

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 fifteen required and elective courses for the Standard Pathway and the Implementation and Prevention Sciences Pathway. Sixteen 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; EPH 100; and EPH 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.

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 612	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

EPH 100	Professional Skills Series ¹	0
EPH 101	Professional Skills Series ¹	0
EPH 509	Fundamentals of Epidemiology	1
EPH 608	Frontiers of Public Health ²	1
S&DS 541	Probability Theory ³	1
or S&DS 551	Stochastic Processes	
or S&DS 600	Advanced Probability	
S&DS 542	Theory of Statistics ³	1
or S&DS 610	Statistical Inference	

¹ Course does not count toward the fifteen required courses.

² Students entering the program with an M.P.H. or relevant graduate degree may be exempt.

³ 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 750	Topics in Biomedical Informatics and Data Science	1
BIS 555	Machine Learning with Biomedical Data	1
BIS 560	Introduction to Health Informatics	1
BIS 567	Bayesian Statistics	1
BIS 568	Applied Artificial Intelligence in Healthcare	1
BIS 620	Data Science Software Systems	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 662	Computational Statistics	1
BIS 691	Theory of Generalized Linear Models	1
BIS 692	Statistical Methods in Computational Biology	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.

Additional Electives

CDE 566	Causal Inference Methods in Public Health Research	1
CDE 634	Advanced Applied Analytic Methods in Epidemiology and Public Health	1
CPSC 540	Database Design and Implementation ¹	1
CPSC 546	Data and Information Visualization ¹	1
CPSC 552/CB&B 663	Deep Learning Theory and Applications ¹	1
CPSC 570	Artificial Intelligence ¹	1
CPSC 577	Natural Language Processing ¹	1
CPSC 582	Current Topics in Applied Machine Learning ¹	1
CPSC 583	Deep Learning on Graph-Structured Data ¹	1
CPSC 640	Topics in Numerical Computation ¹	1
CPSC 670	Topics in Natural Language Processing ¹	1
CPSC 677	Advanced Natural Language Processing ¹	1
CPSC 680	Trustworthy Deep Learning ¹	1
CPSC/CB&B/ MB&B/MCDB 752	Biomedical Data Science: Mining and Modeling ¹	1
ECON 554	Econometrics V	1
EMD 553	Transmission Dynamic Models for Understanding Infectious Diseases	1
ENAS 912	Biomedical Image Processing and Analysis	1
HPM 573	Advanced Topics in Modeling Health Care Decisions	1
HPM 583	Methods in Health Services Research	1
INP/PSYC 558	Computational Methods in Human Neuroscience ¹	1
INP 599	Statistics and Data Analysis in Neuroscience ¹	1
MGT 803	Decision Making with Data ²	2

S&DS 517	Applied Machine Learning and Causal Inference ¹	1
S&DS 551	Stochastic Processes ¹	1
S&DS 562	Computational Tools for Data Science ¹	1
S&DS 563/ENV 758	Multivariate Statistical Methods for the Social Sciences ¹	1
S&DS 565	Introductory Machine Learning ¹	1
S&DS 569	Numerical Linear Algebra: Deterministic and Randomized Algorithms ¹	1
S&DS 580	Neural Data Analysis	1
S&DS 600	Advanced Probability ¹	1
S&DS 610	Statistical Inference ¹	1
S&DS 611	Selected Topics in Statistical Decision Theory ¹	1
S&DS 612	Linear Models ^{1,3}	1
S&DS 618	Asymptotic Statistics	1
S&DS 625	Statistical Case Studies ¹	1
S&DS 631	Optimization and Computation ¹	1
S&DS 632	Advanced Optimization Techniques ¹	1
S&DS 661	Data Analysis ¹	1
S&DS 662	Statistical Computing ³	1
S&DS 663	Computational Mathematics Situational Awareness and Survival Skills ¹	1
S&DS 664	Information Theory ¹	1
S&DS 665	Intermediate Machine Learning ¹	1
S&DS 674/ENV 781	Applied Spatial Statistics ¹	1
S&DS 685	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.

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 ¹	4
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 565	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 620	Data Science Software Systems	1
BIS 687	Data Science Capstone ¹	1

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 687 (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

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 750	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
BIS 662	Computational Statistics	1
BIS 692/S&DS 645	Statistical Methods in Computational Biology	1
CB&B 562	Modeling Biological Systems II ¹	1
CB&B 752	Biomedical Data Science: Mining and Modeling ¹	1
CPSC 519	Full Stack Web Programming ¹	1
CPSC 526	Building Distributed Systems ¹	1
CPSC 539	Software Engineering ¹	1
CPSC 565	Theory of Distributed Systems ¹	1
CPSC 577	Natural Language Processing ¹	1
CPSC 588	AI Foundation Models ¹	1
CPSC 640	Topics in Numerical Computation ¹	1
CPSC 642	Modern Challenges in Statistics: A Computational Perspective	1
EMD 553	Transmission Dynamic Models for Understanding Infectious Diseases	1
HPM 573	Advanced Topics in Modeling Health Care Decisions	1
S&DS 541	Probability Theory ^{1,4}	1
S&DS 551	Stochastic Processes ^{1,5}	1
S&DS 611	Selected Topics in Statistical Decision Theory ¹	1
S&DS 625	Statistical Case Studies ¹	1
S&DS 661	Data Analysis ¹	1

S&DS 664	Information Theory ¹	1
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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 ²	1
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BIS 568	Applied Artificial Intelligence in Healthcare	1
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BIS 634	Computational Methods for Informatics ²	1
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BIS 662	Computational Statistics ²	1
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BIS 691	Theory of Generalized Linear Models	1
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CB&B 555/ AMTH 553/CPSC	Unsupervised Learning for Big Data ¹	1
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553		
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CB&B 663/ AMTH 552/CPSC	Deep Learning Theory and Applications ¹	1
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552		
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CPSC 569	Randomized Algorithms ¹	1
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CPSC 583	Deep Learning on Graph-Structured Data ¹	1
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CPSC 644	Geometric and Topological Methods in Machine Learning ¹	1
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CPSC 670	Topics in Natural Language Processing ¹	1
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S&DS 517	Applied Machine Learning and Causal Inference ¹	1
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S&DS 562	Computational Tools for Data Science ¹	1
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S&DS 565	Introductory Machine Learning ¹	1
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S&DS 569	Numerical Linear Algebra: Deterministic and Randomized Algorithms ¹	1
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S&DS 631	Optimization and Computation ¹	1
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S&DS 632	Advanced Optimization Techniques ¹	1
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S&DS 665	Intermediate Machine Learning ¹	1
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S&DS 674/ENV 781	Applied Spatial Statistics ¹	1
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S&DS 684	Statistical Inference on Graphs ¹	1
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S&DS 685	Theory of Reinforcement Learning ¹	1
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S&DS 686	High-Dimensional Phenomena in Statistics and Learning ¹	1
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Additional electives must be approved by the Data Science Pathway director.

One of the following Database courses:

BIS 550/CB&B 750	Topics in Biomedical Informatics and Data Science ²	1
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BIS 638	Clinical Database Management Systems and Ontologies	1
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BIS 679	Advanced Statistical Programming in SAS and R	1
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CPSC 537	Database Systems ¹	1
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MGT 656	Management of Software Development ³	4
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MGT 660	Advanced Management of Software Development ³	4
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Additional electives must be approved by the Data Science Pathway director.

¹ Course offered in the Graduate School of Arts and Sciences

² This course can only be counted to fulfill the requirement of one category; it cannot be counted twice

³ Course offered at the School of Management

⁴ Cannot fulfill elective if taken as a requirement

⁵ Cannot fulfill elective if taken as a substitute for S&DS 541

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