Graduate Study in STATISTICS

1996-1997

University of Missouri Columbia
INTRODUCTION

Statistics is a modern science concerned with making decisions and inferences from empirical data subject to random variability and error. It deals with designing experiments, sample surveys, summarizing numerical information, building and analyzing statistical models, prediction and choosing between alternative actions. The techniques that are used rely heavily on probability and other mathematical concepts. An appreciation and interest in the area of potential applications usually are helpful. Modern computer technology has further expanded the tools available for processing large data sets and performing large-scale computations.

Because of its importance as a scientific method, the demand for trained statisticians has grown in education, medicine, government, business and industry as well as in the biological, social and physical sciences. The Department of Statistics is committed to train graduate students to meet this demand and develop careers in teaching and research in statistics. Graduates with MA degrees have generally found employment in business, industry or government. Historically, alumni with PhD degrees usually were appointed to positions in other universities and colleges, but in recent years, several have located in various industrial settings or the federal government.

As can be seen in the brief account of the individual faculty members given below, the interest and expertise of the faculty is quite diverse and includes many research areas that are now rapidly developing in statistics. Being a relatively small department, yet with broad interests, graduate students have the opportunity to work informally and closely with faculty members on topics of their choice. Weekly seminars and the consulting center often serve as catalysts for such interactions.

PROGRAM OF STUDY

The Department of Statistics offers undergraduate programs leading to the bachelor of arts degree, bachelor of science and graduate programs leading to the master of arts and doctor of philosophy degrees.

The undergraduate program is aimed at preparing students for careers in statistics and at serving as a good foundation for graduate work in the area. The undergraduate program is flexible and students are encouraged to develop an outside area of application wherein statistical methodology is useful. These areas of application include economics, biology, accounting, finance, marketing, management, medicine,
psychology, sociology, engineering, agriculture and atmospheric science.

The graduate program provides opportunities for graduate study and thesis direction in various areas of probability and statistics, both theoretical and applied. The Statistical Consulting Center, located in the Mathematical Sciences Building, provides opportunities for statistical consulting and assists faculty and graduate students in cooperative research with people in other areas.

■ RESEARCH FACILITIES

Faculty and graduate students of the Department of Statistics are housed together in the Mathematical Sciences Building, along with the Department of Mathematics. Also in the building is an excellent mathematical sciences library. Access to the central computer can be obtained through several regional terminals in the building. Microcomputers and Sun workstations are available for student use within the department.

■ FINANCIAL AID

Many graduate students are supported by teaching or research assistantships. Stipends for half-time teaching and research assistantships for the '96-'97 academic year will be $10,200. Beginning teaching assistants teaching three hours per week, and most fellowship holders, do not have to pay out-of-state tuition or in-state fees. Including fee waivers, the value of a teaching assistantship to a full-time graduate student is more than $17,500. Undergraduate and graduate students may earn extra money by grading papers or working in the Statistical Laboratory. Teaching duties normally consist of teaching three to six hours per week. Fellowships and summer support also are available on a limited basis. Application for Financial Assistance forms are available on request. These forms, along with the results of GRE scores and letters of recommendation, should be returned directly to the Department of Statistics. Applicants for whom English is not their native language must submit TOEFL scores. A score of 535 is required for admission to the department. To receive full consideration for the fall semester, all materials should be received by Feb. 15. Later applications will be considered as long as funds are available.

■ COST OF STUDY

Fees for a full-time freshman, sophomore, junior or senior are $121.00 per credit hour. A student registered at MU will pay an activity fee of $103.25 per semester. Fees for a full-time graduate student are $153.20 per credit hour. Out-of-state tuition for a full-time freshman, sophomore, junior or senior is $361.70 and for a full-time graduate student is $460.60 per credit hour.

■ COST OF LIVING

Room and board in residential housing (double occupancy) range $3915 - $4660 per academic year. The University operates one- and two-bedroom unfurnished apartments for married students or students with children, with the rents ranging from $247 to $328 per month. The rental charge does not include utilities. Off-campus unfurnished apartment costs vary. Food costs in Columbia are moderate.

■ STUDENT GROUP

There are about 15 undergraduate students and about 40 graduate students in statistics. About 20 percent of the students are women. About half of the graduate students are supported by teaching and research assistantships.

■ THE COMMUNITY

Columbia is a city of more than 75,000, including students, in the center of Missouri. There are two other colleges in Columbia: Stephens College and Columbia College. Kansas City and St. Louis are each about 120 miles from Columbia, which is a two-hour drive on Interstate 70. Local recreational opportunities include plays and concerts offered by the University and Stephens and Columbia colleges. Other recreational opportunities include fishing, hunting, golf, tennis and other sports activities. The Ozark region is a two-to-four-hour drive from Columbia and provides camping, hiking, water sports and float trips.

■ THE UNIVERSITY

The University of Missouri was founded in 1839 in Columbia. The University is now a four-campus system with campuses in Columbia, St. Louis, Kansas City and Rolla. In fall '95, 22,313 students were enrolled at Mizzou. MU has 18 schools and colleges, including the Law School, Medical School and Graduate School. A variety of lectures, concerts, films, plays, exhibits and other cultural and recreational activities are provided by the University.
ADMISSIONS

To be admitted as a graduate student in statistics a student must fulfill the admissions requirements of the Graduate School and show likelihood of successfully completing a departmental program. The department's decision to accept a student is based on undergraduate transcripts, GRE scores and letters of recommendation. Applicants for whom English is not their native language must submit TOEFL scores. A score of 535 is required for admission to the department. Applicants for graduate study are expected to have a mathematics background through matrix theory and calculus and preferably have an undergraduate degree in a scientific or engineering area. Application forms for admission may be obtained from Dept. of Statistics, 222 Math Science, Columbia, MO 65211.

COURSES AND DESCRIPTIONS

25 INTRODUCTORY STATISTICAL REASONING (3). Statistical concepts and critical reasoning needed to evaluate conclusions based on quantitative information in health studies, opinion polls, etc. Prerequisite: Grade in the C range or better in Math 10, 14, or 15 or MMPI score 26 or above. Students may not receive credit for both Statistics 25 and 31.

31 ELEMENTARY STATISTICS (3). Collection, presentation of data; averages; dispersion; introduction to statistical inference, correlation and regression. Prerequisite: Grade in the C range or better in Math 10, 14, or 15 or MMPI score 26 or above. Students may not receive credit for both Statistics 25 and 31.

150 INTRODUCTION TO PROBABILITY AND STATISTICS I (3). Designed primarily for students in the College of Business and Public Administration. Probability theory; random variables; expectation; probability distributions; descriptive statistics; sampling distributions. Computer is used to assist in learning concepts. Prerequisite: Grade in the C range or better in Math 60, f,w,s.

185 STATISTICAL METHODS IN NATURAL RESOURCES (3). Statistical methods with emphasis on applications to natural resources and including computer exercises. Prerequisite: Math 108 and a college level computer course. No credit if student has had 150 or 250.

198 HONORS (2 hrs. each). Special work for Honors candidates in Statistics.

207 STATISTICAL ANALYSIS (3). For graduate students and superior seniors with no previous training in statistics. Intensive study of concepts, techniques of statistical analysis, and their applications. Prerequisite: Math 10 or equivalent, f,w,s.

215 ELEMENTS OF PROBABILITY AND STATISTICS (3). Primarily for middle and secondary mathematics education students. Probability, random variables, expectations, descriptive statistics, estimation, hypothesis testing, and regression. Introduction to materials for middle and secondary school use. Prerequisites: Math 61 or Math 80 or equivalent.

250 INTRODUCTION TO PROBABILITY AND STATISTICS II (3). Continuation of 150. Estimation; hypothesis testing; regression; correlation; statistical decision theory; Bayesian inference. Computer is used to assist in learning concepts. Prerequisite: Grade in the C range or better in Stat 150, f,w,s.

292 STATISTICAL METHODS IN HEALTH SCIENCES (3). Basic inference methods, both parametric and non-parametric, appropriate for answering questions arising in health sciences research. Computer exercises involving data from real experiments from health science area. Prerequisite: Math 10 & Graduate standing or instructor's consent.

300 PROBLEMS (1-3). Independent investigations. Reports on approved topics. Prerequisite: consent of faculty member involved. f,w,s.

301 TOPICS (cr. arr.). Organized study of selected topics. Subjects and earnable credit may vary from semester to semester. Repeatable with departmental consent. Prerequisite: junior standing and instructor's consent.

302 SENIOR SEMINAR (3). A capstone course required of and open only to senior statistics majors. Students will participate in statistical consulting, attend colloquia, and review articles in professional journals. Writing of reports will be emphasized.

305 STATISTICAL SOFTWARE AND DATA ANALYSIS (3). Programming with major statistical packages emphasizing data management techniques and statistical analyses for regression, analysis of variance, categorical data, descriptive statistics, nonparametric analyses, and other selected topics. Prerequisites: any 200 or above course in the Statistics Dept. or instructor's consent.

307 NONPARAMETRIC STATISTICAL METHODS (3). Statistical methods when the functional form of the population is unknown. Applications emphasized. Comparisons with parametric procedures. Goodness-of-fit, chi-
square, comparison of several populations, measures of correlation. Prerequisite: 207 or 215 or 250 or 320 or equivalent.

320 INTRODUCTION TO MATHEMATICAL STATISTICS (3) (same as Mathematics 320). Introduction to theory of probability and statistics using concepts and methods of calculus. Prerequisite: Math 201 or instructor's consent. f.w.s.

321 STATISTICAL COMPUTING AND SIMULATION (3). Computing known statistical formulae using statistical software. Graphs in three dimensions. Computing new formulae and simulating operating characteristics using higher languages. Prerequisite: 320 or equivalent, or consent of instructor. f.

325 INTRODUCTION TO PROBABILITY THEORY (3) (same as Mathematics 325). Probability spaces; random variables and their distributions; repeated trials; probability limit theorems. Prerequisite: Math 201 or instructor's consent. f.w.s.

326 STATISTICAL INFERENCE (3) (same as Mathematics 326). Sampling; point estimation; sampling distribution; tests of hypotheses; regression and linear hypotheses. Prerequisite: 325.


328 INTRODUCTION TO STOCHASTIC PROCESSES (3). Study of random processes, including topics selected from: Markov chains, birth and death processes, random walks, Poisson processes, renewal theory, Brownian motion and Gaussian processes, white noise and spectral analysis, applications such as queueing theory, sequential probability ratio test. Prerequisite: 325.

329 APPLIED PROBABILITY (2). Probability in its applied context. Designed for seniors and beginning graduate students. Construction of probability models. Examples in physical and behavioral sciences. Multivariate normal and exponential distributions, extreme value distributions, stochastic processes, queuing. Prerequisite: 325 or equivalent.

345 CATEGORICAL DATA ANALYSIS (3). Discrete distributions, frequency data, multinomial data, chi-square and likelihood ratio tests, logistic regression, loglinear models, rates, relative risks, random effects, case studies. Prerequisite: Statistics 326 or both Statistics 385 and 395.

360 DEMING PHILOSOPHY & STATISTICAL PROCESS CONTROL (3). Statistical control charts, economic design of control charts, acceptance sampling, Pareto chart, and other graphical procedures, Deming philosophy, Taguchi methods. Prerequisites: 320 or 326 or instructor's consent.

370 SAMPLING TECHNIQUES (3). Theory of probability sampling designs. Unrestricted random sampling. Stratified sampling. Cluster sampling. Multistage or subsampling. Ratio estimates. Regression estimates. Double sampling. Prerequisite: 207 or 215 or 250 or 320 or 326.

375 OPERATIONS RESEARCH (3). Study of mathematical and statistical models employed in operations research. Prerequisite: 207 or 215 or 250 or 320 or 326 f.

380 STATISTICAL FORECASTING (3) (same as Management 380, Marketing 380, Finance 380).

385 REGRESSION AND CORRELATION ANALYSIS (3). Measurement of relationships among variables including multiple regression, partial correlation, and some non-parametric methods. Prerequisites: 207 or 215 or 250 or 320 or 326 & Math 80.

386 APPLIED TIME SERIES ANALYSIS (3). A study of univariate and multivariate time series models and techniques for their analyses. Emphasis is on methodology rather than theory. Examples are drawn from a variety of areas including business, economics and soil science. Prerequisites: Stat 326, or both Stat 320 and 385 or instructor's consent.

395 ANALYSIS OF VARIANCE (3). Study of analysis of variance and related modeling techniques for cases with fixed, random, and mixed effects. Exposure to designs other than completely randomized designs including factorial arrangements, repeated measures, nested, and unequal sample size designs. Prerequisite: 207 or 215 or 250 or 320 or 326. f.w.s.

400 PROBLEMS AND SPECIAL READINGS (cr. arr.). Approved reading and study, independent investigations, and reports on approved topics. Prerequisites: graduate standing and consent of faculty member involved. f.w.s.

404 MATHEMATICAL STATISTICS II (3). Theory of estimation and tests of hypotheses including sufficiency, completeness and exponential families. Neyman-Pearson lemma, uniformly most powerful tests, similarity and invariance. Minimax, Bayes and uniformly minimum variance unbiased estimates. Confidence intervals and ellipsoids. Prerequisite: Stat 403 or instructor's consent.

411 STATISTICS SEMINAR (cr. arr.).

416 STATISTICAL CONSULTING (3). Statistical consulting under faculty supervision. Formulation of statistical problem. Planning of surveys and experiments, Statistical Computing. Interpretation and summarization of results in statistical practice. (Prerequisite: 326 and 464 or 385 and 395; end instructor's consent.)

420 BAYESIAN STATISTICS (3). Bayes theorem, subjective probability, likelihood principle, non-informative priors, asymptotic properties, Bayesian computation, hierarchical Bayes, statistical decision, Bayesian hypothesis testing, predictive inference, applications. Prerequisite: Statistics 326, Math 331 and Math 302 or equivalent.

423 EXPERIMENTAL DESIGN (3). Examination and analysis of modern statistical techniques applicable to experimentation in social, physical, or biological sciences. Prerequisite: 385 or instructor's consent.


440 ADVANCED PROBABILITY (3) (same as Mathematics 440). Measure theoretic probability theory. Characteristic functions; conditional probability and expectation; sums of independent random variables, including strong law of large numbers and central limit problem. Prerequisites: 325, Math 310 or instructor's consent.

441 STOCHASTIC PROCESSES (2) (same as Mathematics 441). Markov processes, martingales, orthogonal sequences, processes with independent and orthogonal increments, stationarity, linear prediction. Prerequisite: 440.

452 SPECIAL TOPICS IN STATISTICS (cr. arr.). Prerequisite: instructor's consent.

461 RECENT DEVELOPMENTS IN STATISTICS (3). The content of the course, which varies from semester to semester, will be the study of some statistical theories or methodologies that are currently under development, such as bootstrapping, missing data, nonparametric regression, statistical computing, etc. Prerequisites: Stat 326 or instructor's consent.

463 LINEAR MODELS I (3). Theory and application of multiple regression analysis (Matrix representation of linear models, curve fitting, model building, subset selection, residual analysis, regression diagnostics, ridge and non-linear regression). Prerequisites: Math 331, Stat 326 or Stat 320 and consent of instructor.

464 LINEAR MODELS II (3). Theory and application of analysis of variance (crossed classification, blocking, contrasts and multiple comparisons, repeated measures, random effects and mixed models, analysis of covariance, introduction to designed experiments). Prerequisite: 463.

465 ADVANCED LINEAR MODELS (3). Advanced topics in the theory and application of linear models. Specific content varies with instructor. Prerequisite: 464, Math 302 or 310 or consent of instructor.

466 MULTIVARIATE ANALYSIS (3). Distribution of sample correlation coefficients. Derivation of generalized T² and Wishart distributions. Distribution of certain characteristic roots, vectors. Tests of hypotheses about covariance matrices and mean vectors. Discriminant analysis. Prerequisite: 326, Math 331 and 302 or 310 or instructor consent.

470 THEORY OF NONPARAMETRIC STATISTICS II (3). Estimation, hypothesis testing, confidence intervals, when functional form of the population distribution is unknown. Prerequisite: 403 and 327 or instructor's consent.

490 RESEARCH (cr. arr.).

FUNDAMENTAL COURSES FOR GRADUATE STUDY IN STATISTICS

All graduate students in statistics are strongly encouraged to take Statistics 325, 326, 463 and 464 in their first year unless equivalent courses have been taken previously.
REQUIREMENTS FOR MASTER OF ARTS DEGREE IN STATISTICS

A General Requirements
1. At least 30 semester hours of course work numbered 300 or higher of which at least 18 hours must be from the listings of the Department of Statistics. The 30 hours may not include credit hours for Statistics 302, 315, 320, 385, 395, or more than a total of six hours of 400 or 490.
2. At least 15 semester hours of course work numbered 400 or higher must be taken from the listings of the Department of Statistics. Credit will be given for only two of Statistics 423, 463, 464. The 15 semester hours cannot include more than a total of three hours of 400 or 490.

B Specific Requirements
1. Requirements for courses at the 300 level.
   The following courses are required if equivalent courses were not taken as an undergraduate.
   a. Math 302 or 310 or the equivalent.
   b. Math 331 or the equivalent.
   c. Stat 325 or the equivalent.
   d. Stat 326 or the equivalent.
   The above courses may not be used for more than six hours of credit toward the 300 hours under A-1.
2. Requirements for courses at the 400 Level.
   All candidates must submit a written report demonstrating an independent effort toward producing original work. This report may, with the adviser's consent, take the form of a thesis, a written review on a set of papers in statistics, or an original application of statistics. For this work a student must take at least three credit hours of Statistics 400 or Statistics 490.
   The following courses are recommended, but not specifically required, for the M.A. degree: Statistics 305, 327, 345, 360, 386, 416, 463, 464, 465 and Math 311; Computer Science 103 or 201. There is considerable flexibility in the program leading to the MA degree in statistics.

C M.A. Examination
All candidates are required to present an open seminar on the results of the written report described under B-2. above. The MA examination will consist of an exam of the material presented in the written report and seminar, and over course work.

THE PhD PROGRAM
1. To enter the PhD program in statistics a student must pass the qualifying examination. The PhD Qualifying Examination, which is offered at the beginning of each fall semester, consists of two parts. Part I is based on Statistics 325 and 326. Part II is based on Statistics 463 and 464 and emphasizes the applied aspects of these two courses. A student may not take the qualifying examination more than twice without approval of the graduate faculty of the Department of Statistics. Until it is passed, a student who plans to pursue a Ph.D. in this department must take the qualifying examination each fall semester after completing two semesters, not counting summer semesters, in this graduate program unless permission to not take the examination is granted by the graduate faculty of the Department of Statistics. The examination will be prepared and evaluated by the graduate faculty. A committee of graduate faculty members, appointed by the director of graduate studies, will conduct the examination, have it graded and make recommendations to the graduate faculty.
   Within one semester of passing the qualifying examination, students ask their advisers to recommend a doctoral program committee, which will consist of a minimum of five members, at least three of which are members of the doctoral faculty in statistics and at least one from another MU doctoral program. They also will prepare a plan of study for approval by this committee and the Graduate School.
   2. Students must pass the qualifying examination before taking the Preliminary Examination, which will be taken usually at the beginning of the third year. The examination will be based on 400 level statistics courses. Students taking the examination must have taken at least six 400 level courses (other than Statistics 400, 490 and 416) — either at MU or at comparable institutions. There will be two parts. The first paper will be based on Statistics 403, 463 and 464 (or Statistics 423). The second paper will be based on three other 400 level courses, not including the seven courses listed above, chosen by the student in consultation with his/her doctoral program committee. A student may not take the preliminary examination more than twice without approval of the graduate faculty of the Department of Statistics. The examination will be departmental. A committee of graduate faculty members,
appointed by the director of graduate studies, will conduct the examination, have it graded and make recommendations to the graduate faculty.

3. Students must pass the preliminary examination before taking the Comprehensive Examination. The Doctoral Program Committee will plan and conduct the comprehensive examination. It consists of both written and oral sections. A student in the Ph.D. program who has not passed the comprehensive examination within three years of passing the qualifying examination will be dismissed from the program unless contrary action is taken by the graduate faculty of the Department of Statistics.

A dissertation, prepared under the direction of a dissertation supervisor, is required. The dissertation should be presented in an open seminar as part of the final examination, which will be conducted by the Doctoral Program Committee. The dissertation should be made available for public review, through the Department of Statistics office, for at least one week before the examination.

Additional requirements for the Ph.D. in statistics are determined by the student's Doctoral Program Committee and the director of graduate studies.

## GRADE REQUIREMENT

Any student, while a graduate student in this program, who receives a grade of C or lower in six or more hours of courses offered by the Department of Statistics will be dismissed from the graduate program unless contrary action is taken by the graduate faculty of the Department of Statistics.

Any student, while a graduate student in this program, who receives a grade of C or lower in nine or more hours of courses will be dismissed from the graduate program unless contrary action is taken by the graduate faculty of the Department of Statistics. For each credit hour with a grade of C or lower, except for three credit hours, received in courses offered by the Department of Statistics at the 300 level and above, the student must receive a credit hour with a grade of A in courses offered by the Department at the 300 level and above.

## FACULTY

**Asit P. Basu**, professor of statistics, PhD, University of Minnesota, 1966. His major research interest is in the development of statistical theory for use on reliability theory statistical process control and biomedical problems. He is a fellow of the American Statistical Association, Institute of Mathematical Statistics, and an elected member of the International Statistical Institute.

**Joseph E. Cavanaugh**, assistant professor of statistics, PhD, University of California, Davis, 1993. Research interests include time series analysis, model selection, linear models, and resampling.

**John E. Hewett**, professor of statistics and associate director of the Medical Informatics Group in the School of Medicine, director of undergraduate studies, PhD, State University of Iowa, 1965. His areas of specialization include multivariate analysis, distribution theory and bioinformatics. His current research interests include developing statistical methods appropriate for longitudinal data. He is a fellow of the American Statistical Association.

**Gary F. Krause**, professor of statistics and agronomy, PhD, Virginia Polytechnic Institute, 1963. His areas of specialization are in design of experiments, estimation and statistical genetics. He has done research in plant and animal breeding, experimental technique, sample survey design and digital computing.

**Richard W. Madsen**, professor of statistics and associate chair, PhD, Iowa State University, 1971. His area of interest is applied statistics. Current research interests include generalized binomial models and repeated significance testing for parametric and nonparametric tests. He is a consultant to the School of Nursing and is a member of the Division of Biostatistics in the School of Medicine.

**Paul L. Speckman**, professor and director of graduate admissions of statistics, PhD, University of California at Los Angeles, 1976. His general area of interest is probability theory and mathematical statistics. Current research interests include topics in spline functions, nonparametric regression and semiparametric models.

**Dongchu Sun**, assistant professor, PhD, Purdue University, 1991. His research interest includes Bayesian and decision theory, reliability and survival analysis, sequential analysis, nonparametric statistics, and statistical computation.

**Robert K. Tsutakawa**, professor and director of graduate studies of statistics, PhD, University of Chicago, 1963. He is a past editor of the *Journal of Educational Statistics*. His interests include Bayesian methods, biostatistics and item response theory. He is a fellow of the American Statistical Association.

**Yazhen Wang**, assistant professor, PhD, University of California at Berkeley, 1992. His general research area of interest is probability theory and mathematical statistics. Current research interests include chance point detection
and function estimation via wavelets, statistical inference under order restrictions, asymptotic theory and empirical processes.

Matthew Wood, adjunct instructor and lower division coordinator, PhD, University of California, Davis, 1996. Research interests include classification analysis, discrete longitudinal models, and computational statistics.

Farroll T. Wright, professor and chairman of statistics, PhD, University of Missouri, 1968. Current research interests include asymptotic results, inferences for stochastic processes and order restricted statistical inferences. He is a fellow of the American Statistical Association and the Institute of Mathematical Statistics, and an elected member of the International Statistics Institute.

Emeritus Faculty

Wallace E. Franck, associate professor emeritus of statistics, PhD, University of New Mexico, 1964.

James E. Holstein, associate professor emeritus of statistics, PhD, State University of Iowa, 1962.

Shriniwas K. Katti, professor emeritus of statistics, PhD, Iowa State University, 1960.

W. A. Thompson Jr., professor emeritus of statistics, PhD, North Carolina, 1954.

Frederick Williams, professor emeritus of statistics, PhD, Northwestern University, 1958.