Introduction
The Department of Pharmacology offers a predoctoral training program in Pharmacology. The objective of the Graduate Training Program is to ensure that the student who receives the Ph.D. from this Department is a highly trained, competitive scientist capable of pursuing a productive career in the pharmacological sciences. The student will acquire a broad background of knowledge in the biomedical sciences, detailed knowledge of his or her research area, the ability to pose scientific questions, the skills to seek answers in the laboratory, the ability to present clearly and concisely his or her research in both oral and written form, the ability to carry out a critical analysis of the scientific literature, and the ability to prepare and present formal lectures.

The primary responsibility for the organization and conduct of the graduate education program of the Department rests with the Graduate Education Executive Committee, which is appointed by the Chair of the Department. In addition to faculty appointees, a student delegate provides liaison with the graduate student body. The Graduate School Handbook lists the University-wide requirements for successful completion of the Ph.D. Degree.

Selection Procedures
The Department of Pharmacology considers applications from all interested students, irrespective of sex, racial background or national origin, who have or expect to receive a bachelor's degree in a scientific discipline.

Applications are reviewed by the Graduate Admissions Committee. Initial evaluation is based on grades, Graduate Record Examination scores, three letters of recommendation, a brief statement of career goals, and research experience. The most promising applicants are invited to Chapel Hill for interviews with departmental faculty and students. The Graduate Admissions Committee surveys faculty opinion and decides whether to recommend to the Graduate School that the applicant be admitted.

Residency
Once admitted into the program, all students who are U.S. citizens are expected to apply for in-state residency after the first year. Students can apply on-line every semester, and should appeal negative decisions. Failure of eligible students to apply for in-state residency may result in the student having to pay their own tuition and fees.

Training Objectives
The principal goal of the Graduate Program is to train students for a research career in the pharmacological sciences. Attainment of this goal depends on the accomplishment of a wide set of objectives, including acquisition of a broad knowledge of the pharmacological sciences and related areas such as biochemistry and physiology. Although completion of formal course work provides the necessary building blocks in this process, it is the philosophy of this department that only through intensive laboratory experience in an active research environment can students attain the development necessary for the Ph.D. degree. Thus, beginning with the first day of matriculation and continuing through successful defense of a research dissertation, students are expected to spend the majority of their time in a research laboratory. First-year students invest major effort in the laboratory research rotation program in which three separate research projects are carried out in different laboratories. During each...
of these rotations the student becomes a "full" member of the laboratory and is expected to be an active participant in all lab functions including research meetings, journal clubs, seminars, etc.

**Course Requirements**

The following sections outlines the course requirements for 1) students admitted directly into the pharmacology graduate program, 2) IBMS students joining the program after their first year in the IBMS program, and 3) MD/PhD students entering after completing their 2nd year in medical school. Any student can petition the Graduate Education Executive Committee (GEEC) to waive certain courses in which they have a good undergraduate background. When doing so, the student should include in their petition information about the course already taken (e.g., syllabus, reading assignments, exams, transcript, etc.).

The following courses are required for **students admitted directly into the pharmacology graduate program**:

1. **Pharmacology 643/644** (Cell Structure, Signaling, and Growth Control)
   
   OR

   **Pharmacology 722/723** (Cellular and Molecular Neurobiology).

   These are two-semester interdisciplinary courses that incorporate principles of cellular and molecular pharmacology, physiology, receptors, signal transduction, cell adhesion, neuropharmacology, and other topics. Because of overlap between the two courses in key topics of receptor theory and signal transduction mechanisms, students can choose either course.

2. **Pharmacology 701** (Introduction to Molecular Pharmacology). A one-semester course (2 credit hours) that covers various aspects of molecular and organ pharmacology, including molecular biology, signal transduction, and pharmacokinetics.

3. **Pharmacology 702** (Principles of Pharmacology and Physiology). This course (3 credit hours) focuses on basic pharmacological and physiological principles of drug action. The course has six modules: i) Autonomics/Autocoids, ii) Neuropharmacology, iii) Cardiovascular/Renal Pharmacology, iv) Endocrine Pharmacology, and v) Chemotherapy.

4. **Pharmacology 730** (Seminar in Pharmacology) for 2 credit hours
   
   **PHCO 330** is geared towards techniques and critical evaluation of the literature.

5. **Pharmacology 731** (Seminar in Pharmacology) for 1 credit hour.
   
   Student presentations of papers published by speakers in our seminar program.

6. **Pharmacology 732** (Grant Writing and Responsible Conduct of Biomedical Research). Every student preparing for their qualifying examinations takes this course in June following the end of classes. The course meets three days/week for the entire month and focuses on the development of their qualifying examination pre-proposal, experimental design and grant writing, and the responsible conduct of biomedical research.

7. **PHCO 750** (Data Analysis/Biostatistics). This course is focused on the appropriate tools and tests for analysis of biomedical research data. Students with a good undergraduate background in statistical analysis of biomedical data can petition the GEEC to have this requirement waived.

8. **Electives**. Students must take at least 2 elective courses for a total of at least 3 credit hours. Some elective possibilities include (but are not limited to):

   **Tutorials in Pharmacology**:
   
   Ras Superfamily Proteins & Signal Transduction (Drs. Cox and Der)
   
   Signal transduction (Drs. Harden and Dohlman)
   
   Structure and Function of Ion Channels (Dr. Rosenberg)
   
   Drug Discovery and Development (Dr. Carl)
   
   Adhesion Receptors and Signaling in Cancer & CV Disease. (Drs. Parise and Juliano)
   
   Gene Therapy: Medicine for the 21st Century (Dr. Samulski)
Research Rotations. Each student conducts three research projects, each under the supervision of a different faculty member. Students select rotations from any of the Core Faculty. With approval of the GEEC, students may also perform rotation projects with faculty outside the labs of the Core Faculty, especially when the rotation will provide training in an area that is outside of the expertise of the Core Faculty. Thus, students have a huge range of research opportunities. Rotations must be taken by all entering graduate students. A waiver for one research rotation may be granted if a student has previously completed substantial independent research, including written reports and/or manuscripts. Students seeking such a waiver must petition the GEEC, and provide information (e.g. reports, manuscripts, grant proposals, and/or letters from research advisors) about their previous research.

Each rotation project lasts approximately 10 weeks. Students are expected to work in the laboratory at least 20 hours per week, although in reality students work much longer hours. Students are fully integrated into the laboratory during their rotation projects, and are involved in lab meetings and journal clubs. At the beginning and end of each rotation, the rotation advisor and student review a written statement of expectations for the student’s performance in the laboratory. These discussions provide the student with the advisors’ expectations and critical comments on areas of excellence and weakness.

At the end of each rotation period, students submit a written report and prepare an oral presentation to the faculty and other graduate students. The first two written documents take the form of a meeting-quality abstract (≤ 500 words) and an appendix of all relevant figures and figure legends from their rotation. The written report for the third rotation is a short paper in a manuscript format. For the oral presentations, the first two take the form of a 10-minute slide presentation followed by a 5-minute question-and-answer period, while the third is a poster presentation.
Example of a curriculum. In this example, it is assumed that the student has been able to obtain a waiver for Chem 130 (Biochemistry).

**FIRST YEAR**  
**Fall Semester**  
- Pharmacology 643 or Pharmacology 722  
- Pharmacology 701  
- Pharmacology 731  
- Research Rotations (10 weeks each)  
**Summer**  
- Pharmacology 732 (Grant Writing) June  
- Doctoral Written Exam Due ~Aug 15  

**Spring Semester**  
- Pharmacology 644 or Pharmacology 723  
- Pharmacology 702  
- Pharmacology 730  
- Research Rotations (10 weeks each)

**SECOND YEAR**  
**Fall Semester**  
- Pharmacology 750 (Biostatistics)  
- Pharmacology 730  
- Doctoral Oral Exam Administered  

**Spring Semester**  
- Elective course or tutorial (if needed)  
- Dissertation research

**THIRD, FOURTH AND FIFTH YEARS**  
- Dissertation research  
- Elective course or tutorial (if needed)

Students entering Pharmacology through the IBMS Program  
The following courses are required for students admitted through the IBMS Program. The IBMS student does not need to take PHCO 731 and is required to take only one semester of PHCO 730.

Example of a curriculum.

**FIRST YEAR (IBMS Program)**  
**Fall Semester**  
- Cell Biology 643 or Neurobiology 722  
- Elective course or tutorial  

**Spring Semester**  
- Cell Biology 644 or Neurobiology 723  
- Elective course or tutorial

Students enter the Pharmacology Department at the end of the Spring Semester  
**Summer**  
- Pharmacology 732 (Grant Writing) June  
- Doctoral Written Exam Due ~Aug 15

**SECOND YEAR**  
**Fall Semester**  
- Pharmacology 701 (Receptor Theory block Only)  
- Pharmacology 750 (Biostatistics)  
- Pharmacology 730  
- Doctoral Oral Exam Administered  

**Spring Semester**  
- Pharmacology 702  
- Elective course or tutorial  
- Dissertation research

**THIRD, FOURTH AND FIFTH YEARS**  
- Dissertation research
Students entering Pharmacology through the MSTP Program
The following courses are required for MD/PhD students admitted through the MSTP Program. The MSTP student does not need to take PHCO 702 or PHCO 731.

Example of a curriculum.

**FIRST and SECOND YEARS—Medical School**

**Students enter the Pharmacology Department at the end of the 2nd year in Medical School**

**THIRD YEAR (1st year in graduate school)**

**Summer**
- Pharmacology 732 (Grant Writing) *in consultation with course directors*
- *Doctoral Written Exam Due (TBD)*

**Fall Semester**
- Pharmacology 643 or Pharmacology 722
- Pharmacology 701 (Receptor Theory Block Only)
- Pharmacology 750 (Biostatistics)
- *Doctoral Oral Exam Administered*

**Spring Semester**
- Pharmacology 644 or Pharmacology 723
- Pharmacology 730
- *Dissertation Research*

**FOURTH YEAR (2nd year in graduate school)**

**Fall Semester**
- Pharmacology 730
- *Dissertation research*

**Spring Semester**
- *Elective course or tutorial*
- *Dissertation research*

**FIFTH, SIXTH, AND (maybe) SEVENTH YEARS (3rd, 4th, and 5th years in graduate school)**
- *Dissertation research*

**EIGHTH and NINTH YEARS (SEVENTH and EIGHTH?)—Finish Medical School**

**Course Registration**

Every student in our program is expected to devote full time to research and graduate studies, 12 months per year. For this reason students do not undertake regular outside employment. Students should be aware that their stipend level may be reduced if dropping a course reduces the level of registered course hours below the minimum required for a full-time student.

The program requires up-to-date information on each student's course registration. If a student wishes to change course registration via drop-add, the student should consult with his or her adviser, the course instructor, and, if necessary, the Graduate Education Executive Committee. The student must then inform the Assistant to the Director of Graduate Studies. If, at the time a student drops a course, performance in that course is judged by the instructor to be failing, a grade of "F" is assigned on the student's permanent record and the student becomes ineligible for further registration.

**First Year Review**

The Graduate Education Executive Committee will review each student’s progress at the end of his or her first year in the program. This review will include the student’s grades, evaluation of their rotations, and evaluation of their written rotation reports and oral presentations. Students that are deemed to be having difficulty (low course grades, poor evaluations from rotations, etc.) will be asked to meet with the Director of Graduate Studies to discuss his/her problems.

**Advisers**

The Director of Graduate Studies will serve as an adviser for each entering student from the time of enrollment until a dissertation adviser is selected. Students are also encouraged to develop advisory relationships with other faculty members. The student selects a dissertation adviser and begins dissertation research after successful completion of the Doctoral Written and Oral Examinations.
**Doctoral Preliminary Examination: Overview**

The Doctoral Preliminary Examination comprises both the Doctoral Written Exam and the Doctoral Oral Exam. The objective of the Written Exam is to evaluate the student's ability to identify a significant scientific problem, to formulate a sophisticated and feasible research plan to solve that problem, and to develop these ideas in a scholarly written document. A committee of four faculty members evaluates the Written Exam, and the same committee also evaluates the Oral Exam (see below). The objectives of the Oral Exam for the student are: (1) To defend the research plan described in the Written Exam; and (2) To demonstrate the ability to integrate comprehensive background knowledge in Pharmacology, and to creatively apply this information to the solution of problems posed by the faculty. Students answer questions on the details of experimental design, data analysis and significance of the research proposed. In doing so, the student will be asked questions to determine if the student has a broad background knowledge in Pharmacology and a basic understanding of closely allied areas (e.g., Physiology, Biochemistry, Biostatistics).

The Doctoral Examination Committee will be comprised of four faculty members, two of whom will be from the Standing Committee. Faculty on the Standing Committee will also review abstracts in the Grant Writing course (Pharmacology 332). The other two members of the examination committee will be chosen ad hoc by the Director of Graduate Studies based on the subject of the proposal. The Chair of the Examination Committee will be one of the two ad hoc members. A student's intended thesis advisor cannot serve on her/his examination committee. The chair of each examination committee ensures that the members of the examination committee are familiar with the objectives and procedures of the exam.

**Doctoral Written Examination**

Students are now allowed to write their written proposal on their thesis topic if the project has not been developed by the P.I. for a grant (or that the student has not read the grant in question). Toward the end of the Grant Writing course, each student submits the Abstract and Specific Aims of the proposed Doctoral Written Examination to members of the Standing Committee. The Specific Aims should include sufficient rationale and experimental design to assess the scope, significance, and feasibility of the proposed research. Approval of the Specific Aims will be based on the feasibility and scientific merit of the proposed research and may require several rounds of revision.

After an appropriate topic has been approved, the student prepares a written proposal in the format of an NIH grant application (for guidelines see DWE/DOE Guidelines). The entire research proposal, not including the title page, abstract, and references, must not exceed 15 pages. The proposal should indicate how the research will make a significant contribution to the chosen field. It should describe the hypothesis to be tested, probable methodology, sets of hypothetical results, and possible interpretations. The Doctoral Written Exam is due exactly six weeks after the pre-proposal has been approved by the Standing Committee. Requested changes in the due date may be granted by the Director of Graduate Studies on a case-by-case basis. Six copies of the written proposal should be submitted to the Graduate Program Administrative Assistant by 4 pm of the due date.

It is important that faculty members and others play a limited role in the development of the Doctoral Written Exam. Faculty members are expected to be responsive to specific questions from the students, but faculty should limit their discussion to technical issues and avoid issues of experimental design and hypothesis testing. Faculty should not take the initiative in helping students prepare the written proposal. Under no circumstance should a faculty member read the proposal or provide critical discussion of the proposed studies.

Within 2-3 weeks after submission of the research proposal, each examination committee will evaluate the proposal and decide if it receives a passing or failing grade. This evaluation occurs in the absence of the student. Elements to be taken into consideration in grading the proposal include 1) experimental designs, 2) hypothesis testing, 3) scientific merit, 4) feasibility, and 5) quality of writing (clarity, structure, grammar, etc.).

If the proposal is found to be markedly deficient in scientific and/or organizational quality, the proposal will receive a failing grade. A detailed written critique of the proposal, similar in depth to that prepared by NIH study sections, will be provided to the student. The student will be encouraged to contact the members of the examination committee to discuss the deficiencies of the proposal. The student is
required to submit a rewritten proposal 3 months (give or take a few days) from the time of receiving the failing grade. The examination committee will meet and evaluate the rewritten proposal as described above for the original proposal. If a student fails the Doctoral Written Exam a second time, he/she is removed from the program and must petition the GEEC and the Graduate School for re-instatement into the Graduate Program.

If the original proposal receives a passing grade, the examination committee provides a modest critique of the proposal and defines the four “broad areas” of pharmacology (see below) that will be tested during the Doctoral Oral Examination. In general, these areas should be related to the research proposal. The student may contact the members of the examination committee to discuss the proposal and how to prepare for the Oral Examination.

Doctoral Oral Examination

The Oral Exam typically begins with a 10-15 minute presentation by the student, which is followed by questions from the examination committee. A maximum of 10 overheads/slides are allowed during the introduction. Questions in the oral exam should concentrate on the subject matter of the proposal and on the four broad areas of pharmacology previously assigned to the student. In its entirety, the questioning phase of the Oral Examination cannot exceed two hours. Questions posed by the examination committee will be aimed at assessing the student's written proposal and the student's knowledge of the four broad areas of pharmacology. Testing of the four broad areas may be integrated into testing of the research proposal, and the chair of the committee should insure that the four broad areas are fully examined.

Students should be prepared to discuss the rationale, theoretical foundations, practical limitations, and the importance of the experimental objectives described in the Doctoral Written Exam. Students may be asked to provide alternative strategies for achieving the specific aims proposed. Students are often asked to describe (graph?) the “data” expected from the proposed experiments. Questions on the proposed research often lead to basic questions on the broad areas of pharmacology that provide the fundamental scientific foundation of the proposed experiments.

A high level of accomplishment, both in the defense of the research proposal and in the four broad areas of pharmacology assigned, is necessary to pass the Doctoral Oral Examination. It is expected that the proposed research is of scientific significance and that the student demonstrates, by direct and rational answers, a thorough preparation and clear understanding of major issues. The ability to deal with controversies and limitations of technical approaches is considered essential. Evidence of creative insight weighs heavily in the student's favor.

The Graduate School Handbook states “a student passes an examination only upon approval by at least two-thirds of the members of the examining committee.” Thus, a passing grade is awarded if three of the four members of the committee cast a passing vote. A decision on whether to award an “excellent” grade on the Oral Exam will be based on a unanimous vote by the committee. Immediately following the exam the student will be notified as to whether he or she passed the exam. In the case of failure, the committee chair will prepare a detailed written critique explaining the basis for the failing grade. Students must retake the Doctoral Oral Examination 3 months (give or take a few days) from the date of the first exam. A student who fails a Doctoral Oral Examination for the second time becomes ineligible for further graduate work, and must petition the GEEC and the Graduate School for re-instatement into the Graduate Program.

Broad Areas of Pharmacology for Doctoral Oral Exams

1. Principles of biochemistry and pharmacology (REQUIRED)
   - Michaelis-Menten formulation: $K_m$, $V_{max}$
   - Scatchard transformation
   - Double-reciprocal transformation
   - pH, buffers, Henderson-Haselbach, $pK_a$
   - Analysis of ligand binding; $K_d$, $B_{max}$, competitive, non-competitive inhibition
   - Radioactive decay; first-order rate equation
   - Basic pharmacokinetics
   - Drug metabolism
2. Principles of cell biology
   Replication
   Transcription
   Post-transcriptional RNA processing
   Translation
   Post-translational processing (glycosylation, myristoylation, farnesylation, phosphorylation)
   Endoplasmic reticulum
   Golgi
      Targeting of membrane proteins
      Processing of membrane and secretory proteins
   Lysosomes
   Membrane recycling
      Exocytosis, endocytosis, clathrin-coated pits
   Cytoskeleton
      Microtubules, microfilaments, intermediate filaments
      Mechanisms of cell motility
   Mitochondria
      Energy generation: glycolysis, oxidative phosphorylation

3. Cancer
   Mechanisms of cellular proliferation
   Cell-cycle
   DNA synthesis and repair
   Molecular mechanisms of oncogenesis; oncogenes
   Molecular mechanisms of growth factor signal transduction
   Molecular mechanisms of drug resistance

4. Signaling
   Receptor structure, function, and pharmacology
      Ion channel-linked
      G-protein-linked
      Kinase-linked
      Cyclase-linked
   G-protein activation/inactivation cycle
   Molecular mechanisms of cellular Ca homeostasis
   Inositol phosphate metabolism
   Effectors: kinase, phosphatase, lipase, cyclase regulation

5. Neuroscience
   Molecular mechanisms for membrane and synaptic potentials
      Conductance; Ohm's law
      Equilibrium potentials
      Voltage clamp and patch clamp
      Regulation of ion channels by 2nd messengers and drugs
   Cellular mechanisms of NT synthesis, packaging, and release
   Receptor and channel agonists, antagonists, and blockers
   Anti-Parkinson, anti-depressant, anti-anxiety, anesthetic and anti-epileptic drug actions

6. Endocrinology
   Hormone synthesis, secretion; processing of preprohormones
   Regulation of hormone levels: secretion, feedback control, inactivation, excretion
   Hormone targets and mechanisms of action
      Receptors: cell surface, cytosolic, nuclear
      Signal transduction: cytosolic and genomic effects
   Hormone control of homeostasis, cell/tissue maturation, growth, reproduction
   Hormone deficiency syndromes, hormone therapy, hormone antagonists
   Hormone assays: bioassay, RIA, receptor assay

7. Antimicrobial pharmacology
   Classes of bacterial pathogens
Molecular mechanisms of antimicrobial drugs

8. Cell Interactions and Adhesion
   - Concepts in development/tumorigenesis/thrombosis/immunology
   - Integrin structure/function
   - Extracellular matrix proteins; RGD peptide
   - Receptors and cytoskeleton in adhesion and motility

9. Cardiovascular pharmacology
   - Autonomic control of heart rate and blood pressure
   - Anti-arrhythmic, anti-angina, and anti-hypertensive drug mechanisms
   - Diuretics

10. Membrane transport of ions and small molecules
    - Diffusion
    - Facilitated diffusion
    - Primary active transport
    - Secondary active transport; co-transport

11. Principles of protein purification and characterization, etc.
    - Ion exchange chromatography
    - Gel exclusion chromatography
    - Affinity chromatography
    - SDS-PAGE
    - Immunoblot
    - Methods of ligand binding assays
    - Differential and gradient centrifugation
    - Protein assays
    - Quantification of radioactivity; types of radioactive decay
    - Analytical chemistry: HPLC, spectroscopy, GC/MS

12. Principles of molecular biology
    - Expression cloning
    - cDNA library construction and screening
    - Subcloning in plasmid vectors
    - Genomic cloning
    - Southern, northern, and western blots
    - PCR

Selection of Dissertation Advisor and Committee, and submission of Dissertation Proposal

Upon satisfactory performance in the Doctoral Oral Examination, the student formally selects a dissertation advisor, and begins work on the Doctoral Dissertation. Students should compose a dissertation committee and adhere to the timetable for dissertation committee meetings (see below). A dissertation performed with an adjunct faculty member must be approved in advance by the Graduate Education Executive Committee.

Dissertation Committee

A dissertation committee should be composed within six months of passing the Oral Exam. A dissertation committee consists of five members, four of whom must be tenure-track faculty. Two of the members must have primary appointments in Pharmacology. The other members may be Joint or Adjunct faculty, faculty from other departments, or “limited” members of the Graduate Faculty or “special appointees,” e.g., a Professor from another institution. The dissertation adviser is a member of the committee. At least one member, other than the dissertation adviser, should be expert in the area of the dissertation research. At least one committee member should represent areas in Pharmacology different from the research interests of the sponsor and student. The Chair of the committee must have a primary or joint appointment in Pharmacology and cannot be the dissertation adviser.
The student and dissertation adviser work together to select the dissertation committee. Students should distribute the “Duties of the Dissertation Committee” and “Additional Duties of the Chair of the Dissertation Committee” document (see below) to committee members when they are asked to serve on the dissertation committee. Students submit the names of proposed committee members to the GEEC for approval, and provide a brief statement explaining why each member was selected. When the proposed committee has been approved, the GEEC nominates to the Dean of the Graduate School the persons to serve as the dissertation committee. The Dean formally appoints the committee.

The committee meets with and advises the student periodically during the period of dissertation research. The first committee meeting should occur six months after passing the Oral Examination. During the initial meeting the student informs the committee of the preliminary ideas that may lead to a dissertation project. The committee evaluates the general research direction, and advises the student about the next steps in the research project. The second committee meeting should occur approximately one year after passing the Oral Examination, at which the Dissertation Proposal (see below) is discussed. Subsequent committee meetings should occur at least once per year.

**Duties of the Dissertation Committee**

1. Be available to the student for consultation about experimental designs, problems, and the development of a realistic set of aims for the dissertation.

2. Evaluate and provide feedback on the dissertation proposal. Verify that the dissertation proposal and the anticipated timeline for completing the research are feasible. Help the student focus or expand research aims as necessary.

3. Participate in dissertation committee meetings. The first committee meeting is to be held 6 months after the student passes the Doctoral Oral Exam. Typically, the first meeting is held near the end of the student’s second year in the Graduate Program. The second committee meeting is to be held 6 months after the first committee meeting. The dissertation proposal should be submitted 2 weeks before the second committee meeting and discussed at that meeting. Subsequent committee meetings will be held at least once per year. Committee members may suggest or require meetings at shorter intervals. Committee members should review summaries of committee meetings prepared by the student for accuracy and completeness.

4. Evaluate and provide feedback on the dissertation and participate in the dissertation defense.

**Additional Duties of the Chair of the Dissertation Committee**

1. Assist the student in conducting dissertation committee meetings (to be held annually or at shorter intervals as decided by the committee). Verify that summaries of committee meetings prepared by the student are accurate and complete. Keep summaries of the meetings and records of decisions made by the committee.

2. Make sure that the dissertation proposal is a feasible plan leading to a defensible dissertation within the appropriate timeline.

3. Evaluate the student’s progress towards completion of the dissertation research. Seek out evidence at each committee meeting of the student’s success or failure to advance toward a defensible dissertation. Urge the student and/or advisor to refine the goals of the dissertation when necessary. Communicate with the student’s advisor, the Graduate Program Director, the Departmental Chairman, and/or the Graduate Education Executive Committee any concerns about the student’s progress.

4. Be an impartial mediator of any disputes that might arise between the student and the advisor with regard to the completion, revisions, and/or defense of the dissertation.

**Dissertation Proposal**

After further experimentation to assess the feasibility of various aspects of the research plan, a formal proposal for the dissertation research is then prepared by the student in accord with the guidelines for NIH grant applications (NIH form #398), with the exception that the proposal is less than 12 pages in its total length. This proposal should be submitted to the committee before the second dissertation
committee meeting (approximately one year after passing the Doctoral Oral Exam), and is usually discussed in detail at the second meeting. Approval of the proposal represents an understanding between the student and his/her committee on the subject and scope of the dissertation, and the proposal provides a framework for future committee meetings. Approval of the proposal by the committee satisfies the requirements of the Graduate School for admission to candidacy.

Following all committee meetings, the student prepares a 1-2 page summary of the meeting, discusses this summary with the dissertation advisor, and submits the summary to the dissertation committee and the Graduate Program Administrative Assistant. These summaries provide a written record of the student’s progress. It is the obligation of the committee chairman to ensure that the committee monitors the student's progress with respect to completing his/her degree in a timely manner. This should be accomplished by having the student prepare a time line for the different goals of the proposal for each committee meeting and the committee considering the feasibility of satisfactorily addressing the goals of the proposal within a reasonable period (3 to 4 years of dissertation research).

**Preparation of the Dissertation**

A description of the overall procedure can be found in the Graduate Record of the University of North Carolina at Chapel Hill and A Guide to the Preparation and Submission of Theses and Dissertations. The requirements of the Department of Pharmacology differ in two respects:

References and annotations in the text, the bibliography, and the preparations of tables and graphs should follow the form described in *The Journal of Pharmacology and Experimental Therapeutics*. This form is characterized by citation of references in the text by author's last name(s) and year of publication and by entries in the bibliography that are arranged alphabetically by author and not numbered. See "Notice to Contributors" in a recent volume for details.

It is acceptable that a thesis incorporates publications in which the student played the major role in both the research and the writing. It is the thesis advisor's responsibility to insure that the student input into such publications warrants the document being included into the thesis. When publications are used to present a portion of the thesis work, these should be broadened in Introduction and Discussion to include a scholarly review of the area and a thoughtful insertion of the findings into existing literature. In addition, when the thesis includes multiple publications, these should be interfaced to provide a smooth transition between the resulting chapters. The student is responsible for obtaining the necessary permissions from the journals that hold the copyrights to published materials (see July 1, 1998 memo from the Graduate School).

In some cases, a student may choose to leave the UNC campus before defending their dissertation. This is considered a leave of absence, and the student will no longer be registered for classes or collect a stipend during this time. In order to defend the dissertation, the student must re-register in the same term that the dissertation defense is given. Please note that the student cannot re-register until he/she has submitted a final draft of the dissertation document to the thesis committee. The student must also meet the UNC deadlines for dissertation submission as described in the Graduate School Record. It is the responsibility of the Chair of the student's committee to inform the Director of Graduate Studies and the Graduate Program Assistant when the committee has agreed that the dissertation is defensible. The mentor will cover the cost of tuition and fees for the student to re-register for up to one year after the student leaves the UNC campus, but after such time the responsibility shifts to the student.

**Submission of the Dissertation**

The completed dissertation must be submitted to the dissertation committee not less than 2 weeks before a final committee meeting scheduled by the student. Student attendance at the final committee meeting is optional, but the student must inform the committee at the time the thesis is submitted whether or not he/she intends to attend the final committee meeting. The committee decides at the final committee meeting if the dissertation is a defensible document worthy of the Ph.D. degree. If the dissertation is acceptable, the student may then schedule the Final Oral Examination (Dissertation Defense). The date of the dissertation defense is up to the student and the members of his/her committee. Criticisms and corrections of the dissertation may be provided to the student at any time up to and including the Final Oral Examination. If the dissertation requires major revisions, the committee will instruct the student to submit a revised dissertation to the committee before the Final Oral Examination can be scheduled.
Final Oral Examination

The formal oral presentation of the student's dissertation is open to all faculty and students, and to the public. Upon completion of this presentation and a brief period for general questions, the student's dissertation committee will pose additional questions about the dissertation and related fields. The questioning is usually led by the chairman of the dissertation committee. Additional corrections of the dissertation may be requested by the dissertation committee at the Final Oral Examination.

Other Recommended Training

In addition to research requirements for the Ph.D. degree, students will be encouraged to develop and utilize teaching and writing skills. Practical experience should include presentation of their research at national meetings and may include presentation of formal lectures in a course offered by the Department, and participation in the writing of a formal research grant application.

Pregnancy Leave

Students who become pregnant are entitled to up to two months of paid leave as per University policy. Upon consultation with the mentor, a student may choose to take more than two months leave; however, such leave will require the student to take of leave of absence, and the student will not be paid or receive student health care benefits during this time.

Modification of Course Requirements

In exceptional circumstances, the formal course requirements of the Department may be modified by the GEEC in consultation with the Departmental faculty. Requests for modifications should be initiated by the student as a formal petition to the GEEC.

Financial Assistance

Students who are admitted as doctoral students usually receive an appointment as a graduate assistant, graduate research assistant, or fellow/trainee. Appointees are provided a stipend which includes an allowance for tuition and fees.

Students are generally supported by funds from the Departmental Training Grant, from scholarships, from faculty research grants or from funds at the disposal of the Department Chairman. No student may select an adviser who cannot clearly identify at least two years of financial support. Exceptions to this policy will be granted only with the approval of the GEEC and the Department Chairman.

Beginning in 1987 student stipends are fully taxable, including that part of a service award (e.g. teaching or research assistantships) designated for tuition and fees. The stipend level includes an amount designed to offset projected tax liability of students.

Graduate Courses Offered by the Department of Pharmacology

**Pharmacology 643/644:** (Cell Biology 643/644) Cell Structure, Signaling, and Growth Control (3 credit hours). A lecture and discussion course that introduces key concepts in cell structure, receptors, intracellular signaling pathways, membrane trafficking, cell adhesion, cell cycle, and oncogenesis. Three hours per week. Fall/Spring. Cox.

**Pharmacology 701:** Introduction to Molecular Pharmacology (2). An introductory course on the basic molecular principles of Pharmacology. Includes Molecular Biology, Receptors/Ion channels, Signal Transduction, Drug/receptor interactions, and Pharmacokinetics. Fall. Siderovski/Trejo.

**Pharmacology 702:** Principles of Pharmacology and Physiology (3). Prerequisites: Chemistry 430, or equivalent, or permission of the instructor. Introduces the major areas of pharmacology and physiology and serves as a basis for most advanced courses in Pharmacology. Three lecture hours per week. Spring. Parise.

**Pharmacology 205:** Molecular Basis of Anticancer and Antiviral Pharmacology: Mechanisms and Applications (2). Prerequisites: Pharmacology 702 or permission of the instructor. The mechanisms of action of inhibitors of nucleic acid and protein metabolism and how they may be used to further understanding of cellular regulatory processes, antibacterial, antiviral and anticancer chemotherapy. Two lecture hours per week. Fall. Kole.
Pharmacology 707: (Toxicology 707) Advanced Toxicology (2). Prerequisites: Pharmacology 702 or permission of the instructor. Recent advances in teratogenesis; mutagenesis; food additive, cardio-, hepato-, and pulmonary toxicology and the modes of action of radionuclides, heavy metals, toxins from plants and animals, solvents and propellants, insecticides, and halogenated hydrocarbons that are found in the environment. Two lecture hours per week. Fall. Swenberg.

Pharmacology 911, 912, 913, 914: Introduction to Pharmacological Research (research rotations in Pharmacology). A course for first year doctoral graduate students in Pharmacology. A series of research projects, each pursued for approximately 10 weeks under the supervision of a different faculty member. Twelve or more laboratory hours per week. Fall, Spring, Summer. Kole.

Pharmacology 721: Tutorial in Pharmacology (variable). Prerequisites, Pharmacology 702 or its equivalent, and permission of the instructors. This is a series of advanced courses that will emphasize the development of critical thinking in pharmacology research. Oral presentations and written reports will often be required.

Tutorials have a minimum and maximum enrollment. In most cases the minimum enrollment is 4 and the maximum enrollment is 16.

Students can initiate the process of creating a tutorial by approaching one or more faculty members with an idea for a course topic. Fall, Spring, and Summer sessions.

Ras Superfamily Proteins And Signal Transduction (2) Seminar/discussion course covering recent advances in the role of these proteins in signaling and growth. Fall, alternate years. Der, Cox.

Signal transduction. (2) Prerequisites, Pharmacology 701 and permission of the instructor. Minimum enrollment 4. Molecular mechanisms of receptor-regulated second messenger production will be considered in-depth. Discussion will include consideration of current understanding of agonist-induced desensitization of G protein-coupled receptors, receptor activation of G proteins, regulators of G protein signaling and structure/function of G-proteins. Spring, alternate years. Harden.

Adhesion Receptors & Signaling in Cancer & CV Disease (2) Permission of the instructor required. This course will examine the growing number of families of cell adhesion receptors and their role in biological processes including signal transduction, control of gene expression, hemostasis, cancer, neuronal development, immunobiology, and embryologic development. Emphasis will be on the integrin family, but other receptor families including cadherins, selectins, and immunoglobulin super-family receptors will also be discussed. The course will stress the relationship between receptor structure and function, and will also deal with techniques used for study of cell adhesion receptors. The course will largely deal with the current literature. Student presentations of recent research publications will be a main element of the course. Spring, alternate years. Juliano/Parise.


Structure & Function of Ion Channels. (2) Prerequisites: Cellular and Molecular Neurobiology or permission of the instructors. Minimum enrollment 4. A seminar course that focuses on the mechanisms of ion selectivity, gating, and regulation of ion channels. The format will mostly be detailed discussions of the contemporary literature (combined with a few discussions of the classics). Spring, alternate years. Rosenberg and Oxford.

Discovery Biology & Pharmacogenomics. (2) Prerequisites: Undergraduate molecular biology or biochemistry or permission of the instructor. Minimum enrollment 4. This course will cover a variety of aspects of new biological and computational technologies. The course is predominantly in a lecture format with computer-based and literature assignments. Spring, alternate years. Siderovski and Sondek

Pain, Analgesia and Analgesics. (2) Prerequisite: Pharmacology 702, permission of the instructor. Minimum enrollment 4. Focus: Neural mechanisms which produce and modulate painful sensations. The neuroanatomy, neurochemistry, and physiology of pain relay systems and pain regulatory systems will be discussed. Emphasis will be the discussions of pharmacological management of pain in both the laboratory and clinical settings. Spring, alternate years. Maixner /Dykstra.
**Drug Discovery and Development.** (2). This course will provide an overview of the process of drug discovery and development. The format will include formal lectures by UNC faculty and guest lecturers from the pharmaceutical industry. Topics will include design of screening systems, use of chemical databases, analog development and structure/activity relations, problems of synthesis including enantiomeric purity, problems of scale up and formulation, drug pharmacology and toxicology, drug delivery and the design of clinical trials. Spring. Carl.

**Neuropharmacology of Alcohol and Substance Abuse.** (3). A lecture/discussion course on the biological bases of alcohol and substance abuse. Spring, alternate years. Morrow.

**Protein Kinases as Targets for Novel Pharmacological Inhibitors.** (2) The purpose of this course is to evaluate the use of small molecule inhibitors of protein kinases from a structural and signal transduction perspective with focus on current strategies, successes and limitations of this emerging class of pharmacological agents. Spring, alternate years. Graves.

**Target-Based Drug Discovery And Cancer Treatment.** (2) A lecture/discussion course that emphasizes preclinical and clinical studies for the development of anti-cancer drugs that target signal transduction. Topics include: target identification and validation, drug discovery, the process of government approval for clinical trials, design of clinical trials, and new genetic-based technologies to foster drug development. Spring, alternate years. Der, Cox.

**Pharmacology 722/723:** (Neurobiology 722/723) Cellular and Molecular Neurobiology (variable, up to 5). A lecture and discussion course on several topics in neurobiology, bringing together the physiology, pharmacology, biochemistry, and molecular biology of the nervous system. Topics include: voltage-gated ion channels, electrical signaling, neurotransmission, ligand-gated ion channels, receptors, intracellular signal transduction, axon growth, myelination, and simple models of memory. Students may enroll in selected sections of the course. Fall/Spring. Nicholas.

**Pharmacology 750:** (Biostatistics) Data Analysis (1). Elementary probability theory, probability distributions, estimation, tests of hypotheses, chi-squared procedures, regression, and correlation. Fall. Nicholas.

**Pharmacology 901:** Research in Pharmacology (3 or more). Prerequisite: permission of the Director of Graduate Studies. A research course in which graduate students in pharmacology who have completed research rotations may continue their research projects until they complete the Doctoral Written and Oral Examinations requirements. Fall, spring, and summer sessions. Staff.

**Pharmacology 730:** Seminar in Recent Advances in Pharmacology (1). Students meet as a group with faculty members to summarize and discuss selected aspects of current pharmacological literature. One hour per week. Fall/Spring. Cox and Sondek

**Pharmacology 731:** Seminar in General Pharmacology (1). A series of weekly lecture-seminars by graduate students, faculty members, and visiting scientists on current research in pharmacology. One hour per week, fall. Carl.

**Pharmacology 732:** Grant Writing. (1) Identification of interesting and important biological questions, experimental design, and grant writing. Ethics in biomedical research. Summer, Parise and Johnson.

**Pharmacology 994:** Doctoral Dissertation (variable). Prerequisite: permission of the staff. Fall, spring, and summer sessions. Staff.

**A Selection of Graduate Courses Offered by Other Departments**

**Biochemistry 404:** Enzyme Mechanisms and Metabolic Regulation: Intermediary Metabolism (3). Prerequisites: Chemistry 430 or equivalent. Selected metabolic pathways which illustrate how biochemical reactions are organized, catalyzed and regulated. Spring. Jones, Traut, Wolfenden.

**Biochemistry 505:** Molecular Biology (3). Prerequisites: Biochemistry or genetics and organic chemistry. Mechanisms of replication, transcription, and translation of genetic material in prokaryotic
and eukaryotic systems, gene sequence and organization, biochemical genetics and regulatory mechanisms. Fall. Crews.

**Biochemistry 442:** Biochemical Toxicology (3). Prerequisites: Chemistry 430, and one additional biochemistry course (or permission of Course Director). Biochemical actions of toxicants, and assessment of cellular damage by biochemical measurements. Spring. Holbrook.

**Biochemistry 650 series:** Macromolecular Structure and Dynamics (3 hours per semester). Basic concepts in biophysics, dynamics of macromolecules, assembly/stability of macromolecular complexes, optical spectroscopy, spin resonance spectroscopy, NMR, X-ray crystallography and determination of molecular structure. Students may enroll for individual sections of the course with permission of the instructor. Fall and spring. Lentz.

**Biochemistry 220:** Biochemical Endocrinology (2). Prerequisite: Chemistry 430 or equivalent. Review of endocrine systems and their clinical expression in disease; molecular mechanisms of hormone action; biochemical basis of growth factors and second messengers; recombinant DNA-cloning methods. Spring. Wilson, Nayfeh.

**Chemistry 430:** Introduction to Biological Chemistry (Biology 430) (3). Prerequisite: Chem 262 & 262L; Biology 101. The study of cellular processes including catalysis, metabolism, bioenergetics and biochemical genetics. The structure and function of biological macromolecules involved in these processes will be emphasized. Fall and Spring. Biological Chemistry Faculty.

**Chemistry 431:** Nucleic Acid Chemistry (Biochemistry 431) (3). Prerequisite: Chemistry 430. Study of reactions and chemical properties basic to nucleic acids; chemical synthesis as well as biosynthesis; nucleic acids in protein biosynthesis. Spring. Biological Chemistry Faculty.

**Chemistry 432:** Protein Chemistry (3). Prerequisite, Chemistry 430. Structural properties of proteins; active site chemistry; chemical modification of proteins; metalloproteins; coenzyme-enzyme interactions; organization of enzyme systems. Fall. Biological Chemistry Faculty.

**Chemistry 437:** Membrane Chemistry (Biochemistry 437) (3). Prerequisites: Biology 101, Chemistry 430 & 480; corequisite or prerequisite, Chemistry 480, or 481. Structure and properties of synthetic membranes and of naturally occurring biological membranes. Spring. Biological Chemistry Faculty.

**Chemistry 441L:** Intermediate Analytical Chemistry (2). Prerequisite: Chemistry 481. Prerequisite Chemistry 441; prerequisite or corequisite Chemistry 481; corequisite Chemistry 441L. Spectroscopy, electroanalytical chemistry, chromatography, thermal methods of analysis and signal processing. One four-hour laboratory a week and one one-hour lecture a week. Spring. Analytical Chemistry Faculty and staff. (Fee required)

**Chemistry 480:** Introduction to Biophysical Chemistry (3). Prerequisites: Chemistry 261, one year of college physics, knowledge of differential and integral calculus. Does not carry credit toward graduate work in chemistry or credit toward B.S. degree in chemistry. Application of thermodynamics to biochemical processes; enzyme kinetics; properties of biopolymers in solution. Spring. Physical Chemistry Faculty.

**Chemistry 485:** Chemical Dynamics (3). Prerequisites, Chemistry 481 and 482. Experimental and theoretical aspects of atomic and molecular reaction dynamics. Fall or Spring. Physical Chemistry Faculty.

**Genetics 631/632:** Advanced Molecular Biology (3 per semester). Prerequisites: Chemistry 430 and permission of the instructor. DNA structure, function, and interactions in prokaryotic and eukaryotic systems. Chromosome structure, replication, recombination, and repair. RNA structure, function, and processing. Transcription, gene regulation, translation, and RNA and protein transport. Fall (110) and spring (111). Sancar, Fried.

**Environmental Sciences and Engineering 444:** Industrial Toxicology (2). Toxicological assessment of and a case presentation of related exposure is given. A conceptual approach is utilized to design appropriate programs to prevent worker ill health due to industrial toxicant exposure. Two lecture hours per week. Spring. Staff.
Medicinal Chemistry 805: Molecular Modeling. Prerequisite: Math 231-232, Chemistry 481 and permission of instructor (3). Introduction to Computer Assisted Molecular Design (CAMD) techniques and theory, with an emphasis on the practical use of molecular and quantum mechanics programs (MM2, MNDO, GAUSSIAN). Two lecture and three-four laboratory hours each week. Spring. Tropsha. (School of Pharmacy)

Microbiology 614: Immunobiology (3). Prerequisites: Immunochemistry; genetic control, regulation and development of cells and cell interactions; hypersensitivity, autoimmunity, resistance to infection. Two lectures, one seminar. Fall. Ting.

Physiology 755: Molecular Physiology of Disease (3). Prerequisites: undergraduate courses in biochemistry and cell biology and permission of the instructors. In-depth discussion of selected diseases in the nervous, cardiorenal, endocrine, and respiratory systems. The course will focus and cellular and molecular processes underlying human disease. Spring. Milgram.

Inter-Institutional Graduate Courses
Graduate students may take graduate courses at Duke University, upon approval of the Graduate Education Executive Committee.

The M.S. Degree
Under special circumstances, the department will offer a program leading to the M.S. degree. Applications for acceptance into the M.S. degree program will be reviewed by the GEEC. Requirements for a M.S. degree for this department follows. M.S. degree candidates should also consult the Graduate School Handbook for further rules and regulations.

Required Courses for M.S. Degree
1. Chemistry 430, Introduction to Biological Chemistry. Students with a good undergraduate biochemistry background can petition the GEEC for wavier of this requirement.
2. Pharmacology 643/644 or Pharmacology 722/723 (Blocks 1-5).
4. Pharmacology 702, Principles of Pharmacology and Toxicology.
5. Pharmacology 730 (Seminar in Recent Advances in Pharmacology; 2 semesters required) and Pharmacology 731 (Seminar in General Pharmacology; 1 semester required).
6. Grant Writing (Pharmacology 732).
7. Pharmacology 750, Data Analysis (Biostatistics). Students with a good undergraduate biostatistics background can petition the GEEC for wavier of this requirement.
8. Two Research Rotations in Pharmacology (Pharmacology 911, 912).
9. At least three additional credit hours of electives.
10. At least three credit hours of PHCO 993 (masters research).
M.S. Thesis

A thesis committee consists of no fewer than three members of the Graduate Faculty. At least two members of each thesis committee must be “full” members of the Graduate Faculty with appointments in the Department of Pharmacology. The other member may be a “limited” member of the Graduate Faculty or “special appointee,” e.g., a Professor from another institution. The thesis adviser is a member of the committee. A member of the committee other than the thesis adviser shall serve as the chairperson of the committee.

The committee meets with and advises the student periodically during the period of the thesis research. During the initial meeting the student presents the committee with an outline of the proposed thesis project and through discussion with the committee establishes a set of specific aims for the thesis. The thesis project may be an extension of previous work completed by the student in this department but should extend significantly beyond such research. Typically, it should be possible to complete the proposed research within six months to a year when working full time on the project.

During the course of the thesis research the student should meet with their committee no less frequently than every four months. When there is agreement on the committee that the student has sufficiently met the aims of the thesis project, the student will prepare a written thesis in accordance with the guidelines established by the Graduate School of the University of North Carolina at Chapel Hill for a M.S. Degree.

The completed thesis should be submitted to the committee two weeks in advance of the date of the Final Oral Examination. The completed thesis is defined as a final copy which, in the opinion of both the candidate and advisor, should require no further change.

Final Oral Examination

The final oral presentation of the student's thesis is open to all faculty and students, and to the public. Upon completion of this presentation and a brief period for general questions, the student's thesis committee will evaluate the thesis and may pose additional questions about the thesis and related fields. The questioning is usually led by the chairman of the thesis committee.

This thesis defense also serves as the Oral Comprehensive Examination for the Master’s Degree as required by the Graduate School.