GRADUATE PROGRAMS IN THE BIOMEDICAL SCIENCES

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The School of Medicine is proud to administer doctoral, master’s, professional and certificate graduate programs in the biomedical sciences, described fully in this bulletin under their departmental or center affiliations. The Graduate Education Office provides support and information on the graduate and postdoctoral training programs in the School of Medicine, as well as professional skill development and training grant proposal support. Resources for proposal development as well as current training information are available at the SOM Graduate Education (http://casemed.case.edu/gradprog) website.

Case Western Reserve University School of Medicine has a strong commitment to the importance of diversity in its research and educational programs. The CWRU community celebrates how our individual diversity in race, ethnicity, gender, country of origin, sexual orientation or gender identity enhances our work together. CWRU programs welcome diverse individuals, including those individuals of racial and ethnic groups underrepresented in biomedical science, those with physical disabilities, and those with disadvantaged backgrounds.

Common Academic Requirements
Each graduate program follows the overall regulations established and described in Graduate Studies Academic Requirements pages (http://bulletin.case.edu/bulletinarchives/2017-18/schoolofgraduatestudies/academicrequirements) and documented to the Regents of the State of Ohio. In particular, students and faculty are directed to sections regarding Academic Requirements for Master’s and Doctoral Degrees regarding total and graded course requirements, dissertation advisory committees, maintenance of quality-point average, and other general aspects of graduate study at CWRU. Within those overall expectations, a specific course of study for each graduate program is required and described in each degree plan of study.

Guiding Principles for Graduate Education in the School of Medicine
Training and educating graduate students in the biomedical sciences is a complex process that continually evolves based on the rapid progression of scientific discovery and ever expanding technological landscape. Graduate programs must continually modify their approaches to meet these modern-day needs. Students are expected to master their overall discipline, become experts in their field of research, as well as gain expertise in a diverse, but interrelated professional skill set. That skill set should be clearly defined, widely communicated and integrated across all PhD disciplines at CWRU SOM. Moreover, a set of common principles or goals for educating all graduate students in the SOM helps to guide our programs in course or curriculum development. The School of Medicine Graduate Education Office, in collaboration with the graduate program directors, developed a formal set of Guiding Principles (http://bulletin.case.edu/schoolofmedicine/graduateprograms/Guiding_Principles.pdf) for the education and training of all Ph.D. students in order to help accomplish these important goals.

Graduate Admissions to School of Medicine Programs
Graduate students are admitted to our programs through several streams, including the Biomedical Sciences Training Program (http://www.case.edu/med/BSTP), the Medical Scientist Training Program (http://mstp.cwru.edu), dual-degree initiatives, and direct admission to specific programs (please see individual program entries under their affiliated department pages). Postdoctoral Fellows and Postdoctoral Scholars are appointed through the Office of Postdoctoral Affairs (http://postdoc.case.edu).

Student Affinity Groups
Graduate students interact in vibrant groups in the School of Medicine including the Biomedical Graduate Student Organization (http://casemed.case.edu/gradprog/bgso.cfm) and the Minority Graduate Student Organization (http://casemed.case.edu/gradprog/mgso.cfm), as well as university-wide student organizations such as the Graduate Student Council (http://gsc.case.edu). In addition, doctoral students in the School of Medicine organize the annual Biomedical Graduate Student Symposium.

Professional Development
The Graduate Education Office provides professional development opportunities for trainees including the monthly Career Opportunities for Trainees & Professional Enrichment for Trainees Series (http://casemed.case.edu/gradprog/gradprodev.cfm), Pre-Professional Health Program Series, Enhancing Research and Industry Career Horizons (EnRICH) internship and career exposure program (http://casemed.case.edu/gradprog/EnRICH.php), and the Expanding Teaching Experiences for Doctoral Students (ExTEnD) program (http://casemed.case.edu/gradprog/prodevteaching.cfm).

Biomedical Sciences Training Program (BSTP)
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The Biomedical Sciences Training Program (BSTP) offers a common admission portal to most biomedical PhD degree programs at CWRU School of Medicine. The BSTP includes eleven doctoral programs in the School of Medicine with more than 200 faculty based in both basic science and clinical departments, giving BSTP students a tremendous range of research opportunities in many disciplines. It also provides a distinct advantage over traditional programs, which restrict choices of research area and faculty advisors.

Admissions
Students usually apply in the fall or winter and begin their studies the following summer. The application deadline is January 15th. Priority will be given to applications received by December 1. Applications will be considered by the Admissions Committee as soon as they are complete. In general a year of biology, organic chemistry and mathematics through calculus are required, and biochemistry and molecular biology are strongly recommended. We also seek students with strong backgrounds in physics or math who may be interested in our Structural Biology track.
Experience performing original research is essential. This might include an undergraduate honors thesis, summer research internships, or a technical position after graduation. Letters of recommendation from research mentors that describe creativity, handwork, and promise in science are very important.

**Exams**

The GRE general test is required. Recent classes have earned an average of 70th percentile in each area. A GRE subject test is desirable, but is not required. The Test of English as a Foreign Language (TOEFL) is required for foreign students unless they are from an English-speaking country or have a degree from a university where the instruction is primarily in English. Students may be eligible to apply for the transfer of some graduate credit from their previous institution. Please go here (http://gradstudies.case.edu) for more information. Transfer credit must be requested prior to beginning coursework at CWRU.

**The First Year**

**Coursework**

Students take integrated courses in Cell and Molecular Biology (CBIO 453 Cell Biology I, CBIO 455 Molecular Biology I). These two courses, offered in the fall semester, emphasize the molecular approaches that form the basis of modern biology. We also seek students with strong quantitative training who may have majored in physics or math, and offer alternative courses for these students to acquire foundations in biology. Qualified students also may take more specialized elective courses. All students take IBMS 500: On Being a Professional Scientist: The Responsible Conduct of Research.

**Research Rotations**

The research rotations allow students to explore research areas and become familiar with faculty members and their laboratories. The main purpose of these rotations is to aid students in selecting a laboratory for their thesis work. Students are encouraged to begin their rotations in July. Doing so gives them the opportunity to complete rotations during the summer before classes begin at the end of August. Students must complete at least three rotations.

**Choosing a Thesis Advisor**

During the first year, students select an advisor for their dissertation research. Each student also joins the PhD program with which their advisor is affiliated. Once a student chooses a PhD program, the requirements of that program are followed to obtain the PhD. The emphasis of the PhD work is on research, culminating in the completion of an original, independent research thesis and publishing the results in the scientific literature. PhD programs also focus on educating students to work as professional scientists.

**Participating Training Programs**

- Biochemistry (http://bulletin.case.edu/bulletinarchives/2017-18/schoolofmedicine/biochemistry/#phdtext)
- Cell Biology (http://bulletin.case.edu/bulletinarchives/2017-18/schoolofmedicine/molecularbiologyandmicrobiology/#phdtext)
- Genetics and Genome Sciences (http://bulletin.case.edu/bulletinarchives/2017-18/schoolofmedicine/genetics/#phdtext)
- Molecular Biology and Microbiology (http://bulletin.case.edu/bulletinarchives/2017-18/schoolofmedicine/molecularbiologyandmicrobiology/#phdtext)
- Molecular Virology (http://bulletin.case.edu/bulletinarchives/2017-18/schoolofmedicine/molecularbiologyandmicrobiology/#phdtext)
- Neurosciences (http://bulletin.case.edu/bulletinarchives/2017-18/schoolofmedicine/neurosciences/#phdtext)
- Nutrition (http://bulletin.case.edu/bulletinarchives/2017-18/schoolofmedicine/nutrition/#ph_d_text)
- Pathology (http://bulletin.case.edu/bulletinarchives/2017-18/schoolofmedicine/pathology)
- Pharmacology (http://bulletin.case.edu/bulletinarchives/2017-18/schoolofmedicine/pharmacology/#phdtext)
- Physiology and Biophysics (http://bulletin.case.edu/bulletinarchives/2017-18/schoolofmedicine/physiologyandbiophysics/#ph_d_text)
- Systems Biology and Bioinformatics (http://bulletin.case.edu/bulletinarchives/2017-18/schoolofmedicine/generalmedicals/new/#systemsbioinformaticstext)

These programs have tracks that allow specialization in the following areas: Cancer Biology; Cancer Therapeutics; Cell and Molecular Physiology; Developmental Biology; Experimental Pathology; Immunology; Membrane Structural Biology; Molecular and Cellular Biophysics; Molecular Pharmacology and Cell Regulation; Molecular Pharmacology and Cell Regulation; Organ Systems Physiology; RNA Biology; Structural Biology & Biophysics; Translational Therapeutics.

Training faculty, course offerings, and individual degree requirements are described in detail in the separate listings for each of these programs. All PhD programs have similar requirements, including an original thesis, coursework, examinations, publications in scientific journals with lead authorship, seminars, journal clubs, and other activities.

**BSTP Course**

BSTP 400. Research Rotation in Biomedical Sciences Training Program. 0 - 9 Units.

**CBIO Courses**

CBIO 453. Cell Biology I. 3 Units.

Part of the first semester curriculum for first year graduate students along with CBIO 455. This course is designed to give students an intensive introduction to prokaryotic and eukaryotic cell structure and function. Topics include membrane structure and function, mechanisms of protein localization in cells, secretion and endocytosis, the cytoskeleton, cell adhesion, cell signaling and the regulation of cell growth. Important methods in cell biology are also presented. This course is suitable for graduate students entering most areas of basic biomedical research. Undergraduate courses in biochemistry, cell and molecular biology are excellent preparation for this course. Recommended preparation: Undergraduate biochemistry or molecular biology.
CBIO 455. Molecular Biology I. 3 Units.
Part of the first semester curriculum for first year graduate students along with CBIO 453. This course is designed to give students an intensive introduction to prokaryotic and eukaryotic molecular biology. Topics include protein structure and function, DNA and chromosome structure, DNA replication, RNA transcription and its regulation, RNA processing, and protein synthesis. Important methods in molecular biology are also presented. This course is suitable for graduate students entering most areas of basic biomedical research. Undergraduate courses in biochemistry, cell and molecular biology are excellent preparation for this course. Recommended preparation: Undergraduate biochemistry or molecular biology.

CBIO 456A. Since You Were Born: Nobel Prize Biomedical Research in the Last 21 Years- Section A. 1 Unit.
This course is one of four sections that will cover major advances in biomedical research by review of Nobel Prize-winning topics from the past 21 years. Each section will cover 8 Nobel prize topics (1 topic/2 hour session/week for 8 weeks). Students will read critical research papers of the Nobel prize scientist(s) in preparation for guided in-class discussion led by the faculty mentor. The CBIO456A section will cover Nobel Prizes related to the areas of Genetics & Genome Science, Systems Biology & Bioinformatics, and RNA Biology. These include: 1) 2012 Prize, J. Gurdon and S. Yamanaka: Mechanisms of pluripotent stem cell development and reprogramming; 2) 2010 Prize, R. Edwards: Development of in vitro fertilization; 3) 2009 Prize, E. Blackburn, C. Greider, and J. Szostack: Mechanisms of chromosome protection by telomeres and telomerase; 4) 2009 Prize, Y. Ramakrishnan, T. Steitz, and A. Yonath: Structure/function analysis of ribosomes; 5) 2007 Prize, M. Capecchi, M. Evans, and O. Smithies: Discovery/development of transgenic and gene-deletion methods in mice; 6) 2006 Prize, A. Fire and C. Mello: Discovery/development of RNA interference-gene silencing methods; 7) 2006 Prize, R. Kornberg: Mechanisms of eukaryotic transcription; 8) 1995 Prize, E. Betzig, S. Hell, and W. Moerner: Development of super-resolution fluorescence microscopy.

CBIO 456B. Since You Were Born: Nobel Prize Biomedical Research in the Last 21 Years- Section B. 1 Unit.
This course is one of four sections that will cover major advances in biomedical research by review of Nobel Prize-winning topics from the past 21 years. Each section will cover 8 Nobel prize topics (1 topic/2 hour session/week for 8 weeks). Students will read critical research papers of the Nobel prize scientist(s) in preparation for guided in-class discussion led by the faculty mentor. The CBIO456B section will cover Nobel Prizes related to the areas of Molecular Biology & Microbiology, Molecular Virology, Pathology-Immunology, and Cell Biology. These include: 1) 2016 Prize, Y. Ohsumi: Mechanisms of Autophagy; 2) 2015 Prize, W. Campbell, S. Omura, and Y. Tu: Therapies against roundworms & malaria; 3) 2011 Prize, B. Beutler, J. Hoffman, and R. Steinman: Mechanisms underlying innate immunity and adaptive immunity; 4) 2008 Prize, H. zur Hausen, F. Barre-Sinoussi, and L. Montagnier: Discovery of human immunodeficiency virus and oncogenic papilloma viruses; 5) 2008 Prize, O. Shimomura, M. Chalfie, and R. Tsien: Discovery/development of green fluorescent protein for biological applications; 6) 2005 Prize, B. Marshall and J. Warren: Discovery of Helicobacter pyloris as pathogenic mechanism in peptic ulcers/gastritis; 7) 1999 Prize, G. Blobel: Mechanisms of protein sorting and subcellular trafficking; 8) 1996 Prize, P. Doherty and R. Zinkernagel: Mechanisms of cell-mediated immune defense.

CBIO 456C. Since You Were Born: Nobel Prize Biomedical Research in the Last 21 Years- Section C. 1 Unit.
This course is one of four sections that will cover major advances in biomedical research by review of Nobel Prize-winning topics from the past 21 years. Each section will cover 8 Nobel prize topics (1 topic/2 hour session/week for 8 weeks). Students will read critical research papers of the Nobel prize scientist(s) in preparation for guided in-class discussion led by the faculty mentor. The CBIO456B section will cover Nobel Prizes related to the areas of Biochemistry, Nutrition, Pharmacology, and Pathology-Cancer. These include: 1) 2015 Prize, T. Lindahl, P. Modrich, and A. Sancar: Mechanisms of DNA Repair; 2) 2014 Prize, E. Betzig, S. Hell, W. Moerner: Development of super-resolution fluorescence microscopy; 3) 2012 Prize, R. Lefkowitz and B. Kobilka: Structure/function analysis of G protein-coupled receptors; 4) 2004 Prize, A. Ciechanover, A. Hershko, and I. Rose: Mechanisms of ubiquitin-mediated protein degradation; 5) 2003 Prize, P. Lauterbur and P. Mansfield: Development of magnetic resonance imaging (MRI) methods; 6) 2002 Prize, S. Brenner, H.R. Horvitz, and J. Sulston: Mechanisms for genetic regulation of organ development and programmed cell death; 7) 2002 Prize, J. Fenn, K. Tanaka, and K. Wuthrich: Development of mass spec and NMR methods for biological macromolecules; 8) 2001 Prize, L. Hartwell, T. Hunt, and P. Nurse: Mechanisms of cell cycle regulation.

CBIO 456D. Since You Were Born: Nobel Prize Biomedical Research in the Last 21 Years- Section D. 1 Unit.
This course is one of four sections that will cover major advances in biomedical research by review of Nobel Prize-winning topics from the past 21 years. Each section will cover 8 Nobel prize topics (1 topic/2 hour session/week for 8 weeks). Students will read critical research papers of the Nobel prize scientist(s) in preparation for guided in-class discussion led by the faculty mentor. The CBIO456D section will cover Nobel Prizes related to the areas of Neuroscience, Physiology & Biophysics, and Pathology-Molecular Basis of Disease. These include: 1) 2014 Prize, J. O’Keefe, M-B. Moser, and E. Moser: Mechanisms of nerve cell spatial positioning in the brain; 2) 2013 Prize, J. Rothman, R. Scheckman, and T. Sudhof: Mechanisms of intracellular vesicle trafficking and biomolecule secretion; 3) 2004 Prize, R. Axel and L. Buck: Structure/function of odorant receptors and organization of olfactory system; 4) 2003 Prize: P. Agre and R. Mackinnon: Structure/function analysis of channel proteins in cell membranes; 5) 2000 Prize, A. Carlsson, P. Greengard, and E. Kandel: Mechanisms of signal transduction in the nervous system; 6) 1998 Prize, R. Furchgott, L. Ignarro, and F. Murad: Discovery/mechanisms of nitric oxide as signaling molecule in cardiovascular system; 7) 1997 Prize, S. Prusiner: Discovery/prions as new biological principle of infection in neurological disease; 8) 1997 Prize, P. Boyer, J. Walker, and J. Skou: Mechanisms of mitochondrial ATP synthesis and Na, K-ATPase pump function.
IBMS Courses

IBMS 450. Fundamental Biostatistics to Enhance Research Rigor & Reproducibility. 1 Unit.
This is a required graduate level course for all first year PhD students in the School of Medicine biomedical PhD programs excluding Biomedical Engineering, Population and Quantitative Health Sciences, Molecular Medicine and Clinical Translation Science. This course focuses on providing students with a basic working knowledge and understanding of best practices in biostatistics that can be applied to common biomedical research activities in numerous fields. Weekly sessions involve a combination of basic programming activities, lectures, exercises, hands-on data manipulation and presentation. Topics include experimental design and power analysis, hypothesis testing, descriptive statistics, linear regression, and others with an emphasis on when and in which experimental design a particular test is properly used. The overall goal of the course is to empower students to use these biostatistics to enhance the rigor of their experimental design and reproducibility of their primary data. The major focus is not on theory, but on a practical acquisition of a working knowledge of basic data processing analysis, interpretation, and presentation skills.

IBMS 500. On Being a Professional Scientist: The Responsible Conduct of Research. 1 Unit.
The goal of this course is to provide graduate students with an opportunity to think through their professional ethical commitments before they are tested, on the basis of the scientific community’s accumulated experience with the issues. Students will be brought up to date on the current state of professional policy and federal regulation in this area, and, through case studies, will discuss practical strategies for preventing and resolving ethical problems in their own work. The course is designed to meet the requirements for "instruction about responsible conduct in research" for BSTP and MSTP students supported through NIH/ADAMHA institutional training grant programs at Case. Attendance is required.