Department of Human Genetics

Chair, Department of Human Genetics: Carole Ober

Human Genetics Graduate Program Chair, François Spitz

Professors

- Habibul Ahsan, Public Health Sciences
- Luis Barreiro, Medicine, Genetic Medicine
- Graeme Bell, Medicine, Endocrinology
- Soma Das, Human Genetics
- Daniela Del Gaudio, Human Genetics
- Anna Di Rienzo, Human Genetics
- Yoav Gilad, Medicine, Genetic Medicine
- T. Conrad Gilliam, Human Genetics
- Michelle Le Beau, Medicine
- Mary Sara McPeek, Statistics
- Ivan Moskowitz, Pediatrics, Cardiology
- Dan L. Nicolae, Statistics
- Marcelo Nobrega, Human Genetics
- John Novembre, Human Genetics
- Carole Ober, Human Genetics
- Olufunmilayo Olopade, Medicine
- François Spitz, Human Genetics
- Matthew Stephens, Human Genetics
- Joseph Thornton, Ecology and Evolution

Clinical Professors

- Darrel J. Waggoner, Human Genetics

Associate Professors

- Mengjie Chen, Medicine, Genetic Medicine
- D. Allan Drummond, Biochemistry and Molecular Biology
- Xin He, Human Genetics
- Brandon Pierce, Public Health Services

Assistant Professors

- Jeremy Berg, Human Genetics
- Andrew Dahl, Medicine, Genetic Medicine
- Michael Drazer, Medicine, Hematology
- Hae Kyung Im, Medicine, Genetics Medicine
- Yang Li, Medicine, Genetic Medicine
- Xuanyao Liu, Medicine, Genetics Medicine
- Sebastian Pott, Genetic Medicine
- Maanasa Raghavan, Human Genetics
- Matthias Steinruecken, Ecology & Evolution
- Lixing Yang, Ben May Department for Cancer Research
- Xiaochang Zhang, Human Genetics
- Zhuzhu Zhang, Human Genetics

Research Associate Professors

- Mark Abney, Human Genetics

Research Assistant Professors

- Emma Thompson, Human Genetics

FOR INFORMATION ON THE HUMAN GENETICS PHD PROGRAM PLEASE SEE OUR WEBSITE: https://hgen.uchicago.edu/

FOR INFORMATION ON THE DEPARTMENT OF HUMAN GENETICS PLEASE SEE OUR WEBSITE: https://genes.uchicago.edu/about-human-genetics (https://genes.uchicago.edu/about-human-genetics/)

The graduate program in Human Genetics (https://hgen.uchicago.edu/) (HG) is the home within the Division of Biological Sciences for the study of basic principles of genetics and genomics as applied to human phenotypes. We provide broad training in experimental and computational genetics and genomics, statistical and population genetics, bioinformatics, and clinical genetics. A common theme throughout our research is the application of basic genetic principles and strategies to the study of disease mechanism, disease susceptibility, and the genetic architecture of complex traits. Within this framework, the goals of our program are to:

- Educate students broadly in the basic concepts and practices of human genetics and the disciplines of genomics, population genetics, bioinformatics and systems biology.
- Introduce students to the growing importance of evolutionary concepts and insights to the study of human disease and genetic variation.
- Prepare students for a new world of genetic medicine that will follow basic discoveries in our understanding of multifactorial inheritance.

Students are encouraged to take advantage of interactive and collaborative relationships at departmental, divisional, and university-wide levels. Our faculty bridge between basic and clinical research and train students for careers in academia, industry, and medicine. Recent graduates have obtained post-doctoral positions at Cornell University, Harvard University, the National Institutes of Health, Sanger Centre, UC Berkeley, UCSF, and UCLA. Other graduates hold faculty positions, practice medicine, or work in leadership positions in the biomedical industry.

The Department of Human Genetics has an unwavering commitment to diversity (https://biosciences.uchicago.edu/diversity/), inclusion, free expression, and open discourse. These values are at the core of our roles as scientists, as teachers, and as citizens of a free society. Science, including genetics, plays a central role in many crucial issues of our time. We are committed to generating rigorous scientific knowledge, training future scientists, and preparing our students to be well-informed citizens in a democratic society.

Curriculum and Timeline - First Year (https://hgen.uchicago.edu/program/)

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

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

HG has two tracks, 1) **"**Empirical Track **(**https://hgen.uchicago.edu/page/human-genetics-empirical-track-coursework/**)"** and 2) **"**Computational Track **(**https://hgen.uchicago.edu/page/human-genetics-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://hgen.uchicago.edu/page/human-genetics-empirical-track-coursework/**)"** emphasizes experimental techniques, especially those quantitative in nature, while the **"**Computational Track **(**https://hgen.uchicago.edu/page/human-genetics-computational-track-coursework/**) "** trains students in building computational skills.

HG EMPIRICAL TRACK - Eight [8] courses and at least two [2] lab rotations are required to fulfill the requirements for the PhD in the Empirical Track:

Training under the Empirical Track is focused on experimental techniques.

TWO [2] REQUIRED COURSES: HGEN 47000 Human Genetics I (Autumn) **AND** HGEN 47500 Genetic Mechanisms from Variation to Evolution (Autumn). **NOTE:** A statistics course (e.g. HGEN 47400) of appropriate level given the student's background is also strongly recommended and will be chosen in consultation with the Curriculum Committee.

PLUS THREE [3] CORE ELECTIVE COURSES: HGEN 31100 Evolution of Biological Molecules (Winter) **OR** HGEN 46900 Human Variation and Disease (Spring) **OR** HGEN 47900 Decoding and Engineering Genes and Genomes (Spring) **OR** HGEN 48600 Fundamentals of Computational Biology: Models and Inference (Winter) **OR** HGEN 47100 Intro Statistical Genetics (Winter) **OR** HGEN 47300 Genomics and Systems Biology. Gilad (Spring) **OR** HGEN 47200 Quantitative Genetics for the 21st Century (Spring) **OR** MGCB 31300 Molecular Biology II (Spring) **OR** MGCB 31400 Genetic Analysis of Model Organism (Autumn) **OR** DVBI 36400 Developmental Mechanisms (Winter) **OR** ECEV 35600 Population Genetics I (Winter)

PLUS THREE [3] ELECTIVE COURSES

- HUMAN GENETICS: HGEN 39900 Readings in Human Genetics (Autumn, Winter, Spring, Summer); HGEN 47400 Introduction to Probability and Statistics for Geneticists (Autumn); HGEN 48800 Fundamentals

of Computational Biology: Algorithms and Applications (Spring).BIOCHEMISTRY AND MOLECULAR BIOLOGY: BCMB 30400 Protein Fundamentals (Autumn)

- DEVELOPMENTAL BIOLOGY: DVBI 35600 Vertebrate Developmental Genetics (Winter)
- ECOLOGY AND EVOLUTION : ECEV 35901 Genomic Evolution I (Autumn)
- MOLECULAR GENETICS AND CELL BIOLOGY : MGCB 31200 Molecular Biology I (Winter); MGCB 31600 Cell Biology I (Autumn); MGCB 31700 Cell Biology II (Winter); MGCB 3200 Quantitative Analysis of Biological Dynamics (Spring);
- NEUROBIOLOGY: NURB 33400 Genetic Approaches in Neurobiology (Winter)
- STATISTICS: STAT 24300 Numerical Linear Algebra (Autumn); STAT 24400 Statistical Theory and Methodology I (Autumn, Winter); STAT 24500 Statistical Theory and Methodology-2 (Winter); STAT 35500 Statistical Genetics (Spring)

Note: Students may petition the HG Student Affairs/Curriculum Committee for approval of an elective course not listed above.

PLUS TWO LAB ROTATIONS: BSDG 40100 Section 11 Non-Thesis Research (Autumn, Winter, Spring, Summer)

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

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

The Computational Track (https://hgen.uchicago.edu/page/human-genetics-computational-track-coursework/) curriculum trains students to address fundamental biological questions and to master the three skill sets 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 both to 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

PLUS Two [2] Core Elective Courses Chosen from the Following L**ist:** 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) 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 47200 Quantitative Genetics for the 21st Century (Spring) **OR** HGEN 47300 Genomics and Systems Biology (Spring) **OR** MGCB 32000 Quantitative Analysis of Biological Dynamics (Spring)

PLUS Two [2] Additional Elective Courses Chosen From the Following List: STAT 34300 Applied Linear Statistical Methods (Autumn) **OR** STAT 37790 Topics in Statistical Machine Learning (Autumn) OR ECEV 32000 Introduction to Scientific Computing for Biologists (Winter) **OR** STAT 30900 Mathematical Computation I: Matrix Computation (Autumn) **OR** BIOS 20186 Fundamentals of Cell and Molecular Biology (Spring) **OR** BIOS 20187 Fundamentals of Genetics (Winter) **OR** STAT 24500 Statistical Theory and Methods-2 (Winter) **OR** STAT 32950 Multivariate Statistical Analysis: Applications and Techniques (Winter) **OR** ECEV 42900 Theoretical Ecology (Winter) **OR** STAT 24610 Pattern Recognition (Spring) **OR** STAT 30210 Bayesian Analysis and Principles of Statistics (Spring) **OR** STAT 35500 Statistical Genetics (Spring) **OR** STAT 37710 Machine Learning (Spring)

Note: Students may petition the HG Student Affairs/Curriculum Committee for approval of an elective course not listed above.

Curriculum and Timeline - Second Year **(**https://hgen.uchicago.edu/program/**)**

Students spend the second year developing a research project and preparing a written proposal of dissertation research. This proposal is defended before a qualifying examination committee at the end of the academic year. Students satisfy any remaining course requirements during this year.

Curriculum and Timeline - Advanced Years **(**https://hgen.uchicago.edu/program/**)**

After the qualifying exam, the student performs full-time thesis research while continuing to participate in program events such as seminars, journal clubs, etc. Students are welcome to audit courses in which they have an interest. Finally, in the final year of the program the student writes a dissertation describing his/her research, presents the work in a public seminar and defends it before his/her faculty examining committee. Please view the Human Genetics Handbook for a full description of the academic program and the courses available to our students.

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 Assistantships 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/.

Human Genetics Courses

HGEN 30100. Appl of Scientific Advncmt to Disease Detection & Management. 75 Units.

HGEN 30400. Protein Fundamentals. 100 Units.
The course covers the physical chemical phenomena that define protein structure and function. Topics include: three-dimensional structures of proteins; the principles of protein folding, molecular motion and molecular recognition; protein evolution, design and engineering; enzyme catalysis; regulation of protein function; proteomics and systems biology. Undergraduates are highly recommended to take BIOS 20200 (Introduction to Biochemistry) or equivalent before taking this course.
Instructor(s): E. Ozkan, J. Piccirilli, D. Arac Terms Offered: Autumn
Equivalent Course(s): BCMB 30400, MGCB 30400

HGEN 31100. Evolution of Biological Molecules. 100 Units.
The course connects evolutionary changes imprinted in genes and genomes with the structure, function and behavior of the encoded protein and RNA molecules. Central themes are the mechanisms and dynamics by which molecular structure and function evolve, how protein/ RNA architecture shapes evolutionary trajectories, and how patterns in present-day sequence can be interpreted to reveal the interplay data of evolutionary history and molecular properties. Core concepts in macromolecule biochemistry (folding and stability of proteins and RNA, structure-function relationships, kinetics, catalysis) and molecular evolution (selection, mutation, drift, epistasis, effective population size, phylogenetics) will be taught, and the interplay between them explored.
Instructor(s): J. Thornton Terms Offered: Winter
Prerequisite(s): Comfort with basic computer programming (course will use Python and R); undergraduate biology, chemistry, calculus, and introductory statistics.
Equivalent Course(s): ECEV 31100, BCMB 31100

HGEN 31400. Genetic Analysis of Model Organisms. 100 Units.
Fundamental principles of genetics discussed in the context of current approaches to mapping and functional characterization of genes. The relative strengths and weaknesses of leading model organisms are emphasized via problem-solving and critical reading of original literature.
Instructor(s): Pincus, D, Ferguson, E, Lee, H.C, Zhang, X Terms Offered: Autumn
Equivalent Course(s): MGCB 31400, BCMB 31400, DVBI 31400

HGEN 31600. Cell Biology I. 100 Units.
Eukaryotic protein traffic and related topics, including molecular motors and cytoskeletal dynamics, organelle architecture and biogenesis, protein translocationand sorting, compartmentalization in the secretory pathway, endocytosis and exocytosis,and mechanisms and regulation of membrane fusion.
Instructor(s): A. Turkewitz, B. Glick Terms Offered: Autumn
Equivalent Course(s): DVBI 31600, BCMB 31600, MGCB 31600

HGEN 31800. Current Topics in Human Genetics. 50 Units.
This course will expose student to current research topics in Human Genetics through the Seminar Series. This is a required ½ credit course for all Human Genetics students and will be graded Pass/Fail. (Autumn, Winter, Spring)
Instructor(s): Ann Di Rienzo Terms Offered: Autumn Spring Winter

HGEN 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): BCMB 31900, MGCB 31900, DVBI 31900, GENE 31900

HGEN 33480. Neurogenetics. 100 Units.
This course introduces human and mouse genetics through the lens of neurological disorders. It starts with genetic concepts and the principles of genetic approaches, followed by human genetic studies of neocortex development and original findings in repeat expansion diseases. We will discuss concurrent concepts in genetic diagnosis and therapeutic strategies. This course is open to graduate and upper-level undergraduate students. It combines lectures and discussion sections.
Instructor(s): X. Zhang Terms Offered: Spring
Prerequisite(s): BIOS 20187, NSCI 20101, or consent of instructor
Equivalent Course(s): NURB 33480, NSCI 23480

HGEN 36400. Molecular Phylogenetics. 100 Units.
While evolution by natural selection is an elegantly simple phenomenon, modern research in evolutionary biology contains a variety of controversial, and sometimes confusing, topics. In this course, we will explore, as a group, a select list of controversial or confusing topics in evolutionary biology through a mix of student-led presentations and discussion of the primary literature. Each student will also write a review paper about his or her selected topic.
Instructor(s): J. Thornton, A. Drummond Terms Offered: TBD. offered in alternate years
Note(s): not offered in 2018-19
Equivalent Course(s): ORGB 36400, ECEV 36400

HGEN 39900. Topics: Human Genetics. 300.00 Units.

HGEN 40300. Non-Thesis Rsch: Human Genetics. 300.00 Units.
Research conducted by graduate students prior to the qualifying exam.

HGEN 40400. Thesis Research. 300.00 Units.
Dissertation Research conducted by graduate students.
Instructor(s): A DiRienzo Terms Offered: Autumn Spring Summer Winter

HGEN 46900. Human Variation and Disease. 100 Units.
This course focuses on principles of population and evolutionary genetics and complex trait mapping as they apply to humans. It will include the discussion of genetic variation and disease mapping data.

HGEN 47000. Human Genetics-1. 100 Units.
This course covers classical and modern approaches to studying Mendelian and complex diseases. Topics include gene discovery approaches for monogenic and complex disease and genomics approaches for understanding function. The format includes lectures and student presentations. Autumn
Instructor(s): C. Ober, M. Nobrega

HGEN 47300. Genomics and Systems Biology. 100 Units.
This lecture course explores technologies for high-throughput collection of genomic-scale data, including sequencing, genotyping, gene expression profiling, and assays of copy number variation, protein expression and protein-protein interaction. In addition, the course will cover study design and statistic analysis of large data sets, as well as how data from different sources can be used to understand regulatory networks, i.e., systems. Statistical tools that will be introduced include linear models, likelihood-based inference, supervised and unsupervised learning techniques, methods for assessing quality of data, hidden Markov models, and controlling for false discovery rates in large data sets. Readings will be drawn from the primary literature. Evaluation will be based primarily on problem sets.
Instructor(s): Yang Li Sebastian Pott Joshua A. Weinstein Terms Offered: Spring
Prerequisite(s): Three quarters of a Biological Sciences Fundamentals sequence including BIOS 20187 or BIOS 20235 and STAT 23400 or BIOS 26210 and BIOS 26211
Note(s): CB.
Equivalent Course(s): BIOS 28407, BPHS 47300, CABI 47300, IMMU 47300

HGEN 47400. Introduction to Probability and Statistics for Geneticists. 100 Units.
This course is an introduction to basic probability theory and statisticalo methods useful for people who intend to do research in genetics or a similar scientific field. Topics include random variable and probability distributions, descriptive statistics, hypothesis testing and parameter estimation. Problem sets and tests will include both solving problems analytically and analysis of data using the R statistical computing environment.
Instructor(s): M. Abney Terms Offered: Autumn

HGEN 47500. Genetic Mechanisms from Variation to Evolution. 100 Units.
This course provides a graduate-level introduction to enduring questions regarding the fundamental processes by which genetic information is inherited, regulated, and transformed into organismal phenotypes and how these mechanisms shape and interact with evolutionary processes. We will describe different strategies, including new genome analysis and engineering technologies and statistical/computational principles, that can be used to study the complex, multi-layered organization of genomes, their interactions with varying environments, and ultimately, their evolution.
Instructor(s): John Novembre (primary), Francois Spitz Terms Offered: Autumn
Prerequisite(s): BIOS 201817 or BIOS 20153 or equivalent undergraduate course in Genetics or Evolutionary biology or consent of instructor

Equivalent Course(s): ECEV 47500

HGEN 47800. Quantitative Genetics for the 21st Century. 100 Units.
This course has three parts. In the first four weeks, we take a deep look at some fundamentals of quantitative genetics, focusing on underlying mathematical theory and causal interpretations of basic quantitative genetic models. These include the breeder's equation and related descriptions of the response to natural selection, various methods of estimating heritability, GWAS methods accounting for environmental effects, and explicit causal inference methods like Mendelian randomization. In the next three weeks of the course, we discuss the scientific opportunities and pitfalls of applying these fundamental quantitative genetic tools in challenging settings. This section covers phenotypic prediction with polygenic scores, inferences about quantitative trait evolution, and the application of quantitative genetic tools to complex social traits like educational attainment. Finally, in the third section we examine the relationship between race, genetics, and complex traits. In this section we discuss definitions of race and how they are (or are not) related to genetics, as well as ongoing legitimate scientific debates over how racial classifications are used in medicine. We will also critique pseudoscientific arguments about the relationship between race, genetics and complex traits.
Instructor(s): Jeremy Berg, Andrew Dahl Terms Offered: Spring
Prerequisite(s): R/Python proficiency.
Equivalent Course(s): BIOS 26404

HGEN 47900. Decoding and Engineering Genes and Genomes. 100 Units.
The genome contains the blueprint of the different "programs" that yield the formation of a complex multicellular individual. Thousands of genes and millions of genomic elements regulating gene expression contribute to these genomic programs but we still have only a very limited understanding of who they are, what they do and how. The course will provide an in-depth presentation and discussion of the cutting-edge technologies that can be used to identify the genomic elements (genes, cis-regulatory elements, chromatin features) that determine cell functions and to characterize their modes of action. The course will cover 1) the different tools that allow precision genome editing and chromatin engineering (e.g. CRISPR-Cas9, degrons) 2) the compendium of transcriptomics, chromatin and epigenomic technologies that could be used to identify genomic activities and their determinants (RNA-seq, ATAC-seq, ChiP-Seq, Hi-C etc …) and 3) the novel avenues and challenges opened by single-cell genomic technologies. It will include presentation and critical discussion of the different genomic protocols and computational/statistical data analysis, with a specific focus on emerging single-cell technologies. Applications of these technologies will be presented with analysis of primary research papers and the students will have hands-on experience on analyzing single-cell genomic datasets during computational labs.

HGEN 48600. Fundamentals of Computational Biology: Models and Inference. 100 Units.
Covers key principles in probability and statistics that are used to model and understand biological data. There will be a strong emphasis on stochastic processes and inference in complex hierarchical statistical models. Topics will vary but the typical content would include: Likelihood-based and Bayesian inference, Poisson processes, Markov models, Hidden Markov models, Gaussian Processes, Brownian motion, Birth-death processes, the Coalescent, Graphical models, Markov processes on trees and graphs, Markov Chain Monte Carlo.
Instructor(s): J. Novembre, M. Stephens Terms Offered: Winter
Prerequisite(s): STAT 244
Equivalent Course(s): STAT 35450

HGEN 48800. Fundamentals of Computational Biology: Algorithms and Applications. 100 Units.
This course will cover principles of data structure and algorithms, with emphasis on algorithms that have broad applications in computational biology. The specific topics may include dynamic programming, algorithms for graphs, numerical optimization, finite-difference, schemes, matrix operations/factor analysis, and data management (e.g. SQL, HDF5). We will also discuss some applications of these algorithms (as well as commonly used statistical techniques) in genomics and systems biology, including genome assembly, variant calling, transcriptome inference, and so on.
Instructor(s): Xin He, Mengjie Chen Terms Offered: Spring
Equivalent Course(s): STAT 35460

HGEN 70000. Advanced Study: Human Genetics. 300.00 Units.
Advanced Study: Human Genetics