Network Science Institute
at Northeastern University

Network Science PhD Program
Handbook

ACADEMIC YEAR 2025-2026

ACADEMIC DIRECTOR

Esteban Moro

Professor

College of Science

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Network Science Program Faculty Members

Boston (MA, USA) Campus

ALBERT-LÁSZLÓ BARABÁSI

László Barabási is the Robert Gray Dodge Professor of Network Science and a Distinguished University Professor of Physics. He investigates biological networks, science of success, applications of control theory to networks, development of network models of resiliency in systems.

NICK BEAUCHAMP

Nick Beauchamp is an Associate Professor in the Department of Political Science. He investigates how political opinions form and change as a result of discussion, deliberation, and argument in political domains using techniques from machine learning, automated text analysis, and social network analysis.

JESSICA DAVIS

Jessica Davis is an Assistant Research Professor in the Department of Public Health and Health Sciences at Bouvé College. Her research combines network science methods with data-driven epidemic modeling to respond to emerging infectious disease outbreaks. Her work aims to inform public health policies and enhance preparedness for future outbreaks by bridging the gap between theory and practice.

TINA ELIASSI-RAD

Tina Eliassi-Rad is a Professor of Computer Science and the Inaugural Joseph E. Aoun Chair. Her research lies at the intersection of AI and network science and covers theory, algorithms, and a wide range of applications. She is also interested in the impact of science and technology on society.

BROOKE FOUCAULT WELLES

Brooke Welles is a Professor of Communication Studies in the College of Arts, Media and Design. Her research examines how social networks shape behavior, including how individuals identify resources within their social networks and leverage them to achieve personal and organizational goals.

MICHAEL JOHANSSON

Michael Johansson is a Research Professor in the Department of Public Health and Health Sciences at Bouvé College of Health Sciences. He investigates the dynamics and drivers of infectious disease spread with a focus on research to improve surveillance, prevention, and control for endemic, epidemic, and emerging pathogens.

BRENNAN KLEIN

Brennan Klein is an Assistant Teaching Professor in the Department of Physics and the director of the MS program in Complex Network Analysis. His work focuses on two broad topics: 1) Information, emergence, and inference in complex systems — developing theory and tools for characterizing dynamics, structure, and scale in networks, and 2) Public health and public safety — creating and analyzing large-scale datasets that reveal inequalities in the U.S., from epidemics to mass incarceration.

DIMA KRIOUKOV

Dima Krioukov is a Professor in the Departments of Physics, Mathematics, and Electrical & Computer Engineering. He works on theory and foundations of network science, as well as its applications to real-world networks in computer science, neuroscience, quantum gravity, and cosmology.

DAVID LAZER

David Lazer is a University Distinguished Professor in the Department of Political Science and College of Computer and Information Science, and co-director of the NULab for Texts, Maps, and Networks. His research interests include group learning in technology-mediated environments; consensus and opinion formation in groups, particularly in political settings, or pertaining to governance.

ALINA LUNGEANU

Alina Lungeanu is an Assistant Professor of Communication Studies in the College of Arts, Media and Design, with a joint appointment in the D'Amore-McKim School of Business in the Management and Organizational Development Group. Her research combines insights from social science and network science to examine how team networks configure to advance the frontier of science.

ESTEBAN MORO

Esteban Moro is a Professor in the Physics Department and the Director of the PhD Program in Network Science. His work lies at the intersection of big data, network science, and computational social science, with a focus on human dynamics, collective intelligence, social networks, and urban mobility in areas such as natural disaster management, segregation, and economic resilience in cities. Esteban leads the Social Urban Networks (SUN) group that focuses on developing computational social science tools to address urban challenges.

CHRISTOPH RIEDL

Chris Riedl is a Professor for Information Systems at the D'Amore-McKim School of Business. He employs business analytics and data science to investigate research questions about group-decision making, network science, and social media, and develops novel computational approaches to study collective intelligence mechanisms.

MAURICIO SANTILLANA

Mauricio Santillana is a Professor in the Departments of Physics with a joint appointment in the Department of Electrical & Computer Engineering. His research is in mathematical modeling and scientific computing, specializing in the analysis of big data sets in multiple contexts to understand and predict the behavior of complex systems. He also has expertise in the design and analysis of numerical methods to solve partial differential equations (PDEs) for a diverse array of applications.

SAMUEL V. SCARPINO

Samuel Scarpino is a Professor in the Department of Public Health and Health Sciences at Bouvé College of Health Sciences, and the director of AI + Life Sciences in the Institute for Experiential AI at Northeastern. Sam is a complex systems scientist investigating questions at the intersection of network science and human

behavior, whose work spans a broad range of topics, including infectious disease modeling, forecasting in complex systems, genetic topology of disease, and decision making under uncertainty.

BRIONY SWIRE-THOMPSON

Briony Swire-Thompson is an Assistant Professor in the Department of Political Science with a joint appointment in the Department of Psychology. Her research examines what drives belief in inaccurate information, why people share misinformation online, and how corrections can be designed to maximize impact. She is currently funded by a Pathway to Independence Award from the National Institutes of Health to study cancer misinformation.

ALESSANDRO VESPIGNANI

Alessandro Vespignani is the Director of the Network Science Institute and Sternberg Family Distinguished University Professor with interdisciplinary appointments in the College of Computer and Information Science, College of Science, and the Bouvé College of Health Sciences. His research interests include complex systems & networks and the data-driven computational modeling of epidemics.

Roux Institute (Portland, Maine) Campus

MATTEO CHINAZZI

Matteo Chinazzi is an Associate Research Professor in the Department of Physics and a member of the Roux Institute. He conducts research at the intersection between network science, data science, epidemiology, economics, and artificial intelligence. His research interests include the development of computational and analytical models to study and forecast the spatial spread of infectious diseases and the development of agent-based models to create realistic representations of population dynamics.

GUILLAUME ST-ONGE

Guillaume St-Onge is an Assistant Research Professor in the Department of Physics and a member of the Roux Institute. He works on mathematical and computational methods to model contagion dynamics, notably epidemic forecasts, pandemic preparedness, and global bio surveillance. His research includes the study of nonlinear systems, stochastic processes, complex networks, and human dynamics.

AMANDA PEROFSKY

Amanda Perofsky is an Assistant Research Professor in the Department of Public Health and Health Sciences at Bouvé College, with joint appointments in the Network Science Institute, Roux Institute, and Institute for Experiential AI. She is a computational biologist who combines statistical, mathematical, and machine learning approaches to investigate the ecological, evolutionary, and behavioral drivers of infectious disease dynamics, with aims to improve disease surveillance and outbreak preparedness. She also produces operational forecasts and scenario projections of respiratory virus outbreaks.

Northeastern London (UK) Campus

RICARDO DI CLEMENTE

Riccardo Di Clemente is an Associate Professor at Northeastern University London. Riccardo develops mathematical frameworks to analyze and model the complex social connections that govern human behavior and interactions within cities and online. His research utilizes network theory, complex systems computational social science, and machine learning methods to investigate the digital footprints left by individuals in their daily routines.

IACOPO IACOPINI

Iacopo Iacopini is an Associate Professor at Northeastern University London. His research interests are in complex networks and computational social sciences, with a focus on behavioral contagion, discovery processes, group, and team dynamics.

ISTVÁN Z. KISS

István Z. Kiss is a Professor at Northeastern University London. His research is at the interface of network science, dynamical systems and stochastic processes, and concerns both theoretical and data-driven problems. Examples include network inference, exactness of mean-field models, temporal and higher-order networks, adaptive/dynamic networks, resilience of power networks and the study of spreading processes in general.

GIOVANNI PETRI

Giovanni Petri is a Professor at Northeastern University London. His research spans the analysis of neuroimaging data and AI systems with topological techniques, the formalization of cognitive control models with tools of statistical mechanics and network theory, and the study of the predictability of socio-technical systems.

SOFIA TEIXEIRA

Andreia Sofia Teixeira is an Associate Professor at Northeastern University London. Sofia's work is in the intersection of network science and machine learning, focusing on developing measures, computational models, and simulation frameworks to better understand the structure and dynamics of complex systems in domains such as computational social sciences, computational epidemiology, network neuroscience, health, crypto economics, evolutionary game theory, among others.

Program Overview

Northeastern University offers a full-time doctoral program culminating in a PhD in Network Science. The objective of the program is to train a select group of students to become experts in the interdisciplinary field of network science. Network science research covers a broad range of topics, including Control of Networks, Computation Social Science, Biological Networks, Spreading and Influence, Group-Decision Making, Data and Graph Mining, and Network Geometry.

Faculty Advisor

Each student will be assigned at least one primary faculty advisor from the Network Science doctoral program faculty upon admission to the program. Students admitted to work with faculty members on campuses other than the Boston campus are expected to relocate to their advisor's campus no later than the beginning of their second year of study.

Course Requirements

A minimum of 40 semester hours (SH) of coursework is required. Prerequisites do not count towards the 40 SH requirement. The graduate program may recommend additional coursework based on student research interests and in consultation with the student's faculty advisor.

Prerequisites

Students must complete all course prerequisite requirements or show equivalent knowledge.

Core Requirements (20 SH)

All network science students must take the following five core courses, unless otherwise approved by the PhD Program Director:

1. NETS 5116: Network Science 1
2. NETS 6116: Network Science 2
3. NETS 7332: Machine Learning with Graphs
4. NETS 7334: Social Network Analysis
5. NETS 7335: Dynamical Processes in Complex Systems

Elective Courses (Specializations) (20 SH)

Students must take 20 semester hours (SH) of electives. This coursework must be graduate level (5000-9999) and relevant to the students' research. Students must discuss their course plan with and receive approval from their advisor.

Students may choose to follow a specialization path to deepen their knowledge in methods and/or domain area. Students can take courses from one or from multiple specialization paths:

- Computer Science
- Epidemiology & Public Health
- Math-Physics/Theory
- Computational Social Science

In addition to the courses listed below, further course selections are listed in the Course Descriptions section of this handbook and in the academic catalog.

Students who wish to get program credit for courses not listed in this handbook and/or the academic catalog must get written approval from their advisor and the PhD Program Director. Generally, all academic and technical courses directly related to the student's research area will receive approval. For courses focused on professional skills and development, a maximum of four semester hours may be applied toward the twelve-credit elective program requirement.

COMPUTER SCIENCE SPECIALIZATION	S.H.
PHYS 7332 NETWORK SCIENCE DATA 2	4
NETS 8941 NETWORK SCIENCE LITERATURE REVIEW SEMINAR	2
CS 5800 ALGORITHMS	4
CS 6120 NATURAL LANGUAGE PROCESSING	4
CS 6140 MACHINE LEARNING	4
CS 6220 DATA MINING TECHNIQUES	4
CS 7180 SPECIAL TOPICS IN ARTIFICIAL INTELLIGENCE	4
CS 7260 VISUALIZATION FOR NETWORK SCIENCE	4
CS 7295 SPECIAL TOPICS IN DATA VISUALIZATION	4
CNET 5901 VISUALIZING COMPLEX NETWORKS	2
CNET 5902 COMMUNICATING NETWORK DATA	2
NETS 7976 DIRECTED STUDY	1-4
NETS 7983 TOPICS	4

EPIDEMIOLOGY & PUBLIC HEALTH SPECIALIZATION	S.H.
PHYS 7332 NETWORK SCIENCE DATA 2	4
NETS 8941 NETWORK SCIENCE LITERATURE REVIEW SEMINAR	2
PHTH 5202 INTRODUCTION TO EPIDEMIOLOGY	3
PHTH 5210 BIOSTATISTICS IN PUBLIC HEALTH	3
PHTH 6202 INTERMEDIATE EPIDEMIOLOGY	3
PHTH 6400 PRINCIPLES OF POPULATION HEALTH 1	3
PHTH 6410 PRINCIPLES OF POPULATION HEALTH 2	3
PHTH 6800 CAUSAL INFERENCE IN PUBLIC HEALTH RESEARCH	3
NETS 7370 COMPUTATIONAL URBAN SCIENCE	4
CNET 5126 SPREADING ON NETWORKS: FROM EPIDEMICS TO THE MEMES	4
CNET 5515 COMPLEX NETWORK ANALYSIS FOR BIOLOGICAL SYSTEMS	4
CNET 5901 VISUALIZING COMPLEX NETWORKS	2
CNET 5902 COMMUNICATING NETWORK DATA	2
NETS 7976 DIRECTED STUDY	1-4
NETS 7983 TOPICS	4

MATH-PHYSICS/THEORY SPECIALIZATION S.H.

PHYS 7332 NETWORK SCIENCE DATA 2	4
NETS 8941 NETWORK SCIENCE LITERATURE REVIEW SEMINAR	2
CS 5800 ALGORITHMS	4
MATH 7233 GRAPH THEORY	4
MATH 7243 MACHINE LEARNING AND STATISTICAL LEARNING THEORY 1	4
PHYS 5211 INTRODUCTION TO SCIENTIFIC COMPUTING	4
PHYS 7305 STATISTICAL PHYSICS	4
PHYS 7321 COMPUTATIONAL PHYSICS	4
CNET 5901 VISUALIZING COMPLEX NETWORKS	2
CNET 6061 ANALYZING HIGHER-ORDER NETWORKS	4
CNET 6063 PROBABILISTIC MATHEMATICS OF NETWORKS	4
NETS 7976 DIRECTED STUDY	1-4
NETS 7983 TOPICS	4

COMPUTATIONAL SOCIAL SCIENCE SPECIALIZATION S.H.

PHYS 7332 NETWORK SCIENCE DATA 2	4
NETS 7341 NETWORK ECONOMICS	4
NETS 7350 BAYESIAN AND NETWORK STATISTICS	4
NETS 7360 RESEARCH DESIGN FOR SOCIAL NETWORKS	4
NETS 7370 COMPUTATIONAL URBAN SCIENCE	4
NETS 7976 DIRECTED STUDY	1-4
NETS 7983 TOPICS	4
NETS 8941 NETWORK SCIENCE LITERATURE REVIEW SEMINAR	2
CNET 5126 SPREADING ON NETWORKS: FROM EPIDEMICS TO MEMES	4
CNET 5314 COMPLEXITY IN SOCIAL SYSTEMS	4
CNET 5411 FINANCIAL AND ECONOMIC NETWORKS	4
CNET 5901 VISUALIZING COMPLEX NETWORKS	2
CNET 5902 COMMUNICATING NETWORK DATA	2

Dissertation

Pre-Candidacy

When not taking a full-time courseload, students should register for the following course prior to passing the comprehensive exam (dissertation proposal):

- NETS 8986 Research

Dissertation

After passing the comprehensive exam (dissertation proposal) and successfully reaching candidacy, candidates must register for the following courses, sequentially:

- NETS 9990 Dissertation 1
- NETS 9991 Dissertation 2

Dissertation Continuation

After completing Dissertation 1 and Dissertation 2, candidates should register for the following course until they have completed their dissertation:

- NETS 9996 Dissertation Continuation

Course Plans

Sample Course Plan – 40 SH

YR	FALL	S.H.	SPRING	S.H.
1	NETS 5116 Network Science 1	4	NETS 6116 Network Science 2	4
	Two electives (1, 2)	8	NETS 7334 Social Networks	4
			Elective course (3)	4
2	NETS 7332 Machine Learning with Graphs	4	NETS 7335 Dynamical Processes	4
	Elective course (4)	4	Elective course (5)	4
3	Qualifying Exam Research		Comprehensive Exam (Dissertation Proposal) Research	
4	Dissertation 1		Dissertation 2	
5	Dissertation Continuation		Dissertation Continuation	

Alternate Course Path

Students have the option to complete core coursework in their first year of study. This curriculum pathway is expected for students whose admitting advisor is located outside of the Boston campus and elsewhere in the Northeastern network.

Sample Course Plan, Alternate – 40 SH

YR	FALL	S.H.	SPRING	S.H.
1	NETS 5116 Network Science 1	4	NETS 6116 Network Science 2	4
	NETS 7332 Machine Learning with Graphs	4	NETS 7334 Social Networks	4
	Elective (1)	4	NETS 7335 Dynamical Processes	4
2	Two Electives (2,3)	8	Two Electives (4, 5)	8
3	Qualifying Exam Research		Comprehensive Exam (Dissertation Proposal) Research	
4	Dissertation 1		Dissertation 2	
5	Dissertation Continuation		Dissertation Continuation	

Course Waivers

Students may petition for waivers of specific course requirements based on graduate coursework that demonstrates equivalent academic preparation.

Course waiver petitions must include the following documentation:

- Course identification: Name and course number of the course for which a waiver is sought.
- Transcript: Documentation of previously completed coursework demonstrating successful completion.
- Course syllabus: Detailed syllabus from the previously completed course that clearly demonstrates the academic content, scope, and rigor meet or exceed the requirements of the course for which a waiver is sought.
- Students must demonstrate graduate-level competency in the academic content and learning outcomes equivalent to the course requirements. The prior coursework must align with the academic standards and learning objectives of the target course.

All course waiver requests undergo individual review by the PhD Program Director and the Academic Committee. Decisions are made on a case-by-case basis considering the specific merits of each petition.

Students granted course waivers must fulfill the program's total credit requirement by completing an additional elective course to maintain the required credit hours for degree completion.

Transferring Credits

Students may petition to transfer previously completed graduate coursework to fulfill elective requirements within the program. Transfer credits may not be applied toward core curriculum requirements, nor may credits previously applied to a completed degree be eligible for transfer. For doctoral programs, a maximum

of 30% of the total semester hours of required coursework may be granted upon the recommendation of the admitting college's graduate committee.

Transfer credit petitions must include the following documentation:

- Course identification: Name and course number of the target course for which transfer credit is sought.
- Transcript: Documentation of previously completed coursework demonstrating successful completion.
- Course syllabus: Detailed syllabus from the previously completed course that clearly demonstrates the academic content, scope, and rigor meet or exceed the requirements of the course for which credit transfer is requested.
- Verification of non-application towards prior degree: Official attestation from the issuing institution that the completed course credits were not utilized in the completion of any previous degree requirements.

Students must demonstrate graduate-level competency in the academic content and learning outcomes equivalent to the course requirements. The prior coursework must align with the academic standards and learning objectives of the target course.

All transfer credit requests undergo individual review by the PhD Program Director and the Academic Committee. Decisions are made on a case-by-case basis considering the specific merits of each petition.

Full Time Status

Students must maintain full time status and carry a courseload of at least 8 semester hours (SH) each term, including summer. Students taking any of the following courses are considered full-time:

- NETS 8986 Research
- NETS 9990 Dissertation 1
- NETS 9991 Dissertation 2
- NETS 9996 Dissertation Continuation

Academic Progress & Annual Review

Academic progress is evaluated at the end of the first and second years. Students must maintain a minimum cumulative GPA of 3.0. Students cannot retake courses without the express permission of the PhD Program Director. Students failing to meet GPA requirements or demonstrate satisfactory dissertation progress may be subject to dismissal by the Graduate Program Committee.

In addition to satisfactory progress in coursework, students are expected to excel in their research obligations under the direction and supervision of their faculty advisor. Failure to meet research obligations may result in the loss of funding, termination from the program, or both.

Students' overall progress in the program is formally evaluated at the end of each academic year. The annual review process requires students to submit comprehensive documentation to the Academic Review Committee, including:

1. A record of courses completed during the preceding academic year and proposed coursework for the subsequent year.

2. A concise summary of research progress achieved during the preceding academic year and research objectives for the following year.

This documentation, in addition to similar documentation from the student's advisor, serves as the foundation for the Committee's assessment of satisfactory progress. If the student does not meet satisfactory progress they will be put on academic probation.

Academic Probation

Students may be placed on academic probation when their faculty advisor(s) and the PhD Program Director determine that satisfactory expectations have not been met by the conclusion of a given semester. Unsatisfactory performance encompasses:

- Insufficient progress in coursework or research activities.
- Inadequate communication with faculty advisor(s) or program administration.
- Receipt of an "Unsatisfactory" (U) grade.

Probation is implemented retroactively upon semester completion. Following the assessment period, students determined to have performed unsatisfactorily during the evaluated semester will be placed on probationary status. The subsequent semester serves as the remediation period during which students must demonstrate improved performance.

Students on probation are required to collaborate with their advisor(s) and the PhD Program Director to develop a comprehensive performance improvement plan that includes specific, measurable objectives and corrective actions, a clear timeline for achievement, mechanisms for regularly monitoring progress, and defined criteria for a return to return to good academic standing.

Students who fulfill all performance improvement plan requirements and demonstrate satisfactory progress will be restored to good academic standing upon completion of the probationary period. Students who fail to meet performance improvement plan requirements may be subject to a second probationary term, contingent upon evaluation by the advisor(s) and PhD Program Director.

Students who do not achieve satisfactory performance standards following two semesters on probation may face dismissal from the program. A dismissal may be overridden at the discretion of the PhD Program Director. The student and PhD Program Director must develop a Dismissal Override contract delineating a comprehensive remediation strategy and specific requirements for achieving good academic standing.

PhD Candidacy

A student becomes a PhD candidate upon completion of all required coursework with a minimum cumulative GPA of 3.0, satisfactory completion of the Qualification Exam, and satisfactory completion of the Comprehensive Exam.

Qualification Exam

The Qualification Exam is an hour-long oral examination of the material covered in the core curriculum, consisting of questions selected by Network Science faculty. Students receive between 50 to 80 questions to review for one month before the exam. Students are asked to give a short presentation of their research plans, followed by an oral exam where the qualifying exam panel will ask a subset of the review questions.

All students must sit for the exam in the fall, typically in their third year of the PhD program. Students, by request, may take the exam in the Spring of their first or second year, upon completion of the required core courses and upon receiving approval from both their advisor and the PhD Program Director. Students who fail to pass the Qualifying Exam on their first attempt must retake it in the following spring term.

Students may only take the Qualifying Exam twice.

Students who fail to pass the Qualifying Examination but who have completed all required coursework of the PhD program with a minimum cumulative GPA of 3.0 will be awarded a terminal Master of Science in Network Science degree.

Master in Network Science

Students may receive a master's degree in Network Science upon completion of the required coursework and meet the minimum semester hours for the doctoral degree. No students will be admitted directly into this program to pursue a master's degree. Students must have a cumulative average GPA of 3.0 or higher. The master's degree may be awarded to students "en route" towards their doctoral degree, or to students who have completed the required coursework and meet the minimum semester hours but either fail the Qualifying Exam twice or exit the program for other reasons.

Dissertation

PhD candidates should endeavor to complete their dissertation during their fifth year of study. Upon successful execution of the research plan outlined in the dissertation proposal, the candidate should prepare the dissertation for approval from their Dissertation Committee. The dissertation must present the results of comprehensive research and constitute an original contribution to the field. The work should demonstrate the candidate's capacity to conduct independent scholarly research. It is expected that the dissertation will comprise one or more research studies of sufficient rigor and significance to warrant publication in reputable peer-reviewed journals.

Dissertation Advisor & Committee

The program employs a mentorship model in which graduate students serve as research assistants within faculty laboratories, providing opportunities to pursue interdisciplinary research through network methodologies. Within this laboratory setting, responsibility for research collaboration progressively transitions from faculty advisor to student, culminating in the completion of the student's doctoral dissertation.

Students are expected to formally select their Dissertation Advisor by the conclusion of the spring semester of their second year. In most instances, the student's initial faculty advisor will serve as their Dissertation Advisor. Dissertation Advisors must hold a full-time, tenured, tenure-track, research, or teaching faculty position at Northeastern University. Advisors should be members of the Network Science doctoral program faculty, unless the student receives approval from the Network Science Program Committee.

Students may petition to change their Dissertation Advisor during their course of study. Such changes require formal approval from the prospective Dissertation Advisor, the graduate committee, and the academic director. In the event that a student's advisor departs from Northeastern University, the student may continue their established research trajectory under the guidance of a Northeastern faculty member serving as co-advisor. The designated co-advisor must first consent to assume the role of primary advisor and subsequently receive approval from both the graduate committee and the academic director. Under this

arrangement, the student will maintain dual advisement: an official Northeastern faculty member who will provide ongoing research guidance and administrative oversight, and the former Northeastern advisor. Should a new primary advisor be appointed, the former Northeastern faculty member may serve as an external Dissertation Committee member.

Students must confirm their Dissertation Committee prior to their comprehensive exam. The committee must consist of a minimum of four members:

1. Dissertation Advisor
2. A core member of the Network Science Institute faculty
3. An additional tenured/tenure-track, research, or teaching faculty member from the Network Science Institute or other Northeastern faculty approved by the Dissertation Advisor and program committee
4. An expert in the specific topic of research (can be external to Northeastern University)

Comprehensive Exam (Dissertation Proposal)

The comprehensive exam is expected to be completed in the student's 4th year of study and must precede the dissertation defense by at least two terms unless the student's advisor and the PhD Program Director give their approval for a shorter period of time between the two events.

The examination comprises two components:

Written Dissertation Proposal

Students must develop a comprehensive written research proposal that delineates their dissertation research plan, including a literature review of relevant scholarship, research questions, motivation, methodology, preliminary results (if applicable), and potential impact. The proposal must be distributed to the student's Dissertation Committee at least two weeks prior to the scheduled presentation.

Oral Presentation

Students must deliver a 30-minute oral presentation to their Dissertation Committee in a public forum, followed by a designated Question & Answer period open to all audience members. Subsequently, the Dissertation Committee will assess the proposed research plan and provide comprehensive feedback to the student.

Successful completion of the comprehensive exam requires a satisfactory evaluation of both the written proposal and oral presentation from the Dissertation Committee. Should the proposal and/or presentation fail to meet the Committee's expectations, the student will be required to revise their proposal and/or presentation accordingly. Students are permitted one opportunity to retake the comprehensive examination; failure to achieve a satisfactory outcome on the second attempt will result in dismissal from the program.

Dissertation Defense

The dissertation defense comprises two components: the written dissertation and oral defense of the dissertation. The PhD candidate must distribute the written dissertation to each member of their Dissertation Committee at least two weeks prior to the dissertation defense.

The oral dissertation defense will be open to the public and will include a formal Question & Answer session with the audience. Following the presentation, the Dissertation Committee will deliberate and communicate

whether the candidate has successfully fulfilled the dissertation requirement. Upon the successful completion of the dissertation requirement, the PhD candidate is eligible for graduation.

Students must apply to graduate and follow the formatting guidelines and deadlines of their home college.

Graduation

In order to graduate from the Network Science PhD program, a student must:

- Complete all the academic requirements and milestones as listed in the catalog corresponding to their matriculation year.
- Have a minimum cumulative GPA of 3.000 or higher.
- Be in good academic standing.
- Submit a Petition to Graduate.
- Complete a Graduate Approval Record.
- Submit their dissertation electronically to ProQuest/UMI.

Students should contact the College of Social Sciences and Humanities Graduate Office at gradcssh@northeastern.edu for any specific questions or concerns regarding graduation requirements, forms and deadlines of graduation documents, dissertation format, and submission policies.

For students who began the program in Fall 2019 or prior:

Students who matriculated into the NetSci PhD program prior to Fall 2020 will follow the graduation policies of the College of Science. Students should contact the College of Science Graduate Office at gradcos@northeastern.edu for any specific questions or concerns regarding graduation requirements, forms and deadlines of graduation documents, dissertation format, and submission policies.

College of Science Graduate Student Services

Program Learning Outcomes

1. Students will demonstrate a graduate-level understanding of foundational network science concepts, including:

    a. Formal methods to represent networks as mathematical structures;

    b. Essential data collection and data science techniques for networks;

    c. Statistical descriptors of networks;

    d. Measures and metrics of networks;

    e. Models of networks; and

    f. Dynamical processes on networks.

2. Students will also demonstrate a graduate-level understanding of non-network methods and approaches that enable network research, including:

    a. Probability and statistics;

    b. Measurement and research design;

    c. Machine learning and data science; and

       d.   Research ethics.

3.   Students will be able to describe ongoing research in the field of Network Science.

4.   Students will demonstrate understanding of a substantive domain application complementary to network science.

5.   Students will design and lead independent, original research projects related to network science.

6.   Students will communicate network science concepts, processes, and results effectively, verbally, visually, and in writing.

Student Responsibilities and Expectations

Faculty Advisor

The student's foremost academic obligation is to identify and maintain a faculty advisor throughout their enrollment in the program. Students must maintain good standing with their advisor through adherence to the following professional standards:

Regular Communication: Schedule and honor regular, agenda-driven meetings with the advisor.

Research Management: Establish clear research milestones in consultation with the advisor and provide early notification of any anticipated delays.

Academic and Research Engagement: Attend and actively contribute to all required group meetings and seminars.

Professional Communication: Demonstrate professional integrity, collegiality, and respect for an inclusive laboratory culture.

Feedback Integration: Actively seek and incorporate advisor feedback while engaging in discussions regarding academic progress and career development at minimum once per semester

Students without an active advisor will be placed on academic probation for the duration of that semester. Students must successfully establish an advisory relationship by the conclusion of the probationary semester or incur another semester of probation. After two semesters on probation, students may be dismissed from the program.

Academic Resources

Network Science PhD Program

Students are encouraged to contact the PhD Program Manager or the PhD Program Director for questions about degree progress, registration, program policies, and general support throughout the PhD journey.

Melissa Erlick, PhD Program Manager m.erlick@northeastern.edu

Esteban Moro, PhD Program Director e.moroegido@northeastern.edu

Academic Catalog

The Academic Catalog contains all requirements and expectations for students throughout their program. Students must refer to and follow requirements and policies listed in catalog in the year of their matriculation.

[Current Catalog (for students beginning in Fall 2025)](#)

[Catalog Archives (before Fall 2025)](#)

Degree Audit

The degree audit is the official record of the student's academic progress, including all coursework completed. Students should review this regularly and will be evaluated by the NetSci PhD review committee annually to ensure adequate progress is being made towards degree requirements. Students should contact the PhD Program Manager with any questions or concerns about their record.

[Graduate Degree Audit](#)

Course Registration & Academic Calendars

The Office of the Registrar offers comprehensive resources, including instructional articles and video tutorials, to support students in course registration processes and academic calendar management. Students are encouraged to utilize the following links to access essential academic information and resources.

[Academic Calendar](#)

[Registering for Courses/Dissertation (general instructions)](#)

[Registering for Individual Instruction (Directed Study)](#)

Student Life Resources

Network Science Institute (NetSI)

The Network Science Institute (NetSI) offers students access to collaborative workspaces, research seminars, and opportunities to engage in cutting-edge research projects. The institute fosters academic and professional development through regular events, workshops, and community-building initiatives designed to cultivate a vibrant and inclusive graduate experience. Students are encouraged to actively participate in these activities and contact the PhD Program Manager at m.erlick@northeastern.edu for guidance, support, and information on engagement opportunities.

College of Social Sciences and Humanities

The College of Social Sciences and Humanities (CSSH) provides resources for new and current graduate students. CSSH provides administrative and operational support that bridges the program with Northeastern University. Colleges disseminate key information about course registration, graduation policies, and stipend graduate assistantship deadlines.

Student Financial Services and Student Health Plan

Students should email gradcssh@northeastern.edu for college-level assistance. Full time PhD students may receive student health plan benefits and coverage for course tuition. Students are responsible for additional student fees that range from $100-$200 per year. Students should use the links below for more information, and to view student fees and access the student health plan waiver, if applicable.

Student Financial Services Fees

Student Health Plan Waiver

Health and Wellness

The University recognizes that graduate study presents unique challenges and potential stressors that may impact student wellbeing. In support of our commitment to student success, Northeastern University maintains comprehensive resources designed to promote and sustain optimal health and wellness throughout the graduate academic experience.

The following institutional resources are available to all enrolled graduate students to address various aspects of physical, mental, and emotional wellbeing. Students are encouraged to utilize these services proactively as part of their academic journey.

If additional resources or assistance with matters not addressed through the listed services are needed, students should contact the Senior Program Manager, who will provide appropriate guidance and referral support.

- Leave of Absence and University Withdrawal
- Disability Access Services
- LGBTQA+ Resource Center
- Center for Spirituality, Dialogue, and Service
- Office for University Equity and Compliance (Title IX)
- Graduate Ombuds (confidential, neutral, and informal resource for graduate students seeking to address concerns that may be impacting their studies)
- Graduate Student Government and Groups
- University Health and Counseling Support Groups

International Students

The Office of Global Services (OGS) offers a set of academic and cultural services to support international students. In addition to providing guidance on immigration status and managing requisite documentation, OGS offers comprehensive support services including resource directories and mentorship programs. Students can review all services through the website below.

Office of Global Services

Sample of services offered:

- Global Student Mentor Program
- Immigration Attorneys and Pro-Bono Legal Services
- Tax Information
- Global Student Success (GSS)

International students must maintain proper legal status to remain eligible for study in the United States. Students are advised to review the relevant topics outlined below and access the resources provided for additional guidance and support.

- Maintaining Status
- Research Abroad (international students only)
- F-1 Curricular Practical Training
- Leave of Absence (international students only)

OGS Contact Information:

Email address: ogs@northeastern.edu

Phone number: +1-617-373-2310

Phone Hours: Monday – Friday 8:30am – 4:30pm EST

Key Contacts for F-1 students:

Rachael Elliot, Director of Comprehensive Advising (DSO/ARO)

Desiree Waits, Director of International Student Services, U.S. Global Campus Network

Rachel Hollabaugh, Associate Director of Comprehensive Advising (DSO/ARO)

Alyssa Bulpett, Associate Director of Incoming International Student Services (DSO/ARO)

Simeon Rangelov, Associate Director of SEVIS Compliance & Operations (DSO/ARO)

Support

Students are provided with desk space, a computer monitor, mouse, and keyboard, and access to printers and basic office supplies. Students have access to all four floors of the Network Science Institute at 177 Huntington Ave (floors 2, 4, 10, & 11) with the ability to reserve meeting rooms and classroom spaces for research meetings or group activities.

Stipend Graduate Assistantships (SGAs)

All students are eligible to receive a Stipend Graduate Assistantship (SGA), meant to provide adequate support for basic living costs. The amount provided and any increases for SGAs are determined by the University. Unless students have external funds through external dissertation fellowships, or their employer, for example, the Network Science Program and the university are committed to fund SGAs for 5 academic years. In some cases, faculty advisor grant funds or other NU programs may offer to extend the SGA funding for the student to continue their SGA work and finish their dissertation.

Graduate students receiving funding through SGAs—NetSci Research Assistantships, grant or project funded Research Assistantships, and Teaching Assistantships— have a commitment to work for 20 hours per week. SGA work will differ depending on the project and advisor and will be discussed and clarified each semester by the SGA supervisor. Students must actively engage in the mentorship relationship with their assigned faculty advisors and complete all duties as assigned and supervised by their advisors throughout their appointment period.

Stipend Graduate Assistantships do not automatically renew between academic terms; therefore, students are responsible for maintaining regular communication with their faculty advisors regarding funding continuation. Students should proactively discuss their funding status and work with their advisors to ensure timely confirmation of support with the PhD Program Leadership each term to avoid interruptions in their assistantship funding.

The annual stipend rate at the Network Science Institute for the 2025-2026 academic year is $43,050, inclusive of summer funding. Stipend payments are disbursed on a bi-monthly schedule.

Flex Semester

Graduate students may elect to utilize a flex semester as an alternative to an SGA for one semester during their program of study. The flex semester is designed to allow students to concentrate on their own academic research without concurrent teaching or research obligations. Students must request approval from their faculty advisor to take the flex semester.

During the flex semester, students receive their full stipend through funding provided by the College of Social Sciences and Humanities. Stipend payments are disbursed in two installments over the course of the semester. Taxes are not withheld from these payments; students are advised to consult with a tax professional regarding the reporting of stipend income for tax purposes.

Students utilizing a flex semester maintain full tuition coverage and enrollment in the Northeastern University Student Health Plan.

Experiential Fellowship

Graduate students may pursue professional opportunities outside the university through experiential fellowships or external employment arrangements. If external compensation exceeds the standard SGA amount, students forfeit their SGA funding for the corresponding semester. If external compensation is less than the standard SGA amount, the SGA will supplement the difference to ensure students receive the full stipend amount for the semester.

Students who wish to maintain enrollment in Northeastern University's health insurance plan should decline any external health insurance offers, as acceptance may affect eligibility for university coverage.

External work arrangements should be strategically coordinated with academic semester schedules to prevent any disruption to SGA funding. Upon completion of an experiential fellowship, students typically resume their standard SGA without interruption.

Students may utilize experiential fellowships for professional experiences outside the United States, subject to appropriate visa and regulatory requirements. Students are strongly encouraged to consult with the relevant University offices prior to accepting external opportunities to discuss potential impacts on financial obligations, student status, and benefit eligibility.

Support for Conference & Workshop Travel

Students should initiate conversations with their advisor whenever funding needs arise in relation to professional development. Advisors have the responsibility to allocate their funds when appropriate to support students' work and professional development activities that directly relate to the student's research under their supervision.

Following the advisor's funding commitment, students may then seek additional funding opportunities from Northeastern (such as the PhD Network Travel Grant) and the Network Science Institute (such as the NetSci Travel Award) to supplement their advisor's contribution.

All reimbursements are granted via direct deposit in Concur. Students must submit their expenses for reimbursement in Concur no later than two weeks after the activity ends or the expense occurs.

NetSci Travel Award

The NetSci Travel Award serves as a complementary funding source to support funds that students have already secured from their advisors/labs, university resources, and institutional funding. Students may apply for up to $1,000 per year (September 1, 2025 – August 31, 2026) for professional development opportunities that contribute to their academic and research growth, such as travel to conferences and events. This is only available for students in the five-year funding window who are in good standing. Examples of how these funds can be used include:

- Travel, accommodations, and registration for conferences and academic/research institutes
- Laptops

Students are permitted to keep laptops purchased with these funds.

AY25-26 NetSci Travel Award Application

PhD Network Travel Grant

The PhD Network invites PhD students to make a request once a year (July 1, 2025 – June 30, 2026) for up to $500 in travel funding for conferences & events for which they are presenting research. It is expected that requests for travel funding will be matched with another source (advisor funds, department funds, etc.) and does not exceed 50% of the total cost of the travel. Proposals should be submitted at least 2 months prior to the travel.

PhD Network Travel Funding

NetSI Community Events Funds

The NetSI Community Events Fund supports initiatives that foster connections, knowledge, and relationships among NetSI members. Community events should be related to the research process, and/or impactful and fun applications of network science. Events should attempt to bring together the broader NetSI community. Activities should provide opportunities to explore network science beyond the classroom and foster collaborative discussions and interdisciplinary exchanges. All NetSI members (core and affiliates) are eligible to submit proposals and are encouraged to participate in Community activities.

Graduate Student Association

Students may organize into a formally recognized program as part of the Graduate Student Government managed by Northeastern's PhD Network, called the Graduate Student Association in Network Science (GSA). GSA is managed entirely by the students, with annual "elections" for leadership roles. GSAs may request up to $5000 from the university for student activities on an annual basis.

Course Descriptions

Network Science PhD Core Coursework

NETS 5116 – NETWORK SCIENCE 1
Introduces network science and the set of analytical, numerical, and modeling tools used to understand complex networks emerging in nature and technology. Focuses on the empirical study of real networks, with examples coming from biology (metabolic, protein interaction networks), computer science (World Wide Web, Internet), or social systems (e-mail, friendship networks). Shows the organizing principles that govern the emergence of networks and the set of tools necessary to characterize and model them. Covers elements of graph theory, statistical physics, biology, and social science as they pertain to the understanding of complex systems. (László Barabási, Rodrigo Durantes-Gilardi, Jonah Spector)

NETS 6116 – NETWORK SCIENCE 2
Further exploration of network science and the set of analytical, numerical, and modeling tools used to understand complex networks emerging in nature and technology. Focuses on the empirical study of real networks. Investigates the organizing principles that govern the emergence of networks and the set of tools necessary to characterize and model them. Builds a deeper understanding of complex systems. (Dima Krioukov)

NETS 7332 – MACHINE LEARNING WITH GRAPHS
Covers several advanced topics in machine learning and data mining on graphs, including vertex classification, graph clustering, link prediction and analysis, graph distance functions, graph embedding and representation learning, deep learning for graphs, anomaly detection, graph summarization, network inference, adversarial learning on networks, and notions of fairness in social networks. Seeks to familiarize students with state-of-the-art descriptive and predictive algorithms on graphs. Requires a foundational understanding of calculus and linear algebra, probability, machine learning or data mining, algorithms, and programming skills. (Tina Eliassi-Rad)

NETS 7334 - SOCIAL NETWORKS
Offers an overview of the literature on social networks, with literature from political science, sociology, economics, and physics. Analyzes the underlying topology of networks and how we visualize and analyze network data. Key topics include small-world literature and the spread of information and disease. (Alina Lungeanu)

NETS 7335 - DYNAMICAL PROCESSES IN COMPLEX NETWORKS
Immerses students in the modeling of dynamical processes (contagion, diffusion, routing, consensus formation, etc.) in complex networks. Includes guest lectures from local and national experts working in process modeling on networks. Dynamical processes in complex networks provide a rationale for understanding the emerging tipping points and nonlinear properties that often underpin the most interesting characteristics of socio-technical systems. The course reviews the recent progress in modeling dynamical processes that integrate the complex features and heterogeneities of real-world systems. (Jessica Davis, Alessandro Vespignani)

Network Science PhD Electives (Specialization) Coursework

NETS 7341 – NETWORK ECONOMICS

Covers seminal works in the economics of information and networks, including Akerlof, Arrow, Spence, Stiglitz, and von Hayek. Proceeds through concepts of information, its value, and measurement; search and choice under uncertainty; signaling, screening, and how rational actors use information for private advantage; strategy-given network effects; two-sided (or multisided) network effects, organizational information processing, learning, and social networks; and other micro- and macroeconomic effects such as matching markets. Although primarily a theory course, it may be of interest to any student applying information economics and network economics in academic, commercial, or government policy contexts. Expects students to produce a major paper suitable for publication or inclusion in a thesis. Requires prior completion of graduate coursework in microeconomics and mathematics at the level of introductory calculus and statistics. (Christoph Riedl)

NETS 7350 – BAYESIAN AND NETWORK STATISTICS

Introduces advanced quantitative methods including maximum likelihood, hierarchical models, sampling, and network modeling. Offers students an opportunity to engage in estimating and developing models from the probabilistic and Bayesian perspective and to pursue their own research project, focusing on methodological challenges. Reviews probability and examines maximum likelihood methods for estimating regression models with continuous and categorical dependent variables. Examines a variety of procedures for sampling from posterior distributions including grid, quadratic, Gibbs, and Metropolis sampling. Applies these methods to hierarchical modeling and other simple probabilistic models and then takes a closer look at the statistical modeling of networks as it has been developed in the social sciences (e.g., exponential random graph models, temporal models such as TERGM and SIENA, spatial network models, and stochastic block models). (Nick Beauchamp)

NETS 7360 – RESEARCH DESIGN FOR SOCIAL NETWORKS

Analyzes the architecture of research—how to design ethical research projects that empower the researcher to make useful and interesting claims about the world. Topics include design research about social networks and how to measure such varied relational concepts such as friendship, love, and proximity; the effective study of "recycled" data—data not collected for research—such as Twitter, cell phone, or email data, and the ethical constraints in using this data; and how to design data collection so as to make robust causal claims. (David Lazer)

NETS 7370 – COMPUTATIONAL URBAN SCIENCE

Introduces the field of computational urban science, focusing on methods to collect and analyze urban data. Covers techniques such as geographic information systems, network science, machine learning, spatial models, and causal inference to examine city dynamics and inform urban planning, policy, and research. Explores the application of these methods to real-world urban datasets, including mobile phone data, social media, and transactional data, enabling critical insights into the complexities of urban systems. (Esteban Moro)

NETS 7983 TOPICS

Covers various topics in network science. May be repeated up to two times for up to 12 total credits.

NETS 7976 DIRECTED STUDY

Offers independent work under the direction of a member of the program on a chosen topic. Course content depends on the instructor. May be repeated without limit.

NETS 8941 NETWORK SCIENCE LITERATURE REVIEW

Critically evaluates recent articles in the academic literature surrounding topics and applied research in network science. May be repeated up to three times. (Brennan Klein)

NETS 8986 RESEARCH

Offers an opportunity to conduct full-time research under faculty supervision. May be repeated without limit.

NETS 9990 DISSERTATION TERM 1

Offers experimental and theoretical work for PhD candidates. Requires written dissertation and final oral exam.

NETS 9991 DISSERTATION TERM 2

Offers dissertation supervision by members of the department.

NETS 9996 DISSERTATION CONTINUATION

Offers experimental and theoretical work for PhD candidates. Requires written dissertation and final oral exam.

Other Electives

CNET 5126 SPREADING ON NETWORKS: FROM EPIDEMICS TO MEMES

Explores fundamentals of contagion on networks, starting with simple disease dynamics in mean field systems and building to spreading processes on complex networks. Examines a variety of contagion modeling techniques, which include state-of-the-art techniques for using networks to forecast the trajectory of an infectious disease, the emergence of a best-seller, predicting elections, or even modeling cascading failures in infrastructure networks. Introduces a diverse range of datasets and case studies, which students may draw from for their final modeling/analysis project. From biological pathogens like SARS-CoV-2, Ebola, and influenza to social contagions like fake news, memes, and influencers, complex network analysis gives us powerful tools to understand contagion processes in our modern world.

CNET 5314 COMPLEXITY IN SOCIAL SYSTEMS

Offers an in-depth exploration of complex systems and networks. Emphasizes the modeling of social phenomena using physical models. Focuses on quantitative phenomenology to understand and describe emergent features observed in large-scale social phenomena. Aims to identify general behavioral classes, not based on microscopic definitions but on universal, large-scale characteristics. This approach is used to uncover mechanisms behind various social dynamics such as opinion consensus, cultural dissemination, collective motion, and social hierarchies. Examines a range of contagion phenomena, from biological disease spread to social and technological contagions, highlighting the impact of complexity inherent in social, biological, and cultural aspects on these propagation processes.

CNET 5411 FINANCIAL AND ECONOMIC NETWORKS

Identifies the complex web of financial and economic interactions that shape our global economy. Examines a wide range of relevant and emerging topics of today's interconnected world and approaches to studying these networks. Investigates the integration of techniques, applications, and the impact of network theory in these fields. Explores in-depth three main topics: trade, financial, and socioeconomic networks. Delves into network models of trade, leveraging input-output data to understand production, as well as firm-level supply chain analysis. Considers topics of finance, including banking and online systems, as well as financial transactions. Draws insights into microeconomic topics of knowledge creation, the labor market, and income inequality.

CNET 5515 COMPLEX NETWORK ANALYSIS FOR BIOLOGICAL SYSTEMS

Covers the properties of diverse biological networks and foundational computational methods for analyzing, visualizing, and performing statistical investigations of networked data. Investigates how physicists have uncovered remarkable regularities in networked systems by applying approaches from scaling theory to biological networks. Explores the diversity of biological networks and provides the foundational tools needed to study networks derived from real-world data, including tools from machine learning. Focusing on a series of case studies, studies how to elucidate the structure and function of biological networks using empirical data.

CNET 5901 VISUALIZING COMPLEX NETWORKS

Studies the knowledge and skills necessary to effectively visualize complex network data. Covers foundational principles of network data visualization and effective strategies to present core network properties to a range of different audiences. Offers students an opportunity to obtain experience using various network visualization tools such as Networkx and matplotlib, Gephi, and other web-based tools. Examines case studies to explore diverse network visualization approaches to effectively convey scientific insights, advance policy, and inform the public, including examples from such diverse fields as brain science, supply chains, epidemiology, and urban analytics. Students give and receive feedback, collectively building competency in how to create and interpret visualizations of complex data. Final projects are designed to prepare students for working with clients and collaborators from industry, nonprofits, government agencies, and research.

CNET 5902 COMMUNICATING NETWORK DATA

Examines critical aspects of conveying complex network data effectively and ethically. Explores not only how to simplify and articulate complex network concepts to various audiences but also grapples with the ethical implications of the work, ensuring that communication is not just effective but also responsible and legally compliant. This is done through a combination of lectures and reading, as well as through guest lecturers and case studies. Requires a final project presentation that is based on a previous project selected by the student and that offers new presentations of the material designed for two (imagined) audiences: a general audience and a technically trained audience. Designed to help students bridge the gap between technical network analysis and effective, ethical communication.

CNET 6061 ANALYZING HIGHER-ORDER NETWORKS

Delves into specialized network structures including temporal networks, higher-order networks (such as simplicial complexes and hypergraphs), and multilayer networks. Explores the dynamic aspects of temporal networks, the rich representation of relationships in higher-order networks, and the interconnected systems modeled by multilayer networks. By mastering the analysis and modeling of these advanced network

structures, aims to equip students to address complex real-world challenges across various domains, ranging from epidemiology and social sciences to transportation planning and resilience analysis.

CNET 6063 PROBABILISTIC MATHEMATICS OF NETWORKS

Introduces advanced probabilistic tools and statistical methodologies within the realm of network science. Offers students an opportunity to obtain the skills needed to navigate and analyze the complexities and inherent uncertainties of networked systems. Introduces basic probabilistic computing with probability generating functions, the development of message-passing algorithms, and their various applications in the field of network science. Focuses primarily on modeling complex dynamical systems and tackling statistical inference problems using real-world network data, demonstrating the depth and versatility of these techniques.

ARTG 5130 – VISUAL COMMUNICATION FOR INFORMATION DESIGN

Explores graphic and typographic theory, principles, and practices. Introduces students to visual communication design with a primary focus on typography as the fundamental means of conveying content. Readings locate design and typography within the larger history of visual art and writing development. Covers methods of organizing content through hierarchy and spatial organization of grid structures. Considers relationships between positive and negative space, depth perception, transparency, and color theory. Requires graduate standing or permission of program coordinator or instructor.

BIOL 6401 – RESEARCH METHODS AND CRITICAL ANALYSIS IN MOLECULAR CELL BIOLOGY

Encompasses biochemical and cell biological approaches to understanding cell structure and function, including membranes, organelles, vesicle trafficking, cytoskeleton, cell cycle, and signaling. Structured activities integrate critical analysis of recently published literature and methods. Offers students an opportunity to prepare for the professional practice of molecular cell biology. Permission of instructor required for those students not enrolled in biology.

CHEM 7317 – ANALYTICAL BIOTECHNOLOGY

Focuses on the analytical methods used for the characterization of recombinant DNA-derived proteins for human therapeutic use. Combines the description of advanced analytical methods, in particular HPLC and mass spectrometry, with protein chemistry. An important aspect is the development of a method that can identify protein modifications that are present in a product as a result of biosynthetic modifications, contaminants, or degradative reactions. Provides an integrative overview of the role of analytical methods at the different stages of development and production of protein therapeutics including upstream (cell line development, cell culture), downstream (recovery and purifications), formulation development, stability studies, and clinical assay.

CS 5800 - ALGORITHMS

Presents the mathematical techniques used for the design and analysis of computer algorithms. Focuses on algorithmic design paradigms and techniques for analyzing the correctness, time, and space complexity of algorithms. Topics may include asymptotic notation, recurrences, loop invariants, Hoare triples, sorting and searching, advanced data structures, lower bounds, hashing, greedy algorithms, dynamic programming, graph algorithms, and NP-completeness.

CS 6120 - NATURAL LANGUAGE PROCESSING
Provides an introduction to the computational modeling of human language, the ongoing effort to create computer programs that can communicate with people in natural language, and current applications of the natural language field, such as automated document classification, intelligent query processing, and information extraction. Topics include computational models of grammar and automatic parsing, statistical language models and the analysis of large text corpuses, natural language semantics and programs that understand language, models of discourse structure, and language use by intelligent agents. Course work includes formal and mathematical analysis of language models, and implementation of working programs that analyze and interpret natural language text.

CS 6140 - MACHINE LEARNING
Provides a broad look at a variety of techniques used in machine learning and data mining, and examines issues associated with their use. Topics include algorithms for supervised learning including decision tree induction, artificial neural networks, instance-based learning, probabilistic methods, and support vector machines; unsupervised learning; and reinforcement learning. Also covers computational learning theory and other methods for analyzing and measuring the performance of learning algorithms. Coursework includes a programming term project.

CS 6220 - DATA MINING TECHNIQUES
Covers various aspects of data mining, including classification, prediction, ensemble methods, association rules, sequence mining, and cluster analysis. The class project involves hands-on practice of mining useful knowledge from a large data set.

CS 7180 SPECIAL TOPICS IN ARTIFICIAL INTELLIGENCE
Offers various topics on artificial intelligence. May be repeated up to two times.

CS 7250 – INFORMATION VISUALIZATION: THEORY AND APPLICATIONS
Covers foundational as well as contemporary topics of interest in data visualization to enable the effective representation of data across disciplines, including examples drawn from computer science, physical sciences, biomedical sciences, humanities, and economics. Topics include data visualization theory and methodology, visualization design and evaluation, visual perception and cognition, interaction principles, and data encoding and representation techniques. Students who do not meet course restrictions may seek permission from the instructor.

CS 7260 – VISUALIZATION FOR NETWORK SCIENCE
Covers the principles of information visualization in the specific context of network science. Introduces visual encoding of data and our understanding of human vision and perception; interaction principles including filtering, pivoting, aggregation; and both quantitative and human subject evaluation techniques. Covers visualization techniques for several network types, including multivariate networks with attributes for entities and relationships, evolving and dynamic networks that change over time, heterogeneous networks with multiple types of entities, and geospatial networks. Offers students an opportunity to learn about the design of layout algorithms for node-link and matrix visualizations.

CS 7295 SPECIAL TOPICS IN DATA VISUALIZATION
Offers various topics in data visualization. May be repeated once.

CS 7300 – EMPIRICAL RESEARCH METHODS FOR HUMAN COMPUTER INTERACTION

Introduces concepts related to human subject studies for human computer interaction and personal health informatics. Discusses the methodological foundations, as well as issues of practical implementation and use. Provides an overview of the most common experimental designs used in these fields, and how studies should be proposed, conducted, analyzed, and documented for publication. Covers qualitative methods, including interviewing and focus groups, along with approaches to inductive qualitative data analysis. Methods discussed in the course are useful in any area of science that involves the application of the scientific method to situations involving people interacting with computational artifacts or systems, including observation, hypothesis formation, measurement, and descriptive and inferential statistical analyses.

CS 7340 – THEORY AND METHODS IN HUMAN COMPUTER INTERACTION

Covers the foundations of human abilities, computational artifacts, design, and evaluation. Human computer interaction concerns the design and evaluation of software based on a deep understanding of how humans interact with computers, devices, and sensors. The field merges theories from psychology and computer science, using methods from AI and design. Introduces cognitive, perceptual, and affective theories and theories of individual differences that allow us to design and develop better computer software and systems. Also covers research methods for designing and evaluating computer software systems. Topics discussed in the context of next-generation interaction modalities include sensors, haptics, wearables, and performative interfaces. Students who do not meet course restrictions may seek permission of instructor.

ECON 6140 – ADVANCED APPLIED ECONOMETRICS

Offers students an opportunity to obtain the theoretical tools, computer skills, and experience using econometrics needed to appreciate and do high-quality applied research in economics. Emphasizes understanding how the properties of estimators can be found and their implications for applied research. Introduces the programming language Python, which is integrated into the course. Focuses on methods that are most useful in microeconomic analysis, including classical linear regressions, Gauss-Markov theorem and hypothesis testing, endogeneity, instrumental variable estimation, and causality analysis, heteroskedasticity and serial correlations, nonlinearity, panel data methods, difference-in-difference, and regression discontinuity. This is the first advanced graduate-level course on econometrics.

JRNL 5400 – MEDIA AND ADVOCACY IN THEORY AND PRACTICE

Examines time-tested and cutting-edge methods for shaping and presenting messages across multimedia platforms to effectively disseminate an organization's message, change a public conversation, or shift public opinion. Examines case studies in mainstream media, public advocacy, and strategic communications to explore the motivations and methods of the organizations as well as the tools and techniques used. Examines the practice of digital advocacy by exploring and applying pertinent findings from politics, advertising, and behavioral science that are increasingly employed by professionals looking to "micro-target" voters, "convert" customers, or "nudge" the public. One major component of the course is hands-on workshops through which students are offered an opportunity to learn how to leverage the latest digital tools for communicating across social media and online platforms.

HIST 7370 – TEXTS, MAPS, AND NETWORKS: READINGS AND METHODS FOR DIGITAL HISTORY

Introduces the methods and practice of history in a digital age. Offers students an opportunity to see the wide variety of work being done computationally by historians and other humanists today and to obtain the background to be creative producers of new work and critical consumers of existing projects. The rise of

computing technology and the Internet has the potential to reshape all parts of historical practice, from curation to research to dissemination. Examines the historian's craft in three primary domains: the creation of digital sources, the algorithmic transformations that computers can enact on cultural materials like texts, and the new ecologies of publishing and scholarly communication made possible by new media.

INAM 6300 – MODELS FOR APPLIED INQUIRY IN CREATIVE PRACTICE

Focuses on thoughtful engagement with diverse and emerging forms of critical inquiry, professional engagement, and creative practice for artists, entrepreneurs, and administrators. Through course work and interaction with leading practitioners, offers students an opportunity to gain an understanding of the impact that forms of production and business models have on potential contribution to fields of critical practice and their diverse culture, while developing innovative models for their own creative, critical, and entrepreneurial endeavors.

INAM 7001 – RESEARCH METHODS IN INTERDISCIPLINARY DESIGN AND MEDIA

Offers an overview of research designs and methods across disciplines. Discusses how to select and use these methods and strategies and discusses IRB procedures. Includes guest presentations from faculty across the campus. This course is not meant as a comprehensive methodological training but rather an overview that should be complemented with at least one specialized methods course from a university-wide list of courses in the first semester of study and two others in the second semester of study.

MATH 7233 - GRAPH THEORY

Covers fundamental concepts in graph theory. Topics include adjacency and incidence matrices, paths and connectedness, and vertex degrees and counting; trees and distance including properties of trees, distance in graphs, spanning trees, minimum spanning trees, and shortest paths; matchings and factors including matchings in bipartite graphs, Hall's matching condition, and min-max theorems; connectivity, such as vertex connectivity, edge connectivity, k-connected graphs, and Menger's theorem; network flows including maximum network flow, and integral flows; vertex colorings, such as upper bounds, Brooks, theorem, graphs with large chromatic number, and critical graphs; Eulerian circuits and Hamiltonian cycles including Euler's theorem, necessary conditions for Hamiltonian cycles, and sufficient conditions; planar graphs including embeddings and Euler's formula, characterization of planar graphs (Kuratowski's theorem); and Ramsey theory including Ramsey's theorem, Ramsey numbers, and graph Ramsey theory.

MATH 7243 - MACHINE LEARNING AND STATISTICAL LEARNING THEORY 1

Introduces both the mathematical theory of learning and the implementation of modern machine-learning algorithms appropriate for data science. Modeling everything from social organization to financial predictions, machine-learning algorithms allow us to discover information about complex systems, even when the underlying probability distributions are unknown. Algorithms discussed include regression, decision trees, clustering, and dimensionality reduction. Offers students an opportunity to learn the implications of the mathematical choices underpinning the use of each algorithm, how the results can be interpreted in actionable ways, and how to apply their knowledge through the analysis of a variety of data sets and models.

MATH 7351 – MATHEMATICAL METHODS OF CLASSICAL MECHANICS

Overviews the mathematical formulation of classical mechanics. Topics include Hamilton's principle and Lagrange's equations; solution of the two-body central force problem; rigid body rotation and Euler's

equations; the spinning top; Hamilton's equations; the Poisson bracket; Liouville's theorem; and canonical transformations.

PHYS 5211 INTRODUCTION TO SCIENTIFIC COMPUTING
Presents areas of study or practice to which computational techniques can fruitfully be applied such as climate change, epidemiology, air travel, and finance. Offers students an opportunity to understand the strengths and limitations of frequently used computing methods to tackle current open problems. Identifies ways to validate the results obtained with such techniques. Introduces the background needed to understand well-established numerical and computational approaches and explores their use through practical examples from different disciplines such as physics, chemistry, biology, and finance.

PHYS 7301 – CLASSICAL MECHANICS/MATH METHODS
Covers mathematical methods of physics and classical mechanics. Topics include differential equations, boundary value problems, functions of a complex variable, linear vector spaces, Green's functions, Lagrangian and Hamiltonian mechanics, linear oscillators, and scattering. May include additional topics as time permits.

PHYS 7305 - STATISTICAL PHYSICS
Briefly reviews thermodynamics. Topics include the principles of statistical mechanics and statistical thermodynamics; density matrix; theory of ensembles; Fermi-Dirac and Bose-Einstein statistics, application to gases, liquids, and solids; theory of phase transitions; and thermodynamics of electric and magnetic systems, transport phenomena, random walks, and cooperative phenomena.

PHYS 7321 - COMPUTATIONAL PHYSICS
Covers basic numerical methods for differentiation, integration, and matrix operations used in linear algebra problems, discrete Fourier transforms, and standard and stochastic ordinary and partial differential equations. Specific applications of these methods may include classical chaos, computation of eigenstates of simple quantum systems, classical phase transitions, boundary value problems, pattern formation, and molecular dynamics and classical/quantum Monte Carlo methods to simulate the equilibrium and nonequilibrium properties of condensed phases.

PHYS 7332 – NETWORK SCIENCE DATA 2
Focuses on practical exercises in real network data. It offers students an opportunity to learn how to retrieve network data from the real world, analyze network structures and properties, study dynamical processes on top of the networks, and visualize networks. The main programming language used in this course is Python.

PHYS 7337 - STATISTICAL PHYSICS OF COMPLEX NETWORKS
Covers applications of statistical physics to network science. Focuses on maximum-entropy ensembles of networks and on applicability of network models to real networks. Main topics include microcanonical, canonical, and grand canonical ensembles of networks, exponential random graphs, latent variable network models, graphons, random geometric graphs and other geometric network models, and statistical inference methods using these models. Covers applications of maximum-entropy geometric network models to efficient navigation in real networks, link prediction, and community structure inference.

PHTH 5202 INTRODUCTION TO EPIDEMIOLOGY

Introduces the principles, concepts, and methods of population-based epidemiologic research. Offers students an opportunity to understand and critically review epidemiologic studies. Lectures and discussions aim to serve as a foundation for training in epidemiology, quantitative methods, and population-based health research. The course is a required introductory course for students in the Master of Public Health program and is appropriate for students who are interested in epidemiologic research. Students not meeting course restrictions may seek permission of the instructor.

PHTH 5210 BIOSTATISTICS IN PUBLIC HEALTH

Offers public health students an opportunity to obtain the fundamental concepts and methods of biostatistics as applied predominantly to public health problems and the skills to perform basic statistical calculations Emphasizes interpretation and comprehension of concepts. Topics include descriptive statistics, vital statistics, sampling, estimation and significance testing, sample size and power, correlation and regression, spatial and temporal trends, small area analysis, and statistical issues in policy development. Draws examples of statistical methods from public health practice. Introduces use of computer statistical packages. Requires permission of instructor for students outside designated programs.

PHTH 6202 INTERMEDIATE EPIDEMIOLOGY

Offers an intermediate-level course covering key principles, concepts, and methods of population-based epidemiologic research. Topics include observational study designs, measures of disease occurrence and association, validity and bias, confounding, effect modification, multivariate analysis for stratification and adjustment, critical appraisal and meta-analysis, mediation analysis, missing data analysis, and concepts and methods for strengthening causal inference. Offers graduate students unique opportunities to engage in practical applications, including critical reviews of published epidemiologic journal articles, and to conduct hands-on analyses of empirical datasets using SAS statistical software. Designed to serve as a foundation for further advanced training in specialized branches of epidemiology, quantitative methods, and epidemiologic research.

PHTH 6400 PRINCIPLES OF POPULATION HEALTH 1

Seeks to provide students with historical background and methodological and critical-thinking tools needed to perform high-quality, interdisciplinary research in population health. Using a problem-solving and interdisciplinary framework, offers students an opportunity to gain the skills to develop research hypotheses, design research strategies, analyze data to test study hypotheses, and communicate their findings both orally and in writing. Also offers students an opportunity to gain experience in research methodology and application of basic methods for population health research, including epidemiological and biostatistical concepts. Finally, students demonstrate their mastery of these skills through problem sets and through written proposals that include communication of preliminary data.

PHTH 6410 PRINCIPLES OF POPULATION HEALTH 2

Continues PHTH 6400, exploring additional population health research topics and methods and applying more advanced biostatistical and epidemiological analysis methods.

PHTH 6800 CAUSAL INFERENCE IN PUBLIC HEALTH RESEARCH

Exposes students to causal inference approaches, including causal diagrams and counterfactual theory. Students are also asked to draw upon their own research experiences and prior epidemiology training to evaluate public health studies. Covers how to apply the fundamental concepts of counterfactuals and

causal diagrams; assess threats to validity in study designs and analysis, including confounding, selection bias, and measurement error/misclassification; evaluate the validity of a public health research study's design and analysis with respect to addressing causal questions; and critically analyze scientific literature and apply findings to clinical or policy decisions. Offers students an opportunity to think critically and rigorously about the implications of study design and analysis toward addressing public health questions.