BIOSTATISTICS CONCENTRATION (BIS)

The M.S. with a concentration in Biostatistics is a two-year program that provides training in clinical trials, epidemiologic methodology, implementation science, data science, statistical genetics, and mathematical models for infectious diseases. Students have a choice of three pathways: the *Biostatistics Standard Pathway,* the *Biostatistics Implementation and Prevention Science Methods Pathway,* and the *Biostatistics Data Science Pathway*. In contrast to the more general M.P.H. degree, the M.S. degree emphasizes the mastery of biostatistical skills from the beginning of the plan of study. While graduates of this program may apply to the Ph.D. degree program, the M.S. degree is itself quite marketable as a terminal degree. Part-time enrollment is permitted.

DEGREE REQUIREMENTS

The Biostatistics concentration requires the completion of fourteen required and elective courses for the Standard Pathway and the Implementation and Prevention Sciences Pathway. Fifteen required and elective courses must be completed for the Data Science Pathway. These requirements exclude the Seminar, BIS 525/BIS 526; the Summer Internship, BIS 695; PUBH 100; and PUBH 101. *Note*: Half-term courses cannot count as an elective unless an additional half-term course is taken, and the Biostatistics faculty have approved both courses as an elective. Additionally, all first-year students must participate in an online Public Health Primer course the summer before their first term.

The Graduate School requires an overall grade average of High Pass, including grades of Honors in at least two full-term graduate courses for students enrolled in a two-year program. In order to maintain the minimum average of High Pass, each grade of Pass on the student's transcript must be balanced by one grade of Honors. Each grade of Fail must be balanced by two grades of Honors. If a student retakes a course in which the student has received a failing grade, only the newer grade will be considered in calculating this average. The initial grade of Fail, however, will remain on the student's transcript. A grade awarded at the conclusion of a full-year course in which no grade is awarded at the end of the first term would be counted twice in calculating this average.

CURRICULUM

Required Courses for All Pathways

(or substitutions approved by the student's adviser and the DGS)

BIS 525	Seminar in Biostatistics and Journal Club [1]	0
BIS 526	Seminar in Biostatistics and Journal Club [1]	0
BIS 623	Advanced Regression Models	1
or S&DS 6120	Linear Models	
BIS 628	Longitudinal and Multilevel Data Analysis	1
BIS 630	Applied Survival Analysis	1
or BIS 643	Theory of Survival Analysis	

BIS 678	Statistical Practice I	1
BIS 695	Summer Internship in Biostatistics [1]	0
PUBH 100	Professional Skills Series [1]	0
PUBH 101	Professional Skills Series [1]	0
PUBH 508	Foundations of Epidemiology and Public Health	1
S&DS 5410	Probability Theory [2]	1
or S&DS 5510	Stochastic Processes	
or S&DS 6000	Advanced Probability	
S&DS 5420	Theory of Statistics [2]	1
or S&DS 6100	Statistical Inference	

[1] Course does not count as a credit.

[2] Course offered in the Graduate School of Arts and Sciences.

Additional Required Courses: Standard Pathway

BIS 679	Advanced Statistical Programming in SAS and R	1
BIS 681	Statistical Practice II [1]	1
or BIS 649	Master's Thesis Research	
or BIS 650	Master's Thesis Research	

Electives Five courses are *required*. A minimum of two must be from the biostatistics list. The additional three electives can be taken from either list of approved electives below.

Biostatistics Electives

BIS 536	Measurement Error and Missing Data	1
BIS 537	Statistical Methods for Causal Inference	1
BIS 540	Fundamentals of Clinical Trials	1
BIS 550/CB&B 7500	Topics in Biomedical Informatics and Data Science	1
BIS 555	Machine Learning with Biomedical Data	1
BIS 560	Introduction to Clinical and Translational Informatics	1
BIS 567	Bayesian Statistics	1
BIS 568	Applied Artificial Intelligence in Healthcare	1
BIS 629	Advanced Methods for Implementation and Prevention Science	1
BIS 631	Advanced Topics in Causal Inference Methods	1
BIS 633	Population and Public Health Informatics	1
BIS 634	Computational Methods for Informatics	1
BIS 638	Clinical Database Management Systems and Ontologies	1
BIS 640	User-Centered Design of Digital Health Tools	1
BIS 643	Theory of Survival Analysis [2]	1
BIS 645	Statistical Methods in Human Genetics	1
BIS 646	Nonparametric Statistical Methods and Their Applications	1

BIS 691	Theory of Generalized Linear Models	1
Additional electives must be approved by the Standard Pathway director.		

M.S. Biostatistics (Standard Pathway) students are required to complete a two-semester capstone experience in the second year. This requirement can be fulfilled by:

- taking two semesters of the capstone course: BIS 678 (fall) and BIS 681 (spring) or
- taking the fall semester capstone course, BIS 678, and completing a thesis. The thesis is a yearlong project. Students who plan to complete a thesis should register for BIS 649 (fall; 1 credit) and BIS 650 (spring; 1 credit).

All students who complete a thesis are required to present their research during a public seminar to the Biostatistics faculty and students in order to graduate.

[2] Cannot fulfill elective if substituted for BIS 630.

A minimum of three electives must be taken from either the Biostatistics electives list or the list below:

BENG 5450	Biomedical Image Processing and Analysis	1
CDE 566	Causal Inference Methods in Public Health Research	1
CDE 634	Advanced Applied Analytic Methods in Epidemiology and Public Health	1
CPSC 5371	Database Design and Implementation [1]	1
CPSC 5460	Data and Information Visualization [1]	1
CPSC 5520/ CB&B 6663/ AMTH 5520	Deep Learning Theory and Applications [1]	1
CPSC 5700	Introduction to Artificial Intelligence [1]	1
CPSC 5710	Trustworthy Deep Learning	1
CPSC 5770	Large Language Models: From Foundations to Modern Practice [1]	1
CPSC 5820	Current Topics in Applied Machine Learning [1]	1
CPSC 5830	Deep Learning on Graph-Structured Data [1]	1
CPSC 6400	Topics in Numerical Computation [1]	1
CPSC 6700	Topics in Natural Language Processing [1]	1
CPSC/CB&B/ MB&B/MCDB 7520	Biomedical Data Science: Mining and Modeling [1]	1
CPSC 7760	Topics in Industrial AI Applications	1
ECON 5554	Econometrics V [1]	1
EMD 553	Transmission Dynamic Models for Understanding Infectious Diseases	1
HPM 583	Methods in Health Services Research	1
INP 7599	Statistics and Data Analysis in Neuroscience [1]	1
MGT 803	Decision Making with Data [2]	2
PSYC 5580	Computational Methods in Human Neuroscience	1
S&DS 5170	Applied Machine Learning and Causal Inference [1]	1

S&DS 5510	Stochastic Processes [1,4]	1
S&DS 5620	Computational Tools for Data Science [1]	1
S&DS 5630/ENV 758	Multivariate Statistical Methods for the Social Sciences [1]	1
S&DS 5650	Introductory Machine Learning [1]	1
S&DS 5660	Deep Learning for Scientists and Engineers	1
S&DS 5690	Numerical Linear Algebra: Deterministic and Randomized Algorithms [1]	1
S&DS 5800	Neural Data Analysis [1]	1
S&DS 6000	Advanced Probability [1,4]	1
S&DS 6100	Statistical Inference [1,5]	1
S&DS 6110	Selected Topics in Statistical Decision Theory [1]	1
S&DS 6120	Linear Models [1,3]	1
S&DS 6180	Asymptotic Statistics [1]	1
S&DS 6310	Optimization and Computation [1]	1
S&DS 6320	Advanced Optimization Techniques [1]	1
S&DS 6610	Data Analysis [1]	1
S&DS 6620	Statistical Computing	1
S&DS 6630	Computational Mathematics Situational Awareness and Survival Skills [1]	1
S&DS 6640	Information Theory [1]	1
S&DS 6650	Intermediate Machine Learning [1]	1
S&DS 6740/ ENV 781	Applied Spatial Statistics [1]	1
S&DS 6850	Theory of Reinforcement Learning [1]	1

Additional electives must be approved by the Standard Pathway director.

[1] Course offered in the Graduate School of Arts and Sciences.

[2] Course offered in the School of Management

[3] Cannot fulfill elective credit if substituted for BIS 623.

[4] Cannot fulfill elective credit if substituted for S&DS 5410

[5] Cannot fulfill elective credit if substituted for S&DS 5420

Additional Required Courses: Implementation and Prevention Science Methods Pathway

BIS 629	Advanced Methods for Implementation and Prevention Science	1
BIS 679	Advanced Statistical Programming in SAS and R	1
BIS 681	Statistical Practice II [1]	1
or BIS 649	Master's Thesis Research	
or BIS 650	Master's Thesis Research	
EMD 533	Implementation Science	1

[1] M.S. Biostatistics (Implementation Science Pathway) students are required to complete a two-semester capstone experience in the second year. This requirement can be fulfilled by:

- taking two semesters of the capstone course: BIS 678 (fall) and BIS 681 (spring); or
- taking the fall semester capstone course, BIS 678, and completing a thesis. The thesis is a yearlong project. Students who plan to complete a thesis should register for BIS 649 (fall; 1 credit) and BIS 650 (spring; 1 credit).

Students in this pathway are strongly encouraged to complete a thesis. All students who complete a thesis are required to present their research during a public seminar to the Biostatistics faculty and students in order to graduate.

At least one of the following:

BIS 536	Measurement Error and Missing Data	1
BIS 537	Statistical Methods for Causal Inference	1
BIS 631	Advanced Topics in Causal Inference Methods	1

At least two of the following:

CDE 516	Principles of Epidemiology II	1
CDE 534	Applied Analytic Methods in Epidemiology	1
EMD 538	Quantitative Methods for Infectious Disease Epidemiology	1
HPM 570	Cost-Effectiveness Analysis and Decision-Making [1]	1
HPM 575	Evaluation of Global Health Policies and Programs	1
HPM 586	Microeconomics for Health Policy and Health Management	1
HPM 587	Advanced Health Economics	1
MGT 611	Policy Modeling	2
SBS 541	Community Health Program Evaluation [1]	1
SBS 574	Developing a Health Promotion and Disease Prevention Intervention	1
SBS 580	Qualitative Research Methods in Public Health [1]	1
S&DS 5650	Introductory Machine Learning [2]	1
Alternative electives must be approved by the Implementation Science Pathway director.		

[1] Course is highly recommended

[2] Course offered in the Graduate School of Arts and Sciences.

Additional Required Courses: Data Science Pathway

BIS 678	Statistical Practice I	1
BIS 681	Statistical Practice II [1]	1
or BIS 649	Master's Thesis Research	
or BIS 650	Master's Thesis Research	

[1] M.S. Biostatistics (Data Science Pathway) students are required to complete a two-semester capstone experience in the second year. This requirement can be fulfilled by:

- taking two semesters of the capstone course: BIS 678 (fall) and BIS 681 (spring) or
- taking the fall semester capstone course, BIS 678, and completing a thesis. The thesis is a yearlong project. Students who plan to complete a thesis should register for BIS 649 (fall; 1 credit) and BIS 650 (spring; 1 credit).

All students who complete a thesis are required to present their research during a public seminar to the Biostatistics faculty and students in order to graduate.

Two of the following biostatistics, computer science, and statistical methods courses

BENG 5440	Fundamentals of Medical Imaging	1
BIS 536	Measurement Error and Missing Data	1
BIS 537	Statistical Methods for Causal Inference	1
BIS 540	Fundamentals of Clinical Trials	1
BIS 550/CB&B 7500	Topics in Biomedical Informatics and Data Science	1
BIS 555	Machine Learning with Biomedical Data	1
BIS 567	Bayesian Statistics	1
BIS 629	Advanced Methods for Implementation and Prevention Science	1
BIS 634	Computational Methods for Informatics	1
BIS 645	Statistical Methods in Human Genetics	1
BIS 646	Nonparametric Statistical Methods and Their Applications	1
CB&B 5620	Modeling Biological Systems II [1]	1
CB&B 7520	Biomedical Data Science: Mining and Modeling [1]	1
CPSC 5150	Law and Large Language Models	1
CPSC 5190	Full Stack Web Programming [1]	1
CPSC 5260	Building Distributed Systems [1]	1
CPSC 5390	Software Engineering [1]	1
CPSC 5650	Theory of Distributed Systems [1]	1
CPSC 5770	Large Language Models: From Foundations to Modern Practice [1]	1
CPSC 5880	Advances in Foundation Models [1]	1
CPSC 6400	Topics in Numerical Computation [1]	1
CPSC 6420	Modern Challenges in Statistics: A Computational Perspective [1]	1
EMD 553	Transmission Dynamic Models for Understanding Infectious Diseases	1
MCDB 5000	Biochemistry	1
S&DS 5410	Probability Theory [1,2]	1
S&DS 5510	Stochastic Processes [1,3,4]	1
S&DS 5660	Deep Learning for Scientists and Engineers	1
S&DS 6110	Selected Topics in Statistical Decision Theory [1]	1
S&DS 6450	Statistical Methods in Computational Biology	1
S&DS 6610	Data Analysis [1]	1

S&DS 6640	Information Theory [1]	1
Additional electives must be approved by the Data Science Pathway director.		

One of the following Machine Learning courses:

BIS 555	Machine Learning with Biomedical Data [3]	1
BIS 568	Applied Artificial Intelligence in Healthcare	1
BIS 634	Computational Methods for Informatics [3]	1
BIS 691	Theory of Generalized Linear Models	1
CB&B 5555/ AMTH 5530/CPSC 5530	Unsupervised Learning for Big Data [1]	1
CB&B 6663/ AMTH 5520/CPSC 5520	Deep Learning Theory and Applications [1]	1
CPSC 5690	Randomized Algorithms [1]	1
CPSC 5710	Trustworthy Deep Learning	1
CPSC 5830	Deep Learning on Graph-Structured Data [1]	1
CPSC 6440	Geometric and Topological Methods in Machine Learning [1]	1
CPSC 6700	Topics in Natural Language Processing [1]	1
S&DS 5170	Applied Machine Learning and Causal Inference [1]	1
S&DS 5620	Computational Tools for Data Science [1]	1
S&DS 5650	Introductory Machine Learning [1]	1
S&DS 5690	Numerical Linear Algebra: Deterministic and Randomized Algorithms [1]	1
S&DS 6310	Optimization and Computation [1]	1
S&DS 6320	Advanced Optimization Techniques [1]	1
S&DS 6650	Intermediate Machine Learning [1]	1
S&DS 6740/ ENV 781	Applied Spatial Statistics [1]	1
S&DS 6840	Statistical Inference on Graphs [1]	1
S&DS 6850	Theory of Reinforcement Learning [1]	1
S&DS 6860	High-Dimensional Phenomena in Statistics and Learning [1]	1
Additional electives must be approved by the Data Science Pathway director.		

One of the following Database courses:

BIS 550/CB&B 7500	Topics in Biomedical Informatics and Data Science [3]	1
BIS 638	Clinical Database Management Systems and Ontologies	1
BIS 679	Advanced Statistical Programming in SAS and R	1
CPSC 5370	Database Systems [1]	1
MGT 656	Management of Software Development [5]	4
MGT 660	Mission-Driven Innovation [5]	4
Additional electives must be approved by the Data Science Pathway director.		

[1] Course offered in the Graduate School of Arts and Sciences

[2] Cannot fulfill elective if taken as a requirement

[3] This course can only be counted to fulfill the requirement of one category; it cannot be counted twice

[4] Cannot fulfill elective if taken as a substitute for S&DS 5410

[5] Course offered at the School of Management

Two additional electives are required from the biostatistics, machine learning, or database list. Other courses from Public Health or other departments must be approved by the Data Science Pathway director.

COMPETENCIES

Upon receiving an M.S. in the Biostatistics concentration of Public Health, the student will be able to:

- Select from a variety of analytical tools to test statistical hypotheses, interpret results of statistical analyses, and use these results to make relevant inferences from data
- Design efficient computer programs for study management, statistical analysis, as well as presentation using R, SAS, and other programming languages
- Demonstrate oral and written communication and presentation skills to effectively communicate and disseminate results to professional audiences