Proposal for a Ph.D. Program in Chemical and Physical Biology

Vanderbilt University
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Rationale

Chemical and physical biology is a key focus area for interdisciplinary biomedical research where the power of modern methods in chemistry, computer science, engineering, mathematics, and/or physics are applied to biological problems ranging from isolated macromolecules to complex cellular systems to intact organisms. The tremendous advances in determining the structure, function, dynamics, and interactions of biological molecules in the past decade have driven the creation of this hybrid discipline where it is increasingly necessary to have extensive formal training in the fundamental natural sciences as well as in the biological sciences. The Howard Hughes Medical Institute and the National Institutes of Health have recently underscored the importance of inter-disciplinary training in the emerging area of chemical and physical biology with the announcement of funding to support the development of new programs nationwide. The need for beginning this training at an early stage is documented by the creation of funding programs at the National Institutes of Health to bring advanced undergraduate students majoring in the basic quantitative sciences into summer programs where they apply their fundamental skills to important biological problems with the hope that these students will pursue graduate training in interdisciplinary programs like chemical and physical biology. Our early recognition of the importance of this dual training led to the establishment of the trans-institutional graduate admissions program in chemical and physical biology, called CPB, at Vanderbilt University in 2000.

Traditional departmentally based Ph.D. degree programs are not optimally designed to provide the flexibility for the comprehensive interdisciplinary training that is required in chemical and physical biology. Most departmentally based programs appropriately provide broad training within a given area and even though the recent trend has been to minimize the number of absolutely required courses in some departmental programs, there is often not sufficient flexibility to obtain extensive training in complementary areas without substantially lengthening the program. Moreover, the quantitative natural science disciplines do not offer sufficient exposure to cutting edge biological questions and the biological science disciplines do not offer sufficient exposure and training in the quantitative sciences. The overwhelming trend on the national level has been to develop truly interdisciplinary training programs and research opportunities where individuals are required to master not only the methods but also the approaches of complementary disciplines. Perhaps the most striking example of this trend is found in the National Institutes of Health Roadmap where it is clearly spelled out that research at the interface of the chemical, physical, and life sciences will be essential for progress on the complex biomedical problems of the 21st century. Our own experience with the CPB graduate admissions program in the past four years tells us that many of the best students are now seeking broadly based training at the interface of the chemical, physical, and biological sciences and they are attracted to programs that are optimized to provide such training opportunities. The thing that is currently lacking at Vanderbilt is a Ph.D. degree program that is also interdisciplinary and designed to take full advantage of the broad distribution of expertise in the chemical, physical, and biological sciences on campus. It is now proposed to establish an interdepartmental Ph.D. degree program in Chemical and Physical Biology. This new program will not replace nor supersede any
existing degree program on campus but rather will be the centerpiece for enhancing graduate training in the area of chemical and physical biology, for recruiting the most talented students into the CPB graduate admissions program, and for enhancing faculty research. Additional benefits of a new Ph.D. degree in Chemical and Physical Biology include increasing the visibility of this interdisciplinary research area on campus, strengthening and supporting the activities of existing training grants including Molecular Biophysics, Chemistry Biology Interface, Imaging, Cancer Modeling, and the NSF IGERT in nanoscience and strengthening, expanding, and providing coherence for existing coursework.

**Training Objectives**

The overall objective of the Chemical and Physical Biology Ph.D. degree program is to provide rigorous integrated training at the interface of the chemical and/or physical sciences and the biological sciences. The training program is designed so that students will have a much greater exposure to the biological sciences than is the norm for a student in the pure physical or chemical sciences and a much greater exposure to the chemical and physical sciences than is the norm for a student in the pure biological sciences. The coursework and research components of the program are designed to prepare students for research careers in which they are able to bring state-of-the-art tools of the modern chemical and physical sciences to bear on cutting edge biological problems. Many of the components of the program are already in place and are utilized on an *ad hoc* basis including in the form of individualized degree programs upon request as per regulations set forth in the graduate school manual. The new degree program will formalize the training and consolidate the efforts of many components that are currently widely distributed among departments of the School of Engineering, the College of Arts and Science and the School of Medicine at Vanderbilt.

The specific objectives of the Program are:

1. To consolidate, enhance, and formalize training and research in the area of Chemical and Physical Biology.

2. To integrate and enhance the academic curriculum so that students will obtain the required training in an efficient manner.

3. To continue to build a sense of “community” within the Chemical and Physical Biology area at Vanderbilt so that we can recruit and train the highest quality students and attract and retain the highest quality faculty as the program continues to evolve.

The proposed Ph.D. program will provide students with three separate options in the area of chemical and physical biology: chemical biology; structural biology; or molecular biophysics. The common theme in each of these areas is to provide students with relevant training in the biological sciences that will complement their training in the
chemical and physical sciences so that they can pursue research careers at the interface of these disciplines.

Relationship to the Chemical and Physical Biology Graduate Admissions Program (CPB)

The proposed Ph.D. degree in Chemical and Physical Biology will be an available option to all students that enter the trans-institutional CPB graduate admissions program. The students in the CPB (~ 10/year at steady state) are admitted uncommitted to a specific department or Ph.D. degree program. After two semesters of coursework and three eight to ten week research rotations, the CPB students choose a research advisor and a Ph.D. degree program from among the 10 existing programs that participate in the IGP (Biochemistry, Biological Sciences, Cancer Biology, Cell and Developmental Biology, Genetics, Microbiology and Immunology, Molecular Physiology and Biophysics, Neuroscience, Pathology, and Pharmacology) plus the departments of Chemistry, Mathematics, and Physics in the College of Arts and Science. Chemical and Physical Biology will be an additional degree option for the CPB students that will be optimized to facilitate their training at the interface of disciplines.

Students in the IGP program will also have the option of pursuing a Ph.D. degree in Chemical and Physical Biology provided that they fulfill the training requirements as described more fully in the next section. This option will be more likely in cases where IGP students become interested in one of the areas of Chemical and Physical Biology during their research rotations and then select a mentor and a research project that falls into one of the three tracks of the Chemical and Physical Biology degree program.

Students admitted directly to the departmentally based programs in Chemistry, Mathematics, or Physics could also choose the option of pursuing a Ph.D. degree in Chemical and Physical Biology provided that they choose a mentor that is a member of the training faculty, that their thesis research project falls into one of the three tracks of the Program, and that they fulfill the training requirements described in the next section.

Academic Curriculum for the Chemical and Physical Biology Ph.D.

Ph.D. students in the Chemical and Physical degree program are required to complete a minimum of 24 hours of didactic coursework. The required and elective coursework has been selected to provide students with core fundamental knowledge in chemical biology, structural biology, or molecular biophysics while at the same time allowing considerable flexibility to design a curriculum that meets their research needs and their intellectual interests. Students must select one of three different tracks for their training. The required courses for the chemical biology track, the structural biology track, and the molecular biophysics track are listed below and a list of elective courses for all tracks is provided on page 23.
## Chemical Biology

### First Year – Fall Semester

- **CPBP 310** Graduate Seminar in Chemical Biology 1 credit hour
- Chemical Biology Core Course 3 credit hours
  *To be created*
- Electives 3 credit hours
- **CPBP 302** Research Rotations 1 credit hour
- **IGP 303A** Responsible Conduct in Research 0 credit hour

### First Year – Spring Semester

- **CPBP 310** Graduate Seminar in Chemical Biology 1 credit hour
- Electives 6 credit hours
- **CPBP 302** Research Rotations 1 credit hour

### First Year – Summer

- **CPBP 360** Prep Biomedical Research 9-12 credit hours
- Electives 0-3 credit hours

### Second Year – Fall Semester

- **IGP 322** Research Ethics 1 credit hour
- **BCHM 330** Scientific Communication 1 credit hour
  *(or PHAR 322, CHEM 301a)*
- Electives 0-9 credit hours
- **CPBP 360** Prep Biomedical Research 1-10 credit hours

### Second Year – Spring Semester

- **BCHM 330** Scientific Communication 1 credit hour
  *(or PHAR 322, CHEM 301b)*
- Electives (Any remaining electives) 0-9 credit hours
<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPBP 360</td>
<td>Prep Biomedical Research</td>
<td>2-11</td>
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**Structural Biology**

**First Year – Fall Semester**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
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</thead>
<tbody>
<tr>
<td>BSCI 220</td>
<td>Biochemistry I*</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>(or ≥ 3 1 hour modules in IGP300a)</td>
<td></td>
</tr>
<tr>
<td>CPBP 310</td>
<td>Graduate Seminar in Chemical Biology</td>
<td>1</td>
</tr>
<tr>
<td>Electives</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>CPBP 302</td>
<td>Research Rotations</td>
<td>1</td>
</tr>
<tr>
<td>IGP 303A</td>
<td>Responsible Conduct in Research</td>
<td>0</td>
</tr>
</tbody>
</table>

**First Year – Spring Semester**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPBP 349</td>
<td>Graduate Seminar in Molecular Biophysics</td>
<td>1</td>
</tr>
<tr>
<td>BCHM 300</td>
<td>Introduction to Structural Biology</td>
<td>1</td>
</tr>
<tr>
<td>CHEM 233</td>
<td>Molecular Modeling Methods</td>
<td>4</td>
</tr>
<tr>
<td>CPBP 302</td>
<td>Research Rotations</td>
<td>2</td>
</tr>
</tbody>
</table>

*Students that have taken a comprehensive biochemistry course at the undergraduate level will select 3, or more, modules from the IGP300a bioregulation course.

**First Year – Summer**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBPB 360</td>
<td>Prep Biomedical Research</td>
<td>9-12</td>
</tr>
<tr>
<td>Electives</td>
<td></td>
<td>0-3</td>
</tr>
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**Second Year – Fall Semester**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGP 322</td>
<td>Research Ethics</td>
<td>1</td>
</tr>
<tr>
<td>BCHM 330</td>
<td>Scientific Communication</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(or PHAR 322, CHEM 301a, MP&amp;B 324)</td>
<td></td>
</tr>
<tr>
<td>BCHM 343</td>
<td>Biomolecular NMR Spectroscopy</td>
<td>2</td>
</tr>
</tbody>
</table>
Electives       0-6 credit hours
CPBP 360 Prep Biomedical Research 2-8 credit hours

**Second Year – Spring Semester**

BCHM 303 Biomolecular X-ray Crystallography 2 credit hours  
(Spring)
CPBP 349 Graduate Seminar in Molecular Biophysics 1 credit hour
Electives 0-6 credit hours
CPBP 360 Prep Biomedical Research 3-9 credit hours

**Molecular Biophysics**

**First Year – Fall Semester**

BSCI 220 Biochemistry I* 3 credit hours  
(or ≥ 3 1 hour modules in IGP300a)
CPBP 310 Graduate Seminar in Chemical Biology 1 credit hour
CHEM 232 Quantum Chemistry** 3 credit hours
Electives 0-3* credit hours
CPBP 302 Research Rotations 1 credit hour
IGP 303A Responsible Conduct in Research 0 credit hours

**First Year – Spring Semester**

PHYS 341 Statistical Mechanics** 3 credit hours
CPBP 349 Graduate Seminar in Molecular Biophysics 1 credit hour
Electives 3-6** credit hours
CPBP 302 Research Rotations 1 credit hour

*Students that have taken a comprehensive biochemistry course at the undergraduate level will select 3, or more, modules from the IGP300a bioregulation course.
**These requirements can be waived for students that have had a semester long course in Quantum Mechanics or Statistical Mechanics at the advanced undergraduate or graduate level.

**First Year – Summer**

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPBP 360</td>
<td>Prep Biomedical Research</td>
<td>9-12</td>
</tr>
<tr>
<td>Electives</td>
<td></td>
<td>0-3</td>
</tr>
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**Second Year – Fall Semester**

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGP 322</td>
<td>Research Ethics</td>
<td>1</td>
</tr>
<tr>
<td>BCHM 330</td>
<td>Scientific Communication (or PHAR 322, CHEM 301a, MP&amp;B 324)</td>
<td>1</td>
</tr>
<tr>
<td>Electives</td>
<td></td>
<td>0-9</td>
</tr>
<tr>
<td>CPBP 360</td>
<td>Prep Biomedical Research</td>
<td>1-10</td>
</tr>
</tbody>
</table>

**Second Year – Spring Semester**

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electives</td>
<td></td>
<td>0-9</td>
</tr>
<tr>
<td>CPBP 360</td>
<td></td>
<td>3-12</td>
</tr>
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</table>

All students should complete their 24 hours of didactic coursework by the end of the spring semester of their second year. Normally, they will take their qualifying exam during the second summer in residence at Vanderbilt. After admission to candidacy, students will enroll in CPBP 399 (Ph. D. Dissertation Research) until they have earned the required 72 hours of credit.

**Academic Performance**

All students will be required to maintain a B (3.0) grade point average in their didactic coursework. Student progress and performance will be monitored by the Director of Graduate Studies (DGS). The DGS will meet with each student at least once per semester to evaluate academic standing. If a student’s GPA drops below 3.0, they will be placed on academic probation. If the GPA remains below 3.0 after two additional semesters, the Executive Advisory Committee will evaluate the student’s overall record and performance, and the student may be dismissed from the program. Continued financial support will be contingent upon maintaining a 3.0 GPA and taking a full course load each semester.
Ph.D. Qualifying Examination

To qualify for candidacy for the Ph.D., a student must complete all the required didactic coursework, must be in good academic standing with a GPA of $\geq 3.0$, and must pass a two-part qualifying exam. The qualifying exam will normally be taken in the summer between the second and third years after entry into graduate school. The first part of the exam will be a 10 page written proposal in the area of the dissertation research project. The second part will be an oral defense of the written proposal and demonstration of general knowledge in the area of the dissertation research project. The qualifying exam will be administered by an examining committee composed of 5 members, with a minimum of 3 members being from the CPB training faculty and a minimum of 1 member being from outside this group. The thesis advisor will be not a member of the examining committee. The DGS will be an *ex officio* member of the committee unless they are one of the official members.

The purpose of the written portion of the qualifying exam is to assess the ability of the student to propose significant experiments to test original hypotheses as well as to summarize pertinent literature in the area. The purpose of the oral exam is to assess the ability of the student to defend their choice of specific aims, the importance of their hypotheses, and the suitability of their research design and methods. The oral portion of the exam will also test the ability of the student to consider alternative hypotheses and methods that may be posed by the committee and to demonstrate general knowledge of the research area.

The examining committee will receive the written portion of the qualifying exam at least two weeks prior to the scheduled oral exam. Prior to beginning the qualifying exam, the committee will assess whether there is sufficient scientific merit in the proposal to proceed with the oral exam. If there are no major deficiencies, the exam will take place as scheduled. However, if the committee feels that there are major deficiencies, they can elect to delay the oral exam for up to one month during which time the student will be allowed to revise the written portion of the qualifying exam. At the second meeting, the oral exam will take place even if deficiencies in the written document still remain.

There will be three possible outcomes of the qualifying examination:

1) Unconditional Pass – Both the proposal and the oral exam are acceptable;
2) Conditional Pass – Some aspects of the written proposal and/or the oral exam are not acceptable. The committee, in consultation with the DGS, will determine the conditions and time frame for the student to convert the conditional pass into an unconditional pass;
3) Fail.

In the case of failure, the student will be given up to 6 months to retake the examination. The examining committee, in consultation with the DGS, will determine the time for reexamination. Failure to pass a second qualifying examination will result in
dismissal from the Ph.D. degree program. On successful completion of the oral examination, the student will be admitted to candidacy.

**Dissertation Committee and Final Defense**

Once a student has been admitted to candidacy, the student, in consultation with the thesis advisor and the DGS, will select a dissertation advisory committee that will be chaired by a graduate faculty member other than the research advisor. The committee will be composed of at least 4 graduate faculty members, a minimum of 2 of which will be from the CPB training faculty and one of which will be from outside this group. The student will be required to meet with their dissertation committee within 6 months of admission to candidacy. At that time, they will provide a description of their thesis research project. The student will be required to meet with their dissertation committee at least once every year until they have completed their dissertation research and received permission from the committee to write their dissertation. More frequent meetings can be scheduled if requested by the student or the advisor. The dissertation committee will serve as a resource for direction and assistance throughout the time from admission to candidacy to the thesis defense.

The dissertation committee will be responsible for administering the final public thesis defense and for evaluating whether the student has written an acceptable thesis. A summary of all committee meetings will be prepared by the student and approved by the committee. Copies of these approved summaries will be sent to the DGS and become a part of each student’s permanent record. The chair of the dissertation committee will provide written notification to the DGS of the results of the thesis defense. Provided that all other requirements have been satisfied, the DGS will notify the Dean of the Graduate School that the student has completed the requirements for the Ph.D. degree.

Candidates for the Ph.D. in Chemical and Physical Biology will be required to write an acceptable dissertation, according to the regulations of the Graduate School, that adds to, or modifies in a significant way, what was previously known in the area. Candidates will also be expected to have presented results from their dissertation work at national or international meetings and they must have a minimum of one first authored publication in a peer reviewed scientific journal in their area of study in order to fulfill the requirements for a Ph.D. in Chemical and Physical Biology.

**Research Rotations**

All students admitted to the CPB Graduate Program or the IGP will be required to complete three 8-10 week research rotations with three different faculty members during their first two semesters. These research rotations are designed to provide students with an early opportunity to become familiar with the excitement of research in a given area, to learn the basic methods that are utilized in the studies being carried out in the mentor’s laboratory, and to allow the student to make an informed decision about whether the “fit” in a particular laboratory is right for them. The rotations also allow faculty mentors to
evaluate the student and to judge whether they have the requisite background and motivation to pursue research in their area of investigation.

It is expected that three rotations will be sufficient to permit matching of students with their thesis advisors. However, if a match is not made on the basis of three rotations, a fourth rotation will be arranged in the summer session between the first and second years of graduate training. In order for a student to be admitted to the Chemical and Physical Biology Ph.D. Degree Program, the selected advisor must be a member of the programs’ training faculty.

**Additional Requirements**

All students in the program will be required to take a course that provides instruction on giving oral and poster format scientific presentations, preparing for the qualifying exam, writing grants, and reading and critiquing the scientific literature. Several courses are currently offered (e.g. CHEM 300a,b, MP&B 324, BCHM 330, PHAR 322) that cover these basic topics. All students will also be required to enroll in two seminar series. Students in the Chemical Biology track will enroll in CPBP 310 which is the Vanderbilt Institute of Chemical Biology series in the Fall and Spring semesters. Students in the Structural Biology and the Molecular Biophysics tracks will enroll in CPBP 310 in the Fall semester and in CPBP 349 which is the Molecular Biophysics series in the Spring semester. Both of these seminar series provide students with the opportunity to hear about cutting edge research in these areas from national and international leaders in the field as well as providing them with the opportunity to give a scientific presentation at the end of the semester. All students will also be required to take IGP 322 on research ethics and IGP 303A on responsible conduct in research.

To help students become effective teachers and scientific communicators, all students will be strongly encouraged to participate in the teaching of a course or seminar. A variety of teaching opportunities will be made available to students including teaching in undergraduate, graduate, and professional courses. Relevant examples include leading in class literature discussions, performing activities as a teaching assistant in undergraduate laboratories/courses, or designing and presenting supplemental material in lower level courses. The DGS will maintain a list of teaching opportunities from which students can select where and how they will be involved.

Students will be required to give at least one seminar presentation in each year that they are in the program. This may take the form of a departmental seminar or be a part of one of the interdisciplinary training programs such as Molecular Biophysics or Chemistry Biology Interface. They will also be strongly encouraged to give yearly presentations on their research at national meetings beginning in their second year in the program.
Length of Training

Students and thesis advisors should aim for completion of all degree requirements within a period of five years of beginning graduate studies. Based upon current statistics of similar programs on campus, and on the previous training record of the faculty in this program, this is a reasonable period of time. All students are expected to graduate within six years of entry into graduate school. If additional time beyond six years is necessary to complete all degree requirements, the student will be required to petition the chair of their thesis committee and the DGS, in writing, for an extension. This petition must contain an explanation for the inability to complete training in six years and a realistic projected date for the thesis defense. If an extension is recommended by the Executive Advisory Committee, the DGS will petition the Dean of the Graduate School for an extension.

Primary Training Faculty

Training will be directed by graduate faculty members that have research interests in the area of chemical and physical biology in the Departments of Biochemistry, Biological Sciences, Cancer Biology, Cell Biology, Chemistry, Mathematics, Microbiology and Immunology, Molecular Physiology and Biophysics, Pathology, Pharmacology, or Physics. The faculty have active research programs and in most cases, many years of experience in graduate training. A complete list of training faculty is given below.

This group of faculty have wide ranging research interests with major research emphases on contemporary problems at the chemistry-biology and/or physics/biology interface. This will provide a rich training environment for students in three general areas: 1) chemical biology; 2) structural biology; or 3) molecular biophysics. Each of these three emphasis areas is represented by multiple faculty members as illustrated on pages 19-20 and many faculty members have research programs that span one or more of these boundaries. The trans-institutional investment in these areas has already led to the recruitment of new faculty members and to the establishment of supporting programs including the Biomathematics Study Group, the Center in Molecular Toxicology, the Vanderbilt Institute of Chemical Biology (VICB), the Center for Structural Biology (CSB), the W.M. Keck Vanderbilt Free Electron Laser Center and the Biophotonics Institute, the Mass Spectrometry Research Center, the Vanderbilt University Institute for Imaging Science (VUISS), the Center for Molecular Neuroscience, and the Vanderbilt Institute for Integrative Biosystems Research and Education (VIIBRE). Numerous interactions between the training faculty, all of whom are active participants in one or more of these trans-institutional Centers, Institutes, or study groups, already exist. The proposed Ph.D. degree program in Chemical and Physical Biology will facilitate further interactions between the training faculty and it will provide a degree program that is optimized for training at the interface of disciplines.

Additional training faculty will be added in the future based on the following criteria: research activities in one, or more, of the three emphasis areas of this degree program; definable means of support for graduate students either in the form of peer-
reviewed research support or institutional funds for new junior faculty members, a member of the graduate faculty; and active participation in graduate courses, seminars, and/or other program activities such as administration.

**Administrative Structure**

The Chemical and Physical Biology degree program will be administratively housed in Biomedical Research Education and Training (BRET) office in 350 Light Hall. Roger Chalkley, senior associate dean of BRET, has agreed to provide the administrative support for the program. The administrative structure of the program is defined in the organization chart below.

![Organization Chart](chart.jpg)

The Program Director is responsible for overseeing all aspects of the program with input from both the Executive Advisory Committee and the DGS. The Director will be the official spokesperson for the program and the official representative in all issues related to University policies and programs. In addition, the Director will be responsible for assuring high standards in the academic program, for assessing the qualifications and diversity of the training faculty, and for overall monitoring of the performance of students. The Program Director will also be responsible for initiating and coordinating the recruitment of students from the various admissions programs on campus.

The Executive Advisory Committee will be composed of representatives from the major Centers, Institutes, Training Grants, and Study Groups that interface with the degree program. These include: the Biomath Study Group, the Center for Structural Biology, the Vanderbilt Institute of Chemical Biology, the Vanderbilt University Institute for Imaging Science, the Vanderbilt Institute for Integrative Biosystems Research and Education (VIIBRE), the Molecular Biophysics Training Grant Program, and the Chemistry Biology Interface Training Grant Program. This Committee will be available to advise the Program Director about issues related to policy, academic programs, and student related issues and it will also serve as the Admissions Committee to evaluate applicants to the Ph.D. degree program.

The Director of Graduate Studies will be responsible for monitoring the progress of each student throughout their training. He/she will have the most frequent direct
contact with the students, they will be responsible for explaining the requirements and expectations to the students, and they will be responsible for monitoring performance in coursework. In addition, he/she will attend all qualifying examinations to ensure that equitable standards for requirements and performance are followed. The DGS will also be responsible for keeping the Program Director appraised of student progress including early identification of any potential problems in the didactic or research phases of their graduate training. Finally, they will serve as the student advocate when personal problems arise and in cases of possible faculty irresponsibility or misconduct.

Pool of Applicants and Admissions

All students that are admitted to graduate school via the CPB graduate admissions program are uncommitted to any department or program. They carry out three sequential 8-10 week research rotations during the first two semesters of graduate school and then choose an advisor at the end of the second semester. This pool of students represents a highly qualified group for recruitment into the Chemical and Physical Biology degree program. This statement is supported by the current group of students that have entered graduate school via the CPB graduate admissions program. Of the 17 current students, 14 have either selected mentors, or are currently doing research rotations with training faculty members in the Chemical and Physical Biology degree program. One of the real obstacles for recruiting the best students into the CPB admissions program in the past four years has been that there is no separate degree path in Chemical and Physical Biology for them to pursue. Establishment of this degree program will be a tremendous aid in recruiting and will be an attractive option to those students that choose a mentor and a research project that falls into one of its three tracks.

All entering students in the IGP are also admitted uncommitted to a specific department or program, and they carry out three sequential 8 week research rotations before choosing a mentor and research area at the end of the second semester. In the past 5 years, 37 IGP students have elected to enter laboratories of the training faculty of the Chemical and Physical Biology degree program and many of these have chosen research projects that clearly lie at the interface of disciplines in one of the three tracks defined on pages 5-9. Students that enter laboratories of the training faculty and choose research projects in one of these three tracks in future years will have the option to apply to the Chemical and Physical Biology degree program.

Students that enter directly into one of the departmentally based graduate programs in chemistry, mathematics, or physics, that choose mentors that are in the training faculty of this program, and that pursue dissertation research in one of the three tracks of the program will also have the option to apply to the Chemical and Physical Biology degree program.

Official admission into the Chemical and Physical Biology Ph.D. degree program will normally take place at the end of the second semester of graduate school, when the students have completed their rotations in the CPB or IGP admissions programs or have chosen their mentor and research project in one of the departmentally based programs.
Acceptance into the program depends on satisfactory academic performance, as defined on page 9, above, and completion of all of the first year CPB, IGP, or departmental requirements. Acceptance will also depend on recommendation of the student by the chosen thesis advisor who must be a member of the training faculty of this program.

Financial Support

Stipends, tuition, and fees are awarded to all entering students in the CPB, the IGP, and the departmentally based programs on the basis of academic merit. The first two semesters of stipend support in the CPB and the IGP are provided by the individual programs. The first two semesters of stipend support in the departmentally based programs are provided by the departments. Following the first two semesters, when students have selected a mentor and a research project, there are many different avenues of available support including training grants (e.g. Molecular Biophysics, Chemistry Biology Interface, etc.) for United States citizens or permanent residents, research grants for non-training grant eligible students, and individual fellowships from extramural sources. It is the responsibility of the mentor to secure support for students in all years after they have entered their laboratory, whether it be on training grants or research grants, discretionary funds, or some combination thereof. Minimal administrative costs and support staff for the program will be provided by the BRET office. No costs for the program will be requested from the participating departments.

Periodic Evaluations of the Program

The Chemical and Physical Biology Ph.D. degree program will be evaluated after the first three years and then at five year intervals by an external committee. The external committee will be assembled by the DGS in consultation with the Executive Advisory Committee and the Program Director and will be composed of faculty members from other institutions that have developed similar programs. The external committee will be charged with evaluating all aspects of the program including the quality of the applicant pool, student performance in coursework and research, and the quality and quantity of scientific publications from the students in the program. The committee will provide a written evaluation of the program to the DGS and the Director upon completion of their review.

Conclusion

The critical resources including faculty, courses, seminar series, pools of applicants, and training grant support are already in place to support the development of a trans-institutional Ph.D. degree program in Chemical and Physical Biology. This new program will unify these key components into a cohesive unit that will optimize the interdisciplinary training of students in the areas of chemical biology, structural biology, and molecular biophysics, all of which are areas of emphasis and growth at Vanderbilt. Vanderbilt University demonstrated great vision in establishing the trans-institutional CPB admissions program in 2000, several years before the need for such programs was identified at the national level including the NIH Roadmap and the current HHMI/NIH
venture to fund the development of similar programs nationwide. The creation of this program will not only keep us at the forefront in these areas and help us recruit the best students into the various admissions programs, it will also be an important component of our efforts to obtain additional extramural funding including grants from HHMI and NIH that are currently being prepared for submission.

**Training Faculty Roster**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
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<tbody>
<tr>
<td>Richard Armstrong</td>
<td>Professor of Biochemistry and Chemistry</td>
</tr>
<tr>
<td>Brian Bachmann</td>
<td>Assistant Professor of Chemistry</td>
</tr>
<tr>
<td>Albert Beth</td>
<td>Professor of Molecular Physiology &amp; Biophysics</td>
</tr>
<tr>
<td>Paul Bock</td>
<td>Associate Professor of Pathology</td>
</tr>
<tr>
<td>Darryl Bornhop</td>
<td>Professor of Chemistry</td>
</tr>
<tr>
<td>Alex Brown</td>
<td>Associate Professor of Pharmacology</td>
</tr>
<tr>
<td>Richard Caprioli</td>
<td>Professor of Biochemistry, Chemistry, and Pharmacology</td>
</tr>
<tr>
<td>Walter Chazin</td>
<td>Professor of Biochemistry and Physics</td>
</tr>
<tr>
<td>David Cliffel</td>
<td>Assistant Professor of Chemistry</td>
</tr>
<tr>
<td>David Cortez</td>
<td>Assistant Professor of Biochemistry</td>
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<tr>
<td>Phil Crooke</td>
<td>Professor of Mathematics</td>
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<tr>
<td>Lou Defelice</td>
<td>Professor of Pharmacology</td>
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<tr>
<td>Emmanuele Dibenedetto</td>
<td>Professor of Mathematics</td>
</tr>
<tr>
<td>Martin Egli</td>
<td>Professor of Biochemistry</td>
</tr>
<tr>
<td>Brandt Eichman</td>
<td>Assistant Professor of Biological Sciences</td>
</tr>
<tr>
<td>John Gore</td>
<td>Professor of Biomedical Engineering and Radiology and Molecular Physiology &amp; Biophysics</td>
</tr>
<tr>
<td>Fred Guengerich</td>
<td>Professor of Biochemistry</td>
</tr>
<tr>
<td>Vsevolod Gurevich</td>
<td>Associate Professor of Pharmacology</td>
</tr>
</tbody>
</table>
Richard Haglund  Professor of Physics
Heidi Hamm  Professor and Chair of Pharmacology
Eva Harth  Assistant Professor of Chemistry
Shane Hutson  Assistant Professor of Physics
Tina Iverson  Assistant Professor of Pharmacology
Anne Kenworthy  Assistant Professor of Molecular Physiology & Biophysics
Andrzej Krezel  Associate Professor of Biological Sciences
Dan Liebler  Professor of Biochemistry
Andrew Link  Assistant Professor of Microbiology & Immunology
Terry Lybrand  Professor of Chemistry and Pharmacology
Larry Marnett  Professor of Biochemistry and Chemistry
Hassane Mchaourab  Associate Professor of Molecular Physiology & Biophysics
Jens Meiler  Assistant Professor of Chemistry and Pharmacology
David Piston  Professor of Molecular Physiology & Biophysics and Physics
Ned Porter  Professor and Chair of Chemistry
Carmelo Rizzo  Associate Professor of Chemistry
Sandra Rosenthal  Associate Professor of Chemistry
Charles Sanders  Associate Professor of Biochemistry
Phoebe Stewart  Associate Professor of Molecular Physiology & Biophysics
Michael Stone  Professor of Chemistry
Gerald Stubbs  Professor of Biological Sciences
Gary Sulikowski    Professor of Chemistry
Sun, Zu-Wen    Assistant Professor of Biochemistry
Munirathinam Sundaramoorthy    Assistant Professor of Nephrology and Biochemistry
Michael Waterman    Professor and Chair of Biochemistry
Glenn Webb    Professor of Mathematics
John Wikswo    Professor of Physics, Engineering, and Molecular Physiology & Biophysics

Research Areas of Faculty

Chemical Biology

Richard Armstrong
Brian Bachmann
Darryl Bornhop
Alex Brown
David Cliffel
David Cortez
Fred Guengerich
Eva Harth
Larry Marnett
Ned Porter
Carmelo Rizzo
Sandra Rosenthal
Gary Sulikowski
Zu-Wen Sun

Structural Biology

Walter Chazin
Martin Egli
Brandt Eichman
Tina Iverson
Andrzej Krezel
Terry Lybrand
Jens Meiler
Charles Sanders
Phoebe Stewart
Molecular Biophysics

Albert Beth
Paul Bock
Richard Caprioli
Phil Crooke
Lou Defelice
Emmanuele Dibenedetto
John Gore
Vsevolod Gurevich
Richard Haglund
Heidi Hamm
Shane Hutson
Anne Kenworthy
Dan Liebler
Andrew Link
Hassane Mchaourab
David Piston
James Tam
Michael Waterman
Glenn Webb
John Wikswo

Faculty Research Interests

Richard Armstrong: Mechanistic enzymology; crystallographic analysis of enzymes involved in the metabolism of xenobiotics.

Brian Bachmann: Natural product biosynthetic studies and directed biosynthesis.

Albert Beth: EPR and fluorescence spectroscopy; applications to membrane protein structure and membrane protein dynamics.

Paul Bock: Regulation of plasma proteinases; fluorescence spectroscopy; enzymology.

Darryl Bornhop: Molecular imaging; agent development; nano-sensing for systems biology.

Alex Brown: Lipidomic analysis of cell signaling.
**Richard Caprioli:** Mass spectrometric analysis of neuropeptides and proteins; mass spectrometry methods development.

**Walter Chazin:** Structural biology; DNA replication, recombination, and repair; protein ubiquitination and calcium signaling; NMR spectroscopy.

**David Cliffl:** Bioanalytical measurements of real-time physiology and energy metabolism.

**David Cortez:** Molecular mechanisms of genome integrity; cell cycle signaling.

**Phil Crooke:** Solutions of differential equations; mathematical modeling in medicine.

**Lou Defelice:** Molecular pharmacology of neurotransmitter uptake.

**Emmanuele Dibenedetto:** Partial differential equations; applications to transport and diffusion processes; applications to intracellular signaling, transduction pathways, and molecular cascades in complex signaling systems.

**Martin Egli:** X-ray crystallography; nucleic acid structure; protein-nucleic acid interactions; protein structure.

**Brandt Eichman:** Structural biology of DNA replication machinery; X-ray crystallography.

**John Gore:** Magnetic resonance imaging; functional MRI; contrast mechanisms; nuclear relaxation; brain function.

**Fred Guengerich:** Chemistry and enzymology of bioactivation and detoxification compounds.

**Vsevolod Guervich:** Structure-function studies of arrestin proteins and their role in G-protein coupled receptor desensitization, trafficking, and signaling through alternative pathways.

**Richard Haglund:** Ultrafast laser mass spectrometry; applications to biological macromolecules.

**Heidi Hamm:** Structure, function, and interactions of G-protein coupled receptors; molecular mechanisms of signal transduction; vascular biology.

**Eva Harth:** Structure, function, and dynamics of biopolymers; nanoparticles.

**Shane Hutson:** Biophotonics; interaction of light with matter; laser surgery.
Tina Iverson: X-ray crystallography of membrane proteins.

Anne Kenworthy: Fluorescence microscopy; intracellular trafficking and signaling.

Andrzej Krezel: Structural NMR studies of protein-protein interactions.

Dan Liebler: Protein modification in biochemical, cellular, and animal models; mass spectrometry; proteomics.

Andrew Link: Functional genomics approaches to understanding biological processes; mass spectrometry.

Terry Lybrand: Molecular modeling of protein-protein and protein-ligand interactions; computational biology.

Larry Marnett: Structure and mechanistic enzymology of cyclooxygenase and lipoygenase.

Hassane Mchaourab: EPR and fluorescence spectroscopy; protein structure and function.

Jens Meiler: Computational biology/bioinformatics; prediction and analysis of protein structure; intermolecular interactions with biomolecules.

David Piston: Two-photon excitation fluorescence microscopy; applications to intracellular metabolic dynamics; fluorescence spectroscopy.

Ned Porter: Free radical reactions of lipids; antioxidants and mechanisms of lipid peroxidation; enzyme photoactivation.

Carmelo Rizzo: Chemistry of nucleosides and oligonucleotides; flavoenzymes.

Sandra Rosenthal: Fundamental properties of semiconducting nanocrystals; femtosecond spectroscopy; fluorescent nanocrystals for neuroscience.

Charles Sanders: Structural and chemical biology of membrane proteins; membrane protein misfolding and disease.

Phoebe Stewart: Cryo-EM; structural biology of large protein-protein complexes; virus structure and mechanisms of cell entry.

Michael Stone: NMR spectroscopy; structure of DNA-carcinogen adducts.

Gerald Stubbs: X-ray diffraction analysis of viruses and cytoskeletal filaments.
Munirathinam Sundaramoorathy: Protein structure-function of collagen and sialic acid biosynthesis; X-ray crystallography.

Gary Sulikowski: Biomimetic syntheses of natural products, heterocycles, and oligosaccharides.

Zu-Wen Sun: Histone modifications, chromatin structure, and gene regulation.

Mike Waterman: Structural biology of sterol oxidizing cytochromes P450 in humans and bacteria antibiotic generation.

Glenn Webb: Mathematical modeling of population aging; ededemics; tumor growth; HIV-immune system reactions; HIV drug therapy.

John Wikswo: Electric and magnetic field measurement with action potentials in nerve cells; monitoring and feedback control of cellular metabolism.

Recommended Elective Courses

BCHM 300 Introduction to Structural Biology
BCHM 301 Molecular Structure and Function
BCHM 303 Biomolecular X-ray Crystallography
BCHM 343 Biomolecular NMR Spectroscopy
BCHM 353 Analytical Proteomics
BME 258 Medical Imaging
BME 263 Signal Measurement & Analysis
BSCI 201 Introduction to Cell Biology
BSCI 220 Biochemistry I
BSCI 274 Protein Design
CHEM 202 Introduction to Bio-inorganic Chemistry
CHEM 222 Physical Organic Chemistry
CHEM 223 Advanced Organic Reactions
CHEM 224 Bio-organic Chemistry
CHEM 226 Medicinal Chemistry
CHEM 232 Quantum Chemistry
CHEM 233 Molecular Modeling Methods
CHEM 234 Spectroscopy
CHEM 336 Biochemical Toxicology and Carcinogenesis
IGP 300A Bioregulation
MATH 218 Intro to Math Statistics
MATH 267 Mathematical Models in Biology and Medicine
MATH 297 Fourier and Wavelet Analysis
MP&B 325 Physical Measurements on Biological Systems
MP&B 330 Human Physiology & Molecular Medicine
PHAR 320 Pharmacological Targets and Mechanisms
PHAR 321 Principles of Drug Action
PHAR 324  Receptor Theory
PHAR 330  Chemistry of Lipid Signaling
PHAR 345  Cell & Molecular Neuroscience
PHAR 346  Advanced Molecular Neurobiology
PHYS 228  Physics of Medical Imaging
PHYS 245  Computational Physics
PHYS 330A  Quantum Mechanics I
PHYS 330B  Quantum Mechanics II
PHYS 341  Statistical Mechanics