Committee on Genetics, Genomics, and Systems Biology

Chair

- Luis Barreiro PhD

Professors

- Erin Adams, Biochemistry and Molecular Biology
- Luis Barreiro, Medicine, Genetic Medicine
- Graeme Bell, Medicine, Endocrinology
- Douglas K. Bishop, Radiation & Cellular Oncology
- Anna DiRienzo, Human Genetics
- M. Eileen Dolan, Medicine, Hematology/Oncology
- Wei Du, Ben May Department for Cancer Research
- Richard Fehon, Molecular Genetics & Cell Biology
- Edwin L. Ferguson, Molecular Genetics & Cell Biology
- Yoav Gilad, Human Genetics
- T. Conrad Gilliam, Human Genetics
- Benjamin Glick, Molecular Genetics & Cell Biology
- Michael Glotzer, Molecular Genetics & Cell Biology
- Tatyana Golovkina, Microbiology
- Christopher Gomez, Neurology
- Jean Greenberg, Molecular Genetics & Cell Biology
- Robert Grossman, Medicine, Computational Biomedicine and Biomedical Data Science
- Chuan He, Chemistry
- Barbara Kee, Pathology
- Stephen J. Kron, Molecular Genetics & Cell Biology
- Sonia S. Kupfer, Medicine, Gastroenterology
- Manyuan Long, Ecology & Evolution
- Francesca Luca Human Genetics
- Mary Sara McPeek, Statistics
- Ivan Moskowitz, Pediatrics
- Edwin Munro, Molecular Genetics & Cell Biology
- Marcelo Nobrega, Human Genetics
- John Novembre, Human Genetics
- Carole Ober, Human Genetics
- Olufunmilayo Olopade, Medicine, Hematology/Oncology
- Tao Pan, Biochemistry and Molecular Biology
- Brandon Pierce, Public Health Sciences
- Rama Ranganathan, Biochemistry & Molecular Biology
- Ilaria Rebay, Ben May Department for Cancer Research
- Marsha Rosner, Ben May Department for Cancer Research
- Lucia Rothman-Denes, Molecular Genetics & Cell Biology
- Michael Rust, Molecular Genetics & Cell Biology
- Andrey Rzhetsky, Medicine, Computational Biomedicine and Biomedical Data Science
- Urs Schmidt-Ott, Organismal Biology & Anatomy
- Neil H. Shubin, Organismal Biology & Anatomy
- Francois Spitz, Human Genetics
- Jonathan P. Staley, Molecular Genetics & Cell Biology
- Matthew Stephens, Human Genetics
- Kaloyan M. Tsanov, Medicine
- Joseph W. Thornton, Ecology & Evolution

- Yingming Zhao, Ben May Department for Cancer Research
- Xiaoxi Zhuang, Neurobiology

Associate Professors

- Anindita Basu, Medicine, Genetic Medicine
- Ran Blekhman, Medicine, Genetic Medicine
- Mengjie Chen, Medicine, Genetic Medicine
- D. Allan Drummond, Biochemistry & Molecular Biology
- Jingyi Fei, Biochemistry and Molecular Biology
- Xin He, Human Genetics
- T.C. He, Orthopedic Surgery and Rehabilitation Medicine
- Ellie Heckscher, Molecular Genetics & Cell Biology
- Hae Kyung Im, Medicine, Genetic Medicine
- Paschalis Kratsios, Neurobiology
- Heng-Chi Lee, Molecular Genetics & Cell Biology
- Yang Li, Medicine, Genetic Medicine
- Jocelyn Malamy, Molecular Genetics & Cell Biology
- Megan McNerney, Pathology
- Arvind Murugan, Physics and the James Franck Institute
- Alexander Pearson, Hematology and Oncology
- Alex Ruthenburg, Molecular Genetics & Cell Biology
- Lixing Yang, Ben May Department for Cancer Research

Assistant Professors

- Brett Beaulieu-Jones, Medicine
- Jeremy Berg, Human Genetics
- Andrew Dahl, Medicine, Genetic Medicine
- Evgeny Izumchenko, Medicine, Hematology/Oncology
- Aly Khan, Family Medicine
- Andrew Koh, Pathology
- Xuanyao Liu, Medicine, Genetic Medicine
- Heather Marlow, Organismal Biology & Anatomy
- Sampriti Mukherjee, Molecular Genetics & Cell Biology
- Ronan O'Malley, Human Genetics
- David Pincus, Molecular Genetics & Cell Biology
- Sebastian Pott, Medicine, Genetic Medicine
- Maanasa Raghavan, Human Genetics
- Arjun Raman, Pathology
- Yuval Simons, Medicine
- Matthias Steinruecken, Ecology & Evolution
- Carol Veller Ecology and Evolution
- Aarti Venkat, Medicine
- Jingxin Wang, Medicine
- Joshua Weinstein, Medicine, Genetic Medicine
- Xiaochang Zhang, Human Genetics
- Zhuzhu Zhang, Human Genetics

FOR INFORMATION ON THE COMMITTEE ON GENETICS, GENOMICS & SYSTEMS BIOLOGY PLEASE SEE OUR WEBSITE: http://ggsb.uchicago.edu/

The Committee on Genetics, Genomics & Systems Biology (https://ggsb.uchicago.edu/) (GGSB) is an interdisciplinary PhD granting program that brings together over 70 training faculty (https://ggsb.uchicago.edu/research/) representing numerous departments at the University of Chicago. The GGSB program is aimed at training PhD scholars for careers as independent scientists in basic and applied biomedical research and education, leading to Doctor of Philosophy in Genetics. Our PhD training program combines a foundation in modern genetic analysis with training in current methods for formulating and addressing biological questions in the context of complex systems. The presence of both basic and clinical sciences in the Division of Biological Sciences enhances the

Committee's broad interdisciplinary approach to teaching and research. GGSB provides an exciting environment to pursue rigorous, high quality training with flexibility in designing programs to meet individual needs. GGSB's goal is to provide an intellectually stimulating, collegial, and supportive environment for students to progress smoothly from research training to careers as independent scientists.

DIVERSITY, EQUITY & INCLUSION **(**https://ggsb.uchicago.edu/page/ggsb-and-diversity-equity-inclusion/**)**

GGSB is dedicated to advancing Diversity, Equity, and Inclusion (DEI). In brief, we reject the historical and ongoing systemic biases that cause unacceptable inequities in academia. We strive to ensure GGSB is a supportive and inclusive environment for everyone, regardless of race/ethnicity, religion, sex/gender, age, sexual orientation, and/or disability. Visit the GGSB DEI page for additional information. **(**http://ggsb.uchicago.edu/page/diversity-equity-and-inclusion-1/**)**

Curriculum and Timeline - First Year (https://ggsb.uchicago.edu/page/curriculum-timeline-first-year/)

Formal Coursework: Choice of Two GGSB Tracks: Empirical Track **(**https://ggsb.uchicago.edu/page/ggsb-empirical-track-coursework/**) or** Computational Track **(**https://ggsb.uchicago.edu/page/ggsb-computational-track-coursework/**)**

To obtain a PhD in the Division of Biological Sciences, nine graded courses are required as detailed below.

GGSB has two tracks, 1) **"**Empirical Track **(**https://ggsb.uchicago.edu/page/ggsb-empirical-track-coursework/**)"** and 2) "Computational Track **(**https://ggsb.uchicago.edu/page/ggsb-computational-track-coursework/**)"**. While the two tracks are united by the common goals of using genetic, genomic, and systems biology approaches to address important biological questions, the training focuses are different. Training in the **"**Empirical Track **(**https://ggsb.uchicago.edu/page/ggsb-empirical-track-coursework/**)"** is emphasizes experimental techniques, especially those quantitative in nature, while the "Computational Track **(**https://ggsb.uchicago.edu/page/ggsb-computational-track-coursework/**)"** trains students in building computational skills.

GGSB EMPIRICAL TRACK - FOUR [4] REQUIRED COURSES AND FOUR [4] ELECTIVES PLUS TWO [2] ROTATIONS

Training under the Empirical Track is focused on experimental techniques.

There are five suggested specializations to choose from for students interested in concentrating in the Empirical Track: 1) Model Systems, 2) Population Genetics, 3) Human Genetics, 4) Developmental Genetics, and 5) Genomics & Systems Biology. These five course tracks are suggestions. GGSB encourages students to explore other areas of interest as well.

For the Empirical Track, four [4] required courses and four [4] graded electives must be taken, one of which may be a reading course. The electives can be selected according to the student's interests and the availability of courses.

FOUR [4] REQUIRED COURSES IN GENETICS:

MGCB 31400 Genetics Analysis of Model Organisms (Autumn) **AND** HGEN 47300 Genomics and Systems Biology (Spring)

PLUS ONE [1] OF THE FOLLOWING TWO COURSES: MGCB 31200 Molecular Biology I (Winter) **OR** MGCB 31300 Molecular Biology II (Spring)

PLUS ONE [1] OF THE FOLLOWING FOUR COURSES: ECEV 44000 Molecular Evolution 1: Fundamentals and Principles (Winter) **OR** ECEV 35600 Principles of Population Genetics I (Winter) **OR** ECEV 35901 Genomic Evolution (Autumn) **OR** HGEN 46900 Human Variation and Disease (Spring)

PLUS FOUR [4] ELECTIVE COURSES - For additional information on elective course see the GGSB Empricial Track Coursework page **(**https://ggsb.uchicago.edu/page/ggsb-empirical-track-coursework/**)** (**Note**: Students may petition the GGSB Student Affairs/Curriculum Committee for approval of an elective course not listed).

ADDITIONAL REQUIRED COURSES: HGEN 31900 Introduction to Research. "Allstars" (Autumn) **AND** BSDG 55100 Responsible, rigorous, and reproducible conduct of research: R3CR (Winter)

GGSB COMPUTATIONAL TRACK – THREE [3] REQUIRED COURSES AND THREE [3] CORE ELECTIVES PLUS TWO [2] ADDITIONAL ELECTIVES PLUS TWO [2] ROTATIONS

Computational, mathematical, and statistical tools are essential to research in the biological sciences. The University of Chicago has had a long tradition of excellence in these areas, and to continue that tradition, GGSB has developed a focused curriculum to train students in these areas.

There are four suggested specializations for this track: 1) Population Genetics & Evolution, 2) Statistical Genetics, 3) Computational Genomics, and 4) Computational Cell Biology. GGSB encourages students to explore other areas of interest as well.

The Computational track curriculum trains students to address fundamental biological questions and to master the three skillsets that are essential to computational genomics research: probabilistic modeling, statistical inference, and computational algorithms & data structures. This curriculum is also unique in its focus on communication skills, both in terms of writing and speaking. This emphasis emerges from a perspective that computational biologists need to clearly explain complex algorithms and results in order to both effectively share their research products and to collaborate with diversely trained colleagues.

Three [3] Required Courses in Computational Biology and Statistics: STAT 24400 Statistical Theory and Methods I (Autumn) **AND** HGEN 48600 Fundamentals of Computational Biology: Models and Inference (Winter) **AND** HGEN 48800 Fundamentals of Computational Biology: Algorithms and Applications

AND

Three [3] Core Elective Courses Chosen from the Following List: STAT 24400 Statistical Theory and Methods I (Autumn) **AND** HGEN 48600 Fundamentals of Computational Biology: Models and Inference (Winter) **AND** HGEN 48800 Fundamentals of Computational Biology: Algorithms and Applications

PLUS Two [2] Core Elective Courses Chosen from the Following List: HGEN 47000 Human Genetics I (Autumn) **OR** MGCB 31400 Genetic Analysis of Model Organisms (Autumn) **OR** HGEN 47500 Genetic Mechanisms from Variation to Evolution (Autumn) **OR** HGEN 47100 Introductory Statistical Genetics (Winter) **OR** ECEV 35600 Principles of Population Genetics I (Winter) **OR** ECEV 31100 Evolution of Biological Molecules (Winter) OR BCMB 32200 Biophysics of Biomolecules (Spring) OR HGEN 46900 Human Variation and Disease (Spring) **OR** HGEN 47800 Quantitative Genetics for the 21st Century (Spring) **OR** HGEN 47300 Genomics and Systems Biology (Spring) **OR** HGEN 47900 Decoding and Engineering Genes and Genomes (Spring) **OR** MGCB 32000 Quantitative Analysis of Biological Dynamics (Spring)

ADDITIONAL REQUIRED COURSES: HGEN 31900 Introduction to Research. "Allstars" (Autumn) **AND** BSDG 55100 Responsible, rigorous, and reproducible conduct of research: R3CR (Winter)

ROTATIONS

Students undertake short research projects in at least two different laboratories before beginning their dissertation research. The purpose of the rotation is to expose the student to different research environments, broaden their acquaintance with useful laboratory techniques, and introduce him/her to the conceptual framework of experimental design. The distribution of course offerings makes it difficult for students to undertake rotations in Autumn Quarter of the first academic year. Therefore, rotations are performed in the winter or spring and summer quarters. The winter and spring rotations last 10 weeks to coincide with the academic quarter. The summer rotation lasts 5 weeks, when the student is able to devote full-time to research. Students wishing to do a third rotation may do so during the second half of Summer Quarter.

Curriculum and Timeline - Second Year (https://ggsb.uchicago.edu/page/curriculum-timeline-second-year/)

At the beginning of the second year of training, students choose a research advisor. Most of the second year is spent developing a research project. A Thesis Advisory Committee is chosen by the student in consultation with their mentor and the GGSB Student Advisory Committee. A written research proposal is provided to the Thesis Advisory Committee in advance of the first committee meeting. During this meeting, the student will present and defend their proposal. This first meeting constitutes the Qualifying Exam for PhD candidacy. Following Qualifying Exam, the Thesis Advisory Committee meets with, and advises the student on a regular basis throughout the remainder of their training.

Curriculum and Timeline - Advanced Years (https://ggsb.uchicago.edu/page/curriculum-timeline-advanced-years/)

After passing the Qualifying Exam and throughout the duration of their of their studies, students conduct full-time thesis research while continuing to attend seminars, journal clubs, and other educational meetings. Students are welcome to audit courses in which they have an interest. Finally, each graduating student writes a dissertation culminating in a public Thesis Defense.

Teaching Assistantships (https://biosciences.uchicago.edu/content/teaching-assistant-requirement/)

All graduate students are required to serve as a Teaching Assistant in two courses for academic credit before the PhD degree is awarded. Courses can be undergraduate, graduate, or medical, but must be in the Biological Sciences Division.

The ability to communicate verbally and to teach are important skills for a successful research career. As such, all students are required to serve as teaching assistants (TAs) for two quarters, with responsibilities that may include leading discussion groups, writing problem sets, and running laboratories. Students normally undertake their Teaching Aassistantships during the second and third years. A course designed to train graduate students to be an effective TA may be taken in lieu of one of the two assistantships. The student must receive

approval from the CSAC prior to accepting a TAship. The two required TAships must be completed prior to the end of their fourth year of study. Student MAY NOT fulfill a TAShip requirement during the last quarter of their graduate studies.

APPLICATION: For information about applying to our graduate program, please visit:https://apply-bsd.uchicago.edu/apply/.

Genetics Courses

GENE 31800. Current Topics in Genetics. 50 Units.
This course will expose student to current research topics in genetics for the bi-monthly GGSB Invited Seminar Series. This is a required ½ credit course for all GGSB students and will be graded Pass/Fail. Winter, Spring

GENE 31900. Introduction to Research. 100 Units.
Lectures on current research by departmental faculty and other invited speakers. A required course for all first-year graduate students.
Instructor(s): Staff Terms Offered: Autumn
Equivalent Course(s): HGEN 31900, DVBI 31900, BCMB 31900, MGCB 31900

GENE 35400. Advanced Developmental Biology. 100 Units.
This course provides both an overview of developmental biology and an in-depth coverage of selected topics, emphasizing the origins of classical concepts in the field as well as modern molecular and genetic approaches to the study of developmental processes. Subjects include cell fate determination, growth control, stem cells, signal transduction, neurogenesis, and cell polarity in developing systems. Underlying mechanisms are illuminated through discussion of key experiments. Discussion sections cover selected papers from the developmental biology literature, with emphasis on critical evaluation of experimental evidence.
Instructor(s): "E. Ferguson, R. Fehon" Terms Offered: Winter
Prerequisite(s): "BIOS 20182, 20192, or 20235"
Equivalent Course(s): BIOS 21227

GENE 36420. Statistical Inference in Biology: Intuition from a Historical Perspective. 100 Units.
Biology is undergoing a substantial transition. With the advent of new technologies that enable the collection of massive amounts of data coupled with advances in computational frameworks and hardware, Biology is squarely in the era of statistical learning-inferring models of how Biology works from statistics rather than a deep understanding of complex mechanism. How did this shift come about? Why did this shift come about? How can we really understand how to deal with 'complexity' in Biology? This course is meant to provide students with an intuition regarding statistical inference as an emerging philosophy for studying Biology. As such, this course is centered around key papers that thematically frame (i) each week and (ii) several consecutive lectures of the course. We begin by introducing the concept of reductionism in Biology and its limitations. We move on to describing complexity and how the scientific need for statistical inference frameworks follows from this description. We discuss how these statistical inference frameworks have been implemented and how results from these frameworks have shaped our understanding of complex biological systems through extensive validation efforts and cutting-edge design strategies geared toward engineering synthetic biological systems. Finally, we discuss what key mathematical aspects define statistical inference, including a very short discussion regarding machine-learning and artificial intelligence applications in Biology.
Instructor(s): A. S. Raman Terms Offered: Spring
Prerequisite(s): BIOS 26120 and three quarters of a Biological Sciences Fundamentals sequence, or consent of the instructor.
Equivalent Course(s): BIOS 26420

GENE 39900. Readings: Genetics. 300.00 Units.
A course designed by a student and faculty member. All reading courses must be approved by the Curriculum/Student Affairs Committee prior to registration.
Terms Offered: Summer,Autumn,Winter,Spring

GENE 40100. Thesis Research: Genetics. 300.00 Units.
Thesis Research: Genetics
Instructor(s): Gilad Terms Offered: Summer,Autumn,Winter,Spring

GENE 40200. Non-Thesis Research: Genetics. 300.00 Units.
Non-Thesis Research: Genetics
Instructor(s): Gilad Terms Offered: Summer,Autumn,Winter,Spring

GENE 45100. Chemical Biology of Drug Actions and Metabolism. 100 Units.
This course is designed for graduate and advanced undergraduate students, offering an in-depth exploration of both established and emerging classes of molecular therapeutics for treating cancer, neurological diseases, autoimmune disorders, and rare genetic conditions. The course emphasizes the chemistry and biology underlying drug mechanisms of action and metabolic pathways, highlighting critical pharmacological considerations pivotal in the early stages of drug discovery. This course categorizes drugs by their mechanisms of action rather than clinical indications, providing students, particularly those with backgrounds in biochemistry, chemical biology, or molecular biology, with an advanced understanding of how drugs function at the molecular level and the challenges involved in their development pipelines.

Instructor(s): Jingxin Wang Terms Offered: Spring
Prerequisite(s): None

GENE 46100. Deep Learning in Genomics. 100 Units.
This fast-paced, hands-on course is designed for students who want to apply deep learning techniques to solve problems in genomics. The course focuses on equipping students with the computational skills needed to leverage deep learning in biological research. Throughout the course, students will work with case studies in genomics, applying deep learning tools to real-world data. Topics will include large language models (LLMs) for DNA sequence analysis, gene expression prediction from DNA sequences (e.g., Enformer, SEI, Borzoi), single cell data analysis, and protein language models (e.g., ESM). Students will be expected to quickly become proficient in essential tools such as the Linux command line, Python, R, GitHub, VS Code, Jupyter notebooks, and popular deep learning frameworks. Each unit will introduce a new area of study with required background reading, followed by in-class discussions and hands-on application. Students will train simplified models, apply them to biological datasets, and present their findings. In the final project, students will apply deep learning tools to solve a meaningful problem in genomics.
Instructor(s): Hae Kyung Im, Ran Blekhman Terms Offered: Spring
Prerequisite(s): None