Formal Training Requirements

The goal of this training program is to support pre-doctoral students who seek balanced and rigorous training in mathematics and biology/medicine with a special emphasis on research in mathematical modeling in biology or medicine. The early training includes formal course work, research rotations with participating faculty, and attendance and participation in a seminar series. This training requirement, revised 10 years ago, has been found to suit those of all participating departments and maintain the rigorous and balanced training intended for the trainees. It did not significantly increase the time-to-degree of the trainees. In this renewal application, some changes have also been made to take advantage of increased opportunities at UCLA for trainees to acquire clinically relevant experience/training. Adjustment can also be made by the Executive Committee in the future if deemed necessary and will be in consultation with the participating faculty. The training requirements are summarized below.

Trainees are not expected to be already fully proficient in both biology and mathematics at the start of this program. However, it is expected that trainees are currently pursuing a graduate program in either a mathematical or biological discipline and already have a minimal level of undergraduate background in the other discipline (see the Trainee Selection Guidelines below). As summarized in the following sections, an aim of the didactic portion of this training program is for trainees to demonstrate acquisition of a minimum of 20 quarter units of advanced course work in quantitative methods and 20 quarter units in the biological sciences. Although the goal is graduate level competence in these areas, students can petition to have 8-10 units in each group satisfied by upper-division undergraduate-level courses.

1. Trainees must develop with their advisor(s) a coherent plan for quantitative training that includes completion of five courses (total of 20 quarter units), with at least two courses from a series in Core Methodology and two from a series in Modeling Applications in Biology/Medicine. The Core Methodology series covers basic modeling and computational techniques in the following areas: (1) deterministic modeling, (2) stochastic and statistical modeling, (3) computation/algorithms/numerical methods, (4) optimization, and (5) other applied mathematics. Courses in the Modeling Applications in Biology/Medicine series demonstrate the application of core methodologies to biological or medical research and have substantial mathematical and biological content and exposure to current research problems or the clinical environment. Appendix 1 presents examples of suitable graduate courses in both series currently offered by a variety of mathematical, engineering, and natural science programs. These examples are not exhaustive, and the Executive Committee will review suggestions from participating faculty and update the lists on an annual basis. Moreover, in developing a plan for quantitative training, trainees may petition the Executive Committee to allow substitution of 8 of the 20 quarter units with upper division courses. Examples of courses taken by a recent trainee are presented in Appendix 2.

2. Trainees who are not already in a doctoral program in a biological or biomedical specialty must develop with their advisors a coherent plan for biological training that includes completion of at least 20 quarter units of upper division and graduate courses. At least half should be at the graduate level. The Executive Committee can provide suggestions for coherent course sequences, including those already developed by Biomathematics for students interested in specialty training in Human Genetics, Microbiology Immunology and Molecular Genetics, Molecular Biology, Molecular Cellular and Integrative Physiology, the Neuroscience Interdepartmental Program, or EEB (Ecology and Evolutionary Biology). One notable example has been the ACCESS program at UCLA, which offers a common first year curriculum for graduate students interested in research specialization in the molecular, cellular, and integrative life sciences. To provide more clinically relevant experience to the trainees, several courses that are related to clinical research or translational medicine under development by CTSI will be available in this category. Trainees will be encouraged by the Executive Committee to consider these courses as part of their SIB training.

3. To help prepare trainees for their dissertation research and professional development, trainees are required to complete at least one quarter per year of directed research in the laboratories of the participating faculty.
members. Trainees must also attend the Fall quarter seminar course on Frontiers in Biomathematics (Biomath 200). These requirements provide trainees a broad perspective on how mathematical modeling is being applied in a variety of biological/medical areas and opportunities for trainees to establish personal contacts with active researchers in various fields. This exposure is especially helpful for those who do not yet have a research topic. The advisor or mentor for each trainee, of course, is expected to play an important role in guiding the trainee to select a topic that suits the trainee’s scientific interests and aptitude.

An on-campus retreat is held annually and provides a social gathering of the trainees and participating faculty. Also, during the retreat, each trainee who has had a directed research experience makes an oral presentation of the results of that research, and participating faculty give commentary and feedback on the presentations.

4. In addition, all trainees are required to take a formal class on ethics and responsible conduct in biological/medical research. Examples: Biomath M261 (offered fall quarter only), MIMG C234 (offered in spring quarter only), and Neuro 207 (spring quarter).

Training Timetable

Trainees are expected to take any remaining courses required by their departments/programs concurrently with the ones required by this training program. They are expected to complete the curriculum requirements of the training program in 2 years, although up to an additional year may be requested by petition to complete the requirements under special circumstances, e.g., course series offered every other year or conflicts with requirements of the home department. Courses for the training program will naturally overlap with courses required by the department/program with which the trainee is affiliated, reducing the actual number of extra courses that the trainee needs to take. Moreover, the training program assists trainees in deciding on research topics and is intended to provide quantitative techniques and insights necessary for their dissertation research. Thus, the extra training time added to the regular time-to-degree from their home department is expected to be less than a year.

The emphasis of this training program will continue to be on the early didactic years of graduate training. By the time of completion of the curriculum requirements of the program or earlier, a trainee is expected to have decided on a dissertation research area, selected a laboratory or setting under which to do the work, and chosen a dissertation research mentor or co-mentors. At that time, no later than the end of the third year, the responsibility for the trainee’s financial support is expected to shift to the affiliated laboratory. Because theoretical research may not be performed in a traditional laboratory setting, students pursuing such research with limited access to funding can petition to apply for further extension of training grant support into their research dissertation years. The evaluation of all exceptions is made on a case-by-case basis by the Selection Committee, taking into account the competition for evaluation of all new trainee applicants and renewals.

Trainee Selection

Every student applying to the training program is asked to submit (1) GRE scores, (2) transcripts covering his/her most recent academic degree or program involvement, (3) a statement of purpose and research interests, and (4) letters of recommendation. For incoming students we will accept three letters of recommendation used for their application to a UCLA graduate program. For continuing students we expect two letters of recommendation, at least one of which is from their current faculty advisor or mentor. Although Selection Committee meetings can be held throughout the year, a key meeting is held during Winter Quarter to assist in the recruitment to UCLA of outstanding graduate students interested in the quantitative biosciences. The timing of this meeting allows introduction of applications to the SIB program from incoming students applying for graduate admission to one of the participating programs for competition along with SIB applications from students already enrolled in a UCLA doctoral program.

In evaluating incoming students we are mindful of some ideal standards of undergraduate preparation for the dual areas of training required in this program. In mathematics, these include exposure to multivariate calculus, linear algebra, ordinary differential equations, probability and statistics. In biology we would expect to see a year-long introduction to biological principles as well as a course in biochemistry/molecular
biology. Evidence for successful performance in upper division courses in both areas is helpful for judging that timely completion of the formal requirements is likely. However, in our experience, exceptional strengths in one area can often balance deficits in the other.

**Monitoring and Evaluation**

As noted earlier, the progress and performance of each trainee is monitored closely by his/her advisor, with whom members of the Executive Committee communicate at least quarterly. Yearly, the progress of each trainee is reported (in writing and orally) to the Executive Committee and the Selection Committee, which determine whether progress is satisfactory, whether adjustment is needed, and whether support should be continued. The yearly evaluation and ranking of current trainees for renewal is done competitively and at the same time as evaluation and ranking of new applicants for entry into the training program (see Section e below). The competitive ranking of renewing students also takes into account their rate of progress. Students petitioning for exceptions, e.g., course work beyond the second year or continuation of support into the dissertation years, will have to show compelling cause as well as outstanding academic and research progress.
APPENDIX 1

Examples of Graduate Courses for Quantitative Training

Note: Trainees must develop with their advisor(s) a coherent plan for quantitative training that includes completion of five courses (total of 20 quarter units), with at least two courses in Core Methodology and two in Modeling Applications in Biology. The following examples are not exhaustive, and the Advisory Committee will review suggestions from participating faculty and update the list on an annual basis. Trainees may petition the Advisory Committee to allow substitution of 8 of the 20 quarter units with upper division courses.

Listings below include course descriptions taken from the 2011-12 General Catalog.

a) Core Methodology

(1) Deterministic Modeling

Biomath 201 - Deterministic Models in Biology

201. Deterministic Models in Biology. (4) Lecture, three hours; laboratory, three hours. Preparation: knowledge of linear algebra and differential equations. Examination of conditions under which deterministic approaches can be employed and conditions where they may be expected to fail. Topics include compartmental analysis, enzyme kinetics, physiological control systems, and cellular/animal population models. S/U or letter grading.


M296A. Advanced Modeling Methodology for Dynamic Biomedical Systems. (4) (Same as Computer Science M296A and Medicine M270C.) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 141 or 142 or Mathematics 115A or Mechanical and Aerospace Engineering 171A. Development of dynamic systems modeling methodology for physiological, biomedical, pharmacological, chemical, and related systems. Control system, multicompartamental, noncompartamental, and input/output models, linear and nonlinear. Emphasis on model applications, limitations, and relevance in biomedical sciences and other limited data environments. Problem solving in PC laboratory. Letter grading.


Math 266 A - Applied Ordinary Differential Equations


Math 266 B,C - Applied Partial Differential Equations

266B-266C. Applied Partial Differential Equations. (4-4) Requisite: course 220 or Computer Science M296A. Estimation methodology and model parameter estimation algorithms for fitting dynamic system models to biomedical data. Model discrimination methods. Theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experiment design via applications in physiology and pharmacology. Letter grading.

M203. Stochastic Models in Biology. (4) (Same as Human Genetics M203.) Lecture, four hours. Requisite: Mathematics 170A or equivalent experience in probability. Mathematical description of biological relationships, with particular attention to areas where conditions for deterministic models are inadequate. Examples of stochastic models from genetics, physiology, ecology, and variety of other biological and medical disciplines. S/U or letter grading.

Biomath 203 - Stochastic Models in Biology

(2) Stochastic and Statistical Modeling


M270. Optimal Parameter Estimation and Experiment Design for Biomedical Systems. (4) (Same as Biomedical Engineering M296B, Computer Science M296B, and Medicine M270D.) Lecture, four hours; outside study, eight hours. Requisite: course 220 or Computer Science M296A. Estimation methodology and model parameter estimation algorithms for fitting dynamic system models to biomedical data. Model discrimination methods. Theory and algorithms for designing optimal experiments for developing and quantifying models, with special focus on optimal sampling schedule design for kinetic models. Exploration of PC software for model building and optimal experiment design via applications in physiology and pharmacology. Letter grading.

Statistics 200 A,B - Statistical Theory

200A. Applied Probability. (4)
Statistics M230 - Statistical Computing
(Same as Biostatistics M280.) Lecture, three hours. Requisites: course 100C, Mathematics 115A. Introduction to theory and design of statistical programs; computing methods for linear and nonlinear regression, dealing with constraints, robust estimation, and general maximum likelihood methods. Letter grading.

(3) Computation/Algorithms/Numerical Methods
Chemistry C226A - Computational Methods for Chemists
C226A. Computational Methods for Chemists. (4)
Lecture, four hours; laboratory, four hours. Preparation: programming experience in either BASIC, Fortran, C, C++, Java, or Pascal. Requisites: course 110A, Mathematics 33B. Theorecticing new chemical applications, including simple force fields and resulting statistical mechanics for simple molecules, simple ab-initio methods for organic molecules and nanotubes, and classical and semi-classical dynamics and spectroscopy. Concurrently scheduled with course C126A. S/U or letter grading.

Computer Science 280A-280Z. Algorithms. (4 each)
280A-280Z. Algorithms. (4 each)

Optimization Methods in Biology
Biomath 210 - Optimization Methods in Biology
210. Optimization Methods in Biology. (4)
Lecture, four hours. Preparation: undergraduate mathematical analysis and linear algebra; familiarity with programming language such as Fortran or C. Modern computational biology relies heavily on finite-dimensional optimization. Survey of theory and numerical methods for discrete and continuous optimization, with applications from genetics, medical imaging, pharmacokinetics, and statistics. S/U or letter grading.

Chem. Engineering M280C - Optimal Control
M280C. Optimal Control. (4)
(Same as Electrical Engineering M240C and Mechanical and Aerospace Engineering M270C.) Lecture, four hours; outside study, eight hours. Requisite: Electrical Engineering 103 or Mathematics 151B or comparable experience with numerical computing. Designed for graduate computer science and engineering students. Principles of computer treatment of selected numerical problems in algebraic and differential systems, transforms and spectra, data acquisition and reduction; emphasis on concepts pertinent to modeling and simulation and applicability of contemporary developments in numerical software and computer exercises. Letter grading.

Chem. Engineering 284A - Optimization in Vector Spaces
284A. Optimization in Vector Spaces. (4)

Other Applied Mathematics
Electrical Engr. 211 A,B - Digital Image Processing
211A. Digital Image Processing I. (4)
Lecture, three hours; laboratory, four hours; outside study, five hours. Preparation: computer programming experience. Requisite: course 113. Fundamentals of digital image processing theory and techniques. Topics include two-dimensional linear system theory, image transforms, and enhancement. Concepts covered in lecture applied in computer laboratory assignments. Letter grading.

Math 274 A,B,C - Asymptotic Methods; Perturbation Methods
274A. Asymptotic Methods. (4)

274B-274C. Perturbation Methods. (4-4)
Lecture, three hours. Requisite: course 266A. Boundary layer theory, matched asymptotic expansions, WKB theory. Problems with several time scales: Poincaré method, averaging techniques, multiple-scale analysis. Application to eigenvalue problems, nonlinear oscillations, wave propagation, and bifurcation phenomena. Examples from various fields of science and engineering.

Physics 231 A,B - Methods of Mathematical Physics
231A. Methods of Mathematical Physics. (4)
Lecture, three hours. Not open for credit to students with credit for Mathematics 266A. Linear operators, review of functions of a complex variable, integral transforms, partial differential equations. S/U or letter grading.

231B. Methods of Mathematical Physics. (4)
Lecture, three hours. Not open for credit to students with credit for Mathematics 266B. Ordinary differential equations, partial differential equations, and integral equations. Calculus of variations. S/U or letter grading.

b) Modeling Applications in Biology
Biomath 202 – Structure, Function, and Evolution of Biological Systems
Lecture, four hours. Preparation: knowledge of calculus, differential equations, and partial differential equations. Introduction to concepts, equations, and approximations that describe structure and function of biological systems, evolutionary principles, and network design and dynamics. Topics include cancer initiation and progression, gene expression, epipidemiology, response to fluctuating environments, network structure, and functional traits. S/U or letter grading.

Biomath 206 - Introduction to Mathematical Oncology
Biomed 207B - Applied Genetic Modeling

M207B. Applied Genetic Modeling. (4)
(Same as Biostatistics M239 and Human Genetics M207B.) Lecture, three hours; laboratory, one hour. Requisites: Biostatistics 110A, 110B. Methods of computer-oriented human genetic analysis. Topics include statistical methodology underlying genetic analysis of both quantitative and qualitative complex traits. Laboratory for hands-on computer analysis of sequence data; laboratory reports required. Course complements M207A; students may take either and are encouraged to take both. S/U or letter grading.

Biomed 208 (A or B) - Modeling in Neurobiology

208A. Modeling in Neurobiology for Mathematicians. (4)
Lecture, four hours; laboratory, two hours. Preparation: introductory ordinary partial differential equations, programming experience. Introduction to electrochemical bases for nerve function and mathematical and computational methods for studying this, appropriate for physicists, engineers, and mathematicians. Survey of current leading research areas and software systems. S/U or letter grading.

Biomed M211/Human Genetics M211 – Mathematical and Statistical Phylogenetics

M211. Mathematical and Statistical Phylogenetics. (4)
(Same as Biostatistics M239 and Human Genetics M211.) Lecture, three hours; laboratory, one hour. Requisites: Biostatistics 110A, 110B, Mathematics 170A. Theoretical models in molecular evolution, with focus on phylogenetic techniques. Topics include evolutionary tree reconstruction methods, studies of viral evolution, phylogeography, and coalescent approaches. Examples from evolutionary biology and medicine. Laboratory for hands-on computer analysis of sequence data. S/U or letter grading.

Biomed 213 – Modeling Vascular Networks

213. Modeling Vascular Networks. (4)
Lecture, four hours. Recommended preparation: calculus, differential equations, complex analysis, elementary knowledge of partial differential equations. Introduction to equations that describe fluid flow dynamics and branching, and hierarchical networks to provide survey of models for structure and flow of vascular systems. Vascular systems are nearly ubiquitous in nature, occurring across animals, plants, and other organisms. Coverage of applications to tumor growth and angiogenesis, sleep, allometric scaling, and other phenomena. S/U or letter grading.

Biomed 220 – Kinetic and Steady State Models in Pharmacology & Physiology

220. Kinetic and Steady State Models in Pharmacology and Physiology. (4)

Biomed M230 - Computed Tomography: Theory and Applications

(Same as Biomedical Physics M230.) Lecture, four hours. Computed tomography is three-dimensional imaging technique being widely used in radiology and is becoming active research area in biomedicine. Basic principles of computed tomography (CT), various reconstruction algorithms, special characteristics of CT, physics in CT, and various biomedical applications. S/U or letter grading.

Biomed/Physics M243 – Condensed Matter Physics of the Cell

(Same as Physics M243L.) Seminar, four hours. Designed for graduate students. Basic paradigms of condensed matter physics and applications to biophysical modeling. S/U or letter grading.

Biomed. Engineering M296D - Introduction to Computational Cardiology

M296D. Introduction to Computational Cardiology. (4)
(Same as Computer Science M296D.) Lecture, four hours; outside study, eight hours. Requisite: course CM186B. Introduction to mathematical modeling and computer simulation of cardiac electrophysiological process. Ionic models of action potential (AP). Theory of AP propagation in one-dimensional and twodimensional cardiac tissue. Simulation on sequential and parallel supercomputers, choice of numerical algorithms, to optimize accuracy and to provide computational stability. Letter grading.

Biomed. Physics 210 – Principles of Medical Imaging

210. Computer Vision in Medical Imaging. (4)
Lecture, three hours; discussion, one hour. Recommended requisites: Mathematics 155, Program in Computing 10A. Study of image segmentation, feature extraction, object recognition, classification, and visualization with biomedical applications. Topics include region-growing, edge detection, mathematical morphology, clustering, neural networks, and volume rendering in lectures, case studies, and programming projects. S/U or letter grading.

Molecular & Medical Pharmacology M248 – Introduction to Biological Imaging

M248. Introduction to Biological Imaging. (4)
(Same as Biomedical Engineering M248 and Biomedical Physics M248.) Lecture, three hours; laboratory, one hour; outside study, seven hours. Exploration of role of biological imaging in modern biology and medicine, including imaging physics, instrumentation, image processing, and applications of imaging for range of modalities. Practical experience provided through series of imaging laboratories. Letter grading.

OBEE C219 – Mathematical Ecology

C219. Mathematical Ecology. (6)
Lecture, three hours; discussion, one hour. Requisites: course 100, Mathematics 3B or 31A. Recommended: course 122, Life Sciences 1, Mathematics 3C. Introduction to modeling dynamics of ecological systems, including formulation and analysis of mathematical models, basic techniques of scientific programming, probability and stochastic modeling, and methods to relate models to data. Examples from ecology but techniques and principles applicable throughout life and physical sciences. Concurrently scheduled with course C119. S/U or letter grading.
Appendix 2.
Example of Courses Taken by a Past Trainee

Quantitative Course (>=20 units)
   a) Core courses
   Biomath 201 - Deterministic Models in Biology (4 units)
   Biomath M203 - Stochastic Models in Biology (4 units)
   Biomath 210 - Optimization Methods in Biology (4 units)
   Stat 200A, B - Applied Probability (8 units)
   Stat 201B – Regression Analysis (4 units)
   Stat 238 – Bayesian Inference (4 units)
   Math 251A – Partial Differential Equation (4 units)
   Math 274A – Asymptotic Methods (4 units)
   Math 272A – Continuum Mechanics (4 units)

   b) Modeling Applications in Biology
   Biomath 206 - Introduction to Mathematical Oncology (4 units)
   Biomath 208A - Modeling in Neurobiology (4 units)
   Biomath 213 – Modeling Vascular Networks (4 units)

Biomedical Courses (>=20 units)
   MCDE 144 - Molecular Biology (5 units)
   Neuroscience 205 – systems of Neuroscience (4 units)
   Neuroscience M220 – Biological Learning and Memory (4 units)
   Neuroscience M201 – Cellular/developmental/molecular Neurobiology (6 units)
   Neuroscience M202 – Cellular Neurophysiology (4 units)
   Phy Science 241 – Neuroplasticity and repair (4 units)

SIB Required Courses
   Biomath M261 – Ethics in Patient Research (2 units)
   Biomath 200 – Research Frontiers in Biomathematics (2 units x2)