BIOSTATISTICS
Degree Offered: Doctor of Philosophy

MCW
GRADUATE SCHOOL

Program Description
The PhD program in Biostatistics is designed for students having strong quantitative and computing skills with interest in applying cutting-edge biostatistical research techniques to biological and medical sciences. In this program, students will receive in-depth training on theoretical/methodological/collaborative research in biostatistics and the use of state-of-the-art software. The Division of Biostatistics is a highly collaborative unit and provides lots of opportunities to participate in numerous research projects within MCW and its affiliates.

Admission Requirements
In addition to the general [Graduate School admission requirements](), this program has additional specific requirements.

Any graduate of an accredited college or university with an undergraduate degree in mathematics or closely related fields with strong preparation in mathematics is eligible for admission. Applicants are expected to have completed and performed well in courses in advanced calculus, linear/matrix algebra, and scientific programming. Those who haven't done so may be considered for admission to the program upon approval of the biostatistics admission committee, and if admitted, these requirements must be completed during the first year of study. In addition, the applicant must have strong interest in pursuing statistical research in biomedical sciences.

Fields of Study
- Markov chain Monte Carlo, statistical methods for epidemiology and biology.
- Bayesian statistics, linear and generalized linear models, nonparametric inference, and Monte Carlo methods.
- Multiple comparisons, dose-response studies, clinical trials, multiple endpoints, fMRI/image data analysis.
- Categorical and correlated data analysis, statistical models in epidemiology.
- Estimation with additional information, missing data, censored data, survey data.
- Statistical genetics, linkage and association mapping, haplotype analysis.
- Bioinformatics.
- Survival and competing risks data analysis, inference from stochastic processes and non-linear models.
- Personalized medicine, causal inference.
- Machine learning, high dimensional data analysis, variable selection.

Credits Required to Graduate
60 credits minimum

BIOE 10222 Ethics and Integrity in Science. *1 credit.*
This course provides the basis for understanding the ethical issues related to basic scientific and medical research, including animal and human subject research, fraud, and misconduct, and governmental, institutional, and researcher responsibilities. Bioethics 10222 is offered during the spring and summer terms only.

BIOE 10444 Research Ethics Discussion Series. *1 credit.*
Prerequisite: 10222 Ethics and Integrity in Science.
The course is directed by members of the Bioethics Faculty and provides facilitated discussions of a series of topics in research ethics. Discussions are led by members of the Basic Science faculty and are focused on ethical issues that commonly come up in biomedical research. The course is meant to not only reinforce the basic ethics taught in the online course Ethics and Integrity in Science, which is a prerequisite, but also to explore the gray areas of the individual topics. The intent is to offer students illustrative examples of ethical issues that might arise in their careers, to emphasize the ethical principles that apply in such situations, and the provide practical guidance on how these types of situations should be correctly handled. This course is offered as a discussion series. Students are expected to attend and participate in the discussion. Bioethics 10444 is offered during the spring terms only.

BIOS 04214 Design and Analysis of Clinical Trials. *3 credits.*
Prerequisites: 04231 Statistical Models and Methods I or concurrent registration
This course covers issues in clinical trials including the clinical trial protocol, sources of bias in clinical trials, blinding, randomization, sample size calculation; phase I, phase II, phase III and hybrid trials; interim analysis, stochastic curtailment, Bayesian designs, and administrative issues in study design.

BIOS 04220 Research Seminar. *1 credit.*
Students present plans for an analysis of research projects and research data. Projects and examples from classical and current literature are discussed by students and faculty.

BIOS 04221 Biomedical Applications and Consulting. *3 credits.*
Prerequisites: 04231 Statistical Models and Methods I
Theory of consulting, communication, and statistical techniques most often used in consulting and biomedical applications, practical experience in the real consulting setting and writing statistical reports.

BIOS 04222 Statistical Consulting. *1 credit.*
Prerequisites: 04231/04231 Statistical Models and Methods I & II
This course is designed for students to gain experience in statistical consulting by working with the biostatistics faculty members on various consulting projects.

BIOS 04224 Biostatistical Computing. *3 credits.*
Prerequisites: 04231 Statistical Models and Methods I or concurrent registration
This course will cover the details of manipulating and transforming data required for statistical analysis. Topics include reshaping the data from a per-case to a per-event within a case and vice-versa. It will also cover the techniques necessary to write functions and macros in both SAS and R for developing new/modified data analysis methods. How to use R packages and C/C++ codes in R will also be covered. The LaTeX document production system is also introduced.

BIOS 04231 Statistical Models and Methods I. *3 credits.*
Prerequisite: Three semesters of calculus and one semester of linear algebra
This course will cover statistical techniques for basic statistics. Topics include one-sample/two-sample tests, analyses for count data and contingency tables, basic nonparametric methods including sign, rank-sum and signed-rank tests, simple linear regression model and inference, checking model assumptions, model diagnostics, correlation analysis, one-way analysis of variance, Kruskal-Wallis one-way ANOVA, simple logistic regression, and weighted linear regression. SAS/R will be used throughout the course.

BIOS 04232 Statistical Models and Methods II. *3 credits.*
Prerequisite: 04231 Statistical Models and Methods I
Factorial, nested, split-plot and repeated measures designs, multiple regression and variable selection, multiple comparisons, logistic regression, discriminant analysis, principal components and factor analysis, rates and proportions, introduction to survival analysis.

BIOS 04233 Introduction to Statistical and Machine Learning. *3 credits.*
Prerequisite: 04232 Statistical Models and Methods II
This course will provide an introduction to statistical learning. Core topics include variable selection, penalized linear regression such as lasso, dimension reduction including principal component analysis, flexible regression techniques including kernel smoothing/smoothing splines/generalized additive models/regression trees, support vector machine, clustering, and random forests. Other topics that can be covered include but are not limited to ridge regression, group lasso, fused lasso, adaptive lasso, SCAD, Bayesian lasso, Bayesian group lasso, Bayesian CART, BART, neural network, feature screening, graphical models, and quantile regression.

BIOS 04275 Applied Survival Analysis. *3 credits.*
Prerequisites: 04231 Statistical Models and Methods I
The following topics will be covered in this course: Basic parameters in survival studies; Censoring and truncation, competing risks; Univariate estimation including the Kaplan-Meier and Nelson-Aalen estimator; tests comparing two or more populations, the log rank test; Semi-parametric regression, the Cox model; Aalen's Additive hazards regression model; regression diagnostics.

BIOS 04285 Introduction to Bayesian Analysis. *3 credits.*
Prerequisites: 04231 Statistical Models and Methods I
This course introduces basic concepts and computational tools for Bayesian statistical methods. Topics covered include one and two sample inference, regression models and comparison of several populations with normal, dichotomous and count data.

BIOS 04295 Reading and Research. *1-9 credit(s).*
The course of study for Reading and Research is designed by each student with his/her advisor to focus on readings in literature in the student's field, to build bibliographic resources for the dissertation, and to conduct supervised, independent research.

BIOS 04313 Advanced Statistical Computing. *3 credits.*
Prerequisites: 04232 Statistical Models and Methods II, Statistical Inference II, 04224 Biostatical Computing*
Numerical algorithms useful in biostatistics including likelihood maximization using the Newton-Raphson method, numerical integration using quadrature and Monte Carlo

methods, interpolation using splines, random variate generation methods, the data augmentation algorithm, Markov chain Monte Carlo and the Metropolis-Hastings algorithm.

BIOS 04363 Advanced Statistics I. *3 credits.*
Prerequisites: 04232 Statistical Models and Methods II, Statistical Inference II*
This course covers both the theoretical framework and practical aspects of statistical models. The course will cover likelihood inference, properties of likelihood, exponential families and GLM, large sample properties of likelihood-based inference, likelihood-based regression models, GEE, conditional and marginal likelihood, asymptotics of penalized regression.

BIOS 04365 Linear Models I. *3 credits.*
Prerequisites: Statistical Inference II*
Review of matrix algebra and vector spaces, multivariate normal distribution and quadratic forms, least squares estimation, testing nested models, weighted least squares, one-way ANOVA, testing contrasts, multiple comparison, partial and multiple correlation coefficients, polynomial regression, lack-of-fit tests.

BIOS 04384 Statistical Genetics. *3 credits.*
Prerequisites: 04365 Linear Models I, Statistical Inference II*
Fundamental elements of mathematical and population genetics, and statistical theory of the methods of human genetic analysis. Topics include Hardy-Weinberg equilibrium, models for polygenic and multifactorial inheritance, variance components estimation familial aggregation, linkage and association analysis, disequilibrium mapping and ascertainment problems.

BIOS 04385 Advanced Bayesian Analysis. *3 credits.*
Prerequisites: 04285 Introduction to Bayesian Analysis
A combination of Bayesian principles, tools, and methods; emphasis is on models, computations, and analysis. Likelihood function, prior, posterior, and predictive distributions, Bayes factors, HPD regions, conjugate and non-informative priors in the exponential family, Markov chain Monte Carlo methods for the generalized linear model, hierarchical models, restricted parameter spaces and censored data, examples of Bayesian analyses of complex biomedical models.

BIOS 04386 Theory of Survival Analysis. *3 credits.*
Prerequisites: 04275 Applied Survival Analysis, Statistical Inference II*
Analysis of survival data using counting process techniques. Topics include the mathematical theory of counting process, martingales, asymptotic properties for estimation of the survival and cumulative hazard functions, proportional hazards and additive hazards regression models, multivariate survival data, and empirical process.

BIOS 04399 Doctoral Dissertation. *1-9 credit(s).*
This course is required for the completion of the PhD degree. The PhD candidate must submit a dissertation based on original research of a high scholarly standard that makes a significant contribution to knowledge in their chosen field.

BIOS 24150 Bioinformatics in Omics Analysis. *3 credits.*
Prerequisites: 04231 Statistical Models and Methods I and 04224 Biostatistical Computing, or consent of instructor.
The course aims to introduce modern statistical and computational methods in high-throughput omics data analysis. The first half of the course focuses on fundamental statistical and computational methods applicable in different types of high-throughput omics data. The second half covers selected important topics in bioinformatics and aims to give students a systematic view of the omics data analysis. The goals of the course include: (1) to motivate students from quantitative fields into omics research (2) to familiarize students from biological fields with a deeper understanding of statistical methods (3) to promote inter-disciplinary collaboration atmosphere in class. Students are required to have a basic statistical training (i.e., elementary statistics courses, basic calculus, and linear algebra) and basic programming proficiency (R programming is required for homework and the final project).

*Taken at UW-Milwaukee

[Courses taken at UW-Milwaukee](#)
MTHSTAT 871 Mathematical Statistics I. *3 credits.*
MTHSTAT 872 Mathematical Statistics II. *3 credits.*

Required Courses as Needed
BIOS 04002 Master's Thesis Continuation. *0 credits.*
Prerequisites: 04299 Master's Thesis
This is a form of registration available to students who have completed all of the required coursework, including thesis credits but have not yet completed the writing of the Thesis. Continuation status is limited to three consecutive terms following the completion of Thesis credits.

BIOS 04003 Doctoral Dissertation Continuation. *0 credits.*
Prerequisites: 04339 Doctoral Dissertation
This is a form of registration available to students who have completed all of the required coursework, including dissertation credits but have not yet completed the writing of the Dissertation. Continuation status is limited to three consecutive terms following the completion of Dissertation credits.

BIOS 04299 Master's Thesis. *1-6 credits.*
Students in the Ph.D. degree program who cannot or elect not to complete that program may be allowed to transfer to the Master's program. This transfer must be approved by the student's advisor, the Program Director, the Chair, and the Graduate School. To transfer to the Master's Program, the student must be in good academic standing according to regulations established by the Graduate School.

Elective Courses
A minimum of six credit hours of graduate-level electives in a non-statistical field such as biological/medical science, mathematics, and computer science is a requirement for a candidate seeking the PhD degree in Biostatistics.