

Research in Sample Census Methods in Agriculture

Agriculture Experiment Station Projects 1207 and 1312, with Professor Norman Strand as leader, were terminated December 15. This work now will be carried on under Project 1753.

During the 17 years the two projects were in effect, work included five studies on theory problems in sampling, two years of a livestock marketing study, eight years of objective "at harvest" corn yield and forecast surveys, three of object "at harvest" sorghum yield and forecast surveys, four of objective pasture production studies and three objective hay production studies.

In addition, there were three years of population frame or list building studies, and a one-year revision of the Master Sample of Agriculture. Each year new studies or continuation studies were planned in cooperation with the Research and Development Branch of the Statistical Reporting Service, USDA. These totaled approximately 35 different studies over the years.

Work continued on the Soil Conservation Service agreement on National Soil and Water Conservation Inventory. Since completion of the initial phase last summer, data has been reviewed by the 40 states and territories included in the study. Summary tables have been prepared from the initial runs. These consist of nine "camera ready" tables per county. About 20 of the 40 states have had this part of their work completed in the current year.

Statistical and Economic Analysis for Long-Term Experiments

Dr. Wayne Fuller remained as director of Agriculture Experiment Station Project 1578. During the year graduate student George Battese was supported by the project.

Nitrogen response functions for corn, oats and hay were estimated for the five rotations in the rotation experiment on Carrington-Clyde soil. Nitrogen carryover was approximated using data from other experiments. It was concluded that nitrogen carryover was lower in the CCO rotation than in rotations containing meadow.

Optimal rates of fertilization and returns per acre were determined for each rotation at several price ratios. At all price ratios investigated return per acre was highest for continuous corn.

USDC, Bureau of the Census Research Project

The present project of this continuing cooperative program between the Statistical Laboratory and the U.S. Bureau of the Census is concerned with the study of the design of household and farm samples, and estimation procedures based on such samples. Dr. Wayne Fuller continues as director of the project, Cco-9165.

An attempt has been made to establish bounds on the nonresponse for the mean, post-stratification, and regression estimators. While regression and post-stratification reduce the bounds on the bias, their use does not guarantee a reduction in bias.

A sampling scheme has been developed with efficiency approximately equal to one per stratum for which an unbiased estimator of the variance is available. The selection is based upon the random selection of one of several possible sets of stratum boundaries. A program for the selection of unequal probability samples using "random stratum boundaries" has been developed and is now in use.

Investigation of estimators for skewed populations continued. Tests for skewness and estimators constructed conditional on these tests, as well as estimators constructed from "Winsorized" samples, are being considered.

Design and Analysis of Sample Surveys

Research activities supported by the U. S. Office of Education under Contract OEC-3-6-002041-2041 have been concentrated on three topics. Dr. J. H. Sedransk continued as project director.

1. Estimation of the cumulative distribution function (c. d. f.) for a finite population.

The objectives are to provide estimators for the c. d. f. of a finite population, and then to determine the "optimal" sample design. For simplicity, it is assumed that the finite population consists of N units $(u_1, u_2, \ldots, u_N)$ with $y_1 < y_2 < \ldots < y_N$ where Y is the variable under study. Sampling is assumed to be without replacement.

At present, numerical solutions to the optimization problem are being generated, and these will be compared with "rules-of-thumb" being developed by considering variations of the problem. In particular, if one assumes that sampling is *with replacement,* it is easy to determine the optimal selection probabilities for the units since terms involving π_{ij} are absent. These optimal probabilities suggest approximations for the optimal values of the π_i in the "without replacement" case. Further, asymptotic expansions have been developed, and these may yield useful approximations for the optimal values of the π_i and π_{ij}.

2. Some contributions to the theory of two-phase sampling.

Graduate student K. T. deGraft-Johnson has been

carrying out research on some aspects of the theory of two-phase sampling. In particular, he has completed an analytical investigation of the relative efficiencies of some ratio-type estimators under two double sampling schemes, and is now investigating their performance using several specific finite populations. This numerical study includes comparisons based on the asymptotic results obtained earlier, and on "Monte Carlo" sampling of the finite populations.

In addition, the use of optimal stratum boundaries in conjunction with two-phase sampling is being studied. With this approach, one uses the values of X(the concomitant variable) obtained in the preliminary sample to define optimal stratum boundaries. A subsample is then selected within each stratum and Y is measured for all elements in the subsample. This procedure should be superior to the usual "double sampling for stratification" where the values of X obtained in the preliminary sample are used only to estimate the stratum "weights."

3. Comparison of equal and unequal probability sampling design.

A problem having applications in many fields is to develop and compare sample designs appropriate if there is no list of units available prior to sampling and it is considered infeasible to visit any sampling unit more than once. Problems of selection bias preclude the use of equal probability systematic sampling.

Three papers based on research supported by this contract have been submitted for publication. The abstract of one, "Planning Some Two-factor Comparative Surveys," appears in the publications section. The others, and additional publications, are expected to appear in the future.

PUBLICATIONS and PROFESSIONAL ACTIVITIES

Research conducted by Statistical Laboratory staff members is reported at professional meetings and published in professional journals. Staff members also participate in many professional activities in connection with various professional societies, and are involved with the publication of the journals. Such activities during the past fiscal year are recorded in this section.

Shashikala Sukhatme and George Zyskind served as referees for Biometrics during the year. H. T. David, J. H. Sedransk and George Zyskind served as editorial collaborators for Technometrics. Editorial collaborators for the Journal of the American Statistical Association included T. A. Bancroft, C. P. Cox, H. T. David, C. P. Han, D. V. Huntsberger, Richard Lund, J. H. Sedransk, Justus Seely, B. V. Sukhatme and George Zyskind.

H. T. David served as referee for the Annals of Mathematical Statistics, W. A. Fuller was a member of the editorial council for the American Journal of Agricultural Economics and Oscar Kempthorne is a consulting editor in statistics for Appleton-Century-Crofts, division of Meredith Publishing Company. J. H. Sedransk was a reviewer for Mathematical Reviews. J. K. Sengupta has been elected an associate editor of *International Economic Review,* published simultaneously from Wharton School, University of Pennsylvania and Tokyo, Japan. James Walsh is editor of Iowa Psychologist, associate editor of Perceptual and Motor Skills and on the editorial board of Psychological Reports.

RECORD OF PUBLISHED RESEARCH

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

***Barry C. Arnold:** "Parameter Estimation for a Multivariate Exponential Distribution." Journal of the American Statistical Association, 63:323, 848-852. September 1968. Reprint Series No. 230, Statistical Laboratory, Iowa State University.

Simple consistent estimates are derived for the parameters of a multivariate exponential distribution. The mean squared error of the estimates is computed, and a lower bound for their efficiency is derived. A precise lower bound for the efficiency is computed in the bivariate case. It does not seem feasible to compute the efficiency precisely in the multivariate case. Some attention is given to the behavior of the estimates when observations are rounded prior to analysis.

T. A. Bancroft: *Topics in Intermediate Statistical Methods, Volume 1.* 129 pp., Iowa State University Press, Ames. 1968.

The material in this book was originally developed as a seminar on intermediate statistical methods for first year graduate students at Iowa State University. Topics were selected which would aid in solving questions concerning increasingly complicated applications of statis-

tics to actual research situations. Topics for this first in a two-volume series are of particular benefit to research scientists and graduate students in the fields of biology, agriculture, veterinary medicine, medicine and public health, and in certain fields of engineering.

Contents include: *Analysis of Variance: Unequal Subclass Frequencies for Two-Way Classifications.* (Introduction. Notation for multiple classified data. General procedure for testing the significance of a set of parameters in a model. Model specification in a two-way classification. Equal numbers in the subclasses. Analysis for two-way classifications with unequal and disproportionate subclass frequencies: exact methods applicable to fixed models. Method of weighted squares of means. Summary of exact methods.)

Approximate Methods for a Two-Way Classification with Unequal and Disproportionate Subclass Frequencies. (Introduction. Method of unweighted means. Method of expected subclass numbers.)

Analysis of Variance: Unequal Subclass Frequencies for Three-Way Classifications. (Introduction. Notation for a three-way classification. Equal subclass frequencies. Proportional subclass frequencies. Exact method applicable to fixed models with unequal and disproportionate subclass frequencies. Weighted squares of means. Summary of exact methods for a three-way classification.)

Approximate Methods for a Three-Way Classification with Unequal and Disproportionate Subclass Frequencies. (Introduction. Method of unweighted means. Method of expected subclass numbers.)

Extension of Exact and Approximate Methods to N-Way Classifications with Unequal and Disproportionate Subclass Numbers. (Introduction. Method of fitting constants. Method of weighted squares of means. Preliminary test for interaction in the population. Method of unweighted means. Method of expected subclass numbers.)

Analysis of Covariance. (Introduction. Illustration of a covariance model for a two-way classification with a single observation in the subclasses. Principle uses of covariance. Standard covariance computations for a randomized block design. Analysis of covariance for a two-factor experiment in randomized blocks with a single observation per treatment combination. Covariance analysis of multiple classification tables with unequal subclass numbers.)

Orthogonal Polynomials. (Use of orthogonal polynomials. The usual model assumed when using orthogonal polynomials. Formulas for estimating A_j coefficients. Analysis of variance for polynomial regression using orthogonal polynomials. Use of orthogonal polynomials for more than one Y-value for each X-value. Approximate method for unequal Y subclass frequencies.)

Multiple Comparison Procedures. (Introduction. Scheffe's method. Multiple comparison procedures based on the studentized range. Difficulty of assessing the relative merits of multiple comparison procedures. Summary and recommendations. Multiple comparison procedures for unequal size samples. Multiple comparison procedures for means adjusted by covariance. Comparing treatment means with a control mean.)

(NOTE: This volume has been named to the list of "Outstanding Academic Books for 1968" by the editors of Choice, journal of the American Library Association.)

***T. A. Bancroft** and **Roy D. Hickman:** "Thesis Requirements for the Masters Degree in Statistics at American Universities." The American Statistician, 22:4, 28-30. October 1968. Reprint Series No. 229, Statistical Laboratory, Iowa State University.

In this paper the following are explored: whether institutions offering the masters degree program also offer a Ph.D. program in statistics; whether universities reporting a masters degree program requiring a thesis are considering offering, in addition, a professional degree at the masters level, such as a Masters of Statistics; and thesis requirements for the masters degree in statistics at the various institutions. Replies from 54 departments in 47 colleges and universities are tabulated.

***Gordon Booth** and **J. H. Sedransk:** "Planning Some Two-factor Comparative Surveys." Journal of the American Statistical Association, 64:326, June 1969. Reprint Series, Statistical Laboratory, Iowa State University.

In this paper it is assumed that, using a sample survey, two factors are to be studied, comparisons between the "levels" of the factors are of greatest interest, and there is "interaction" between the factors. Attention is concentrated on situations in which only two levels of each factor are to be compared, but extensions to more complex surveys are discussed.

Assuming independent sampling, optimal sample size allocations are obtained. Where these allocations require recourse to programming algorithms, approximate solutions are given.

If independent sampling is not feasible, a double sampling procedure is suggested. To indicate how subsampling from the first phase sample is to be carried out, a sampling rule (possessing optimal conditional precision properties) is derived. Then a procedure to determine the optimal first phase sample size is given.

Finally, it is demonstrated that this double sampling procedure can be applied to estimation of the (finite) population mean when double sampling with stratification is used.

R. L. Chamberlain and **D. Jowett:** *The OMNITAB Programming System: A Guide for Users.* 135 pp., Houston Data Service Center, Shell Oil Company. 1968.

This manual is constructed in two sections. The first section is an introduction to a basic set of commands which are nevertheless sufficient to solve a wide range of problems. The basic set of commands bears the same relationship to OMNITAB as basic English does to the English language. It will permit the solution of many

straightforward problems effectively, if inelegantly. It is quite possible to master this first section in an hour, and proceed to the solution of simple problems. Sophistication, as represented by the second section, will be acquired by practice.

The second section contains a complete and detailed account of all the commands and modes of operation available in OMNITAB, which include roughly 180 different operations or commands. These commands make almost any kind of data manipulation possible for the person who has little or no experience using the computer. Because this new version is written in FORTRAN, it is fairly simple to add statements that might be of particular interest to someone in the field of chemistry, for example.

*C. Philip Cox: "Some Observations on the Teaching of Statistical Consulting." Biometrics, 24:4, 789-801. December 1968. Reprint Series No. 235, Statistical Laboratory, Iowa State University.

In the past the training of statistical consultants has been largely empirical, consultants often having learned by an apprenticeship-type procedure. It is suggested that the apprenticeship process could be beneficially complemented by systematized course-wise training in appropriate consultee disciplines and in the principles and practices of statistical consulting. Some general and some particularly statistical aspects of consulting are then discussed towards implementing such a program for aspiring consultants in biological research.

General requirements noted include the ability to work in a team, contributing more than specifically statistical prowess; an understanding of the inductive scientific method; and the ability to communicate in the relevant biological disciplines.

The more statistical aspects are discussed in relation to the inductive scientific method of biological experimentation under the headings: objectives of the experiment and hypothesis formulation; plan and design; execution of experiments; statistical analyses; interpretation and inferences. Recommendations made include: that actual participation in experimentation would benefit aspiring consultants, and that intensive seminar discussion of sound or videotape recordings of actual consulting sessions would form an excellent component of the supplementary course instruction.

C. Smith, E. L. Jensen, L. N. Baker and **D. F. Cox:** "Quantitative Studies on Blood Group and Serum Protein Systems in Pigs. I. Segregation Ratios and Gene Frequencies." Journal of Animal Science, 27:4, 848-855. July 1968. Journal Paper No. J-5779, Iowa Agriculture and Home Economics Experiment Station, Ames, Project 1424.

Fifteen blood group and seven serum protein systems have been identified in the domestic pig. However, the significance of these polymorphisms in pig populations is still undetermined. The problem was studied using data on 17 blood systems together with pedigree and performance records on the same pigs. The relative viabilities of different genotypes or phenotypic classes were studied using segregation data from known matings. The changes over a period of time in gene frequency at the various loci were examined to study the dynamics of these simple genetic systems.

E. L. Jensen, C. Smith, L. N. Baker and **D. F. Cox:** "Quantitative Studies on Blood Group and Serum Protein Systems in Pigs. II. Effects on Production and Reproduction." Journal of Animal Science, 27:4, 856-862. July 1968. Journal Paper No. J-5778, Iowa Agriculture and Home Economics Experiment Station, Ames, Project 1424.

Twelve blood group and four serum protein systems were studied to determine relationships with ten performance traits in pigs. The two basic questions posed in this analysis were: what effects do these systems have on performance traits, and what is their usefulness in selection and pig improvement?

Thomas E. Doerfler (Booz-Allen Applied Research, Chicago): "Size and Power of Some Tests Under Experimental Randomization." Technical Documentary Report 68-0179 Aerospace Research Laboratories, Office of Aerospace Research, United States Air Force, Wright-Patterson Air Force Base, Ohio. September 1968.

This report deals with an investigation of the behavior of competitive tests for the paired design under experiment randomization. The tests considered are the Fisher randomization test (R), the Wilcoxon paired test (W), the Sign test (S), and the normal law F test (F). The paired design with N pairs results in the drawing at random of one of 2^N possible plans and the performance of the tests in this population of repetitions is considered. Theoretical and Monte Carlo results are presented.

The general conclusion is that the R and W tests are definitely superior to the other two tests. The R test is slightly superior to the W test in having a greater number of possible significance levels, but at sizes of test possible with both, the powers of the two tests are very close. The relationship of the results to asymptotic theory is discussed.

Wayne A. Fuller: "Grafted Polynomials as Approximating Functions." Australian Journal of Agricultural Economics, 13. June 1969. Journal Paper, Iowa Agriculture and Home Economics Experiment Station, Ames. Project 1005.

The use of segments of polynomials to approximate production surfaces and time series trends is described and illustrated in this paper. These segmented curves are restricted to be continuous, and have a continuous derivative(s) at the join points.

*Irving J. Hall (Sandia Corporation, Albuquerque, New Mexico) and **Akio Kudô** (Kyushu University, Japan): "On Slippage Tests—(I) A Generalization of Neyman-Pearson's Lemma." Annals of Math-

ematical Statistics, 39:5, 1693-1699. October 1968. Reprint Series No. 228, Statistical Laboratory, Iowa State University.

The main purpose of this paper is to discuss slippage problems without assuming the usual condition of invariance on the procedures (i.e., invariant under change of scale and shift of location).

For the sake of simplicity, attention is concentrated on a zero-one loss function. In this situation attention should be paid to the probability of correct decisions which allows use of the terminology of hypothesis testing quite analogously.

In Section II a generalization of the Neyman-Pearson lemma to slippage problems is given. As in the case of hypothesis testing this allows solving problems where the null hypothesis is simple and the alternatives are simple and in some cases where the alternatives are composite. When the null hypothesis is composite the generalization of the Neyman-Pearson lemma can be used in some cases to obtain a uniformly most powerful test by introducing an adequate least favorable probability distribution over the space of the null hypothesis.

***Irving J. Hall** (Sandia Corporation, Albuquerque, New Mexico), **Akio Kudô** (Kyushu University, Japan) and Neng-che Yeh: "On Slippage Tests—(II) Similar Slippage Tests." Annals of Mathematical Statistics, 39:6, 2029-2037. December 1968. Reprint Series No. 233, Statistical Laboratory, Iowa State University.

This is a continuation of a previous paper of Hall and Kudô (1968). The purpose of this paper is to explore the possibility of applying the concept of similarity in hypotheses testing to slippage tests.

***Chien-pai Han** and **T. A. Bancroft:** "On Pooling Means When Variance Is Unknown." Journal of the American Statistical Association, 63:324, 1333-1342. December 1968. Reprint Series No. 240, Statistical Laboratory, Iowa State University.

Given two random samples from normal populations, the experimenter wishes to estimate the mean of the first population. Whether to pool the two samples or not is made to depend on the result of a preliminary test.

The bias and mean square error of the sometimes-pool estimator are given. The relative efficiency of the sometimes-pool estimator to the never-pool estimator is tabulated and the tables can be used to determine a proper choice of the significance level of the preliminary test. A pooling procedure for means, based on prior information, is discussed when the prior distribution is normal.

***Chien-pai Han:** "Testing the Homogeneity of a Set of Correlated Variances." Biometrika, 55:2, 317-326. 1968. Reprint Series No. 226, Statistical Laboratory, Iowa State University.

To test the equality of a set of p variances when the p variates are correlated with common correlation coefficient, four test procedures are proposed, namely: the asymptotic test, the modified Bartlett test, the multiple correlation test and the F_{max} test. Comparisons among these four tests were made. A Monte Carlo study showed that, when $p = 3$, the sample size needed is about 40 in order that the asymptotic theory holds, while for $p = 4$ it needs about 50.

***Chien-pai Han:** "A Note on Discrimination in the Case of Unequal Covariance Matrices." Biometrika, 55:3, 586-587. 1968. Reprint Series, Statistical Laboratory, Iowa State University.

A discriminant function is derived in the case of unequal mean vectors and unequal covariance matrices in two multivariate normal populations. The variates are assumed equally correlated. The discriminant function depends on the size and the shape components and the component of sum of squares of the variates.

***Chien-pai Han:** "Testing the Homogeneity of Variances in a Two-Way Classification." Biometrics, 25:1, 153-158. March 1969. Reprint Series No. 241, Statistical Laboratory, Iowa State University.

Two test procedures are proposed for testing the homogeneity of column variances in a two-way classification, namely, the multiple correlation test and the F_{max} test. The multiple correlation test is an exact test; its distribution is well known. The distribution of the F_{max} test is derived when the number of rows is large.

***Chien-pai Han:** "Distribution of Discriminant Function when Covariance Matrices Are Proportional." Annals of Mathematical Statistics, 40:3, 979-985. June 1969. Reprint Series, Statistical Laboratory, Iowa State University.

Suppose X_{px1} is an observation to be classified into one of two multivariate normal populations with mean vectors μ_1 and μ_2, covariance matrices Σ and $\sigma^2\Sigma$ ($\sigma^2 > 1$) respectively. We assume Σ and σ^2 are known. The discriminant function is derived by using the likelihood ratio procedure and its distribution is found when μ_1 and μ_2 are either known or unknown.

Roy D. Hickman: "Farm Business Record and Analysis Systems of Iowa Farm Operators." Agricultural Education Research Publication No. 27, Department of Agricultural Education, Iowa State University. Iowa Agriculture and Home Economics Experiment Station, Project 1622.

This monograph reports results of a sample survey study of Iowa farm operators, the objectives of which were: (1) to determine procedures and practices in farm business record keeping and analysis used by Iowa farm operators; (2) to determine the degree to which farm records are kept and used by farm operators for analysis purposes; and (3) to investigate relationships between certain farm operator and farm business characteristics and the degree to which farm records are

kept and used for analysis purposes. A stratified multistage cluster sample was drawn using master sample of agriculture materials, and 345 farm operators meeting specified criteria were interviewed.

This paper contains an explanation of the survey design, field procedure and data collection techniques, development of index scores to reflect the degree of records kept and used for analysis purposes, classification of respondents by certain farm and farmer characteristics, and findings and implications of the study.

*Klaus Hinkelmann (Virginia Polytechnic Institute, Blacksburg): "Partial Tetra-Allel Crosses." Theoretical and Applied Genetics, 38:3, 85-89. 1968. Journal Paper No. J-5831, Iowa Agriculture and Home Economics Experiment Station, Ames, Project 890. Reprint Series No. 224, Statistical Laboratory, Iowa State University.

The construction of partial tetra-allel crosses (PTAC) is considered using BIB and PBIB designs with blocks of size four. It is shown how this can lead to certain types of balanced designs. An explicit procedure is given for constructing circulant PTAC's. The analysis of PTAC's—estimation of general effects of the lines involved and analysis of variance—is illustrated in terms of an example.

John Gurland and **Paul Hinz:** "Testing Fit and Analysing Untransformed Data for the Negative Binomial Distribution." Pp. 163-174 in *The Future of Statistics,* edited by Donald G. Watts, Academic Press, New York. 1968.

Two questions are considered in this paper: is the underlying distribution negative binomial, and how should data be analyzed which comes in the form of samples from several negative binomial distributions?

The methods of data analysis presented in this paper offer an alternative to those presently used for discrete data from a negative binomial distribution. With minor modifications, these methods can be applied to other distributions such as the Neyman type A, Poisson Pascal, and Poisson binomial. In fact, a single analysis can be based on more than one type of distribution and use of several different types of estimates. Other modifications will permit tests of assumptions such as a common value of the parameter k in several negative binomial distributions.

Donald K. Hotchkiss: "Establecimiento de Restricciones en el Modelo de Regression Derivado por el Methodo de Minimos Cuadrados" (in Spanish). Agrociencia, 1:2, 15-32.

The appendix to this article describes the steps for imposing restrictions on the "design" matrix in order to obtain a solution for the parameters in the normal equations. Three types of restrictions are discussed: $\Sigma\tau_i = 0$, $\tau_i = 0$ and a set of (a-1) orthogonal contrasts. The changes in the design matrix that result from imposing these restrictions are presented in the "restricted design" matrix. Using the example in the article, the procedure for obtaining an overall F test for treatment effects is described. Contrasts among the various means are made using each type of restriction.

W. W. Marion, R. A. Jungk, **D. K. Hotchkiss,** R. W. Berg and M. L. Hamre: "Class, Weight and Method of Chilling Influences on Water Absorption by Turkeys." Food Technology, 22:10, 1319-1322. 1968. Journal Paper No. J-5849, Iowa Agriculture and Home Economics Experiment Station, Ames, Project 1637.

The influence of class, size, grade and method of chilling turkeys on water absorption during post-mortem chilling was investigated in ten Iowa, Minnesota and Wisconsin processing plants. A negative, essentially linear, relationship was found between water absorption and turkey weight. Moreover, with a slight adjustment for differences among plants, the data on water absorption by both toms and hens were justifiably pooled and considered as a single set of data for statistical analysis. The data on fryer turkeys, on the other hand, exhibited no significant relationship between water uptake and weight of the turkey.

Method of chilling turkeys and grade significantly affected water absorption, the former having a more pronounced effect. Mechanically chilled turkeys and turkeys of lower grade absorbed more water than tank chilled and grade A turkeys.

David Jowett: "Inheritance of Glume Size and Awn Length in Sorghum." Crop Science, 8, 342-345. 1968.

Genetic studies on the inheritance of awn length and glume size in sorghum indicate that (a) both characters are inherited in a quantitative fashion, (b) short awns and small glumes are strongly (but incompletely) dominant, (c) awnless is apparently due to an accumulation of short-awn alleles, (d) epistasis is important in the inheritance of glume size but not of awn length, and (e) linkage may be important in the inheritance of awn length.

Analysis into Mather's D and H components of variance was unsatisfactory owing to the high correlation of D and H. Analysis into Hayman's components of the mean was more satisfactory, but cannot be regarded as quantitatively accurate.

G. E. P. Box, H. O. Hartley and **Oscar Kempthorne:** "The Future of Departments of Statistics." Pp. 103-137 in *The Future of Statistics,* edited by Donald G. Watts, Academic Press, New York. 1968.

This material was originally presented as a panel discussion at a conference on the Future of Statistics, held to commemorate the completion of the Computer Sciences-Statistics Center at the University of Wisconsin, Madison. The panel discussed such topics as a definition of statistics, needs for statistics, undergraduate and graduate majors, user's courses, statistical consultation, balance between theoretical and applied statistics, and the changing phases of the statistical outlook.

R. S. Kleber (St. Olaf College, Northfield, Minnesota): "The Probability of Duplication in Sampling with Replacement." The American Mathematical Monthly, 75:10, 1084-1087. December 1968.

In this paper the author considers three related problems in combinatorial probability:

I. A random sample of size K is taken with replacement from a population of size N. What is the probability P that at least one item is chosen more than once?

II. Given a population of size N and a probability P, what is the size K of the smallest random sample that can be taken with replacement such that the probability is at least P that at least one item is chosen more than once?

III. Given a random sample size K and a probability P, what is the size N of the largest population from which the sample can be taken with replacement such that the probability is at least P that at least one item is chosen more than once?

The solution to problem I is well known. The author obtains highly accurate approximation formulas for the solutions to problems II and III.

Richard E. Lund: "Estimators in Multiple Frame Surveys." Proceedings of the Social Statistics Section, American Statistical Association. 1968.

The use of two frames is required in many survey situations to provide adequate coverage of the universe of interest. When the frames are overlapping, either the elimination of duplicate elements or special estimation techniques are required. Optimum sample allocation under varying costs is also a problem. H. O. Hartley (1962) proposed appropriate estimators for two general cases and submitted minimum variance sample allocation formulas.

An alteration in the Hartley estimators is suggested in this paper. The determination of the weights for the two samples in the overlapped segment is based on actual sample numbers obtained. The resulting estimators have a variance always equal to, or less than, the estimators proposed by Hartley. Complexity of the estimators is not increased. The allocation formula for one case is simplified. The efficiency of the estimators is found to be insensitive to moderate deviations from optimum allocation.

Richard E. Lund: "Uso de Doble Marco en Muestreo." Agrociencia, 3:1. 1969. (in Spanish)

The use of two or more frames is often required in surveys in Mexico. A review of the estimation and sample allocation techniques developed in "Estimators in Multiple Frame Surveys" is presented. Examples of Mexican survey situations are used.

K. L. Mehra (University of Alberta, Canada) and P. K. Sen: "On a Class of Conditionally Distribution-Free Tests for Interactions in Factorial Experiments." Annal of Mathematical Statistics, 40:2, 658-664. April 1969.

Nonparametric analysis of variance tests for factorial experiments, available in the literature, relate mostly to main effects in two-way layout linear models without interactions. Although the approach of Lehmann (1964) (see also Puri and Sen, 1967) can be adapted to construct tests for interactions, such tests are rather tedious to apply and are only asymptotically disribution-free. To obviate these drawbacks, the theory of permutationally distribution-free rank order tests for main effects, developed independently by the two authors, Sen (1968), Mehra (1968) (see also Mehra and Sarangi, 1967), is further extended in this paper to provide suitable tests for interactions in factorial experiments. The asymptotic power-efficiencies of the proposed tests are also studied.

***Charles J. Mode** (State University of New York at Buffalo, New York): "A Multidimensional Age-Dependent Branching Process with Applications to Natural Selection. I." Mathematical Biosciences, 3, 1-18.1968. Journal Paper No. J-5759, Iowa Agriculture and Home Economics Experiment Station, Ames, Project 1669. Reprint Series No. 238, Statistical Laboratory, Iowa State University.

A multidimensional version of an age-dependent branching process of Bellman and Harris is studied. In the Introduction the model is described and some of its biological limitations are discussed; in Section 2 it is shown that the mean functions of the process satisfy a system of linear integral equations of the renewal type, and a solution to the system of integral equations is obtained; and in Section 3 the limiting behavior of the mean functions is studied. The analytic techniques used rely heavily on the theory of the Laplace transform and the Perron-Frobenius theory of positive matrices. Further analytic results as well as applications to the theory of natural selection will be developed in a companion article.

***Edward Pollak:** "On Random Genetic Drift in a Subdivided Population." Journal of Applied Probability, 5:2, 314-333. August 1968. Journal Paper No. J-5371, Iowa Agriculture and Home Economics Experiment Station, Ames, Project 1505. Reprint Series No. 237, Statistical Laboratory, Iowa State University.

In this paper it is assumed that there is a haploid population in which generations do not overlap. The population is divided into K parts, each of which contain N adults in any generation. These are obtained by a random sampling of the offspring of the previous generation. It is also assumed that the probability that an adult individual in one subpopulation has an adult offspring in one of the other subpopulations is the same small positive number, no matter which two subpopulations are considered.

If the population initially has individuals of two types, A and a, it is of interest to study approximations, if n is large, to

(1) the rate at which A or a is lost between generations n-1 and n,

(2) the probability that A and a are both still present in generation n,

(3) the joint distribution of the frequencies of A in the subpopulations.

A solution is given for the first problem. It is found that if the mean number of migrants per generation from one subpopulation to one of the other subpopulations is at least as large as 1, the population behaves almost as if it were not subdivided. But if this number is considerably less than 1, then the rate at which one or the other type is lost is slower than in an undivided population. The other two problems are discussed for $K=2$ and solved for some values of the migration probability.

*A. W. Qureshi (West Pakistan Agricultural University, Lyallpur) and **O. Kempthorne:** "On the Fixation of Genes of Large Effects Due to Continued Truncation Selection in Small Populations of Polygenic Systems with Linkage." Theoretical and Applied Genetics, 38:6, 249-255. 1968. Journal Paper No. 5870, Iowa Agriculture and Home Economics Experiment Station, Ames. Reprint Series No. 231, Statistical Laboratory, Iowa State University.

In this paper the authors report results of a study undertaken to examine the fixation of genes of large effects by directly simulating on a computer the processes of truncation selection and Mendelian segregation with ten linked loci. In the simulation the diploid nature of the process is followed throughout.

Linkage has been shown to cause faster fixation of genes in the absence of selection. With selection, linkage tends to delay fixation. But in the case of very low recombinations, there appears to be a level of population size and selection intensity, below which there is more rapid fixation because of linkage. Selection for dominant genes in the case of very close linkage delays fixation for a number of generations, and this delay results in reducing the depressing effect of linkage.

*A. W. Qureshi (West Pakistan Agricultural University, Lyallpur), **O. Kempthorne** and L. N. Hazel: "The Role of Finite Population Size and Linkage in Response to Continued Truncation Selection. I. Additive Gene Action." Theoretical and Applied Genetics, 38:6, 256-263. 1968. Journal Paper No. 5872, Iowa Agriculture and Home Economics Experiment Station, Ames. Reprint Series No. 232, Statistical Laboratory, Iowa State University.

In an attempt to analyze long-term response in finite dioecious populations, selection processes are simulated on a computer with situations of parental population size, linkages between loci, selection intensity, and heritability, specified in a 3^4 factoral design. A diploid polygenic system of 40 loci on 4 chromosomes is considered for additive genes. Linkage levels are specified as free recombinations, adjacent loci 5 map units apart, and as clusters on chromosomes with a distance of only .5 units between adjacent loci. Parental populations of 8, 16, and 64, truncation selection of $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{8}$ of the progeny each generation, and initial heritability of 1, $\frac{1}{3}$ and 1/9 are simulated for various populations.

The effects and interactions of all these factors on the curvilinearity of response in later generations are analyzed.

*A. W. Qureshi (West Pakistan Agricultural University, Lyallpur): "The Role of Finite Population Size and Linkage in Response to Continued Truncation Selection. II. Dominance and Overdominance." Theoretical and Applied Genetics, 38:6, 264-270. 1968. Journal Paper No. J-5905, Iowa Agriculture and Home Economics Experiment Station, Ames. Reprint Series No. 232, Statistical Laboratory, Iowa State University.

The subject matter of this second paper in this series of Monte Carlo studies deals with a genetic model where gene effects at 40 loci are similar and additive but the genotypic value of a heterozygote at each locus is not equal to the mean of the genotypic values of the two homozygotes.

Two special cases of dominance are considered: complete dominance of desirable genes, and pure overdominance with the genotypic values of the homozygotes equal. The aspects examined are the changes in the whole polygenic system arising from truncation selection and the dependence of these changes on population size, selection intensity and the linkage of the several loci.

*Hans T. Schreuder (North Carolina State University, Raleigh), **Joseph Sedransk** and Kenneth D. Ware: "3-P Sampling and Some Alternatives, I." Forest Science, 14:4, 429-453. 1968. Journal Paper No. J-5700, Iowa Agriculture and Home Economics Experiment Station, Ames. Reprint Series No. 234, Statistical Laboratory, Iowa State University.

The relationship of 3-P sampling to some other forms of unequal probability sampling is given first in this paper. The true variance and an unbiased sample-based estimator for the variance of the "unadjusted estimate" are then derived. For the "adjusted estimate" there are theoretical expressions for the bias, approximations for the true variance, and a sample-based estimator of the variance.

Comparisons based on repeated Monte Carlo sampling indicate that the bias of the adjusted estimate is small for these populations of trees. The true variance of the adjusted estimate is much smaller than that of the unadjusted estimate. But the approximations for the true variance and the sample-based estimator of variance for the adjusted estimate appear somewhat unreliable. For the true variance the best approximation is based on successive modifications of the ordinary formula for p.p.s. sampling with replacement and fixed sample size.

Numerical results contrast the unconditional and conditional properties (bias and variance) of the 3-P

estimates, illustrate the variability of sample size and the consequent difficulty of planning such a survey, and provide data for planning 3-P sampling in populations like these. Logical considerations indicate that 3-P sampling should be more fully compared with alternative selection rules and estimators that may use concomitant information more effectively in certain circumstances. Some alternative methods for appropriate probability samples and a numerical investigation of their properties are to be reported in part II, a sequel to this paper.

J. H. Sedransk: "Some Elementary Properties of Systematic Sampling." Skandinavisk Aktuarietidskrift. 1969.

In many sample surveys, systematic sampling is employed in lieu of simple random sampling. Here, systematic sampling is compared with the simple random and stratified random sampling procedures. The comparisons are made utilizing two different assumptions about the "exchangeability" of the random variables under investigation. For the systematic sampling method, several appropriate estimators of variance are suggested.

Karl A. Fox and **J. K. Sengupta:** "The Specification of Econometric Models for Planning Educational Systems: An Appraisal of Alternative Approaches. Kyklos, International Review for Social Sciences, XXI:4, 665-694. 1968.

An appraisal of alternative approaches to the specification of econometric models for planning educational systems is attempted here. An educational system is defined at various levels: at the national level, at the level of a particular university and at the level of a particular department of discipline in a specific university. The alternative econometric models for educational systems are appraised under three broad categories: (a) aggregative national models based on input-output analysis in some form, (b) models (sometimes probabilistic) to explain and predict the private demand for education, and (c) microanalytic models based on disaggregative analysis of a single unit (university, college or department) and its subdivisions.

The emphasis in the appraisal is to consider the operationality, and also some basic weaknesses, of the different models with a view to suggesting further generalizations. The view is taken here that previous econometric models for optimal planning of a single department within a university need to be considerably generalized before operational decision rules useful for conscious policy making can be developed.

J. K. Sengupta: "Econometric Models of Risk Programming." Econometric Annual, Indian Economic Journal, XV:4, 423-441. 1968.

The object of this paper is to investigate and evaluate some of the simple methods of probabilistic programming, when the coefficients of the objective function admit of variability which may be reasonably interpreted as probabilistic.

The following three types of decision rules are analyzed in this study:

(1) The expectation criterion, by which the expected value of the objective function is maximized.

(2) The fractile criterion by which the α-fractile of the cumulative distribution of the objective function is maximized with the value of α, $(0 \leq \alpha \leq 1)$, preassigned by the decision-maker.

(3) The safety-first type portfolio criterion by which the variance of total profit is minimized under suitable restrictions (i.e., discounting) on the total expected profit and on the crop-specific estimate of (sample) variance.

The nature of optimal solutions derived under these criteria and their possible usefulness in specifying optimal production plans are analyzed.

J. K. Sengupta: "A Computable Approach to Risk Programming." Pp. 543-566 in *Papers in Quantitative Economics,* edited by J. P. Quirk and A. M. Zarley. University Press of Kansas. 1968.

From an economic viewpoint the characterization of risk in linear probabilistic programming models is incomplete in two respects. First, non-normal situations are usually neglected. Second, the extreme behavior which is usually based on very small samples, a feature of most common occurrence in economic models, is generally left out in preference for an average behavior.

The object of this paper is to present some computable methods for relaxing these limitations. These methods are operational and in principle computable, hence applicable to several types of linear economic models both static and dynamic.

Two basic points remain unexplored in this presentation. First, the sequential aspect of revising optimal strategies over time, especially in dynamic models. Second, the interaction between prior and posterior probabilities with what has been called empirical Bayes estimators.

***J. K. Sengupta:** "Safety-First Rules Under Chance-Constrained Linear Programming." Operations Research, 17:1, 112-132. January-February 1969. Reprint Series No. 239, Statistical Laboratory, Iowa State University.

The approach of chance-constrained linear programming is analyzed here in the context of safety-first principles based on Tchebycheff-type inequalities. The analysis attempts to define relatively distribution-free tolerance levels and the incidence of non-normality in chance-constrained linear programming.

J. K. Sengupta and K. A. Fox: *Economic Analysis and Operations Research: Optimization Techniques in Quantitative Economic Models.* 489 pp., North Holland Publishing Company, Amsterdam. June 1969. Volume Ten in the Series entitled Studies in Mathematical and Managerial Economics.

This book provides a balanced treatment of the theory and application of optimization techniques in quantitative economic models. The authors synthesize the major approaches to optimization in static, dynamic, probabilistic simulation and control theory frameworks and show how nonlinear, dynamic stochastic and variational programming, control theory and Monte Carlo

obtain for the small-dispersion items; that the next smallest difference should occur with the large dispersion items; and that the largest differences (large enough to be statistically significant) should be exhibited by the moderate-dispersion items. Exactly this relation was demonstrated. The usefulness of the dispersion item parameter as a predictor of anchor effects and

John J. Hartman and **James A. Walsh:** "Simulation of Newspaper Readership: An Exploration in Computer Analysis of Social Data." Social Science Quarterly, 49, 840-852. 1969.

In this paper the authors consider how information about a pending event of community importance is dispersed through a small community by a locally oriented newspaper. Further, parameter estimates from one community are used to examine rather exhaustive data collected in another community.

In this simulation effort, data from two different studies already collected and reported elsewhere served to develop an attrition model and as basic parameter estimates in the simulation. The present study has been labeled "exploratory," since data already collected were utilized because the basic variables in this simulation were demographic and communication variables.

The specific area being simulated centered on notification and discussion of a pending civil defense exhibit in the community. Some variables manipulated in the model arose from the specific content area (civil defense); however, these variables have been considered under the rubric "attitudinal and saliency variables." Hence, variables relating to attitudes and saliency of the content were viewed as concomitant in this readership study, but attitudes and degree of saliency must be anchored to a content area. The content of the message does not alter the basic model; however, it does guide selection of the variables for manipulation in the simulation.

In this study newspaper readership did not require further overt action on the part of the inoculated individuals but merely considered whether the individual was 1) likely to have seen the newspaper, 2) likely to have seen a particular article, and 3) likely to have read the article.

George Zyskind, Oscar Kempthorne, F. B. Martin (University of Minnesota, Minneapolis), **E. J. Carney** (University of Rhode Island, Kingston) and **E. N. West:** "Linear Models and Analysis of Variance Research Procedures." Technical Documentary Report 68-0119, Aerospace Research Laboratories, Office of Aerospace Research, United States Air Force, Wright-Patterson Air Force Base, Ohio. July 1968.

Research on some related linear model theory and analysis of variance procedures is described. Chapter I is introductory, giving a general outline of topics described in the report.

Chapter II presents a formulation of aspects of best and simple least squares linear estimation in linear models with arbitrary, possibly singular, covariance structure. Chapter III develops a generalization of the famed Gauss-Markoff theorem, applying to situations including a singular variance-covariance structure of the observations. Chapter IV deals with simple combination of information in linear models originating from uncorrelated distinct sources of information.

Chapter V deals with some formulations of sampling from balanced complete experimental structures, and with theoretical and computational aspects arising in the calculation of variances of variance components. Chapter VI presents results of a Monte Carlo investigation of significance levels generated by the Behrens-Fisher fiducial procedure and by the Welch Aspin procedure. Chapter VII presents a brief discussion of certain nonparametric test procedures based upon ranks and, in particular, points up the problems arising from the inevitable grouping error of measurement.

Correspondence

"Teaching Statistics with OMNITAB." David Jowett and R. L. Chamberlain. Biometrics 24:3, 723-725. 1968.

Book Reviews

C. Philip Cox: Review of *Elementary Statistical Methods* by G. B. Wetherill. Biometrics, 25:1, 184-185. 1969.

J. H. Sedransk: Review of *Prediction Analysis* by John R. Wolberg. Journal of the American Statistical Association, 64:326. 1969.

J. H. Sedransk: Review of *Sampling Theory* by Des Raj. Mathematical Reviews. 1969.

James A. Walsh: Review of *Statistical Theories of Mental Test Scores* by Frederic Lord and Melvin Novick. Educational and Psychological Measurement, 28:4, 1266-1269. 1968.

James A. Walsh: Review of *Statistical Methods* by George W. Snedecor and W. G. Cochran. Educational and Psychological Measurement, 29:2, 431-433. 1969.

Richard D. Warren: Review of *The Young Businessman: Small Company or Large?* by Ronald E. Herington and David C. Dionne, et al. American Sociological Review, 33:5, 828. 1968.

ABSTRACTS OF THESES

Joseph Leo Abbey: "Series Representation of Multivariate and Sequential Uniformly Minimum Variance Unbiased Estimates for Exponential Families," Ph.D. thesis. Iowa State University Library. August 1968.

This investigation deals with the following problem in statistical estimation: Given a sample x from a population with a distribution belonging to the Koopman-Darmois exponential family, obtain a function $h_c(x)$ of x which is optimal for estimating a given estimable parametric function, $g(\Theta)$, in the sense of being unbiased and having least variance at a prespecified point Θ_0 or, in the case of existence, of being the uniformly minimum variance unbiased estimator (UMVUE) for $g(\Theta)$.

For the fixed sample situation, it is well known that

for the class of distributions considered, the Rao-Blackwell theorem yields the UMVUE of any such $g(\Theta)$, provided an unbiased estimator of $g(\Theta)$ is available. This thesis gives a method for obtaining the UMVUE in this situation in series form without the availability of any unbiased estimator of $g(\Theta)$. The variance of the UMVUE is also given in series form. This latter expression provides a criterion for nonestimability if it diverges.

The method is applicable as well in the sequential case.

When the UMVUE does not exist, the expression given for the variance provides a sharper bound than the bounds given by Blackwell and Girshick (1947) and Wolfowitz (1947) under assumptions different from those made in this thesis.

Finally, for the special case in which the sample size is fixed and the parameter Θ is scalar, criteria have been obtained for the pointwise convergence of the series giving the UMVUE.

Sorachai Bhisalbutra: "Efficiency of Two-way Stratified Systematic Sampling Designs." M.S. thesis. Iowa State University Library. August 1968.

The design essentially tries to combine the good points of stratification and systematic sampling, making maximum use of the auxiliary information. It is the objective of this study to investigate the efficiency of two-way stratified sampling designs with one unit per stratum. As is well known, it is not possible to evaluate the precision of the estimates in the case of such design. A design band on several random starts has been suggested as an alternative design which makes it possible to evaluate the precision of the estimates.

If there is interest in estimating totals for the whole population, as well as subtotals for different subregions and size strata, it may be desirable to adopt stratified sampling design with one unit per stratum rather than stratified systematic sampling design. But if regional estimates are not needed and the estimates of the total for the population as a whole are sufficient, stratified systematic sampling design with two random starts may be preferred over stratified sampling design with one unit per stratum.

Richard LaVern Chamberlain: "Dependencies in Tests for Randomness." M.S. thesis. Iowa State University Library. March 1969.

The problem of finding the best method for generating random numbers on a computer led to the examination of tests for randomness.

Many of the tests for randomness used in the literature were presented and discussed. The test statistic for each test was given and problems connected with its implementation were pointed out.

As an alternative approach to the problem, a random variable, which might be called a counting variable, was introduced. This variable was applied to binary sequences and compared to the counts made by the standard tests. Using the somewhat natural dependencies between various forms of the counting variable, some conditional distributions were derived. These distributions were then used to construct a testing procedure. This procedure was then compared to the test statistics used in the standard tests.

Finally, the new test procedure was examined on the computer. Several sets of numbers were tested; some were supposed to be random while others had known non-random sequences implanted in them.

Shang-Wang Chang: "Equilibrium Points of Non-Zero-Sum Games and Axiomatic Derivation of Decision Criteria." Ph.D. thesis. Iowa State University Library. May 1969.

In this study, generalizations of equilibrium point existence proofs from zero-sum games to non-zero-sum games are presented.

First, Wald's and one of Teh's theorems are generalized. Next, the existence of an equilibrium point in the two-person case is demonstrated under a certain uniqueness assumption, with Y compact and X homeomorphic to a compact subset of Banach space. Similar conditions on all X_i yield the existence of an equilibrium point of an n-person game.

Certain generalizations of k-stage games are discussed, and conditions given for the existence of equilibrium points. Equilibrium points of n-person-matrix game are characterized in a manner analogous to the well-known characterization for zero-sum two-person games. An example illustrates that this characterization is useful in construction.

Certain axiomatic derivations for decision criteria are extended in the last chapter from the finite to the countable case.

Godfrey Coker: "A Survey of Factors Influencing Farmers' Use of Agricultural Chemicals: Sample Design, Estimation and Analysis." M.S. thesis. Iowa State University Library. May 1969.

A sample survey of Iowa farmers was carried out by the Cooperative Extension Service and the Department of Sociology and Anthropology, Iowa State University, for the purpose of investigating farmers' attitudes and behavioral characteristics towards agricultural chemicals. The design used in the research study was a two-stage multistage sample, which was self-weighting.

Estimates of the population means for several variables were calculated on a mean per unit basis. Variance estimates were calculated using the correct procedure (applicable to the survey as designed) and two alternative procedures based upon relatively more simple designs (statified simple random sample and simple random sample from an infinite population). The variance estimates obtained by using these SRS designs, through not much different from each other, were less than the variance estimates obtained by using the "correct" procedure. Comparing the lengths of the confidence intervals for population means obtained by using the simple random sampling estimators and

the "correct" estimator method, the interval lengths were shorter in all cases using the simple random sample estimators.

These results would indicate that the use of variance estimates based upon relatively simpler designs, that is, incorrect variance estimation procedures, can result in rather substantial underestimation of the variance.

Alternative methods of estimation were investigated with reference to one variable, amount of money spent on agricultural chemicals. The estimation methods were mean per unit, ratio, and regression. Comparing the variance estimates obtained for this variable using the three methods, the ratio estimation methods gave the smallest variance while the regression method resulted in the largest variance estimate. The fact that the variance obtained by using the regression estimation method was larger than that using the ratio method of estimation was due to (1) the approximation of the variance of the ratio estimator by ignoring the within-county term, and (2) the use of a regression estimator in which the sample mean of the ancillary variable was a ratio of two random variables.

Patricia Sullivan Conn: "Asymptotic Properties of Sequences of Positive Kernels." Ph.D. thesis. Iowa State University Library. May 1969.

The major motivation for this thesis is the study of the asymptotic properties of non-stationary random walks between two absorbing barriers. Much of the work in the body of this thesis is based on a special property of the spectra of positive valued matrices and kernels.

Necessary and sufficient conditions for strong ergodicity are provided in the case of non-stationary Markov processes with finite or finite interval state spaces and uniformly positive transition matrices or kernels. Applied to a random walk between absorbing barriers, these results imply that the sequence of conditional densities converges if and only if the sequence of right characteristic functions associated with the dominant characteristic values of the transtion kernels converges.

Convergence rates also are examined for the sequence of conditional densities to which Theorem 2.1.1 applies and the rate of convergence of this sequence is related to that of the sequence of right characteristic functions associated with the dominant roots of the transition kernels. These results, applied to Markov processes, give the known result that positivity implies weak ergodicity. Applied to random walks between absorbing barriers, these results imply that initial information is asymptotically lost, although the sequence of conditional densities may fail to converge, if the sequence of left characteristic functions associated with the dominant roots of the transition kernels converges in an appropriate manner. It is also established that the convergence of a sequence of positive kernels implies the convergence of the sequences of their dominant roots and associated characteristic functions.

Applications of these considerations to the truncation of sequential tests are given.

James Sullivan DeGracie: "Analysis of Covariance when the Concomitant Variable is Measured with Error." Ph.D. thesis. Iowa State University Library. August 1968.

Four cases of analysis of covariance have been covered in this thesis: the classical analysis of covariance model; the case when the concomitant variable is assumed measured without error, normally distributed and independent of the error in the dependent variable; the case when the concomitant variable is measured with error and can be expressed as $x_{ij} = X_{ij} + u_{ij}$, where X_{ij} and u_{ij} are normal and independently distributed and independent of the error in the dependent variable; and the case when the concomitant variable is measured with error and can be expressed as $x_{ij} = X_{ij} + u_{ij}$, where X_{ij} is a constant and u_{ij} is a normally distributed variable independent of the error in the dependent variable.

Much of this thesis is concerned with the problem of obtaining an estimator for the slope of the model in the fourth case stated above. A number of estimators are proposed and compared with respect to their biases and mean-square errors. The biases are carried to $0(\frac{1}{r})$ and the mean-square errors to $0(\frac{1}{r^2})$, where r is the number of replicates in the experiment. The estimator selected as preferred is then used in proposed estimation and testing procedures for treatment effects.

The models are extended to more than one concomitant variable. In this case both bias and mean-square-error are carried to $0(\frac{1}{r})$. Estimation and testing for the first three cases are treated as subcases of case 4.

Sharon Ruth Earley: "A Comparison of the Differential Efficiency of Least Squares and Simulation Techniques in Predicting Responses to MMPI Items." M.S. thesis. Iowa State University Library. August 1968.

In order to predict individual responses to individual psychological test items, an additive, linear, least squares equation was formulated. It predicts responses on the basis of five item parameters: probability of endorsement, net shift in the probability of endorsement from one administration to another, consistency in endorsement from one administration to another, social desirability scale value, and the standard deviation of the social desirability scale value.

Under the assumption that people parameters (measures of social desirability, acquiescence, and lying response sets) would aid in prediction, several simulation models were constructed. These models consisted of sets of decision rules approximating known personality theory. The best simulation, however, used only item parameters.

A comparison of the two procedures, least squares

and simulation, revealed that both predict more accurately than the base rate, that both predict more accurately than either probability of endorsement or social desirability scale value alone and that simulation predicts more accurately than least squares.

Gregory Bruce Fawcett: "Utilizing Cluster Characteristics to Predict Regression Coefficients Estimated Within the Clusters." M.S. thesis. Iowa State University Library. August 1968.

The emphasis of this thesis is upon defining and empirically examining a modification of the usual statistical prediction process.

The technique suggested integrates cross-cluster information into a prediction equation initially constructed independently within each cluster. This "predicted regression" technique is analogous to stagewise regression. The difference is that the regression coefficients (not the independent variables) are predicted rather than estimated in the traditional least squares way.

Mechanically this technique can be described as a two-stage application of the least squares procedure. Initially a prediction model of the form $Y = X\beta$ is defined independently within each cluster. The estimated coefficients $\hat{\beta}$ are then regressed on cross-cluster information as $\beta = Z\alpha$. Finally, the "predicted regression coefficients", $\hat{\hat{\beta}}$, are used to predict the original criterion, Y as $\hat{Y} = X\hat{\hat{\beta}}$.

Various error structures were theoretically examined in an effort to arrive at a model suitable for an empirical investigation. Then an attempt was made to predict the academic success of medical students as a linear function of student ability measures. The clusters considered were medical schools and the cross-cluster information was institutional characteristics of these schools.

On the basis of this investigation, the predicted regression technique was compared empirically with the usual multiple linear regression procedure. Although the comparison suffered from inadequate data, conservatively speaking it was concluded that the predicted regression technique should yield at least as good prediction as the traditional multiple least squares approach.

Omar Manuel Henriquez: "Logistic Models for Spore Count Data from Artificially Induced Epiphytotics." M.S. thesis. Iowa State University Library. August 1968.

Data on the development of epiphytotics of crown rust in oats, obtained by Cournoyer (1967) in the Department of Botany and Plant Pathology, has been used to study the characterization of fungal epiphytotics by estimating daily spore concentrations.

Near isogenic lines of host plants, either pure or mixed, two crown rust treatments (pure race 264 and a mixture of races 203, 216, 264, 290, 294 and 321) were combined in a 2^2 factorial in two replicates.

The cumulative daily concentration of spores over each replicate was estimated and the fit to a logistic growth model investigated by four fitting procedures. Of the four procedures used, the one presented by Schultz (1930), an iterative procedure, worked the best, resulting in a smaller sum of residuals squared than any other method.

The Pearl-Reed method, not being a least square procedure, gave a very high sum of residuals squared. The internal regression procedure did not work at all with the odd number of data points. The deletion of the first day led to a very poor fit.

A special procedure, the direct least square procedure, which has the virtue of great simplicity and flexibility, requires further mathematical-biological research.

Muzammil Husain: "Construction of Regression Weights for Estimation in Sample Surveys." M.S. thesis. Iowa State University Library. May 1969.

A modification in the usual linear regression estimator theory for constructing regression weights based on k auxiliary variates has been developed. Quadratic programming was used to compute optimum regression weights subject to linear constraints. These regression weights can be constrained to be always positive. Once calculated they can be applied in a particular multivariate regression estimation problem to any number of characteristics whose population estimates might be needed.

For large samples falling beyond the capacity of available computer programs, a grouping procedure has been suggested. An illustrative example has been given to demonstrate the application of this grouping procedure.

The modified regression estimator developed in this thesis possesses two desirable properties: (i) The bias of this estimator will always be less than or equal to the ordinary regression estimator. (ii) The estimator will generally give a smaller variance.

James John Immordino: "Extension of Kendall-Friedman Two Way Analysis of Variance to Two Factors Crossing Blocks." M.S. thesis. Iowa State University Library. August 1968.

The primary objective of this thesis was to provide nonparametric statistical tests when a factorial arrangement was imposed on the treatments involving two main effects and one interaction. The nonparametric statistical tests presented are useful when the measurement of the variable is in at least an ordinal scale.

The basic step in the application of the method was based on the following considerations and operations: Two independent rankings were formed for each main effect crossing blocks. Using this operation the problem was reduced to the following:

What are the expected variances and covariance of two sums of ranks derived from one set of data? The

problem is considered in the context of a parametric model; that is, the application of the Kendall and Friedman procedure in the context of a location problem where the investigator is interested in the null hypothesis that different treatments are equally effective.

If one could measure the treatments' effects directly then one would impose a model such as

$$Y_{ijn} = \mu + \alpha_i + \beta_j + \gamma_n + (\beta\gamma)_{,n} + e_{ijn}$$

where α is random and β and γ are fixed. Also, it is assumed the error is normally and independently distributed and the other sources of variances are uncorrelated. However, the measurement process is indirect and the only information available about the dependent variable is the order of the treatment combinations within blocks.

This ranking is fallible in that the measurement takes place with error. Nothing is assumed about the distribution of the error except that it is independent of the level of β and γ.

The results provide for only two independent tests and are applicable when one can assume either no interaction or only one main effect.

Khadija Khatun: "An Application of Digital Computers to the Analysis of Sample Survey Data: The 1966 Iowa Outdoor Recreation Survey." M.S. thesis. Iowa State University Library. November 1968.

The objective of this study was to employ the digital computer in the analysis of a particular sample survey. This survey, concerning the outdoor recreational participation patterns and preferences of Iowa residents 12 years of age and older, was carried out in the fall of 1966 by the Department of Forestry and the Statistical Laboratory.

The sample was designed as a two-stage cluster sample with stratification. The specific data with which this study was concerned were the total number of days participation during the period June 1 to Labor Day, 1966, of each person interviewed for 13 selected outdoor recreational activities. The parameters for which estimates were desired were (1) mean number of days participation per person and its associated variance for each activity, and (2) total number of days participation for all members of the population and the variance of the estimate.

The generation of these estimates was accomplished by an electronic computer program. The necessary arrays and scalar variables were formed and defined. A flow-chart indicating the necessary operations to be performed was developed. A program was then written and the desired estimates and their variances were produced. The computations were carried out on an IBM 360 Model 65 computer with operating system. In addition to the estimates of means and totals and their variances, the output record contained an array of stratum means and number of persons interviewed for each activity. Means of the marginal distributions of the two-way stratification, geographic area by population zone, were also included in the output for comparative purposes.

G. Nicholas Lauer: "Testing the Mean of a Normal Population in an Incompletely Specified Model with Unknown Variance." M.S. thesis. Iowa State University Library. May 1969.

In this thesis, the use of a preliminary test of significance (P. T. S.) in making inferences about the mean of a normal population is investigated.

In particular, given one random sample of size n_1 from $N(\mu_1, \sigma^2)$ and a second random sample of size n_2 from $N(\mu_2, \sigma^2)$ where σ^2 is unknown, it is desired to make a test $\mu_1 = \mu_0$. It is suspected that the two populations are the same so a size α P. T. S. of H_{10}: $\mu_2 = \mu_1$ is made. If H_{10} is accepted, then the two samples are pooled for the final test of H_{20}: $\mu_1 = \mu_0$. If H_{10} is rejected in the P. T. S., then only the first sample is used to make the final test.

It is the goal of this investigation to determine a size for the P. T. S. which will increase the power of the final test relative to a standard never-pool procedure and satisfy other criteria. To accomplish this, expressions for the power are derived and transformed. Then, after some discussion of the size of the sometimes-pool testing procedure, numerical computations are carried out for the two illustrative cases $n_1 = 4$, $n_2 = 4$ and $n_1 = 4$, $n_2 = 8$. The levels, $\alpha = .05, .10, .25, .50$, are considered for each case. It is determined that α levels of approximately .25 and .50 respectively are best in these instances. Possible implications of these results to more general cases are then briefly examined.

Ronald J. Mead: "Size and Power of Analysis of Variance Test Procedures for Incompletely Specified Fixed Models." M.S. thesis. Iowa State University Library. November 1968.

In this thesis the incompletely specified model problem is formulated for fixed models when only one preliminary test is made. The derivations of recursion formulas for evaluating size and power in this situation are sketched. A number of graphs of the size and power for specific values of the parameters are included. Based on these graphs, recommendations are made concerning a choice of the probability level of the preliminary test to control the size and power of the overall inference procedure.

Control of size was seen to present little problem with the fixed model, but a preliminary test could result in a loss of power unless the recommendations are followed.

Frank Burke Martin: "Contributions to the Theory of Estimation in the General Linear Model." Ph.D. thesis. Iowa State University Library. November 1968.

This work contains three loosely joined topics which present, in order, contributions to the theory of best linear unbiased estimation in the general linear model,

the combination by simple weighting of such estimators (b.l.u.e.'s) from several independent sets of data, and the construction of classes of incomplete block designs having within block replication for estimation of σ^2 and various degrees of balance but, in any case, simple analysis.

The first topic concerns a unified approach to the construction of normal type equations yielding b.l.u.e.'s, in the linear model $Y = X\beta + e$ with $\mathrm{Cov}(e) = \sigma^2 V$. The procedure is unaffected by the possible singularity of the V matrix. There is constructed a class $\mathcal{Y}$ of conditional or generalized inverses of V such that for any V^* in $\mathcal{Y}$ the equations $X'V^*X\hat{\beta} = X'V^*Y$ (Generalized Normal Equations) yield the b.l.u.e.'s of every estimable parametric function in exactly the same manner as do the equations when V^{-1} exists. The properties of these G. N. E. are developed and shown to be almost identical to the ordinary case of V invertible. The distribution of $(Y-X\hat{\beta})'V^*(Y-X\hat{\beta})$ is developed under normality and the G. N. E. are shown to be equivalent to the minimization of this form over β unconstrained. Restrictions, $\Lambda'\beta =$ constant, may be written into any model and the above technique applied with no modification.

The second topic concerns the presentation of conditions under which a linear parametric function having b.l.u.e.'s in several sets of independent data is best estimated from the combined data by simply weighting its several separate b.l.u.e.'s. The loss incurred by ignoring sets of data in which the function is not estimable is explored as is the relative efficiency of indiscriminate use of simple weighting.

The third and last topic concerns the construction of incomplete block designs having replicates in blocks yielding estimators of the between experimental unit error, σ^2, which are unaffected by block-treatment interaction. An extensive table of such designs having balance is presented. The circular matrix appears as an important tool of construction; and as a natural consequence of its properties, it is possible to construct a large new class of incomplete block designs (with 0 or 1 incidence) having very simple analysis.

Richard Walter Mensing: "Method of Images in the Plane." Ph.D. thesis. Iowa State University Library. August 1968.

Planar versions of the invariance principle and the method of images have been applied to three problems in planar random walk. In problems (1) and (2) asymptotic computations are simple for a particular one of a class of random walks, so that the invariance principle provides absorption results for tied and untied Wiener processes, as well as asymptotic results for the rest of the class in either problem. In problem (3) on the other hand, the process computations are simple so that the invariance principle provides asymptotic results for a certain class of random walks with drift.

(1) Let δ_n be a path in the plane starting at (0, 0) and generated by n i.i.d. random vectors with zero mean and covariance matrix $n^{-1}I$. Let D'_n be the event that δ_n stays within a region enclosed by a certain boundary Γ and $P_n(D'_n)$ the probability of D'_n.

Let D' be the event that $W(t) \epsilon C_\Gamma$ for all $t \epsilon [0, 1]$ where C_Γ is the cylinder in R^3 with base Γ and $W(.)$ is a continuous function from [0, 1] to R^2 with $W(0) = (0, 0)$. Let $P_W(D')$ be the probability of D' under bivariate Wiener measure on the usual σ — algebra of subsets of the set of all $W(.)$.

Then for certain symmetric Γ's (e.g., equilateral and isoceles right triangles),

$$P_W(D') = \lim_{n\to\infty} P_n(D'_n) = 1 - 2\Pr[N \epsilon \Omega_\Gamma]$$

where N is a standard bivariate normal random vector and Ω_Γ is a certain subset of R^2. Here the first equality follows from the invariance principle for i.i.d. random vectors and the second from an extension to the plane of the method of images.

(2) Let π_n be a path in the plane consisting of (n/q) steps of each of q types, starting at and returning to the origin. Let $E_{\alpha n}$ be the event that π_n is on or outside Γ at or before the $[\alpha n]^{th}$ step, $0 < \alpha < 1$, and let $P_n(E_{\alpha n})$ be the probability of $E_{\alpha n}$ under random permutation of steps.

Let E_α be the event that $W(t) \epsilon C'_\Gamma$ for some $t \epsilon [0, \alpha]$, where $W(.)$ is a continuous function from [0, 1] to R^2 with $W(0) = W(1) = (0, 0)$. Let $P_D(E_\alpha)$ be the probability of E_α under bivariate tied Wiener measure.

Then for steps obtainable by projection from steps oriented as the edge of the (q-1)-dimensional simplex of edge length proportional to $n^{-1/2}$, and the Γ of (1),

$$P_D(E_\alpha) = \lim_{n\to\infty} P_n(E_{\alpha n}) = \Theta(\alpha, \Gamma)$$

where $\Theta(\alpha, \Gamma)$ is a certain converging series. Here the first equality follows from an adaptation of the invariance principle for dependent random variables and the second from the method of images.

(3) Let ρ_n be a path in the plane starting at (0, 0) and generated by n i.i.d. random vectors with means $(\mu_1 n^{-1}, \mu_2 n^{-1})$ and covariance matrix $n^{-1}I$. Let $P^n\ \mu_1, \mu_2$ be the probability that ρ_n escapes across an equilateral triangle boundary Γ and first escapes across a given side A of Γ.

Let $P\mu_1, \mu_2$ be the probability that a particle under Brownian motion with drift (μ_1, μ_2) first escapes C_Γ across A. Then

$$\lim_{n\to\infty} P^n\ \mu_1, \mu_2 = P\mu_1, \mu_2 .$$

This follows from an adaptation of the argument for the invariance principle in (1).

Mallika Mokkhaves: "Estimation of Population Mean and Population Proportion Using Ratio and Regression Methods." M.S. thesis. Iowa State University Library. August 1968.

One of the problems treated in this thesis is the problem of allocating the sample sizes to the different strata when the separate ratio and regression estimators are employed to estimate the population mean. Using suitable cost function it has been shown that the population mean can be estimated with maximum precision when the sample is allocated to different strata in proportion to $W_i S_{yi} \sqrt{1 - \rho_i^2} / \sqrt{c_i}$ or $W_i S_{yi} \sqrt{1 - \rho_i^2}$ if c_i is the same from stratum to stratum—where W_i is the proportion of units; S_{yi}^2 is the population mean square; ρ_i is the correlation coefficient between y, the variable under study, and x, the auxiliary variable; and c_i is the cost per unit for the i-th stratum.

Since this allocation involves S_{yi} and ρ_i which are rarely known in practice, the allocation cannot be used practically. The usual practice employed in such a situation is to take a preliminary sample of size n' and use it to estimate S_{yi} and ρ_i for each stratum. Then the sample size to be allocated to the different strata is determined on the basis of the estimated values of s_{yi} and ρ_i, namely $n_i \propto W_i s_{yi} \sqrt{1 - r_i^2}$.

It has been shown that for appropriate choice of n', the allocation based on estimated values of S_{yi} and ρ_i is more efficient than proportional allocation.

The second part of the thesis deals with the estimation of the ratio $\frac{p_i}{p_j}$. The various estimates considered are: $R_{n1} = \frac{\hat{p}_i}{\hat{p}_j}$; $R_{n2} \cong \frac{\hat{p}_i}{\hat{p}_j} - \frac{1}{(n-1)} \cdot \frac{\hat{p}_i}{\hat{p}_j^2}$; $R_{n3} \cong \frac{\hat{p}_i}{\hat{p}_j + \frac{1}{(n-2)}}$; $R_{n4} \cong \frac{\hat{p}_i}{\hat{p}_j} - \frac{\hat{p}_i}{n\hat{p}_j^2}$; and $R_{n5} = \frac{\hat{p}_i}{\hat{p}_j + \frac{1}{n}}$.

Assuming that the population size, N, is large, it has been found that R_{n1} is a biased estimate involving terms of order $\frac{1}{n}$; R_{n2}, R_{n3} and R_{n4} are almost unbiased in the sense that their biases are of order $\frac{1}{n^2}$ while the estimate R_{n5} is unbiased.

On comparing their efficiency, it has been found that $MSE(R_{n2}) = MSE(R_{n3}) = MSE(R_{n4}) = MSE(R_{n5}) < MSE(R_{n1})$. Taking into account both the bias and the mean square error, any of the estimates R_{n2}, R_{n3}, R_{n4} or R_{n5} may be preferred to R_{n1} if the sample size, n, is so large that terms of order $\frac{1}{n^2}$ can be considered to be negligible. However, if n is not so large as to make terms of order $\frac{1}{n^2}$ negligible, then R_{n5} may be preferred.

Syed Taqi Mohammad Naqvi: "Inference for Components of Variance Models." Ph.D. thesis. Iowa State University Library. March 1969.

The random one-way classification model has been examined with a view to better understanding of statistical inference about components of variance. The problem is approached from three points of view: (i) Bayesian analysis, (ii) likelihood principle and (iii) goodness of fit.

Bayesian solutions are presented using non-informative priors which do not contain any sample element. A reasonable informative prior is also considered and the Bayesian solution presented. Likelihood inference about the components of variance is examined. Artificial sets of data covering a wide range of cumulative F-values and three sample sizes, representing small to moderately large sample sizes, have been chosen for the purpose of illustration.

The contours of equal likelihoods from 50 to 99 percent of the maximum likelihood are presented. The relation between the posterior distribution and the likelihood for non-informative priors is investigated and extensively illustrated.

A measure of goodness of fit for the observed data with respect to hypothesized values of parameters is defined. The critical values for 95 and 99 percent of fit for the chosen sample sizes are tabulated and contours of equal goodness of fit are presented. These are compared with the likelihood contours. Some asymptotic cases are investigated.

It is felt that a reasonable interpretation of the data should be made on the basis of both the likelihood and the goodness of fit.

Chandubhai Maganbhai Patel: "Comparison of Some Methods of Probability Sampling." M.S. thesis. Iowa State University Library. November 1968.

The use of sample surveys for the population characteristic is an important tool in modern social and economic planning. The most common designs are simple random sampling, stratified random sampling and systematic sampling. It is known that in the presence of linear trend, stratified sampling with one unit per stratum has smaller variance than systematic sampling, which in turn has smaller variance than simple random sampling ($n > 1$).

Two new sampling schemes are investigated in this thesis. In these schemes all sample elements are selected with equal probability and all pairs of sample elements are selected with positive probabilities. The variance of the estimated mean is compared with that of other sampling designs. In the presence of linear trend, it is observed that Scheme I (circular selection) is more precise than random sampling but loses to systematic sampling and stratified sampling with two units per stratum. However, when the population is arranged in a specific order, it is observed that variance of the mean for Scheme I is less than that of stratified sampling with two units per stratum. Also, it has been shown that, in the presence of linear trend, the variance of Scheme II (for populations with strong linear trend)

is less than that of stratified sampling with one unit per stratum.

A small sampling experiment was conducted to compare the variance of the estimated variances for alternative sampling procedures. The estimated variance for Scheme II was more efficient than that of stratified sampling with two units per stratum when the populations contained a strong trend.

The chief advantage of the two new designs over systematic sampling and stratified sampling with one unit per stratum is that an unbiased estimator of variance is possible.

Martin Stephen Rosenzweig: "Ordered Estimators for Skewed Populations." Ph.D. thesis. Iowa State University Library. November 1968.

The problem of estimating the population mean on the basis of a sample which contains a few "very large" observations is investigated.

It is assumed that the tail of the distribution giving rise to the large observations can be well approximated by the tail of a member of the Weibull family with shape parameter, β, less than one. Since the mean is the best linear unbiased estimator for the Weibull distribution with shape parameter one, tests of the hypothesis $\beta < 1$ against the alternative $\beta = 1$ are developed.

One simple test statistic is

$$F = \sum_{i=m+1}^{n} Z_i \Big/ \sum_{i=1}^{m} Z_i$$

where $Z_i = (n-i+1)\,(x_{(i)}-x_{(i-1)})$ $i = 2, 3, \ldots, n$ $n=2m$.

Under the null hypothesis, F is distributed as Snedecor's F with 2m and 2m degrees of freedom. Under the alternative hypothesis

$$F(x) = 1 - e^{-\left(\frac{x-a}{b}\right)^{1/3} + c} \qquad x \geqq bc^3 + a$$

$$a > 0, b > 0, c > 0$$

the approximate density of the test statistic is

$$f_1(f) = \text{const} \sum_{i=1}^{m}\sum_{j=1}^{m} (-1)^{i+j}\, \alpha_{ij}\, (a_{2m-j+1}\, f + a_{m-i+1})^{-2}$$

where α_{ij}, a_{2m-j+1} and a_{m-i+1} are constants depending upon the parameters of the parent Weibull distribution.

A second statistic was developed to test $\beta = \beta_0$, where β is the true parameter value, of the Weibull.

The test statistic as

$$T = \frac{\Sigma\, C_k Z_k}{\Sigma\, Z_k}$$

where $C_k = -(n-k+1)\sqrt{\dfrac{n!}{(n-k)!}\sum_{i=0}^{k-1} \dfrac{(-1)^i}{i!(k-i-1)!}\left[\dfrac{1}{(n+i-k+1)^2}\,\dfrac{n(n+1-k+1)}{(n-k+1)!} - \dfrac{n!}{(n-k+1)!}\sum_{i=0}^{k-2}\dfrac{(-1)^i}{i!(k-i-1)!}\left[\dfrac{1}{(n+i-k+2)^2}\,\dfrac{n(n+i-k+2)}{(n+i-k+2)^2}\right]\right]}$

$$Z_k = (n-k+1)\, Y^{\beta_0}_{(k)} - Y^{\beta_0}_{(k-1)}$$

and

$Y_{(k)}$ is the order statistic from

$$F(y) = 1 - e^{-(y/\lambda)^{\beta}} \quad \lambda > 0, \beta > 0, y \geqq 0.$$

The suggested estimation procedure is as follows:

1. Select a 'cutoff' value x_0, and on the basis of x_0 divide the sample into two groups containing respectively the large and small values.

2. Calculate the mean of the small observations.

3. Test the distribution for skewness, i.e., do the data accept the hypothesis of shape parameter equal to one?

4. Dependent upon the outcome of the test, use a linear function of the order statistics to estimate the population mean of the large observations,

5. Calculate $x = p\bar{x}_1 + (1-p)\tilde{x}_2$ where p and 1—p are the sample proportions below and above the cutoff point respectively, $\bar{x}$ is the mean of the small values, and $\tilde{x}_2$ is the estimator described in step 4.

The estimator presented in step 5 is examined in some detail and weights are derived for the linear function of the order statistics to (i) minimize the variance for the unbiased estimator, or (ii) minimize mean square error in a restricted sense.

The finite population case is considered and the necessary adjustments in the estimation procedure are indicated.

Carl Ziervogel Roux: "The Mathematical Theory of Genetic Loads." Ph.D. thesis. Iowa State University Library. May 1969.

The key assumption underlying the theory of genetic loads is the existence of Hardy-Weinberg equilibria at all loci that influence fitness. The conditions under which such equilibria can be expected to exist in an infinite population were investigated in some detail for the case of two loci with an arbitrary number of alleles per locus. This procedure had the advantage of simplifying the notation to a considerable extent, while nevertheless retaining enough generality in many circumstances to allow straightforward generalization to the case of n loci.

To keep the mathematics workable, two life phases,

infant and adult, nonoverlapping generations and a uniform environment were assumed. In order to ensure the existence of Hardy-Weinberg equilibria, it was further necessary to assume no sex difference in fitness, random mating and that the expected number of offspring of a mating pair is the product of two means, one corresponding to each parent.

It seems that in general the only modes of gene action that lead to the existence of Hardy-Weinberg equilibria at all loci are those of additive and multiplicative gene action between loci with regard to the product of viability and fecundity. In both cases the necessary and sufficient conditions for local stable equilibria for two loci were derived. Under the assumption of additive gene action between loci, conditions for the local equilibria to become global equilibria are indicated. In the case of multiplicative gene action between loci, the foregoing local result was extended to the case of n loci.

The load theory was investigated in the context of the assumptions that would result in Hardy-Weinberg frequencies. It was found that if the necessary inbreeding is accomplished rapidly, so that selection does not vitiate the description of the genotypic array by the inbreeding coefficient, the regression of the number of infant offspring per infant mating pair on the inbreeding coefficient will allow the estimation of the genetic loads for fitness in the case where the value of the maximal genotype is known.

There are two obstacles to useful application of the theory. The first is that the value of the maximal genotype is unknown and will be impossible to estimate in most cases. The second is that the stage designated as infancy corresponds to the moment of conception before any differential mortality occurs. In an experimental situation it is only possible, in general, to observe the number of births. It is shown that if there is a significant degree of mortality before birth, the load theory will no longer apply.

The load theory in the case of metric traits, as exemplified by the trait viability, was also examined. This case is more amenable than that of fitness, although it is pointed out that considerable doubt exists about the applicability of the load ratio theorems that distinguish between mutation and segregation loads. The effect of differential mortality was also considered. It is concluded that nonmultiplicative epistasis causes the concepts and theory of genetic loads to be inapplicable.

Justus Frandsen Seely: "Estimation in Finite-Dimensional Vector Spaces with Application to the Mixed Linear Model." Ph.D. thesis. Iowa State University Library. March 1969.

In this dissertation a basic set of ideas is presented through which unbiased and/or minimum variance unbiased estimation may be studied whenever the class of possible estimators $\overline{\mathcal{A}}$ satisfies the following conditions:

(a) $\overline{\mathcal{A}}$ is a real finite-dimensional linear space.

(b) There is an assumed or known underlying class of probability measures $\{(\mathcal{U}, \text{S.P}): \text{P} \in \mathcal{P}\}$.

(c) Each $\overline{a} \in \overline{\mathcal{A}}$ is S-measurable and P-square integrable with respect to all $\text{P} \in \mathcal{P}$.

(d) There is a parameter space Ω and functions E and Var on $\overline{\mathcal{A}} \times \Omega$ which describe, as functions over Ω, the possible expectations and variances of an element $\overline{a} \in \overline{\mathcal{A}}$ with respect to the class $\mathcal{P}$.

Conditions c and d may be weakened if interest is confined only to unbiased estimation. It is not necessarily assumed that the complete structure of $\mathcal{P}$ is known, but only that certain moments (first moments for unbiased estimation and first and second moments for minimum variance unbiased estimation) of the elements in $\overline{\mathcal{A}}$ may be described through the parameter space Ω and the functions E and Var.

Much of the formulation is motivated by problems especially relevant in the study of a general mixed linear model $y = X\beta + e$ with the following covariance structure:

$$\text{E}[ee'] = \sum_{i=1}^{m} \nu_i V_i .$$

Concerning such a model special attention is concentrated upon (a) unbiased quadratic estimation for parametric functions of the form $\Sigma_i \lambda_i \nu_i$, (b) special results on best linear unbiased estimation for parametric functions of the form $\lambda'\beta$, and (c) $\overline{\mathcal{A}}_\theta$ — best estimation ($\overline{a} \in \overline{\mathcal{A}}$ is said to be an $\overline{\mathcal{A}}_\theta$ — best estimator for a parametric function g if it is an unbiased estimator for g and if it attains the minimum possible variance among all unbiased estimators for g in $\overline{\mathcal{A}}$ at the particular parameter point $\Theta \in \Omega$) for parametric functions of the form $\Sigma_i \lambda_i \nu_i$ when e has a multivariate normal distribution and $\overline{\mathcal{A}}$ has one of the forms $\{a'y + y'Ay\}$, $\{y'Ay\}$, or $\{y'Ay : AX = 0\}$.

To obtain a unified formulation for a linear space $\overline{\mathcal{A}}$ satisfying conditions a—d, the elements in $\overline{\mathcal{A}}$ are taken (without loss of generality) to be in an inner product representation. That is, an element $\overline{a} \in \overline{\mathcal{A}}$ is taken to be of the form $\overline{a}(y) = (a, \phi(y))$ where a is an element of a linear space $\mathcal{A}$, $(,)$ is an inner product on $\mathcal{A} \times \mathcal{A}$, and ϕ is a mapping from $\mathcal{U}$ into $\mathcal{A}$ such that the image of $\mathcal{U}$ under ϕ contains a spanning set for $\mathcal{A}$. Under this type of formulation the expectation μ_θ and the covariance operator Σ_θ of the function ϕ are defined for each $\Theta \in \Omega$ as in Kruskal's coordinate-free approach to the linear model. To be able to concentrate on particular parametric functions a $\mu_\theta = H \zeta_\theta$ representation is introduced. $A\mu_\theta$

$= H \zeta_\theta$ representation consists of a linear operator H from some inner product space $(\mathcal{R}, <, >)$ into $\mathcal{A}$ and a collection $\{\zeta_\theta : \Theta \in \Omega\}$ such that $\mu_\theta = H \zeta_\theta$ for all $\Theta \in \Omega$. Using a $\mu_\theta = H \zeta_\theta$ representation the parametric functions of interest are of the form $< \lambda, \zeta_\theta >$ so that by an appropriate choice of the operator H interest can be concentrated on particular parametric functions.

One of the most interesting features throughout the entire formulation is the wide applicability of the ideas and concepts which have evolved in linear model theory. In fact, under suitable interpretation the study of a linear space $\overline{\mathcal{A}}$ which satisfies conditions a-d is exactly the same as the study of the space of linear estimators used in fixed linear model theory.

Donald J. Soults: "Asymptotic Value Distributions for Matrix Games." Ph.D. thesis. Iowa State University Library. August 1968.

This research is directed toward finding asymptotic value distributions for k x n zero-sum matrix games with independent and identically distributed payoff coefficients. Three payoff distributions are considered: uniform [0, 1], inverse-uniform [1, ∞], and normal.

In the normal k x n case, we find a norming under which the payoff distribution is asymptotically bounded away from 0 and 1.

In the normal 2 x n case, the k x n result is sharpened and it is shown that

$$\lim_{n \to \infty} \Pr \{ \sqrt{2}\, V_n \leq t a(n) + b(n) \} = 1 - w(t)$$

where

$$w(t) = \int_{-\infty}^{+\infty} e^{t+y^2} \; e^{-e^{t+y^2}} \left[\frac{e^{-y^2}}{\sqrt{\pi}} + 2y\phi\left(\sqrt{2}\, y\right) \right] dy$$

and a(n), b(n) are the norming constants applicable to normal extremes.

Although much has been accomplished in the general area of stochastic linear programming, relatively little has been done on "passive" stochastic linear programming problems, i.e. the purely distributional aspects of stochastic linear programming which are closely related to the subject of this research. The equivalence of game-value distributions and the distributions of the optimal solutions to certain special stochastic linear programming problems (objective function coefficients and right-hand-side coefficients all 1's, and the matrix coefficients independent and identically distributed random variables) can be utilized with the results of this thesis. Together they can provide the asymptotic distribution of the inverse of the optimum of such special programs when the matrix coefficients are N(0, 1) and the asymptotic distribution of the optimum when the matrix coefficients are inverse-uniform.

Malte Sund: "Prediction of Success of German Medical Students." M.S. thesis. Iowa State University Library. May 1969.

The relationship between grades received in three official examinations in the medical school of Munich, Bavaria, Germany and grades received in 12 courses during the last year of Bavarian humanistic gymnasia was investigated with multiple regression techniques.

The greater proportion of students were admitted to medical school without selection. The data consisted of records for both selected and unselected students.

For two prediction situations it was found that grades received in the nine scientific high school subjects can be weighted equally; the remaining three non-scientific subjects and other variables can be dropped from the model. The estimated proportion of variance in the independent variables (medical school grades) explained by the reduced model lies somewhere between approximately 20 percent and approximately 45 percent. Considering the nature of the data, this estimate is probably closer to 45 percent.

PAPERS AND SPEECHES

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

Munir Ahmad and **Masashi Okamoto:** "The Estimation of Parameters of Truncated Bivariate Correlated Poisson (BCP) Distribution," at joint meetings of the American Statistical Association and Biometric Society (ENAR and WNAR), Pittsburgh, August 20-23.

Munir Ahmad and **Masashi Okamoto:** "Truncated Bivariate Poisson Distributions," at the annual meeting of the Institute of Mathematical Statistics, University of Wisconsin, August 27-30.

T. A. Bancroft: "The Role of Statistics as a Separate Discipline of the Mathematical Sciences," at an NSF luncheon at ISU, July 19.

T. A. Bancroft and D. K. Hotchkiss: "The Organization of Mu Sigma Rho," at joint meetings of the American Statistical Association and the Biometric Society (ENAR and WNAR), Pittsburgh, August 20-23.

Richard Chamberlain: "OMNITAB—A Programming Language," seminars to staff and students at the University of Manitoba, Canada, January 24.

R. L. Chamberlain and **David Jowett:** "The OMNITAB Programming System," at the statistical society meetings in Iowa City, April 23-25.

R. L. Chamberlain: "The OMNITAB Programming System: A Guide for Users," a seminar for the Department of Biomathematics, M. D. Anderson Hospital and Tumor Institute, University of Texas, Houston, May 2.

C. P. Cox: "Some Observations on Statistical Consulting," a seminar at Case Western Reserve University, Cleveland, November 1.

J. D. Borwanker and **H. T. David:** 'Binomial Sequential Design of Experiments with General Loss and Unequal Sampling Costs," at the annual meeting of the Institute of Mathematical Statistics, University of Wisconsin, August 27-30. Abstract 30 in Annals of Mathematical Statistics, 39:5, 1771-1772, October 1968.

H. T. David: "A Class of Stochastic Control Problems," a chemical engineering seminar at ISU, October 10.

H. T. David: "Loss Functions and the Inadmissibility of Information Sources," at Ohio State University, November 7.

H. T. David: "Statistics in Engineering," for the Engineering College Seminar Series at ISU, February 25.

H. T. David: "Statistics for Physicists," a one-quarter course presented as seminars for Nuclear Physics at ISU, spring quarter.

H. T. David and **Kenneth Mount:** "Asymptotic Minimax Character of Certain Likelihood-Ratio Procedures Related to Goodness-of-Fit," at the First International Symposium on Nonparametric Techniques in Statistical Inference, Indiana University, June 1-6.

Thomas Fears and **K. L. Mehra:** "Extensions of the Chernoff and Savage Theorems to p-Dependent Sequences (preliminary report)," at the annual meeting of the Institute of Mathematical Statistics, University of Wisconsin, August 27-30. Abstract 38 in Annals of Mathematical Statistics, 39:5, 1774, October 1968.

F. B. Cady and **W. A. Fuller:** "Uses of Computers in Agronomic Research," at the annual meeting of the American Society of Agronomy, New Orleans, November 10-15.

W. A. Fuller: "Elements of Least Squares Analysis" and "Samples and Surveys," lectures for the Department of Mathematics, Morningside College, Sioux City, Iowa, as part of the visiting lecturer in statistics program, December 12-13.

W. A. Fuller: "The Estimation of Distributed Lags," a seminar at the University of Missouri, March 27.

W. A. Fuller: "Elements of Least Squares Analysis" and "Samples and Surveys," lectures at Doane College, Crete, Nebraska, April 16 and at Midland Luther College, Fremont, Nebraska, April 17-18 as part of the visiting lecturer in statistics program.

Wayne Fuller: "Sampling with Random Stratum Boundaries," at the statistical society meetings in Iowa City, April 23-25.

Wayne Fuller: "Sampling with Random Stratum Boundaries," a seminar at the Bureau of the Census, Washington, D. C., May 21.

Wayne Fuller: "Estimation of Simultaneous Equations," May 26 and "Elements of Least Squares Analysis," May 27 at the University of Denver as part of the visiting lecturer in statistics program.

Chien-pai Han: "A Note on the Discrimination in the Case of Unequal Covariance Matrices," at the annual meeting of the Institute of Mathematical Statistics, University of Wisconsin, August 27-30. Abstract 50 in Annals of Mathematical Statistics, 39:5, 1778, October 1968.

Dean Isaacson: "Probability for Mathematicians," a mathematics seminar at ISU, April 8.

Blanche M. Cournoyer, J. A. Browning and **David Jowett:** "Crown Rust Intensification Within and Dissemination from Pure Live and Multiline Varieties of Oats," and

Hideo Tachibana, **David Jowett** and W. F. Fehr: "Determination of Losses in Soybeans Caused by *Rhizoctonia soloni,*" at the annual meeting of the American Phytopathological Society which met in conjunction with the American Institute of Biological Sciences at Ohio State University, September 2-6.

David Jowett and **R. L. Chamberlain:** "The Utilization of the Computer in Statistical Consulting at Iowa State University," and

David Jowett: "The Computer in College Instruction," a panel discussion, and

David Jowett, D. F. Cox and **R. L. Chamberlain:** "Teaching Statistics Using OMNITAB," at a workshop on The Computer in College Instruction at Worcester Polytechnic Institute, Massachusetts, September 3-6.

David Jowett and **R. L. Chamberlain:** "Experience with OMNITAB," at the 2nd IBM Symposium on Statistical Computing, New York City, December 16-17.

David Jowett: "Teaching Statistics Using the Computer," seminars at the University of Minnesota, May 8, and at Ohio State University, May 22.

David Jowett, D. F. Cox and **R. L. Chamberlain:** "Teaching Statistics Using OMNITAB," at the Summer Workshop, Instructional Use of Computers in Statistics, University of North Carolina, June 17-19.

Oscar Kempthorne: "Aims, Logic and Methods of Transformations," at joint meetings of the American Statistical Association and Biometric Society (ENAR and WNAR), Pittsburgh, August 20-23. Abstract 1525 in Biometrics, 24:4, 1034, December 1968.

Barrie Latter: "Barriers to Progress under Continued Selection in *Drosophila,*" and "Models of Quantitative Genetic Variation and Computer Simulation of Selection Response," seminars for the Department of Animal Science, University of Nebraska, December 6.

Barrie Latter: "Genetic Control of Development in Plateaued Populations of *Drosophila,*" and "Quantitative Genetic Analysis in an Asexual Species—*Saccharum,*" seminars at the University of Minnesota, February 20-21.

Barrie Latter: "Genetic Control of Development in Plateaued Populations of *Drosophila,*" a seminar at the University of Chicago, March 10.

Barrie Latter: "Genetic Control of Variability," a seminar at the University of North Carolina, April 14.

Barrie Latter: "Genetic Control of Variability in Plateaued Populations," a seminar at Purdue University, May 21.

Richard E. Lund: "Estimators in Multiple Frame Surveys," at joint meetings of the American Statistical Association and Biometric Society (ENAR and WNAR), Pittsburgh, August 20-23.

Richard E. Lund: "Comparison of Costs for Various Sampling Designs," a seminar at Monterrey Institute of Technology, Monterrey, Mexico, November 5.

Richard E. Lund: "Analysis of Survey Data" and "Problems with Sampling Frames," seminars at Oklahoma State University, February 17-18.

Ahmed Memon and **Masashi Okamoto:** "On the Distribution of the Z Statistics in Discriminant Analysis," and "W Statistic in Covariate Discriminant Analysis," at the annual meeting of the Institute of Mathematical Statistics, University of Wisconsin, August 27-30.

A. G. Mexas: "Statistical Programming Languages—I. AARDVARK" and "Algorithms for Analysis of Variance," at North Dakota State University, November 21-22.

A. G. Mexas: "AARDVARK—A Computer Language for Analysis of Variance," at the statistical society meetings in Iowa City, April 23-25.

Roger Mrachek: "Ordination Techniques," an ecology seminar at ISU, November 6.

David R. Thomas and **Peter C. O'Brien:** "Procedures for Selecting the Best Reliability Distribution," at joint meetings of the American Statistical Association and Biometric Society (ENAR and WNAR), Pittsburgh, August 20-23.

T. Yanagimoto and **Masashi Okamoto:** "Ranking and Rank Correlation (preliminary report)," at the annual meeting of the Institute of Mathematical Statistics, University of Wisconsin, August 27-30. Abstract 88 in Annals of Mathematical Statistics, 39:5, 1790, October 1968.

Masashi Okamoto: "Some Topics on Discriminant Analysis," a seminar at Courant Institute of Mathematical Sciences, New York University, October 8.

Masashi Okamoto: "W* Statistic in Covariate Discriminant Analysis," a seminar at Harvard University, October 9.

Edward Pollak and **Oscar Kempthorne:** "Malthusian Parameters in Diploid Genetic Populations," at joint meetings of the American Statistical Association and Biometric Society (ENAR and WNAR), Pittsburgh, August 20-23. Abstract 1534 in Biometrics, 24:4, 1037, December 1968.

Martin Rosenzweig and **Wayne A. Fuller:** "A Test for Skewness," at the Princeton American Society of Quality Control Conference, December 7.

J. K. Sengupta and B. C. Sanyal: "A Distributional Analysis of Linear Programs Under Risk," at the annual meeting of the Institute of Mathematical Statistics, University of Wisconsin, August 27-30. Abstract 72 in Annals of Mathematical Statistics, 39:5, 1785. October 1968.

Ravindra Singh and **B. V. Sukhatme:** "Some Contributions to the Theory of Construction of Strata," at the annual meeting of the Institute of Mathematical Statistics, University of Wisconsin, August 27-30. Abstract 74 in Annals of Mathematical Statistics, 39:5, 1785-1786, October 1968.

E. Walter Coward, Jr., Allan L. Bashor, **Richard D. Warren** and Gerald E. Klonglan: "Social Psychological Aspects of Market Interactions in a Subsistence Economy: a Case of Path Analysis," and

Dean R. Yoesting, Joe M. Bohlen and **Richard D. Warren:** "A Longitudinal Study of Occupational Aspirations and Attainments of Iowa Young Adults," at the Rural Sociological Society meeting in Boston, August 23-26.

Leroy Wolins: "Methodological Consideration in Longitudinal Research," at the Life Insurance Agency Management Association, Hartford, Connecticut, April 21.

PARTICIPATION IN PROFESSIONAL ACTIVITIES

Dr. T. A. Bancroft was elected president-elect of the American Statistical Association for 1969. He has been named chairman of the ASA Committee on Elections, a member of the ASA Exploratory Committee on Federal Statistics, and continues to serve on two other committees organized by ASA: the Advisory Committee on Statistical Policy to the Bureau of the Budget and the Committee on the Preservation of Documents of Distinguished Statisticians.

Dr. Bancroft serves as a member of the council of the International Biometric Society, a member of the Regional Advisory Board of the Biometric Society (ENAR), and a member of the Committee on Affiliations of the Biometric Society. He continues as a member of the National Research Council, Division of Biology and Agriculture, as a representative of the Biometric Society.

During the statistical society meetings in Iowa City, April 23-25, Dr. Bancroft was a member of the program committee, chairman of a section on Contributed Papers, and co-coordinator of the Department Chairmen's Luncheon on Training. He has been appointed to a committee organized by the Veterans' Administration to work on the establishment of a training grant program in biostatistics, was elected an associate member of the Inter-American Statistical Institute, and continues as a member of the Board of Directors of Mu Sigma Rho.

Professor C. Philip Cox was elected a Fellow of the American Statistical Association, and elected chairman of the ASA Biometrics Section. He will serve as a member of the program committee for the 1969 annual meeting.

Dr. D. F. Cox has been granted faculty improvement leave for 1969-70 to study statistical methods and theory at Cornell University.

Dr. H. T. David continues on the organizing committee of the NSF Visiting Lecturer Program in Statistics. He has served as vice president of the Iowa Chapter, American Statistical Association; was chairman of the program committee for the IMS central regional meetings in Iowa City, April 23-25, and is national secretary-treasurer of Mu Sigma Rho. Dr. David is a member of the ISU Annuities and Insurance standing committee, a member of the Sciences and Humanities Scholastic Standards committee, and a member of the ISU Daily Publication Board.

Wayne A. Fuller has been named a participating lecturer in the Visiting Lecturer Program in Statistics sponsored by the American Statistical Association, the Biometric Society and the Institute of Mathematical Statistics, with financial support from the National Science Foundation. He continues on the curriculum committee for the College of Sciences and Humanities and is national vice president of Mu Sigma Rho.

Dr. D. K. Hotchkiss is national president of Mu Sigma Rho. He is ASA faculty representative for ISU, and has been elected a member of the academic standards committee of the College of Sciences and Humanities. Dr. Hotchkiss and Eric West attended the 81st session of the Iowa Academy of Science in Cedar Falls April 18.

Dr. D. V. Huntsberger will be president of the Iowa State Chapter of Sigma Xi during 1969-70; he served as vice president this year. He is a member of the Board of Directors of Mu Sigma Rho.

Dr. J. L. Hutter participated in a six-week NSF institute "Mathematical Applications in Political Science," at Virginia Polytechnic Institute which began June 17.

Dr. David Jowett organized a session on "Computer Languages for Statisticians" for the statistical society meetings in Iowa City April 23-25.

Oscar Kempthorne is chairman of a Committee of Presidents of Statistical Societies (COPSS) committee for the R. A. Fisher Memorial Lecture Series, and a member of the ASA S. S. Wilks Memorial Medal Committee. He is a member of the Mu Sigma Rho Board of Directors.

Dr. Kempthorne was chairman of a session on Discrimination and Classification, discussant for a session on Bayesian Applications and a member of the program

committee for the statistical society meetings in Iowa City April 23-25. He served as chairman of the session on Paired Comparisons and discussant for the session on Goodness-of-Fit at the First International Symposium on Nonparametric Techniques in Statistical Inference at Indiana University June 1-6.

Dr. Barrie Latter attended the Poultry Breeders Roundtable in Kansas City May 7-8.

Dr. J. K. Sengupta served as organizing chairman and a session chairman for the NSF-sponsored Joint Seminar in Theoretical and Applied Economics which met in Ames May 24.

Professor Norman Strand was on assignment in Seoul, Korea, during July, August and September as a member of the USAID Mission. He advised the South Korean government on survey designs, data collection procedures and analytical procedures pertaining to Korean agriculture. The study was sponsored by the Statistical Reporting Service, United States Department of Agriculture.

Dr. B. V. Sukhatme was chairman of a session on Sampling at the statistical society meetings in Iowa City, April 23-25.

Dr. Leroy Wolins attended the meeting of the Psychometric Society in Princeton, New Jersey, April 16-18.

Dr. David Jowett, W. J. Kennedy, Bud Meador, Abel Mexas, Vincent Sposito and Eric West attended the Conference on Statistical Computation at the University of Wisconsin, April 27-30. Sposito represented the Statistical Numerical Analysis and Data Processing Section at the annual SHARE library meetings in Los Angeles.

Staff members and graduate students initiated into Phi Kappa Phi included Dr. D. V. Huntsberger, A. Ronald Gallant, Gauri Ghai and Charlotte Bentley.

Students who were named associate members of Sigma Xi include Omar Henriquez, W. J. Kennedy, James Mellon, Kenneth Mount, Vincent Sposito and Eric West.

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 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.

During spring quarter the number of students enrolled in statistics courses topped the 1400 mark for the first time, with a record 1418. A new course offered this year, during second summer session 1968, drew an enrollment of 10. With the title Stochastic Processes, the course covered stationary processes with emphasis on the time domain; transformations and derived processes; normal and Poisson processes; renewal theory; Markov chains; and harmonic analysis of processes.

Two important changes in requirements for graduate degrees were adopted this year: A non-thesis M.S. program is now available to qualified students, and the foreign language requirement is now optional.

Previously, all M.S. candidates were required to submit an original thesis and complete 45 credit hours. Now a non-thesis option requires the completion of 51 credits plus satisfactory performance on a written examination.

There is no longer a uniform language requirement for graduate students majoring in statistics. The department encourages the student to prepare himself in foreign languages and in computer language, but specific requirements for the M.S. and Ph.D. degrees are at the discretion of the student's advisory committee.

COURSE OFFERINGS IN STATISTICS

The courses offered by the Department of Statistics during the academic year 1968-69 were as follows:

Courses for Undergraduate Students Only

201,	Principles of Statistics	5	FWS*	Jobson, Winger
201A,		3	WS, SS_1	Lin, Madsen, Mount, Schmid, Tang
201B		3	FS	Lin, Madsen, Mount, Pyne, Tang, Veale
327	Elementary Business Statistics	3	F	Jobson
341,	Introduction to Theory of	3	F	Huntsberger
342,	Probability and	3	W	Huntsberger
343	Statistics	3	S	Huntsberger
380	Statistical Applications of Digital Computers	3	FWS	Mexas, West

*Because the fiscal year began July 1, 1968, and ended June 30, 1969, the courses taught in the second summer session of 1968 through the first summer session of 1969 are reported here. Symbols indicate the quarter each course was taught: SS_2—Second Summer Session, F—Fall, W—Winter, S—Spring, SS_1—First Summer Session.

Courses for Graduate Minors and Undergraduates

401,	Statistical Methods for Research Workers	4	FW, SS_1	C. P. Cox, D. Cox, Hinz, Hotchkiss, Hunts-berger, Hutter, Jowett, Mensing, S.Sukhatme, Tang, Walsh, Warren, Wolins
402		4	SS_2 WS	Burmeister, D. Cox, Hinz, Hunts-berger, Hutter, Jowett, Mensing, S.Sukhatme, Walsh, Warren, Wolins
411	Experimental Design for Research Workers	3	S, SS_1	D. Cox, Hotchkiss, Jowett
421	Survey Design for Research Workers	3	SS_2 S	B. Sukhatme
431	Elementary Statistical Quality Control	3	S	Mensing
436	Genetic Statistics for Research Workers	3	S	Jowett
446,	Statistical Theory for	3	F	Han
447,	Research Workers	3	W, SS_1	Han, Hinz
448		3	SS_2 S	Hinz, Huntsberger
481,	Processing of Statistical	2	W	Mosier
482	Data	2	S	Mosier
499	Special Problems	Arr.	FWS, SS_1	Bancroft, D. Cox, Warren, West
499H	Special Problems, Honors Program	2	S	Wolins
499X	Nonparametric Methods	3	F	Wolins

Courses Primarily for Graduate Students, Major and Minor

501	Intermediate Statistical Methods	3	F	Bancroft
505	Psychometrics	3	S	Wolins
506	Factor Analysis	3	F	Walsh
511,	Design of Experiments	3	W	Zyskind
512		3	S	Kempthorne
521,	Design of Surveys	3	W	B. Sukhatme
522		3	S	Sedransk
531	Industrial Statistics: Sampling Inspection	3	F	David
535	Biological Statistics	3	S	C. P. Cox
536,	Genetic Statistics	3	F	Pollak
537		3	W	Pollak
538	Econometric Statistics	3	F	Fuller
539	Operations Research	3	W	David
540	Operations Research Methods and Economic Analysis	3	S	Sengupta
541,	Theory of Probability	3	F	Meeden
542,	and Statistics	3	W	Meeden
543		3	S	Han
545	Stochastic Processes	3	SS_2	Pollak
580	Computational Techniques in Statistics: Methods	3	W	Kennedy
581	Computational Techniques in Statistics: Theory	3	S	Kennedy
599	Special Topics	Arr.	SS_2 FWS, SS_1	
	A. Theory			David, Fuller, Han, Isaacson, Mensing, S.Sukhatme, Warren
	B. Methods			C. P. Cox, D. Cox, Fuller, Jowett, Kennedy, Sposito, Warren
	C. Design of Experiments			Zyskind
	X. Socio-metrics			Warren

Courses for Graduate Students, Major and Minor

601	Advanced Statistical Methods	3	F	C. P. Cox
611,	Advanced Design of	3	W	Zyskind
612	Experiments	3	S	Kempthorne
641	General Theory of Linear Hypothesis	3	F	Zyskind
642	Probability and Distribution Theory	3	W	Isaacson
643	Theory of Estimation and Testing of Hypotheses	3	S	Meeden
646	Time Series	3	S	Fuller
647	Multivariate Analysis	3	F	Okamoto
648	Seminar on the Theory of Statistics and Probability	3	SS_1	Meeden
649	Recent Developments in Probability and Statistics	3	SS_2	David
699	Research	Arr.	SS_2 FWS, SS_1	Arnold, Bancroft, C. P. Cox, D. Cox, David, Fuller, Han, Hickman, Jowett, Kemp-thorne, Mehra, Pollak, Sedransk, B.Sukhatme, Warren, Wolins, Zyskind

SUMMER INSTITUTE

Students from Afghanistan, Brazil, India, Pakistan and Thailand participated in the fifth Demonstration Course in Survey Methods, taught during the second summer session. Each participant received a certificate of achievement upon completion of the course.

During this annual summer institute, international students have an opportunity to get experience by conducting an actual small-scale sample survey. Dr. Roy Hickman directed the planning and execution of the survey, assisted by members of the Statistical Laboratory's Survey Group. Dr. B. V. Sukhatme presented a short course in sampling methods.

GRADUATE STUDENTS

The April issue of Annals of Mathematical Statistics listed doctoral dissertations in statistics for the years 1967 and 1968. Iowa State had 15 Ph.D. graduates during that time, ranking second to the University of California at Berkeley with 16.

Ph.D. Candidates

Joseph Abbey
Hosni Abou-Seada
George Battese
Gordon Booth
Leon Burmeister
Alfonso Carrillo
Richard Chamberlain*
Shang-Wang Chang
Patricia Conn
Isidoro David
James S. DeGracie
Pamela Doctor
Thomas Fears
G. L. Ghai
Soner Gonen
Charles Graham
Joseph Grimes
Muzammil Husain
Cary Isaki
Ronald Jacobson
Louis Jensen
Leon Jordan
William Kennedy
John Kinney
John Lin
Roland Loup
Charles MacIssac
Brain Macpherson
Richard Madsen
Angel Martinez
Frank B. Martin
Donald McElhone
James Mellon
Richard Mensing
Abel Mexas
Kenneth Mount
Nimmagadda Murthy
Syed T. M. Naqvi
Peter O'Brien
Martin J. O'Connell
Panagiotis Papaioannou
C. M. Patel*
Martin Rosenzweig
Ahmed Salem
J. R. Schmid
Nell Sedransk
Justus Seely
Donald Soults
Vincent Sposito
Richard Stein
Victor Tang
Lonnie Vance
James Veale
William Warde
Eric West
Milton Winger
Franklin Wolf

*received M.S. during the year

M.S. Candidates

Guillermo Adames-Suari
Yahia Ahmed
Robert E. Albert
Forrest Aspengren
Sirisin Assakul
Sorachai Bhisalbutra
Richard Chamberlain
Pathra Chatkeo
Eliahou Cohen
Godfrey Coker
K. T. deGraft-Johnson
Sudha Desai
Sharon Earley
Gregory Fawcett
Amiri Gamshadzahi
A. Ronald Gallant
John Goebel
Omer Gucelioglu
Bonnie Hanson
Nancy Heath
Omar Henriquez
Her Tzai Huang
James Immordino
Charles Ingwell
Jairof Jayavadhanangkur
J. D. Jobson
Henry Kelker
Khadija Khatun
G. N. Lauer
Dennis Mar
Ronald J. Mead
Kenneth Merritt
Mallika Mokkhaves
C. M. Patel
David Pyne
Vipanee Rojanavanich
Ivan Sampaio
Jan Shoemaker
Wendell Smith
Malte Sund
Nantit Supamongkon
Terrance Svejda
Jane Toben
Choosak Udomsri
Fredric A. Vogel
Chartsee Xumsai

Degrees Granted and Positions Taken

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

Recipients of the Ph.D. Degree

Joseph Abbey (August 1968, under H. T. David) is teaching in the Economics Department at the University of Ghana.

Shang-Wang Chang (May 1969, joint mathematics-statistics major under H. T. David) accepted a position as assistant professor at Stanislaus State College, Turlock, California.

Patricia Sullivan Conn (May 1969, under H. T. David) is an assistant professor in the Division of Mathematical Sciences, Purdue University at Ft. Wayne, Indiana.

James S. DeGracie (August 1968, under Wayne Fuller) is employed by CEIR, Inc. at the Dugway Proving Ground, Utah.

Frank B. Martin (November 1968, under George Zyskind) continues as an assistant professor with the Division of Biometry in the School of Public Health, University of Minnesota.

Richard Mensing (August 1968, under H. T. David) remains at the Statistical Laboratory, as an assistant professor.

S. T. M. Naqvi (March 1969, under Oscar Kempthorne) returned to Tando Jam, West Pakistan, where he is a statistician with the Agriculture Research Institute.

Martin S. Rosenzweig (November 1968, under Wayne Fuller) accepted a position as assistant professor in the Department of Statistics and Operations Research at the University of Pennsylvania.

Carl Z. Roux (May 1969, under Oscar Kempthorne) returned to the University of Stellenbosch, Republic of South Africa, where he is senior research officer with the Department of Agriculture.

Justus Seely (March 1969, under George Zyskind) is an assistant professor in the Department of Statistics at Oregon State University.

Donald Soults (August 1968, under H. T. David) is employed by the Commercial Airplane Division of the Boeing Company in Renton, Washington.

Recipients of the M.S. Degree

Sorachi Bhisalbutra (August 1968, under B. V. Sukhatme) returned to Thailand.

Richard Chamberlain (March 1969, under Barry Arnold) remains at Iowa State, working toward his doctorate.

Godfrey Coker (May 1969, under Roy Hickman) returned to Sierra Leone.

Sharon Earley (August 1968, under James Walsh) joined Kimberly-Clark Corporation as a psychometrist with the Psychological Services Department.

Gregory Fawcett (August 1968, under Leroy Wolins) is working toward a doctorate in economics at Iowa State.

Omar Henriquez (August 1968, under David Jowett) returned to the Universidad Austral de Chile where he is teaching and has been appointed Vice President of Academic Affairs.

Muzammil Husain (May 1969, under Wayne Fuller) returned to West Pakistan.

James Immordino (August 1968, under Leroy Wolins) continued study in statistics at Iowa State during fall quarter and is now employed in Trenton, New Jersey, as a member of the Information Analysis System with Western Electric.

Khadija Khatun (November 1968, under Roy Hickman) returned to the University of Dacca, East Pakistan, where she is employed by the Institute of Statistical Research and Training.

G. Nicholas Lauer (May 1969, under C. P. Han) remains at Iowa State, working toward his doctorate.

Ronald J. Mead (November 1968, under T. A. Bancroft) continues as an operations research analyst with American Oil Company in Chicago.

Mallika Mokkhaves (August 1968, under B. V. Sukhatme) returned to Thailand.

C. M. Patel (November 1968, under Wayne Fuller) remains at Iowa State, working toward his doctorate.

Malte Sund (May 1969, under Leroy Wolins) returned to Germany where he is a statistician with an Office for the Study of Medical Education in Munich.

The George W. Snedecor Award in Statistics

The 1969 George W. Snedecor Award was presented to Peter C. O'Brien, who came to Iowa State in 1965 as a graduate assistant. Since 1966 he has been supported by a National Institutes of Health traineeship.

The award has been given since 1954 to the student selected by the graduate faculty in statistics as the department's most outstanding candidate for the Ph.D. degree. It consists of a year's membership in the Institute of Mathematical Statistics, a subscription to the Institute's Annals and a cash gift. It is named in honor of the Statistical Laboratory's founder and first director.

UNDERGRADUATES

Undergraduate enrollment dropped as students interested in computation work enrolled in the newly organized Department of Computer Science. Dr. D. V. Huntsberger, undergraduate adviser, advised about 32 students during the year.

Recipients of the B.S. Degree

Michael Dennis Anderson, November
Thomas Benedict, August
Douglas Doyle Eland (joint economics-statistics), May
Judith Enfield, August
Wesley Vern Finestead (joint mathematics-statistics), May
Janice Rae Johnson, May
Lawrence C. Kinyon, May
William George Kruhm, May
Michelle Ellen McGrane, November
Sue Ellen Ritchie, May
Kent Allen Rogers (joint mathematics-statistics), May
G. Beth Van Sittert, May
Ruthanne Veale, August

Iowa State University Statistics Club

Under the leadership of Sue Ritchie, the Statistics Club sponsored a varied program of professional meetings, tours and informal get-acquainted events, including a bowling party and picnic.

Dr. Leroy Wolins discussed "The Role of Statistics in Psychology" at the November meeting, and graduate Scott Krane, Director of Research for Hallmark Cards, Inc., spoke in February.

In December club members toured the National Animal Disease Laboratory with statistics graduate students Gordon Booth and Charles Graham who are NADL employees. Booth and Graham described how statistics is used in research conducted at the Laboratory.

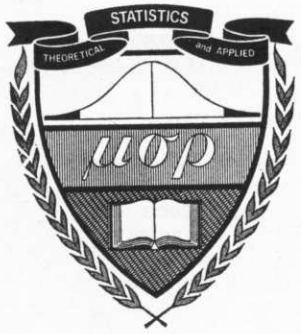
IBM personnel presented a program on the use of remote terminals to a joint meeting of Statistics Club, Computer Science Club and Mathematics Club in January. Subsequently, the Stat Club used this in its Veishea display, which won second place honors in the physical sciences division of the College of Sciences and Humanities.

Ten club members participated in the April field trip to Iowa City to attend the spring regional meetings of IMS (Central Region), Biometric Society (ENAR) and ASA (Biometrics Section and Section on Physical and Engineering Sciences.) Dr. Robert V. Hogg, chairman of the Department of Statistics at SUI, presented a special session for the undergraduates in which he described a survey he had completed on undergraduate programs in statistics. John Lehman, executive director of the American Statistical Association, participated in the session and met with the students at dinner to discuss job opportunities and how undergraduates can function in ASA.

Statistics Club officers for 1969-70 are Russell Mangels, president; Nancy Allen, vice president; Lloyd Golosi, secretary and Charles Miller, treasurer. Dr. D. K. Hotchkiss is advisor.

Mu Sigma Rho

During its first year of existence, Mu Sigma Rho, the national statistical honor society which was established at the Statistical Laboratory last year, adopted an official key and crest and prepared information for other schools wishing to establish a chapter. Dr. D. K. Hotchkiss continues as president.



Mu Sigma Rho Crest

The Iowa Alpha Chapter at Iowa State continues under Eric West's presidency. Plans have been made to elect new members and officers in the fall.

SEMINARS

Statistical Laboratory—Department of Statistics Series

The Statistical Laboratory and Department of Statistics continued to sponsor weekly seminars which presented the most recent statistical research. These seminars, available on a non-credit basis to all students and faculty members, provide an opportunity to explain and discuss statistical theory and methodology. The series includes frequent appearances by guest speakers from other institutions, thus enlarging the range of topics.

Dr. B. V. Sukhatme, Dr. James Walsh and Dr. Dean

Isaacson composed the 1968-69 seminar committee. Topics and speakers presented during the year included:

Fall Quarter 1968

September	11	Present Status and Outlook of Statistics. T. A. Bancroft.
September	18	Replications within Incomplete Blocks. Frank B. Martin, University of Minnesota.
September	25	(joint Statistical Laboratory and Department of Chemical Engineering) Generalized Polynominal Programming. Gary Blou, Dow Chemical Company.
October	2	W* Statistic in Covariate Discriminant Analysis. Ahmed Memon, West Pakistan Agricultural University; and Masashi Okamoto.
October	9	On Error Structures and Optimality of Ordinary Analysis of Variance Procedures. George Zyskind.
October	16	Method of Images in the Plane. Richard Mensing.
October	21	Some Sequential Hypothesis Tests Utilizing Concomitant Information. Charles Sampson, Eli Lilly and Company.
October	30	Activities of the Statistical Numerical Analysis and Data Processing Section. W. J. Kennedy and Bud Meador.
November	1	Asymptotic Value Distributions for Stochastic Matrix Games. Donald J. Soults, Boeing Commerical Aircraft Division. (given by H. T. David)
November	6	Methods for Estimating, Interpreting and Summarizing Correlations. Leroy Wolins.
November	13	Asymptotic Expansion of Some Distributions in Multivariate Analysis. N. Sugiura, University of North Carolina and Hiroshima University, Japan.

Winter Quarter 1969

December	4	Nonparametric Regression Analysis. K. L. Mehra, University of Alberta, Canada.
December	11	Agricultural Statistics in the Republic of Korea. Norman Strand.
December	18	The Fredholm Determinants and Cramér-Smirnov Tests. Shashikala Sukhatme.
January	8	Sampling with Random Stratification Boundaries. Wayne Fuller.
January	15	Estimation in a Finite Dimensional Vector Space of Estimators. Justus Seely.
January	22	Malthusian Parameters in Diploid Genetic Populations. Edward Pollak.
January	29	Equilibrium Points for Payoff Functions with Unique Maxima Over Non-convex Domains. Shang-Wang Chang.
February	5	Statistical Inference, with Special Reference to Components of Variance. Oscar Kempthorne.
February	12	Implications of the Structural Hypothesis on the Precision of Generalized Classical Linear (GCL) Structural Estimators: A Particular Case. F. Lee Brown, Jr., Purdue University.
February	19	Optimum Stratification. B. V. Sukhatme.

Spring Quarter 1969

March	12	Distribution of Discriminant Function When Covariance Matrices are Proportional. Chien-pai Han.
March	19	Bayesian Hypotheses Testing as a Two-Set Prediction Problem. Glen Meeden.
March	26	Bounds on the Efficiency of a Classification Procedure. Herman Chernoff, Stanford University.
April	2	Sequences of Positive Kernels. Patricia Conn, Purdue University.
April	9	On Certain Computational Aspects of the Linear Classification Model. Abel Mexas.
April	16	Problems in Sequential Model Building for Prediction in Regression. W. J. Kennedy.
April	30	A Test of Fit for the Negative Binomial and Other Contagious Distributions. Paul Hinz.
May	5	GENSTAT, A Cooperative System of Statistical Programs. J. A. Nelder, Rothamsted Experimental Station, Harpenden, England.
May	14	Asymptotic Minimax Character of Certain Likelihood Ratio Procedures Related to Goodness of Fit. Kenneth Mount.

Applied Statistics Series

Designed especially for research workers who use statistics as a primary research tool, the applied statistics series serves staff members and graduate students from all areas of the campus. Dr. David Cox and Dr. David Jowett were in charge of the series. Programs during the year included:

September	24	Statistics, Chemical Engineering and the Gordon Research Conference. Anthony Frey, Department of Chemical Engineering, ISU.
October	8	The Examination of Residuals. David Jowett.
October	29	Probability Plotting. Richard Chamberlain.
December	17	Some Recent Developments in the Selection of Subsets of Independent Variables in Regression Analysis. Brian D. Macpherson.
January	21	Retrospective Studies on the Relationship Between Oral Contraceptives and Blood Clotting Diseases. Roland Loup.
January	28	Partitioning the Degrees of Freedom for Fixed Effects in General Least Squares Analyses. Walter R. Harvey, Ohio State University.
February	18	A Survey of the Utilization of Statistics in Mexican Agricultural Research. D. K. Hotchkiss.
March	25	A Factor Analysis Model to Describe Soil Genesis. J. H. Huddleston, Department of Agronomy, ISU.
April	8	Accounting for Bias Due to Selection in Mixed Model Estimation and Prediction. C. R. Henderson, Cornell University.
April	15	Choosing a Predictive Model—Some Old, Some New Approaches. Harry Smith, Jr., University of North Carolina.
May	6	How Should We Fit Response Surfaces? J. A. Nelder, Rothamsted Experiment Station, Harpenden, England.

Quantitative Genetics Series

This seminar series, planned especially for staff members and graduate students in the departments of statistics, genetics, animal science, poultry science, agronomy and horticulture, was again under the direction of Dr.

Oscar Kempthorne and Dr. Edward Pollak. The following topics were presented:

October	1	Computer Simulation of Selection Response in *Drosophila*. Barrie Latter.
October	22	Variance in Inbreeding Coefficients and Gene Frequencies. Ben Bereskin, Regional Swine Breeding Laboratory.
November	12	Recent Results on the Theory of Assortative Mating. F. M. Scudo, University of Chicago.
January	14	Results of Long-time Mouse Selection Experiments. R. E. Comstock, University of Minnesota.
January	15	Balanced Performance Through Balanced Breeding. D. L. Harris, DeKalb Agricultural Association, DeKalb, Illinois.
January	28	Estimation of Breeding Values, Variance Components and Fixed Effects with Maximum Likelihood Procedures. Walter R. Harvey, Ohio State University.
February	18	Genetic Control of Development in Plateaued Populations. Barrie Latter.
March	18	Genetic Models Including Epistasis. Eduardo Casas, Statistical Center, National School of Agriculture, Chapingo, Mexico.
April	8	Some Examples of Bias Due to Selection in Animal Breeding Estimation and Selection Index Problems. C. R. Henderson, Cornell University.
April	29	Genetic Loads: Hardy-Weinberg Equilibria in Random Mating Populations. Carl Roux.
May	6	Genetic Loads: Theory and Applications. Carl Roux.

FORD FOUNDATION MEXICAN PROJECT

Dr. Barry Arnold and Dr. Richard Lund remain at the Statistical Center of the National School of Agriculture in Chapingo, Mexico, as the Ford Foundation-sponsored project between the Statistical Center and the Statistical Laboratory reaches the end of its fourth year. Dr. D. K. Hotchkiss returned to Iowa State in December.

Classwork in Chapingo was interrupted during the early part of the fiscal year by a student strike which lasted four months. However despite the strike, a total of 19 courses were offered by the Center. Aggregate student enrollment was 180 persons. Visiting staff members presented courses in experimental design, general statistical methods, statistical theory, survey sampling and econometrics. Even during the strike, staff members provided instruction on an informal basis outside the university, for those who wished to participate.

Full-time student enrollment in the statistics program climbed to 14 students during the year. In addition, five persons are enrolled on a special part-time basis. Two master's degrees were granted. Dr. Arnold initiated two courses in statistical theory for master's degree candidates, and gave a series of lectures on elementary set theory for interested students.

The visiting staff has enabled Mexican staff members to continue work toward advanced degrees. Sigifredo Romero initiated work toward a master's degree in computer science at Iowa State in the fall. Alfonso Carrillo will be returning with his Ph.D. from Iowa State to resume his teaching and research duties during the summer. Two other Mexican staff, Angel Martinez and Ignacio Mendez, are still enrolled in Ph.D. programs, at Iowa State and North Carolina, respectively.

Consulting services are handled jointly by the visiting professors from Iowa State and the Chapingo staff. Visiting professors are used as senior consultants to resolve the more difficult problems.

The consulting consisted principally of setting up the proper analysis of experiments that have been completed, and assisting in the analysis of the data when the more complicated studies have involved the use of the computation center.

More requests are being received for assistance in the designing of experiments, particularly when the large number of treatments on the experimental material suggests a complicated system of blocking for control of variation.

Consultants come from the Instituto Nacional de Investigaciones Agricolas and various departments in the graduate college. In addition, scientific groups outside the government research branches have begun to use the consulting services.

The survey section staff, which Dr. Lund serves as a consultant, have worked chiefly on the data collection and analysis of a survey for evaluating various activities of the Mexican Extension Service. Surveys for evaluating the research activities of INIA and INIP (research institutes) were completed. The INIP report on the utilization of statistical principles in Mexican livestock and poultry research has been prepared.

One of the recommendations in the report resulted in the establishment of a seminar series for the INIP professional staff. The topics and speakers included: "Statistical Inference and Tests of Hypothesis," R. E. Lund; "Proper Replication of the Experimental Unit," M. Gorya Treveno; "Selection and Spacing of Treatments," J. Escobar; "Controlling Variation Through Experimental Design," D. K. Hotchkiss; and "Sampling Techniques," R. E. Lund.

The visiting professors assisted in organizing and participated in several other seminar series in Mexico this past year which emphasized statistical principles with applications to Mexican research.

The association of statisticians working in Mexico City and Chapingo organized a series of seminars which were presented to the public on a monthly basis. The visiting staff who participated and their topics were: D. K. Hotchkiss, "Restricted Randomization in the Assignment of Experimental Units to Treatments" (presentation cancelled due to student strike); R. E. Lund, "Problems in the Analysis of Sampling Data"; Barry Arnold, "Statistical Inference Incorporating Preliminary Tests of Significance."

Dr. Arnold organized the students' spring quarter seminar series for the statistical center at Chapingo, selecting topics, assisting with presentations and criticizing final presentations.

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