Masters in Quantitative and Systems Biology (QSB) Program

offered by

The Department of Molecular Biosciences, Northwestern University

Syllabus for 2021-2022

(version 2021-4-22)

Note: Syllabus is subject to revision as course scheduling and availability changes.

Courses whose quarter and time are not yet determined for 2021-2022

IBiS ### – Computational Network Analysis
Description: TBD
Instructor: Rosemary Braun
Time: Quarter and time TBD

Summer pre-quarter activities

Required activities:
Select thesis lab with assistance of the Program director
Develop a pre-arrival plan with thesis advisor
Begin reading background papers on field and project, begin any online courses/training

Year-round NU workshops, journal clubs and meetings (partial listing)

Registration costs included as part of QSB program)

NU Information Technology Workshops and Training:
https://www.it.northwestern.edu/research/campus-events/index.html
Description: Every year NUIT offers many workshops and training events, including:
Workshops:
R-fundamentals: Parts I, II and III
Programming Concepts Workshop
Git and GitHub: Introduction
Quest (NU supercomputer cluster) Introduction
Python: Scikit-learn (machine learning module for Python)
R: ggplot2
Data Drop-In Hours and Consultations:
NU provides free consultations and assistance for researchers
Time: TBD
DataCamp online courses
R, Python, SQL, command line, git, spreadsheets, and more
R User Group – meets monthly, Thursdays 4 PM

NSF-Simons Center for Quantitative Biology Journal Club:
https://www.quantitativebiology.northwestern.edu/resources/journal-club/
Description: Journal Clubs are held monthly to advance interdisciplinary communication and integrate knowledge between math and biology.
Time: Friday 2:00 PM

Data Science Nights: http://www.data-science-nights.org

Description: Monthly hack nights on popular data science topics, organized by northwestern university graduate students and scholars. each night will feature refreshments, a talk on data science techniques or applications, and a hacking night with data science projects or learning groups of your choice. Aspiring, beginning, and advanced data scientists are welcome!

Time: TBD (Pizza is served for in person sessions)

Data Visualization and Communication Practicum presented by the Biotechnology Training Program

Description: An all-day event in which invited speakers from NU as well as outside institutions and companies present their research/work data processing and presentation.

Time: TBD

September pre-quarter and early quarter activities

Required activities:

NICO 401 – Introduction to Programming for Big Data

Description: This course provides an introduction to the foundational skills needed by data scientists. Prior knowledge of programming is not needed.

Notable extra skills & opportunities: programming in Python

Instructors: Luis Amaral and Adam Pah

Time: Sept. ??-?? Times 9:30-12; 1:30-4 PM, course format: TBD

Imaging workshop – TBD

High Throughput Analysis Workshop - – TBD

12th Annual Biophysics Symposium

Time: Friday, Sept 16 9:00 12:30 & 17 9:00-1:00 format: TBD

Fall Quarter Classes (start Wed September 16, 2020)

Required for credit courses: QSB 401, at least one of IBiS 410 or ES_APPM 421, plus one other option below. However, taking both IBiS 410 and ES_APPM 421 are recommended.

Required non-credit course: IBiS 423 Ethics (or supplemental work if IBiS423 conflicts with other courses)

Required: (select one or both of IBiS410 or ES_APPM 421)

QSB 401 – Introduction to life sciences research and presentation

Description: Students receive specific training in the area of the master's thesis project and also develop written and oral presentation skills

Notable extra skills & opportunities: training on equipment students will use in labs. E.g. confocal, HTAL, Keck instruments. Written and oral presentations (e.g. "elevator talk", project summaries, thesis committee presentations)

Instructor: Greg J. Beitel

Time: Independent study + Thurs 9-10:30 AM Pancoe 4103 (hybrid; synchronous)

IBIS 423 - Ethics in Biological Research (or equivalent supplemental work if IBiS 423 conflicts with other class)
Description: Topics and standards for ethics in biological research will be covered.
Notable extra skills & opportunities: Ethics training required by NIH and NSF
Instructor: Deborah Klos
Time: 9:30-11:30 (Tues) (online, synchronous)

IBIS 410 – Quantitative Biology
Description: Quantitative approaches to molecular and cell biology, focused on developing an understanding of connections between biomolecule structure and dynamics, and behavior of cells. The course will also include review of topics from statistics of random variables and statistical data analysis relevant to biology and biophysics.
Notable extra skills & opportunities: programming with Matlab
Instructor: John Marko
Time: 12:40-1:30 (MWF) (online, synchronous)

ES_APPM 421 - Models in Applied Mathematics.
Description: Applications to illustrate typical problems and methods of applied mathematics. Mathematical formulation of models for phenomena in science and engineering, problem solution, and interpretation of results. Examples from solid and fluid mechanics, combustion, diffusion phenomena, chemical and nuclear reactors, and biological processes.
Notable extra skills & opportunities: customized primer on the basics of computer programming (for students who have not taken a course in programming); Matlab programming bootcamp in matrix manipulation, image analysis, and ODE solvers; critical reading primary literature in the field of quantitative biology,
Instructor: Madhav Mani
Time: online, asynchronously
Syllabus: https://www.whatdoyourdatasay.com/syllabus

Annual Conference on Quantitative Approaches in Biology hosted by the NSF-Simons Center for Quantitative Biology
Time: November TBA

Recommended elective courses: If only one of IBiS 401 or Biol_Sci354 is taken, choose one of the courses below or the additional course options list (subject to student eligibility and course availability):

NICO 402 – Project for Introduction to Big Data
Description: Student will build on the skills learned in NICO 401 by pursuing a research project analyzing a large data set.
Notable extra skills & opportunities: programming in Python
Instructor: Adam Phah
Time: independent study

ES_APPM 495: An Introduction to RNA Sequencing Analysis
Description: This course will give an introduction to the theory and practice of analyzing high-throughput RNA sequencing data. "Practice" here means that by the end of the

course you will be able to analyze your own RNA sequencing data: to be able to download the data from a repository or sequencing core, perform quality checks, align the reads to a reference genome (or, alternatively, generate pseudocounts), do a differential expression analysis (and other types of analysis), and to be able to investigate possible causes when one or more of the steps do not go as expected. In addition, the course will also cover some of the "theory" of these steps, i.e., we will discuss the mathematical and statistical assumptions made in order to perform the various steps described above. Understanding how the various algorithms work is important for both debugging problems that occur during the analysis steps and for improving new types of analysis that may be necessary when novel data sets are encountered.ce students to the theory and practice of analyzing high-throughput RNA sequencing data.

Time: Thursdays 2:00-4:00 pm

Instructor: William L. Kath, x1-8784, kath@northwestern.edu

IBiS 402 - Eukaryotic Molecular Biology

Description: Genome and gene structure and organization; transcription and its control, aspects of signaling and developmental control of gene expression; RNA processing, translation and their regulation; DNA replication and its control; molecular analysis of disease; applications of molecular biology in biotechnology.

Notable extra skills & opportunities: Literature-based analysis course

Instructor: Rick Morimoto

Time 9-11:00 (MTh) (online, synchronous)

Biol_Sci 361 - Protein Structure and Function

Description: This course explores the relationship between the three dimensional structure of proteins and their function. First we cover basic principles of protein architecture. We then focus on the relationship between protein structure and function. Classes of proteins discussed in detail include enzymes, DNA binding proteins, membrane proteins, and nucleotide binding proteins. Methods for determining protein structures are also briefly covered. Finally, students will learn how to display and manipulate three dimensional macromolecular structures on the computer.

Notable extra skills & opportunities: 3-D modeling of protein structures

Instructor: Amy Rosenzweig

Time TBD

Chem_Eng 376 – Principles of Synthetic Biology

Description: At its core, synthetic biology is inspired by the power and diversity of the living world. It is an endeavor predicated on the idea that we can learn to more reliably and rapidly engineer biological function for compelling applications in medicine, biotechnology, and green chemistry. What is unique to synthetic biology is the application of an engineering-driven approach to accelerate the design-build-test loops required for reprogramming existing, and constructing new, biological systems. In this course the field of synthetic biology and its natural scientific and engineering basis are introduced.

Notable extra skills & opportunities: Synthetic Biology

Instructor: Michael Jewett

Time MTBD

STAT 330– Applied statistics for Research 1

Description: Design of experiments and surveys, numerical summaries of data, graphical summaries of data, correlation and regression, probability, sample mean, sample proportion, confidence intervals and tests of significance, one and two sample problems, ANOVA.

Notable extra skills & opportunities: Statistics

Instructor: Martin Tanner

Time TBD

Winter Quarter (Classes start Monday Jan. 4)

Total courses required: 3. Required courses: QSB 499 and Biol_Sci 323 plus one of Bio_Sci 378, IBiS 407 or other courses on the additional course list.

Required:

QSB 499 – Independent study

Description: Research and full participation of QSB students in seminars, lab meetings and journal clubs that are typical of the thesis lab.

Biol_Sci 323 – Bioinformatics: Biological Sequence and Structure Analysis

Description: The course explores through case studies and classroom discussions, the principles and practical applications of computational tools in contemporary molecular and structural biology research. Besides gaining an appreciation for the algorithmic aspects of these tools, students will learn to code with python and R, design and perform experiments *in silico*, and critically evaluate results.

Notable extra skills & opportunities: programming with python and R

Instructor: Ishwar Radhakrishnan

Time TBD

Recommended elective courses: Choose one from the courses below or the additional course options list (subject to student eligibility and course availability):

IBIS 406 – Cell Biology

Description: This course is intended to provide IBIS students with detailed knowledge of selected areas of modern eukaryotic cell biology through analysis of scientific literature and in-depth background research. Students will investigate current hot topics in eukaryotic cell biology, including the methods and reagents used in cell biology research, and will critically evaluate primary data from recent scientific publications. Students are expected to think judiciously about cell biology research and confidently present their ideas in both oral and written form.

Instructor: Curt Horvath

Time: TBD

IBIS 407 – Genetics and Epigenetics

Description: Exploration of the classic and contemporary scientific literature on genetic and epigenetic control of phenotype, genetic analysis, genetic interactions, genetic model systems and genetic experiments. The focus of the course will be on learning to think about genetic data and to design genetic experiments and screens to answer biological questions.

Instructor: Jason Brickner

Time: TBD

STAT 395 - Elementary Bayesian Statistics

Spring Quarter (Classes start Tues, March 30, 2021)

Total courses required: 3. Required courses: QSB 499, STAT 465 (or IBiS 432 ro STAT 351); one of IBIS 404, IBiS 401 or other courses on the additional course list.

Required (unless student has taken STAT 330):

QSB 499 – Independent study

Description: Research and full participation of QSB students in seminars, lab meetings

Stats 465 – Statistical Methods for Bioinformatics and Computational Biology

Description: The goal of this course is to provide an introduction of statistical methodologies in important topics in bioinformatics and computational biology. The course covers statistical methodologies used in two major topics, including gene expression data analysis and high-throughput DNA sequence analysis. Statistical theory and methods in this course include Z-test, t-test, regression, ANOVA, multivariate data analysis, Bayesian statistics, bootstrap, Monte-Carlo simulation, clustering algorithms, Markov Chain, Hidden Markov Chain, mixture model, etc. Students will learn basic knowledges and programming skills to perform most common bioinformatic analyses of data generated from current molecular biology research. The lectures will cover both principles of genomics and basic R coding to perform the statistical analyses. Students who are interested in bioinformatic research, gene expression analysis and high throughput sequence data analysis are highly encouraged to take this class.

Notable extra skills & opportunities: Statistical methods and programming with R

Instructor: Jiping Wang

Tu, Thurs 9:30 - 10:50 PM

Recommended elective courses: Choose one from the courses below or the additional course options list (subject to student eligibility and course availability):

IBIS 404 – Principles and Methods in Systems Biology

Description: This course uses mathematical-based experimental analysis and modeling to study biological problems. The class will introduce quantitative techniques, computational tools and biological systems that help investigators analyze heterogeneous complex data about molecular networks to uncover meaningful relationships about key components.

Notable extra skills & opportunities: programming with "R".

Instructor: Rich Carthew

Time: MWF 1-2 PM

IBiS 401 – Molecular Biophysics

Description: The course provides a wide survey of contemporary Molecular Biophysics emphasizing the major techniques used to study the structure and mechanism of biological macromolecules. The course covers structure determination techniques, such as crystallography, NMR and cryoEM, as well as selected single molecule approaches. Students get a chance to read and present recent manuscripts in the

literature to help solidify the concept learned in class.
Instructor: Alfonso Mondragón
Time: Tu, Thu 9-10:30

IBiS 491 – Development and Evolution of Body Plans
Description: Animals are complex living machines, but unlike artificial machines, animals must build themselves from scratch. This course will explore the molecular mechanisms underlying the self-assembly of the embryonic body plan. The course will focus on the biological principles of embryonic pattern formation, regulation of gene expression, morphogenetic movements and signal transduction, organized over broad physical scales from single cells to complete organs, and from minutes to complete life cycles. Course material will draw from both current and historical approaches, with a strong emphasis on biological criteria for knowing, including a weekly critical discussion of original literature. Most class meetings will be 50-60 minutes. Additional time has been scheduled to allow for sufficient time for weekly discussions on original literature.
Instructor: Shelby Blythe
Time: Tu, Thu 9-10:30

IBIS 432 – Statistics for Life Sciences
Description: This is a practical statistics course with emphasis on the application of statistical methods and data analysis techniques to the life sciences. We will cover topics including descriptive statistics, normal distribution, random variables, sampling distribution, confidence intervals, hypothesis tests, p-values and multiple correction, linear regression, model selection, diagnostics, logistic regression, contingency tables, resampling, clustering, dimension reduction, and genomics data analysis. By the end of the quarter, students will be able to (1) formulate statistical questions for a life science question; (2) use visualization techniques to explore the data; (3) choose the appropriate statistical methods and justify the choice; (4) perform data analysis using R programming; (5) describe and present the data analysis results.
Notable extra skills & opportunities: Statistical methods used in quantitative and systems biology; programming in R.
Instructor: Hongmei Jiang
Time: Tu, Thu 11-12:30

STAT 351-0 - Design and Analysis of Experiments
Description: To be able to plan and design a variety of experiments: one-way and two-way layouts, incomplete block designs, factorial designs, random effects, split-plot and nested designs. To be able to perform the proper statistical analysis and draw valid conclusions from a specific experiment.
Notable extra skills & opportunities: Statistical methods, experimental design
Time: Tu, Thu 2-3:30

Summer Quarter

Required course: QSB 590

Recommend workshops (non-credit): IBIS 421, Next Generation Sequencing (NGS), Imaging Workshop, High Throughput Analysis Workshop

QSB 590 (3 units) – Independent study with thesis

Description: Research, written thesis, thesis defense and public presentation of thesis work. Full participation of QSB students in seminars, lab meetings and journal clubs that are typical of the thesis lab.

Recommended elective courses and workshops:

IBIS 421 – Rigor and Reproducibility in experimental design

Description: The primary focus of this course will be on education in rigor and reproducibility (R&R) in research. Experimental design and data analysis will be discussed through analysis of case studies on the topics of rigorous statistical analysis, transparency in reporting, data and material verification and sharing. The course will also establish best practice guidelines for image-based data and description of biological materials to uniquely identify the reagents (in particular antibodies, cell lines and animal models). Students will demonstrate knowledge and use of the techniques discussed in through presentation of experimental design and data analysis based on their current doctoral research.

Notable extra skills & opportunities: Rigor and reproducibility training important for academic and industry research and is required by NIH training programs.

Instructor: Deborah Klos

Times: Mon/Wed, 6/21-7/23, 9:30-11:30AM

Standard QSB Program is completed at the end of Summer Quarter

Optional 2nd Fall Quarter

QSB 595 (0 units) – Internship in NU core or lab or outside

Optional 2nd Winter Quarter

QSB 595 (0 units) – Internship in NU core or outside

Ongoing Career Development Programs

QSB students are encouraged to participate in career development programs that are co-sponsored by IBiS, DGP and NUIN programs, and by Northwestern's Graduate School (TGS):

- BioSurvival Skills are a series of workshops on topics such as presentation skills, grant and CV writing, and job hunting (offered by IBiS, DGP and NUIN).
- BioOpportunities invites alumni and other professionals to talk about careers available to graduate students (offered by IBiS, DGP and NUIN)
- Northwestern Professional Development in the areas of Career Exploration, Leadership and Management, Speaking and Presenting, Teaching and Writing and Research (offered by TGS http://www.tgs.northwestern.edu/professional-development/core-competencies/index.html).