HARVARD UNIVERSITY PH.D. PROGRAM IN HEALTH POLICY
DECISION SCIENCES CONCENTRATION
2021-2022

Decision sciences are the collection of quantitative techniques that are used for decision-making at the individual and collective level. They include decision analysis, risk analysis, cost-benefit and cost-effectiveness analysis, decision modeling, and behavioral decision theory, as well as parts of operations research, microeconomics, statistical inference, management control, cognitive and social psychology, and computer science. The concentration in decision sciences prepares students for research careers that involve the application of these methods to health problems. Examples of research topics in health decision sciences include: cost-effectiveness analysis of medical technologies and pharmaceuticals; optimal screening policies for cancer and other chronic diseases; measurement and evaluation of health outcomes, including quality of life; policy simulation modeling of diseases such as HIV, tuberculosis, cancer, and asthma; and optimal resource allocation for biomedical research.

This curriculum guide is organized under the following four subheadings:

- REQUIRED COURSES
- ADDITIONAL COURSES
- FACULTY MEMBERS
- COURSE DESCRIPTIONS

Verification of all course offerings listed below, including instructors and class times, is suggested before determining a final course schedule. Final Harvard course information may be accessed from my.harvard.edu

Incoming students should have completed courses that cover multivariate calculus and linear algebra before entering the program. For reference, the Harvard course equivalents would be Mathematics 21a and 21b. This prerequisite may be satisfied by taking courses during the summer prior to matriculation.

REQUIRED COURSES

Students in the decision sciences concentration must satisfy the requirements listed below. If students have had prior courses or training that would make any of these courses redundant and wish to be waived from a specific requirement, they should discuss this situation with their advisors. Further, students may petition to substitute alternative courses that cover the required course contents. In unusual circumstances, students may petition to be exempt from any specific course content requirements, if they state the case that this material is not relevant to their area of application. However, they may face the risk that some of this content would be useful in completing the qualifying examination.

Highly recommended course options within each category are marked with an asterisk (*). Any future changes in the core requirements for the PhD in Health Policy program supersede the requirements listed below.

Decision Analysis, Cost-Effectiveness and Cost-Benefit Analysis
The following four classes are required.

RDS 280†	Decision Analysis for Health and Medical Practices	Pandya; TTh 2–3:30 (Fall 2)
RDS 282	Economic Evaluation of Health Policy and Program Management	Resch; MW 2–3:30 (Spring 2)
RDS 284‡	Decision Theory	Hammitt; MW 11:30–1 (Fall)
RDS 285	Decision Analysis Methods in Public Health and Medicine	Menzies; MW 2–3:30 (Spring 1)

† *Note: RDS 286 Decision Analysis in Clinical Research may be substituted for RDS 280, but RDS 286 is only open to HSPH degree or Program in Clinical Effectiveness students. Any other interested students must request instructor permission to enroll in this course.*
‡ *Note: RDS 284 may not be offered every year*

Economics
Two semesters of intermediate microeconomic theory with calculus are required:

ECON 2020A	Microeconomic Theory I	Gitmez; MW 8:30–9:45 (Fall)
ECON 2020B	Microeconomic Theory II	Lopomo; MW 9–10:15 (Spring)

Some students may find it useful to take either API-101Z or ECON 1011A prior to taking ECON 2020A, but these courses will not count toward the concentration requirements. Note that students who have entered the program with little to no economics background have successfully completed ECON2020A even without taking the following courses:

API 101Z	Resources, Incentives, and Choices I: Markets and Market Failures	Saavedra; MW 10:30–11:45 (Fall)
ECON 1011A	Intermediate Microeconomics: Advanced	Glaeser; TTh 12:00–1:15 (Fall)

Probability and Statistics
All students in the decision sciences concentration are required to complete full-semester courses in probability theory, statistical inference, econometrics, and Bayesian data modeling. Suggested courses that meet these requirements include:

- Probability theory / statistical inference:

ECON 2110	Econometrics I	Bruich; MW 1:30–2:45 (Fall)
STAT 110*	Introduction to Probability	Blitzstein; TTh 1:30–2:45 (Fall)

- Econometrics:

ECON 2115*	Econometric Methods II	Layton; MW 1:30–2:45 (Spring)
GHP 525	Econometrics for Health Policy	Bauhoff; TTh 8–9:30 (Fall)

- Likelihood inference and Bayesian data modeling:

BST 249	Bayesian Methodology in Biostatistics	Miller; TTh 3:45–5:15 (Spring)
GOV 2001*	Quantitative Social Science Methods I	King; M 3–5:45 (Fall)

Equivalent courses, or higher level courses in probability and statistics, may be substituted for the courses listed above.

Operations Research

Students are required to complete one full-semester course in operations research. The following courses satisfy the operations research requirement:

APMTH 121	Introduction to Optimization: Models and Methods	Levine; TTh 9–10:15 (Fall)
MIT 15.053*	Optimization Methods in Business Analytics	Orlin; TBA (Spring)
MIT 6.251J/15.081J	Introduction to Mathematical Programming	Bertsimas; TTh 1–2:30 (Fall)

Epidemiology

One half-semester course in epidemiology is required.

EPI 201	Introduction to Epidemiology: Methods I	Mittleman; TTh 9:45–11:15 or 11:30–1 (Fall 1)

Teaching Requirement

All decision sciences students are expected to have at least 5 HSPH credits (equivalent to one full semester) of experience as teaching fellows in the core decision sciences courses. This is not a requirement of your funding package, and you will be paid additionally for this work.

ADDITIONAL COURSES

All decision science students are expected to complete at least two full semester courses from any of the options below. In addition, the following courses may be used to supplement the required curriculum in decision science, allowing students to specialize in areas of particular interest. Upon consultation with their advisors, students may, in special instances, substitute equivalent or higher level courses from this list in place of required courses listed above.

Economics

ECON 2465	Health Economics	Cutler; TTh 10:30–11:45 (Spring)
ECON 3117	Seminar in Health Economics	Cutler; W TBA (Spring)

Multi-Person Decisions

ECON 2052	Game Theory I: Equilibrium Theory	Horner; M 9–11:45 (Fall)
GOV 2005	Formal Political Theory I	Buisseret; W 12–2:45 (Fall)

Behavioral Economics and Psychology of Decision Making

ECON 2030	Psychology and Economics	Laibson, Schleifer; TBA (Spring)
ECON 2035	Psychology and Economic Theory	Rabin; M 3–5:45 (Fall)
ECON 2040	Experimental Economics	Enke; T 3–5:45 (Fall)
ECON 2050	Behavioral Economics, Law and Public Policy	Not Offered in 2021-2022
ECON 2338	Behavioral Development Economics	Rao; TTh 3–4:15 (Spring)
GHP 237	Behavioral Economics and Global Health	McConnell; TTh 2–3:30 (Spring 2)
HBSDOC 4420	Behavioral Approaches to Decision Making	Not Offered in 2021-2022
MLD 304	Science of Behavior Change	A: Rogers; MW 10:30–11:45 (Fall) *OR* B: Rogers; MW 3–4:15 (Fall)

Policy and Program Evaluation

API 302	Analytic Frameworks for Policy	Zeckhauser; TTh 10:30–11:45 (Fall)
GHP 228	Econometric Methods in Impact Evaluation	Cohen; F 8–11:15 (Spring)
HPM 543	Quantitative Methods for Policy Evaluation	Curto; MW 9:45–11:15 (Spring 2)

Probability and Statistics

BST 230	Probability I	Pagano; MW 2–3:30 (Fall)
BST 231	Statistical Inference I	Gray; MW 9:45–11:15 (Spring)
STAT 111	Introduction to Statistical Inference	Shephard; TTh 1:30–2:45 (Spring)
STAT 210	Probability I	Blitzstein; TTh 10:30–11:45 (Fall)
STAT 211	Statistical Inference I	Janson; MW 10:30–11:45 (Fall)

Data Analysis

APMTH 207	Advanced Scientific Computing: Stochastic Methods for Data Analysis, Inference and Optimization	Pan; TTh 9:45–11 or TTh 2:15–3:30 (Fall)
BST 210	Applied Regression Analysis	Lake; TTh 11:30–1 (Fall); Glynn; TTh 8–9:30 (Spring)
BST 213	Applied Regression for Clinical Research	Orav; MW 8–9:30 (Fall)
BST 223	Applied Survival Analysis	Haneuse; TTh 9:45–11:15 (Spring)
BST 226	Applied Longitudinal Analysis	Fitzmaurice; TTh 2–3:30 (Spring)
BST 228	Applied Bayesian Analysis	Stephenson; TTh 9:45–11:15 (Fall)
BST 232	Methods	Coull; MW 8–9:30 (Fall)
BST 249	Bayesian Methodology in Biostatistics	Miller; TTh 3:45–5:15 (Spring)
BST 267	Introduction to Social and Biological Networks	Onnela; MW 3:45–5:15 (Fall 2)
GOV 1021	Spatial Models of Social Science	Kelly; T 3–5:45 (Fall)
GOV 2002	Quantitative Social Science Methods II	TBA; TBA (Spring)
GOV 2003	Causal Inference with Applications	Blackwell; MW 10:30–11:45 (Fall)
GOV 2004	Introduction to Machine Learning	Lo; T 3–5:45 (Spring)
STAT 139	Linear Models	Rader; MW 1:30–2:45 (Fall)
STAT 149	Generalized Linear Models	Glickman; MW 1:30–2:45 (Spring)
STAT 160	Design and Analysis of Sample Surveys	Not Offered in 2021-2022
STAT 171	Introduction to Stochastic Processes	Sen; TTh 12–1:15 (Spring)
STAT 186	Introduction to Causal Inference	Murphy; TTh 1:30–2:45 (Spring)
STAT 220	Bayesian Data Analysis	Not Offered in 2021-2022
STAT 221	Monte Carlo Methods & Other Computational Tools for Statistical Learning	Not Offered in 2021-2022
EDU S030	Intermediate Statistics for Educational Research: Applied Linear Regression	Eidelman; Split Schedule T 10:30-11:45 and T 3-4:15 (Spring)
EDU S052	Intermediate and Advanced Statistical Methods for Applied Educational Research	Ho; Split Schedule M 9-10:15 and T 10:30-11:45 (Spring)
API 222	Machine Learning and Big Data Analytics	A: Saghafian; MW 3–4:15 (Fall) *OR* B: Saghafian; TTh 12–1:15 (Fall)
MIT 17.802	Quantitative Research Methods II: Casual Inference	Hidalgo; TBA (Spring)

Epidemiology and Clinical Trials

BST 214	Principles of Clinical Trials	Wypij; MW 2–3:30 (Spring 1)
EPI 204	Analysis of Case-Control, Cohort and Other Epidemiologic Data	Song; MW 9:45–11:15 (Spring 2)
EPI 207	Advanced Epidemiologic Methods	Robins; MW 3:45–5:15 (Fall 1)
EPI 221	Pharmacoepidemiology	Hernandez-Diaz, Gagne; MW 2–3:30 (Fall 1)
EPI 233	Research Synthesis and Meta-Analysis	Papatheodorou; W 3:45–5:15 (Spring)
EPI 289	Epidemiologic Methods III: Models for Causal Inference	Dickerman; MW 9:45–11:15 (Spring 1)

Disease and Health Systems Modeling

EPI 260	Mathematical Modeling of Infectious Diseases †	Lipsitch; TBA (Spring 2)
EPI 501	Dynamics of Infectious Diseases (Intro)	Not Offered in 2021-2022

GHP 201	Advanced Modeling for Health System Analysis & Priority Setting	Verguet; TTh 9:45–11:15 (Spring 2)
GHP 501	Modeling for Health System Analysis & Priority Setting	Verguet; TTh 9:45–11:15 (Spring 1)

† *Note: Infectious Disease Modeling courses typically are offered in alternate years.*

Decision Theory, Optimization Theory, and Operations Research

ECON 2057	Stochastic Choice	Strzalecki; W 3–5:45 (Fall)
ECON 2059	Decision Theory	Not Offered in 2021-2022
STAT 234	Sequential Decision Making	Murphy; W 12–2:45 (Spring)
MIT 6.255J/ 15.093J	Optimization Methods	Bertsimas, Parrilo; TTh 1–2:30 (Fall)
MIT 14.128	Dynamic Optimization and Economic Applications	Not Offered in 2021-2022
MIT 15.871	Introduction to System Dynamics	Rahmandad; MW 1–2:30 or 2:30–4 (Fall, first half) Sterman, Keith; TBA (Spring, first half)
MIT 15.872	System Dynamics II	TBA; TBA (Spring, second half)
MIT 15.879	Research Seminar in System Dynamics	Keith; F 9–12 (Fall/Spring)

Ethics of Resource Allocation

ECON 2082	Social Choice Theory	Not Offered in 2021-2022
ID 250	Ethical Basis of the Practice of Public Health	Wikler, Norheim; MW 8–9:30 (Fall 1)

FACULTY ASSOCIATED WITH THE DECISION SCIENCES TRACK

Jane J. Kim, Chair, Decision Sciences concentration, and K.T. Li Professor of Health Economics, Harvard T. H. Chan School of Public Health; Dean for Academic Affairs, Harvard T. H. Chan School of Public Health

Jessica Cohen, Bruce A. Beal, Robert L. Beal, and Alexander S. Beal Associate Professor of Global Health, Harvard T.H. Chan School of Public Health

Goodarz Danaei, Bernard Lown Associate Professor of Cardiovascular Health, Harvard T. H. Chan School of Public Health

Kenneth A. Freedberg, Professor of Medicine, Harvard Medical School; Professor in the Department of Health Policy and Management, Harvard T. H. Chan School of Public Health

G. Scott Gazelle, Professor of Radiology, Harvard Medical School; Professor in the Department of Health Policy and Management, Harvard T. H. Chan School of Public Health

Thomas Gaziano, Assistant Professor of Medicine, Harvard Medical School; Associate Professor in the Department of Health Policy and Management, Harvard T.H. Chan School of Public Health

Sue J. Goldie, Roger Irving Lee Professor of Public Health, Harvard T. H. Chan School of Public Health; Director, Center for Health Decision Science, Harvard T.H. Chan School of Public Health

James K. Hammitt, Professor of Economics and Decision Sciences, Harvard T. H. Chan School of Public Health

Laura Hatfield, Associate Professor of Health Care Policy, Harvard Medical School

M. G. Myriam Hunink, Adjunct Professor of Health Policy, Harvard T. H. Chan School of Public Health; Professor of Clinical Epidemiology and Radiology, Erasmus University Medical Center Rotterdam

Nicolas Menzies, Associate Professor of Global Health, Harvard T. H. Chan School of Public Health

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Stephen Resch, Lecturer on Health Decision Science, Harvard T. H. Chan School of Public Health

Soroush Saghafian, Associate Professor of Public Policy, Harvard Kennedy School

Joshua Salomon, Adjunct Professor of Global Health, Harvard T. H. Chan School of Public Health; Professor of Medicine, Stanford University School of Medicine

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Natasha Stout, Associate Professor, Harvard Pilgrim Health Care Institute and Harvard Medical School

Stephane Verguet, Associate Professor of Global Health, Harvard T. H. Chan School of Public Health

Milton C. Weinstein, Research Professor of Health Policy and Management, Harvard T. H. Chan School of Public Health

Davene Wright, Assistant Professor, Harvard Pilgrim Health Care Institute and Harvard Medical School

Jennifer Yeh, Assistant Professor of Pediatrics, Harvard Medical School

Richard C. Zeckhauser, Frank P. Ramsey Professor of Political Economy, Harvard Kennedy School

COURSE DESCRIPTIONS

REQUIRED COURSES

Decision Analysis, Cost-Effectiveness and Cost-Benefit Analysis

(SPH) RDS 280. Decision Analysis for Health and Medical Practices
This course is designed to introduce the student to the methods and growing range of applications of decision analysis and cost-effectiveness analysis in health technology assessment, medical and public health decision making, and health resource allocation. The objectives of the course are: (1) to provide a basic technical understanding of the methods used, (2) to give the student an appreciation of the practical problems in applying these methods to the evaluation of clinical interventions and public health policies, and (3) to give the student an appreciation of the uses and limitations of these methods in decision making at the individual, organizational, and policy level both in developed and developing countries.
Course Prerequisites: BST201 or BST202&203 or BST206&207 or BST206&208 (all courses may be taken concurrently). Introductory economics is recommended but not required.

(SPH) RDS 282. Economic Evaluation in Health Policy and Program Management
This course features the application of health decision science to policymaking and program management at various levels of the health system. Both developed and developing country contexts will be covered. Topics include: [1] theoretical foundations of cost-effectiveness analysis (CEA) with comparison to other methods of economic evaluation; [2] challenges and critiques of CEA in practice; [3] design and implementation of tools and protocols for measurement and valuation of cost and benefit of health programs; [4] use of evidence of economic value in strategic planning and resource allocation decisions, performance monitoring and program evaluation; [5] the role of evidence of economic value in the context of other stakeholder criteria and political motivations.
Course Prerequisites: Students must have taken RDS280 or RDS286. Prior coursework in Microeconomics is recommended.

(SPH) RDS 284. Decision Theory
Introduces the standard model of decision-making under uncertainty, its conceptual foundations, challenges, alternatives, and methodological issues arising from the application of these techniques to health issues. Topics include von Neumann-Morgenstern and multi-attribute utility theory, Bayesian statistical decision theory, stochastic dominance, the value of information, judgment under uncertainty and alternative models of probability and decision making (regret theory, prospect theory, generalized expected utility). Applications are to preferences for health and aggregation of preferences over time and across individuals.

(SPH) RDS 285. Decision Analysis Methods in Public Health and Medicine
An intermediate-level course on methods and health applications of decision analysis modeling techniques. Topics include Markov models, microsimulation models, life expectancy estimation, cost estimation, deterministic and probabilistic sensitivity analysis, value of information analysis, and cost-effectiveness analysis.
Course Note: Familiarity with matrix algebra and elementary calculus may be helpful but not required; lab or section times to be announced at first meeting.
Course Prerequisites: (BIO201 or ID201) and (RDS280 or RDS286).

Economics

(FAS) Economics 2020A. Microeconomic Theory I
Jointly listed in HKS as API-111 and in HBS as 4010
A comprehensive course in economic theory designed for doctoral students in all parts of the university. Topics include consumption, production, behavior toward risk, markets, and general equilibrium theory. Also looks at applications to policy analysis, business decisions, industrial organization, finance, and the legal system.
Prerequisite: Multivariate calculus and one course in probability theory. Thorough background in microeconomic theory at the intermediate level.

(FAS) Economics 2020B. Microeconomic Theory II
Jointly listed in HKS as API-112 and in HBS as 4011
A continuation of Economics 2020a. Topics include game theory, economics of information, incentive theory, and

welfare economics.
Prerequisite: Economics 2020A.

(HKS) API-101Z. Resources, Incentives, and Choices I: Markets and Market Failures
This course applies microeconomic reasoning to public policies. It considers economic incentives and organizations; models of economic behavior; the operation of markets; the price system and how it works; the consequences of market failure and interventions in markets; and policy objectives and instruments.
Prerequisite: The Z section of this course presumes the ability to use basic calculus.

(FAS) Economics 1011A. Intermediate Microeconomics: Advanced
Economics 1011A is similar to Economics 1010A, but more mathematical and covers more material. The course teaches the basic tools of economics and to apply them to a wide range of human behavior.
Prerequisite: Mathematics 21a or permission of the instructor.

Probability and Statistics

(FAS) Economics 2110. Econometrics I
Jointly listed in HKS as API-114 and in HBS as 4170
Economics 2110 and 2115 comprise a two-course sequence for first-year graduate students seeking training in econometric methods at a level that prepares them to conduct professional empirical research. Economics 2110 (fall) reviews probability and statistics, then covers the fundamentals of modern econometrics, with a focus on regression methods for causal inference in observational and experimental data.
Prerequisites: Undergraduate courses in probability and statistics, regression analysis, linear algebra, and multivariate calculus.

(FAS) Statistics 110. Introduction to Probability
A comprehensive introduction to probability. Basics: sample spaces and events, conditional probability, and Bayes' Theorem. Univariate distributions: density functions, expectation and variance, Normal, t, Binomial, Negative Binomial, Poisson, Beta, and Gamma distributions. Multivariate distributions: joint and conditional distributions, independence, transformations, and Multivariate Normal. Limit laws: law of large numbers, central limit theorem. Markov chains: transition probabilities, stationary distributions, convergence.
Prerequisite: Mathematics 1b or equivalent.

(FAS) Economics 2115. Econometric Methods II
Jointly listed in HKS as API-115 and in HBS as 4175
Economics 2110 and 2115 comprise a two-course sequence for first-year graduate students seeking training in econometric methods at a level that prepares them to conduct professional empirical research. Economics 2115 (spring) covers topics (different methods) in current empirical research. Faculty members from across the university will teach modules each covering a different method of causal inference, including but not limited to instrumental variables, panel data methods, and regression discontinuity and kink designs. The course will emphasize a mixture of theory and application, with problem sets focused on the replication or extension of recent papers utilizing these methods.
Prerequisite: Economics 2110 or the equivalent.

(SPH) GHP 525. Econometrics for Health Policy
This is a course in applied econometrics for doctoral and advanced master level students. The course has two primary objectives: (1) to develop skills in linking economic behavioral models and quantitative analysis, in a way that students can use in their own research; (2) to develop students' abilities to understand and evaluate critically other peoples' econometric studies.
The course focuses on developing the theoretical basis and practical application of the most common empirical models used in health policy research. In particular, it pays special attention to a class of models identifying causal effects in observational data, including instrumental variable estimation, simultaneous equations and two-stage-least-squares, quasi-experiments and difference-in-difference method, sample selection, treatment effect models and propensity score methods.
Lectures will be complemented with computer exercises building on public domain data sets commonly used in health research. The statistical package recommended for the exercises is Stata.
Course Note: Students are expected to be familiar with probability theory (density and distribution functions) as well as the concepts underlying basic ordinary least square (OLS) estimation.

Course Activities: Optional review and computer lab sessions will be held.
Course Prerequisites: BST210 or BST213; or equivalent course taken at Harvard Chan or HGSE with instructor permission.

(SPH) BST 249. Bayesian Methodology in Biostatistics
Jointly listed in FAS as Biostatistics 249
General principles of the Bayesian approach, prior distributions, hierarchical models and modeling techniques, approximate inference, Markov chain Monte Carlo methods, model assessment and comparison. Bayesian approaches to GLMMs, multiple testing, nonparametrics, clinical trials, survival analysis.
Prerequisite: BST231 and BST232, or signature of instructor required.

(FAS) Government 2001. Quantitative Social Science Methods I
This class introduces students to quantitative methods and how they are applied to political science research. It has two overarching goals. First, we focus on the theory of statistical inference - using facts you know to learn about facts you don't know - so that you can truly understand a wide range of methods we introduce, feel comfortable using them in your research, digest new ones invented after class ends, implement them, apply them to your data, interpret the results, and explain them to others. Second, students learn how to publish novel substantive contributions in a scholarly journal. A substantial portion of those in this class publish a revised version of their class paper as their first scholarly journal article. Please see http://j.mp/G2001 for details.

Operations Research

(FAS) Applied Mathematics 121 / Engineering Sciences 121. Introduction to Optimization: Models and Methods

Introduction to basic mathematical ideas and computational methods for solving deterministic and stochastic optimization problems. Topics covered: linear programming, integer programming, branch-and-bound, branch-and-cut, Markov chains, Markov decision processes. Emphasis on modeling. Examples from business, society, engineering, sports, e-commerce. Exercises in AMPL, complemented by Maple or Matlab.
Prerequisite: Applied Mathematics 21b or Mathematics 21b (linear algebra) or equivalent preparation in linear algebra.

(MIT) 15.053. Optimization Methods in Business Analytics
Introduces optimization methods with a focus on modeling, solution techniques, and analysis. Covers linear programming, network optimization, integer programming, nonlinear programming, and heuristics. Applications to logistics, manufacturing, statistics, machine learning, transportation, game theory, marketing, project management, and finance. Includes a project in which student teams select and solve an optimization problem (possibly a large-scale problem) of practical interest.

(MIT) 6.251J. Introduction to Mathematical Programming
(Same subject as 15.081J)
Introduction to linear optimization and its extensions emphasizing both methodology and the underlying mathematical structures and geometrical ideas. Covers classical theory of linear programming as well as some recent advances in the field. Topics: simplex method; duality theory; sensitivity analysis; network flow problems; decomposition; integer programming; interior point algorithms for linear programming; and introduction to combinatorial optimization and NP-completeness.

Epidemiology

(SPH) EPI 201. Introduction to Epidemiology: Methods I
EPI201 introduces the principles and methods used in epidemiologic research. The course discusses the conceptual and practical issues encountered in the design and analysis of epidemiologic studies for description and causal inference. EPI201 is the first course in the series of methods courses designed for students majoring in Epidemiology, Biostatistics and related fields, and those interested in a detailed introduction to the design and conduct of epidemiologic studies. Students who take EPI201 are expected to take EPI202 (Methods II).
Course Note: Thursday or Friday lab required.

ADDITIONAL COURSES

Economics

(FAS) Economics 2465. Health Economics
This course surveys topics in health economics. It touches on public sector issues, the industrial organization of health care markets, interactions between health and labor markets, and health in developing countries. Theory and empirical work are presented.

(FAS) Economics 3117. Seminar in Health Economics
Focuses on theory, econometric models, and public policy of health care. Frontier work in health economics presented and discussed by instructors and outside speakers.
Note: May be taken for credit only by dissertation students writing a research paper. Offered jointly with the Kennedy School as SUP-951.

Uncertainty and Multi-Person Decisions

(FAS) Economics 2052. Game Theory I: Equilibrium Theory
Equilibrium analysis and its applications. Topics vary, but typically include equilibrium refinements (sequential equilibrium), the equilibria of various classes of games (repeated games, auctions, signaling games) and the definition and application of common knowledge.
Prerequisite: Economics 2010a.

(FAS) Government 2005. Formal Political Theory I
A graduate seminar on microeconomic modeling, covering price theory, decision theory, social choice theory, and game theory.

Behavioral Economics and Psychology of Decision Making

(FAS) Economics 2030. Psychology and Economics
Explores economic and psychological models of human behavior. Topics include bounded rationality, intertemporal choice, decision making under uncertainty, inference, choice heuristics, and social preferences. Economic applications include asset pricing, corporate finance, macroeconomics, labor, development, and industrial organization.
Prerequisite: Knowledge of multivariable calculus and econometrics.

(FAS) Economics 2035. Psychology and Economic Theory
Jointly listed in HBS as 4155
This course explores ways that psychological research indicating systematic departures from classical economic assumptions can be translated into formal models that can be incorporated into economics. Topics include ways utility theory can be improved--such as incorporating reference dependence, news utility, social preferences, self image, and other belief-based tastes--and ways we can relax assumptions of perfect rationality--such as incorporating focusing effects, limited attention, biased prediction of future tastes, present-biased preferences, biases in probabilistic judgment, and errors in social inference. The course will emphasize (a) careful interpretation and production of new evidence on relevant departures,(b) formalizing this evidence into models that can, with discipline and rigor, generate sharp predictions using traditional economic approaches, and (c) exploring economic implications of those models presented. Although we will primarily emphasize (b), the course is meant to be useful to students whose interests lie anywhere in this spectrum, under the premise that all such research will be improved by a greater appreciation of the full spectrum. The course is intended for PhD students in the Business Economics and Economics programs and others who have a solid background in microeconomic theory at the level of introductory PhD courses in these programs. While obviously appropriate to those wishing to specialize in "behavioral economics", the course is also designed for those interested in doing research in particular fields of economics. And while the course centers on theoretical models (learning and evaluation will center around solving formal problem sets), the theory is focused towards its empirical implementability and economic relevance, so that the course is also designed for those interested in theory-influenced empirical research.

(FAS) Economics 2040. Experimental Economics

This course provides an introduction to experimental methods and their applications in economics. We will focus on (i) the use of lab experiments in establishing causal effects, testing models, and illuminating mechanisms; (ii) field experiments in behavioral economics; and (ii) the measurement of preference parameters and behavioral traits in lab-in-the-field settings. Topics include bounded rationality, wishful thinking, moral values and social image concerns, gender, the measurement of preferences in lab and large-scale survey settings, and the explanatory power of behavioral traits for field behaviors. We will cover methodological topics including the relationship between experiments and theory, simple process-tracing techniques, internet experiments, and surveys. Students will become acquainted with the full process of designing an experiment, and class discussions will place heavy emphasis on the development of early-stage research ideas. The course is intended not just for those with an interest in behavioral and experimental economics per se, but also for those who wish to measure behavioral parameters in non-lab settings in applied work or to conduct field experiments.

(FAS) Economics 2050. Behavioral Economics, Law and Public Policy
This seminar will explore a series of issues at the intersection of behavioral economics and public policy. Potential questions will involve climate change; energy efficiency; health care; and basic rights. There will be some discussion of paternalism and the implications of neuroscience as well.

(FAS) Economics 2338. Behavioral Development Economics
This graduate level course will focus on the intersection of two rapidly growing fields in economics - development economics, and behavioral economics. We will study applications of behavioral economics to development questions, and ask whether there is a special behavioral science of poverty and development. Methods covered willinclude field experiments, lab experiments, tests of theory and combining experiments with structural estimation.

(SPH) GHP 237. Behavioral Economics and Global Health
This course provides an overview of behavioral economic theory and surveys the most recent evidence in behavioral economics applied to global health. The course will introduce students to the process of defining and diagnosing challenges in global health policy that are rooted in human behavior. They will also learn how to design solutions to these problems using principles from behavioral economics and rigorously test those solutions in applied settings.

(HBS) HBSDOC 4420. Behavioral Approaches to Decision Making
This course provides an overview of the field of behavioral decision making. The focus of the course is the individual as a less-than-perfect decision maker in individual and competitive contexts. These major contexts include: negotiations, marketing, motivation and incentive design, and individual judgment and decision making (JDM) more broadly. We will start with March and Simon's (1958) seminal work on bounded rationality, work through the groundbreaking research of Kahneman and Tversky, and update these lines of inquiry through the current decade. We will examine the implications of imperfect behavior for theoretical development, as well as help individuals to make wiser decisions and organizations design better systems. This course will involve students in an intensive, thorough survey of the intersection of analytic and behavioral perspectives on behavior and decision making. In each class we will cover an area in depth, explicate some major perspectives in the field, review a select set of readings, and discuss some of the critical issues that have been raised with regard to theory and experimentation. At least half of the classes will include guest lectures by top leading professors who will describe the main insights of the topic while also presenting their contributions to the literature.

(HKS) MLD 304. Science of Behavior Change
Over the last 30 years, psychologists and economists have joined forces to study how people process information and actually make decisions, rather than how they would make decisions if they were fully rational and selfish. This research program (dubbed behavioral economics or behavioral science) has provided an understanding of how people's decisions deviate from "optimal" choices as well as the consequences of such deviations. This course is devoted to understanding the nature, causes, implications and applications of these limitations. This course focuses on how these judgment, decision-making and behavior tendencies can inform the design and development of welfare-enhancing interventions.

The Science of Behavior Change (MLD 304) has one central objective: to improve students' abilities to design policies and interventions that improve societal well-being. It accomplishes this by focusing on how to leverage insights about human decision making to develop interventions ("nudges"). This will be accomplished by building on the toolbox that standard economics provides for influencing behavior (namely, incentives and information) with the insights from behavioral science.

There are three additional, though secondary, goals for this class. First, it will help you better understand the science of how humans make judgments and decisions. We will review research on human thinking from social psychology, cognitive psychology, political science, organizational behavior, decision science, and economics. In the process you will also learn how randomized experiments work and why they are critical for making inferences about causal relationships.

Second, this course aims to improve the quality of your own judgments and decisions. People are poor intuitive statisticians, meaning that when they "just think" about situations for which some data or casual observations exist, they tend to make serious inferential errors, in turn leading to systematically biased decisions. We will study some errors that are particularly important for real world problems and look for easy-to-implement solutions.

Third, this course aims to increase your familiarity with randomized experiments so you can be a smarter consumer of claims that interventions cause certain outcomes. The class will be suffused with randomized experiments and we will repeatedly discuss how confident one can be that intervention X causes outcome Y.
Applications of the material covered in this course include policy design, healthcare, energy, politics, education, finance, negotiation, risk management, diversity, human resource management, and organization of teams, among others.

Policy and Program Evaluation

(HKS) API-302. Analytic Frameworks for Policy
This course is jointly listed in FAS as Econ 1415.
This course develops abilities in using analytic frameworks in the formulation and assessment of public policies. It considers a variety of analytic techniques, particularly those directed toward uncertainty and interactive decision problems. It emphasizes the application of techniques to policy analysis, not formal derivations. Students encounter case studies, methodological readings, modeling of current events, the computer, a final exam, and challenging problem sets.
Suggested prerequisites: An understanding of intermediate-level microeconomic theory and the basics of decision analysis; API-101, API-102, or equivalent, are sufficient.

(SPH) GHP 228. Econometrics Methods in Impact Evaluation
The objective of this course is to provide students with a set of theoretical, econometric and reasoning skills to estimate the causal impact of one variable on another. Examples from the readings explore the causal effect of policies, laws, programs and natural experiments. We will go beyond estimating causal effects to analyze the channels through which the causal impact was likely achieved. The course will introduce students to a variety of econometric techniques in impact evaluation and a set of reasoning skills intended to help them become both a consumer and producer of applied empirical research. Students will learn to critically analyze evaluation research and to gauge how convincing the research is in identifying a causal impact. They will use these skills to develop an evaluation plan for a topic of their own, with the aim of stimulating ideas for dissertation research. This is a methods class that relies heavily on familiarity with regression analysis and econometrics. Coursework in econometrics is a pre-requisite for the course without exception. The course is intended for doctoral students who are finishing their course work and aims to help them transition into independent research. The aim of this course is to prepare doctoral students for the dissertation phase of their research and thus they will be given priority in enrollment. The course is also open to masters students, conditional on having adequate training and the course having enough space.
Prerequisite: Coursework in econometrics is required and some coursework in economics is beneficial but not strictly required. Some previous experience with regression analysis and applied economic research will be a huge advantage. Students seeing applied regression analysis for the first time in this course will most likely struggle with the reading.

(SPH) HPM 543. Quantitative Methods for Policy Evaluation
This course will give students the tools that they need to evaluate policy interventions, social programs, and health initiatives. Did the program achieve its goals? Did it reach its target audience? Could it have been more effective? In order to answer these questions, students will develop a flexible set of analytical tools, including both the ability to design an evaluation study and the ability to evaluate existing studies critically.
By the end of the course students will be able to construct a well-designed study to answer well-posed questions, gauge the adequacy of available data, implement an econometric analysis, interpret the results of such studies, and

draw policy implications. The course will focus on health policies and programs such as public insurance expansions and public health campaigns, but the techniques will be broadly applicable to other realms such as welfare or education.
Course Note: The material in this course is inherently quantitative, and builds on a base of statistics fundamentals. The prerequisite is a course in basic statistics and probability, such as BIO 200, BST 201, BST 202/203, ID 538, ID201 or equivalent. This includes knowledge of confidence intervals and hypothesis testing. It also includes familiarity with the statistical package of your choice- ideally STATA, but SAS or SPSS are fine. During the course students will be given data sets to analyze, but there will be no instruction on the mechanics of opening and manipulating the data with a statistical software package. Students should contact instructor if they are uncertain about whether they have adequate preparation for the class.
Prerequisite: BIO200 or BST201 or BST202&203, or BST206&(207 or 208) or ID538 or ID201 or equivalent.

Probability and Statistics

(SPH) BST 230. Probability I
Jointly listed in FAS as Biostatistics 230
Axiomatic foundations of probability, independence, conditional probability, joint distributions, transformations, moment generating functions, characteristic functions, moment inequalities, sampling distributions, modes of convergence and their interrelationships, laws of large numbers, central limit theorem, and stochastic processes.
Course Prerequisites: You must be a Biostatistics student or have taken BST222 to register for this course. If you have taken BST222 and are not a Biostatistics student, please ask the instructor for an instructor override.

(SPH) BST 231. Statistical Inference I
Jointly listed in FAS as Biostatistics 231
A fundamental course in statistical inference. Discusses general principles of data reduction: exponential families, sufficiency, ancillarity and completeness. Describes general methods of point and interval parameter estimation and the small and large sample properties of estimators: method of moments, maximum likelihood, unbiased estimation, Rao-Blackwell and Lehmann-Scheffe theorems, information inequality, asymptotic relative efficiency of estimators. Describes general methods of hypothesis testing and optimality properties of tests: Neyman-Pearson theory, likelihood ratio tests, score and Wald tests, uniformly and locally most powerful tests, asymptotic relative efficiency of tests.
Prerequisite: Biostatistics 230.

(FAS) Statistics 111. Introduction to Statistical Inference
The course is designed for undergraduates as their first introduction to rigorous statistical inference. Understanding the foundations will allow you to see more deeply into individual methods and applications, placing them in context and able to learn new ones (and invent new ones!) much faster having understood broad principles of inference.
Prerequisite: Mathematics 19a and 19b or equivalent and Statistics 110.

(FAS) Statistics 210. Probability I
Random variables, measure theory, reasoning by representation. Families of distributions: Multivariate Normal, conjugate, marginals, mixtures. Conditional distributions and expectation. Convergence, laws of large numbers, central limit theorems, and martingales.
Prerequisite: Statistics 110 or equivalent required.

(FAS) Statistics 211. Statistical Inference I
Foundations of frequentist and Bayesian inference, and decision theory. Likelihood, sufficiency, and ancillarity. Point estimation, unbiasedness, maximum likelihood, method of moments, minimum-variance. Parametric and non-parametric hypothesis testing, confidence intervals. Selective inference: multiple testing, familywise error rate, false discovery rate. Bayesian inference, conjugate priors, credible intervals. Admissibility, Stein's phenomenon, empirical Bayes. Time permitting: post-selection inference and the bootstrap.
Prerequisite: Statistics 111 and 210 or equivalent.

Data Analysis

(FAS) APMTH 207. Advanced Scientific Computing: Stochastic Methods for Data Analysis, Inference and Optimization

Develops skills for computational research with focus on stochastic approaches, emphasizing implementation and examples. Stochastic methods make it feasible to tackle very diverse problems when the solution space is too large to explore systematically, or when microscopic rules are known, but not the macroscopic behavior of a complex system. Methods will be illustrated with examples from a wide variety of fields, like biology, finance, and physics.

(SPH) BST 210. Applied Regression Analysis
Topics include model interpretation, model building, and model assessment for linear regression with continuous outcomes, logistic regression with binary outcomes, and proportional hazards regression with survival time outcomes. Specific topics include regression diagnostics, confounding and effect modification, goodness of fit, data transformations, splines and additive models, ordinal, multinomial, and conditional logistic regression, generalized linear models, overdispersion, Poisson regression for rate outcomes, hazard functions, and missing data. The course will provide students with the skills necessary to perform regression analyses and to critically interpret statistical issues related to regression applications in the public health literature.
Prerequisites: ID201 or BST201 or (BST202 and BST203) or (BST206 and (BST207 or BST208)).

(SPH) BST 213. Applied Regression for Clinical Research
This course will introduce students involved with clinical research to the practical application of multiple regression analysis. Linear regression, logistic regression and proportional hazards survival models will be covered, as well as general concepts in model selection, goodness-of-fit, and testing procedures. Each lecture will be accompanied by a data analysis using SAS and a classroom discussion of the results. The course will introduce, but will not attempt to develop the underlying likelihood theory. Background in SAS programming ability required.
Course Prerequisites: ID201 or BST201 or (BST202 & BST203) or [BST206 & (BST207 or BST208)]. Concurrent enrollment allowed.

(SPH) BST 223. Applied Survival Analysis
BST 223 is a course on survival analysis, or more generally time-to-event analysis, with the primary audience being graduate students pursuing a Masters degree in biostatistics or a PhD in one of the other departments at the Harvard Chan School. Covered in the course will be: an introduction to various types of censoring and truncation that commonly arise; the mathematical representations of time-to-event distributions, such as via the hazard and survivor functions; nonparametric methods such as Kaplan-Meier estimation of the survivor function and log-rank test for hypothesis testing; semi-parametric and parametric regression modeling techniques, such as the Cox model, the accelerated failure time model, the additive hazards model and cure fraction models; survival analysis within the causal inference paradigm; the analysis of competing and semi-competing risks; outcome-dependent sampling schemes, such as nested case-control and case-cohort designs; and, power/sample size calculations for studies with time-to-event endpoints. Throughout, equal emphasis will be given to the theoretical/technical underpinnings of survival analysis and to the use of real world data examples.
Course Prerequisites: BST210 or BST213 or BST 232 or BST 260 or PHS2000A.

(SPH) BST 226. Applied Longitudinal Analysis
This course covers modern methods for the analysis of repeated measures, correlated outcomes and longitudinal data, including the unbalanced and incomplete data sets characteristic of biomedical research. Topics include an introduction to the analysis of correlated data, analysis of response profiles, fitting parametric curves, covariance pattern models, random effects and growth curve models, and generalized linear models for longitudinal data, including generalized estimating equations (GEE) and generalized linear mixed effects models (GLMMs).Course Activities: Homework assignments will focus on data analysis in SAS using PROC GLM, PROC MIXED, PROC GENMOD, and PROC GLIMMIX.
Course Prerequisite: BST210 or BST213 or BST232 or BST260 or PHS2000A.

(SPH) BST 228. Applied Bayesian Analysis
This course is a practical introduction to the Bayesian analysis of biomedical data. It is an intermediate Master's level course in the philosophy, analytic strategies, implementation, and interpretation of Bayesian data analysis. Specific topics that will be covered include: the Bayesian paradigm; Bayesian analysis of basic models; Bayesian computing: Markov Chain Monte Carlo; STAN R software package for Bayesian data analysis; linear regression; hierarchical regression models; generalized linear models; meta-analysis; models for missing data. Programming and case studies will be used throughout the course to provide hands-on training in these concepts.
Prerequisites: (BST210 or PHS 2000A&B) and BST222, or permission of the instructor.

(SPH) BST 232. Methods
Jointly listed at FAS as Biostatistics 232
Introductory course in the analysis of Gaussian and categorical data. The general linear regression model, ANOVA, robust alternatives based on permutations, model building, resampling methods (bootstrap and jackknife), contingency tables, exact methods, logistic regression.
Prerequisite: BST 210 and BST 222 or permission of the instructor.

(SPH) BST 249. Bayesian Methodology in Biostatistics
General principles of the Bayesian approach, prior distributions, hierarchical models and modeling techniques,approximate inference, Markov chain Monte Carlo methods, model assessment and comparison. Bayesian approaches to GLMMs, multiple testing, nonparametrics, clinical trials, survival analysis.
Prerequisite: BST231 and BST232 or instructor permission required.

(SPH) BST 267. Introduction to Social and Biological Networks
Many systems of scientific and societal interest consist of a large number of interacting components. The structure of these systems can be represented as networks where network nodes represent the components and network edges the interactions between the components. Network analysis can be used to study how pathogens, behaviors and information spread in social networks, having important implications for our understanding of epidemics and the planning of effective interventions. In a biological context, at a molecular level, network analysis can be applied to gene regulation networks, signal transduction networks, protein interaction networks, and more. This introductory course covers some basic network measures, models, and processes that unfold on networks. The covered material applies to a wide range of networks, but we will focus on social and biological networks. To analyze and model networks, we will learn the basics of the Python programming language and its NetworkX module.
The course contains a number of hands-on computer lab sessions. There are five homework assignments and four reading assignments that will be discussed in class. In addition, each student will complete a final project that applies network analysis techniques to study a public health problem.
Prerequisites: BST201 or ID201 or (BST202 & 203) or [BST206 & (BST207 or 208)]

(FAS) Government 1021. Spatial Models of Social Science
This course will survey the theory and application of airborne and satellite remote sensing, primarily as a tool for spatial social science. Students will learn the basics of electromagnetic radiation, reflection and absorption, satellite and sensor technology, and digital image analysis, with a focus on data acquisition and preparation. Students will learn the use of software for image processing and analysis, the fundamentals of raster GIS, and the use of a scriptable online platform for quick remote processing. Applications will have a social focus, including urbanization and development, infrastructure, settlement morphology, change detection, and interactions between the human and natural environments. Available for undergraduate and graduate students.

(FAS) Government 2002. Quantitative Social Science Methods II
This course provides a rigorous foundation necessary for quantitative research in the social sciences. After reviewing the basic probability theory, we offer a systematic introduction to the linear model and its variants -- the workhorse models for social scientists. We cover the classic linear regression model, least squares estimation and projection, fixed and random effects models, principal components analysis, instrumental variables, flexible regression models, and regularization for high dimensional data. In covering these topics, we deepen our knowledgeof fundamental concepts in statistical inference while also demonstrating how these methods are applied in political science.

(FAS) Government 2003. Causal Inference with Applications
Substantive questions in empirical scientific and policy research are typically causal. This class introduces students to both statistical theory and the practice of causal inference. As theoretical frameworks, we discuss potential outcomes, causal graphs, randomization and model-based inference, sensitivity analysis, and partial identification. We also cover important methodological tools, including randomized experiments, regression discontinuity designs, matching, regression, instrumental variables, difference-in-differences, and dynamic causal models.
Course Requirements: Gov 2001 and 2002 or the permission of the instructor.

(FAS) Government 2004. Introduction to Machine Learning
This course serves as a graduate-level introduction to machine/statistical learning for social scientists. It will cover some, but not all, common techniques to collect, analyze and utilize large and unstructured data for social science questions. The general goal of this course is to introduce students to modern machine learning techniques and

provide the skills necessary to apply the methods widely. Note, this course does not utilize Python or Julia. All computation work is conducted in R.

(FAS) Statistics 139. Linear Models
An in-depth introduction to statistical methods with linear models and related methods. Topics include group comparisons (t-based methods, non-parametric methods, bootstrapping, analysis of variance), linear regression models and their extensions (ordinary least squares, ridge, LASSO, weighted least squares, multi-level models), model checking and refinement, model selection, cross-validation. The probabilistic basis of all methods will be emphasized.
Prerequisite: Statistics 110 and Math 21a and 21b, or equivalent.

(FAS) Statistics 149. Generalized Linear Models
Sequel to Statistics 139, emphasizing common methods for analyzing continuous non-normal and categorical data. Topics include logistic regression, log-linear models, multinomial logit models, proportional odds models for ordinal data, Gamma and inverse-Gaussian models, over-dispersion, analysis of deviance, model selection and criticism, model diagnostics, and an introduction to non-parametric regression methods.
Note: Examples will be drawn from several fields, particularly from biology and social sciences.
Prerequisite: Statistics 139 or with permission of instructor.

(FAS) Statistics 160. Design and Analysis of Sample Surveys
Methods for design and analysis of sample surveys. The toolkit of sample design features and their use in optimal design strategies. Sampling weights and variance estimation methods, including resampling methods. Brief overview of nonstatistical aspects of survey methodology such as survey administration and questionnaire design and validation (quantitative and qualitative). Additional topics: calibration estimators, variance estimation for complex surveys and estimators, nonresponse, missing data, hierarchical models, and small-area estimation.
Prerequisite: Statistics 111 or 139 or with permission of instructor.

(FAS) Statistics 171. Introduction to Stochastic Processes
An introductory course in stochastic processes. Topics include Markov chains, branching processes, Poisson processes, birth and death processes, Brownian motion, martingales, introduction to stochastic integrals, and their applications.
Prerequisite: Statistics 110 and Math 21a and 21b, or equivalent.

(FAS) Statistics 186. Introduction to Causal Inference
Causal inference concerns the very difficult, challenging problem of addressing questions such as, "Would vaccinating children 16 and younger against COVID 19 lead to fewer deaths among public school teachers?" and "Would providing Harvard students access to a mobile health application designed to help them manage school stress, lead to improved school performance?" This class will include 4 modules. The first module introduces the nuanced world of causal inference along with a fundamental tool: the language of potential outcomes. The second module covers randomized experiments and how data from randomized experiments can be used to make causal statements. The third module introduces the rather tricky problem of using observational (non-randomized) data to attempt to make causal statements. The final module introduces a new and challenging area in which the goal is to make causal inference about the effect of sequences of treatments.
Prerequisite: (1) Stat 110 AND Stat 111 or (2) Gov 2000 AND Gov 2001.

(FAS) Statistics 220. Bayesian Data Analysis
Basic Bayesian models, followed by more complicated hierarchical and mixture models with nonstandard solutions. Includes methods for monitoring adequacy of models and examining sensitivity of models.
Note: Emphasis throughout term on drawing inferences via computer simulation rather than mathematical analysis.
Prerequisite: Statistics 110 and 111.

(FAS) Statistics 221. Monte Carlo Methods & Other Computational Tools for Statistical Learning
Computational methods commonly used in statistics: random number generation, optimization methods, numerical integration, Monte Carlo methods including Metropolis-Hastings and Gibbs samplers, approximate inference techniques including Expectation-Maximization algorithms, Laplace approximation and variational methods, data augmentation strategies, data augmentation strategies.
Note: Computer programming exercises will apply the methods discussed in class.

Prerequisite: Linear algebra, Statistics 111, and knowledge of a computer programming language (R or Matlab) required; Statistics 220 recommended.

(EDU) S-030. Intermediate Statistics for Educational Research: Applied Linear Regression
Are scores on high stakes tests primarily a function of socioeconomic status? Do mandatory seat belt laws save lives? In this course, students will learn how to use a set of quantitative methods referred to as the general linear model--regression, correlation, analysis of variance, and analysis of covariance--to address these and other questions that arise in educational, psychological, and social research. The course strategy will be to learn statistical analysis by doing statistical analysis. During the semester, students will address a variety of substantive research questions by analyzing dozens of data sets and fitting increasingly sophisticated regression models.
Prerequisite: Permission of instructor required. Enrollment procedure will be posted on the course website.

(EDU) S-052. Intermediate and Advanced Statistical Methods for Applied Educational Research
This course is designed for those who want to extend their data analytic skills beyond a basic knowledge of multiple regression analysis and who want to communicate their findings clearly to audiences of researchers, practitioners, and policymakers. S-052 contributes directly to the diverse data analytic toolkit that the well-equipped empirical researcher must possess in order to perform sensible analyses of complex educational, psychological, and social data. The course begins with general linear models and continues with generalized linear models, survival analysis, multilevel models, multivariate methods, causal inference, and measurement. Specific methods exemplifying each of these topics include regression, discrete-time survival analysis, fixed- and random-effects models, principal components analysis, instrumental variables, and reliability, respectively. S-052 is an applied course. It offers conceptual explanations of statistical techniques and provides many opportunities to examine, implement, and practice these techniques using real data. Students will learn to produce readable and sensible code to enable others to replicate and extend their analyses. Attendance at weekly sections is required.
Prerequisite: Successful completion of S-040 (B+ or better allowed, A- or A recommended) or an equivalent course or courses that include 12 or more full hours of class time on multiple regression and its direct extensions.

(HKS) API 222. Machine Learning and Big Data Analytics
In the last couple of decades, the amount of data available to organizations has significantly increased. Individuals who can use this data together with appropriate analytical techniques can discover new facts and provide new solutions to various existing problems. This course provides an introduction to the theory and applications of some of the most popular machine learning techniques. It is designed for students interested in using machine learning and related analytical techniques to make better decisions in order to solve policy and societal level problems.
We will cover various recent techniques and their applications from supervised, unsupervised, and reinforcement learning. In addition, students will get the chance to work with some data sets using software and apply their knowledge to a variety of examples from a broad array of industries and policy domains. Some of the intended course topics (time permitting) include: K-Nearest Neighbors, Naive Bayes, Logistic Regression, Linear and Quadratic Discriminant Analysis, Model Selection (Cross Validation, Bootstrapping), Support Vector Machines, Smoothing Splines, Generalized Additive Models, Shrinkage Methods (Lasso, Ridge), Dimension Reduction Methods (Principal Component Regression, Partial Least Squares), Decision Trees, Bagging, Boosting, Random Forest, K-Means Clustering, Hierarchical Clustering, Neural Networks, Deep Learning, and Reinforcement Learning.
Prerequisite: An understanding of intermediate-level statistics and probability theory (e.g., API-201, API-202, or equivalent courses).

(MIT) 17.802. Quantitative Research Methods II: Causal Inference
Survey of statistical methods for causal inference in political science and public policy research. Covers a variety of causal inference designs, including experiments, matching, regression, panel methods, difference-in-differences, synthetic control methods, instrumental variables, regression discontinuity designs, quantile regression, and bounds.
Prerequisite: 17.800 or 17.803

<u>Epidemiology and Clinical Trials</u>

(SPH) BST 214. Principles of Clinical Trials
Designed for individuals interested in the scientific, policy, and management aspects of clinical trials. Topics include types of clinical research, study design, treatment allocation, randomization and stratification, quality control, sample size requirements, patient consent, and interpretation of results. Students design a clinical

investigation in their own field of interest, write a proposal for it, and critique recently published medical literature.
Course Prerequisites: BST201 or ID201 or (BST202 & 203) or [BST206 & (BST207 or 208)] or PHS 2000A.

(SPH) EPI 204. Analysis of Case-Control, Cohort and Other Epidemiologic Data
This course will examine, through practical examples, the use of regression methods for analyses of epidemiologic data, primarily case-control and cohort studies. Methods used will include linear, logistic, Poisson, conditional logistic and Cox regression models. The lectures will focus on the principle ideas and issues underlying the regression analyses, and the computer labs will provide practical experience applying those methods, using SAS software. Issues to be dealt with include dose-response, confounding, violation of standard assumptions, and interaction. It will emphasize analysis and interpretation of results in the context of the study design. Familiarity with basic SAS is required, as this will be used in the labs. This can be met through BIO 113 (Introduction to Data Management and Programming in SAS) or other significant SAS experience.
Course Activities: Written group projects, class discussion, quizzes, homework.
Course Note: Computer lab is required, please sign up for one lab session when registering.
Course Prerequisites: (BST210 (concurrent enrollment allowed) or BST213 or PHS2000A/B) and (EPI200 or EPI201 or EPI208 or EPI505) and EPI202.

(SPH) EPI 207. Advanced Epidemiologic Methods
Provides an in-depth investigation of statistical methods for drawing causal inferences from observational studies. Informal epidemiologic concepts such as confounding, selection bias, overall effects, direct effects, and intermediate variables will be formally defined within the context of a counterfactual causal model and with the help of causal diagrams. Methods for the analysis of the causal effects of time-varying exposures in the presence of time dependent covariates that are simultaneously confounders and intermediate variables will be emphasized. These methods include g-computation algorithm estimators, inverse probability weighted estimators of marginal structural models, g-estimation of structural nested models. As a practicum, students will reanalyze data sets using the above methods.
Course Activities: Class discussion, homework, practicum and final examination.
Course Note: Familiarity with logistic regression and survival analysis is expected; lab time will be announced at first meeting.
Course Prerequisites: EPI204 or (BST210 and EPI289) or BST233. Students outside of HSPH must request instructor permission to enroll in this course.

(SPH) EPI 221. Pharmacoepidemiology
This course provides an overview on inference about the effects of pharmaceuticals and other medical products on health outcomes from case reports, case series, vital statistics and other registration schemes, cohort studies, and case-control studies. Decision-making with inadequate and imperfect data is examined from the perspectives of manufacturers, regulators, and researchers. This course is intended primarily as an introduction to pharmacoepidemiology for students wishing to pursue a career in pharmacoepidemiology as well as a survey course for those who may be consumers of pharmacoepidemiologic studies, but may also have more general interest as an applied mid-level course with a methodological emphasis.
Course Activities: Written individual and group assignments, modelled after real-world scientific contributions (e.g., letter to the editor, peer review of pharmacoepidemiologic study) and class discussion.
Course Note: Knowledge of epidemiology at the level of EPI 2012 and a basic understanding of drug use and nomenclature are assumed.

(SPH) EPI 233. Research Synthesis and Meta-Analysis
Concerned with the explosion of biological data for etiologic inquiry and the use of existing data to inform public health decision-making, the course focuses on research synthesis and meta-analysis. This course provides an introduction to the rationale, methods, and implications for conducting a synthesis of research findings. You will receive step-by-step guidance on how to conduct and evaluate systematic reviews that may also include a meta-analysis. The course will introduce research databases, reference management software, pooled estimates and sources of heterogeneity and bias, and practical applications.
Course Activities: Students will learn the principles of a systematic review, to use existing meta-analysis software to apply principles outlined in the course on example data sets, and, on a topic of their choice, to conduct a critical review or meta-analysis that appropriately weights effect estimates in each study, assesses uncertainty, and incorporates other kinds of scientific data in the overall analysis.
Course Prerequisites: Course Restricted to HSPH Degree Students and PHD-PHS students who have completed at least 1 semester and have not taken BST 225.

(SPH) EPI 289. Epidemiologic Methods III: Models for Causal Inference
Causal Inference is a fundamental component of epidemiologic research. EPI289 describes models for causal inference, their application to epidemiologic data, and the assumptions required to endow the parameter estimates with a causal interpretation. The course introduces outcome regression, propensity score methods, the parametric g-formula, inverse probability weighting of marginal structural models, g-estimation of nested structural models, and instrumental variable methods. Each week students are asked to analyze the same data using a different method.
Course Note: EPI289 is designed to be taken after EPI201/EPI202 and before EPI204 and EPI207. Epidemiologic concepts and methods studied in EPI201/202 will be reformulated within a modeling framework in EPI289. This is the first course in the sequence of EPI core courses on modeling (EPI289, EPI204, EPI207). EPI289 focuses on time-fixed dichotomous exposures and time-fixed dichotomous and continuous outcomes. Continuous exposures and failure time outcomes (survival analysis) will be discussed in EPI204, and time-varying exposures in EPI207. Familiarity with either SAS or R language is strongly recommended.
Course Prerequisite(s): EPI201 and EPI202; may not be taken concurrently.

Disease and Health Systems Modeling

(SPH) EPI 260. Mathematical Modeling of Infectious Diseases
This course will cover selected topics and techniques in the use of dynamical models to study the transmission dynamics of infectious diseases. Class sessions will primarily consist of lectures and demonstrations of modeling techniques. Techniques will include design and construction of appropriate differential equation models, equilibrium and stability analysis, parameter estimation from epidemiological data, determination and interpretation of the basic reproductive number of an infection, techniques for sensitivity analysis, and critique of model assumptions. Specific topics will include the use of age-seroprevalence data, the effects of population heterogeneity on transmission, stochastic models and the use of models for pathogens with multiple strains. This course is designed for students with a basic understanding of mathematical modeling concepts who want to develop models for their own work.
Course Note: Previous course in calculus is required.
Prerequisites: EPI501; may be taken concurrently.

(SPH) EPI 501. Dynamics of Infectious Diseases
This course covers the basic concepts of infectious disease dynamics within human populations. Focus will be on transmission of infectious agents and the effect of biological, ecological, social, political, economic forces on the spread of infections. We will emphasize the impact of vaccination programs and other interventions. The dynamics of host-parasite interaction are illustrated using basic mathematical modeling techniques. A key component of the course is the introduction to the programming mathematical modeling techniques. A key component of the course is the introduction to the programming language R, which we will use for all mathematical modeling activities and examples.
Course Activities: In-class demonstrations and practical sessions, written homework assignments and final class debate. Previous coursework in epidemiology and programming helpful but not required.

(SPH) GHP 201. Advanced Modeling for Health System Analysis & Priority Setting
This course directly builds on GHP 501, and offers advanced methods for modeling for health system analysis and priority setting in global health. Students will apply a range of techniques to address central topics, including: health disparities; medical impoverishment and financial risk protection; economic evaluations for health policyassessment; health system modeling; health system performance and country performance on health.
Through readings, basic programming using R software (www.r-project.org), and research projects, students will develop their research skills around three main areas of application, with an emphasis on low- and middle-income countries:

I. Economic evaluation for health policy assessment
II. Health system modeling
III. Efficiency, equity, and performance

Prerequisite: GHP 501

(SPH) GHP 501. Modeling for Health System Analysis & Priority Setting
This course offers an introduction to modeling for health system analysis and priority setting in global health, and its key quantitative methods. Students will learn to use a range of tools to address central concerns and topics, including: health disparities; medical impoverishment and financial risk protection; economic evaluations for health

policy assessment; health system performance and country performance on health. Modeling for health system analysis – and therefore this course – draws from the disciplines of global public health, health services research, epidemiology, economics and applied mathematics. Through readings, homework, basic programming using R software (www.r-project.org), and a research assignment, students will gain solid quantitative knowledge of the field.
The course is designed around three main areas of inquiry and application, with an emphasis on low- and middle-income countries:

I. Economic evaluation for health policy assessment
II. Health system modeling
III. Efficiency, equity, and performance

Decision Theory, Optimization Theory, and Operations Research

(FAS) Economics 2057. Stochastic Choice
In traditional microeconomic theory the choice correspondence is deterministic. This coure explores models of stochastic choice, such as random utility, discrete choice models in econometrics, and models of rational inattention, imperfect cognition, and drift-diffusion in behavioral economics.
Prerequisite: Basic microeconomic theory at the level of Mas Colell, Whinston, Green; being comfortable with abstract models.

(FAS) Economics 2059. Decision Theory
This course prepares students for pure and applied research in axiomatic decision theory. We start with a rigorous treatment of the classical topics that are at the heart of all of economics (utility maximization, expected utility, discounted utility, Bayesian updating, dynamic consistency, option value). We then delve into a number of modern topics inspired by the observed violations of the classical models ("exotic preferences" used in macro-finance, ambiguity aversion, temptation and self-control). The last part of the course explores the recently flourishing literature on stochastic choice (which is related to, but distinct from, discrete choice econometrics).
Prerequisite: Basic microeconomic theory at the level of Mas Colell, Whinston, Green; being comfortable with abstract models.

(FAS) Statistics 234. Sequential Decision Making
This graduate course will focus on reinforcement learning algorithms and sequential decision making methods with special attention to how these methods can be used in mobile health. Reinforcement learning is the area of machine learning which is concerned with sequential decision making. We will focus on the areas of sequential decision making that concern both how to select optimal actions as well as how to evaluate the impact of these actions. The choice of action is operationalized via a policy. A policy is a (stochastic) deterministic mapping from the available data at each time t into (a probability space over) the set of actions. We will consider both off-line and on-line methods for learning good policies.
Mobile health is an area that lies within multiple scientific disciplines including: statistical science, computer science, behavioral science and cognitive neuroscience. This makes for very exciting interdisciplinary science! Smartphones and wearable devices have remarkable sensing capabilities allowing us to understand the context in which a person is at a given moment. These devices also have the ability to deliver treatment actions tailored to the specific needs of users in a given location at a given time. Figuring out when and in which context, which treatment actions to deliver can assist people in achieving their longer term health goals. In the last 15-20 minutes of many of the classes we will brainstorm about how the methods we discussed during that class might be useful in mobile health.

This course will cover the following topics: Markov Decision Processes, on-policy and off-policy RL, least squares methods in RL and Bayesian RL, namely posterior sampling. Most of the course will focus on Bayesian RL via posterior sampling. This is particularly useful in mobile health as posterior sampling facilitates off-policy and continual learning. Also the Bayesian paradigm facilitates use of prior data in initializing an RL algorithm. Other topics from statistics, machine learning and RL that I think are potentially important in mobile health but that we won't cover are (you could consider in your class project) include: 1) transfer learning (using data on other similar users to enable faster learning); 2) non-stationarity (dealing with slowly changing or abrupt changes in user behavior); 3) interpretability of policies (enabling communication with behavioral scientists by making connections to behavioral theories); 4) using approximate system dynamic models to speed up learning, 5) hierarchical RL, 6) experience replay and 7) multi-task learning.

(MIT) 6.255J/15.093J. Optimization Methods
Introduces the principal algorithms for linear, network, discrete, robust, nonlinear, and dynamic optimization. Emphasizes methodology and the underlying mathematical structures. Topics include the simplex method, network flow methods, branch and bound and cutting plane methods for discrete optimization, optimality conditions for nonlinear optimization, interior point methods for convex optimization, Newton's method, heuristic methods, and dynamic programming and optimal control methods. Expectations and evaluation criteria differ for students taking graduate version; consult syllabus or instructor for specific details.
URL: http://stellar.mit.edu/S/course/15/fa08/15.093/index.html

(MIT) 14.128. Dynamic Optimization and Economic Applications
Dynamic systems: local and global analysis. Deterministic and stochastic dynamic programming: theory and numerical implementation. Euler equations. Markov processes: weak and strong convergence. Applications.

(MIT) 15.871. Introduction to System Dynamics
Introduction to systems thinking and system dynamics modeling applied to strategy, organizational change, and policy design. Students use simulation models, management flight simulators, and case studies to develop conceptual and modeling skills for the design and management of high-performance organizations in a dynamic world. Case studies of successful applications of system dynamics in growth strategy, management of technology, operations, public policy, product development, and others. Principles for effective use of modeling in the real world. Meets with 15.873 first half of term when offered concurrently. Students taking 15.871 complete additional assignments
Note: You must pre-register and participate in Sloan's Prioritization process to take this subject.

(MIT) 15.872. System Dynamics II
Emphasizes tools and methods needed to apply systems thinking and simulation modeling successfully in diverse real-world settings, including supply chains, forecasting, project management, process improvement, service operations, and platform-based businesses, among others. Uses simulation models, management flight simulators, and case studies to deepen the conceptual and modeling skills introduced in 15.871. Through models and case studies of successful applications students develop proficiency in how to use qualitative and quantitative data to formulate and test models, and how to work effectively with senior executives to implement change successfully. Expectations and evaluation criteria differ for students taking half-term graduate version; consult syllabus or instructor for specific details.
Note: You must pre-register and participate in Sloan's Prioritization process to take this subject.

(MIT) 15.879. Research Seminar in System Dynamics
Doctoral level seminar in system dynamics modeling, with a focus on social, economic and technical systems. Covers classic works in dynamic modeling from various disciplines and current research problems and papers. Participants critique the theories and models, often including replication, testing, and improvement of various models, and lead class discussion. Topics vary from year to year.

Ethics of Resource Allocation

(FAS) Economics 2082. Social Choice Theory
A basic course in social choice theory and its analytical foundations. The subject matter will include possibility theorems in voting and in welfare economics. Attention will be paid to implementation theory, the theory of justice, and the analysis of liberties and rights.

(SPH) ID 250. Ethical Basis of the Practice of Public Health
This course serves as an introduction to ethical issues in the practice of public health. Students will identify a number of key ethical issues and dilemmas arising in efforts to improve and protect population health and will become familiar with the principal arguments and evidence supporting contesting views. The class aims to enhance the students' capacity for using ethical reasoning in resolving the ethical issues that will arise throughout their careers.

Unlike courses in medical ethics, which mainly examine ethical dilemmas facing individual clinicians, the population-level focus of this course directs our attention to questions of ethics and justice that must be addressed at

the societal level.

These include:

- What social response is required of a just society to the needs of its members for protecting and restoring health?
- Is population health something other than the aggregate of the health concerns of the individuals who make up a society at a given time? And what are the ethical implications of the answers?
- When are inequalities in health inequitable, and what priority should be assigned to reducing disparities in health when pursuing this goal might compromise the effort to maximize population health?
- Which ethical choices, if any, are unavoidable in developing the methodologies for measurement of health and of the global burden of disease?
- Which ethical choices if any are unavoidable in developing and using methods for priority-setting such as cost-effectiveness analysis and cost-benefit analysis? Are the ethical commitments of the profession of public health consistent with some methods and not others?
- Should the institution of universal health coverage be guided by ethical precepts and if so, what are these values and how should they guide policy?
- Can and should public health's dedication to improving population health conflict with the priorities of some individuals whose choices to not reflect such high priority for health? Should these individual preferences always be respected? Are there effective strategies that pursue population health in the face of such conflicts while preserving the individual's freedom to make unhealthy choices?
- How should responsibility for poor health be assigned, and what are the ethical implications of this assignment for poor health due to health problems due to smoking, obesity, and other unhealthy behavior? To the extent that the socio-economic health gradient reflects differences in how well people take care of themselves are these disparities in health individual failings rather than social injustices?