The Pennsylvania State University
Intercollege Graduate Degree Program in Bioengineering

Graduate Student Handbook

2016

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I. General Information

The Penn State Intercollege Graduate Degree Program (IGDP) in Bioengineering is a degree granting program that includes faculty members from multiple departments and colleges at Penn State. This list includes faculty with their primary appointment in the Biomedical Engineering Department and affiliated faculty who have their primary appointments in other departments. All faculty who advise M.S. and Ph.D. students in Bioengineering must be members of the IGDP in Bioengineering.

Graduate Program Office

The Graduate Program Office for Bioengineering is located in 206 Hallowell Building. The graduate staff assistant, Jenna Sieber, is available to assist students between the hours of 8:00-4:00 Monday through Friday. If she is unavailable, you may contact Lisa Daub, Administrative Staff Coordinator in 205 Hallowell Building.

The Graduate Program Office can help with the following:

- answer administrative questions and supply forms
- schedule controlled bioengineering classes
- schedule candidacy, comprehensive, and final oral exams
- submit theses and dissertations for printing
- prepare contracts
- prepare letters for leaving the country for international students

Keys: Keys may be obtained by asking your adviser to send an email to Gary Meyers at gmeyers@engr.psu.edu detailing which lab keys are needed. Keys can then be picked up at his office in 111Hallowell Building. Once you leave the Bioengineering Program, all keys need to be returned to Gary.

Purchasing Equipment and Supplies: Graduate students may be responsible for purchasing supplies for their lab. Before ordering any supplies or equipment, please see Brooke Carrico for the correct procedures for ordering and completing the forms. In addition, be prepared and know what budget numbers to use. Consult your adviser for this information.

Mail: All graduate students will have a mailbox in 234 Hallowell Building or in Millennium Sciences Building. Inter-university mail and all outgoing mail is picked up at 1:00 Monday–Friday. Students may put personal mail in the outgoing wire basket as long as it has postage.

Sending FedEx or UPS Packages: The office staff in Hallowell can send out packages. Bring package to 205 Hallowell along with shipping information, phone number of recipient, budget number to be charged, weight and whether or not the package needs insured.

Packages are delivered in 234 Hallowell daily by Fed EX and UPS. Each student is responsible for checking deliveries of their lab supplies. This room is used by the entire department for many functions, so please be diligent in retrieving your packages.

II. Registration and Tuition

Tuition Bills

After enrolling in classes, all students will receive an e-mail notification from the Penn State Bursar's Office requiring payment of tuition. Students should follow the instructions outlined in the e-mail to file the tuition bill electronically. Do not ignore this e-mail. Tuition and fees are covered under assistantships/fellowships. Tuition will not be paid until the student completes the appropriate payroll paperwork and the assistantship is processed. After the assistantship has been processed, students should file the tuition bill on LionPath (http://www.bursar.psu.edu/paybill.cfm). Students will need to log in to their Student Center on LionPath, click "Manage My Account/Make a Payment" tab, choose the option "make changes or adjustments to my bill", click the appropriate box for "Assistantship/Fellowship", change the tuition amount owed to "zero" and submit the bill on-line to confirm registration. By filing the bill online, it confirms your registration and places you into "registered status."

Full-time Academic Status

Full-time academic status is achieved by taking appropriate course loads as shown in the following pages. Most loan granting agencies and other organizations will consider a 9-12 credit course load to be full-time status, fulfilling their registration requirements. The U.S. Immigration and Customs Enforcement (ICE) requires that all international students on student visas must achieve "full-time academic status" during the Fall and Spring semesters. For ICE purposes, a course load of nine credits is considered full-time during Fall and Spring semesters, and during the Summer semester, international students do not have to register. All M.S. and pre-comprehensive Ph.D. students should register for BIOE 600 research credits to achieve this 9 credit minimum for full-time status. Any graduate student registered for BIOE 601 is considered to have a full-time academic status (Note: Student must have passed the Ph.D. comprehensive exam in the prior semester before registering for BIOE 601). Students must request registration for BIOE 590, 600 and 601 through the graduate staff assistant. For full details, see the Graduate Degree Programs Bulletin website at http://bulletins.psu.edu/bulletins/whitebook/index.cfm.

Course Load

It is recommended by the department that all full-time students and students receiving assistantships or fellowships should register for 12 credits per semester. These credits can consist of course credits (400 and 500-level), and research credits (600- level). Graduate courses carry numbers from 500 to 699 and 800 to 899. Advanced undergraduate courses numbered between 400 and 499 may be used to meet some graduate degree requirements. A graduate student may register for or audit courses below the 400 level in order to make up deficiencies or to fill in gaps in previous education but not to meet requirements for an advanced degree and only by the recommendation of the adviser and/or advisory committee. Undergraduate courses in the Department of Biomedical Engineering are denoted by BME.

The Graduate School requires that all students receive a cumulative grade point average of 3.0 or better to graduate. Students must have a 3.0 minimum GPA in order to take the Candidacy and Comprehensive Exams. Only grades of C or better count toward MS and PhD course requirements.

After passing the comprehensive exam, all Ph.D. students must maintain "continuous registration," which requires them to register for BIOE 601 for the Fall and Spring semesters. If Ph.D. students use University facilities during Summer Session or plan to take their comprehensive exam during the summer,* they must be registered. *Students who take their comprehensive exam during the summer should apply for free summer tuition (STAP). Students will receive an email in April about applying for STAP. For more information, please visit the following website: http://www.gradschool.psu.edu/index.cfm/graduate-funding/fellowships/programs/summer/

BIOENGINEERING (BIOE) Course List: http://www.bioe.psu.edu/students/GRCourses.html

Student Insurance

Health insurance is mandatory for all international students (and their dependents) who are supported on assistantships/fellowships or who are self-supported. US students on other health care plans may file a waiver on-line with the Student Insurance Office if they are covered under another health insurance plan. International students may file a declination form on-line but they must present evidence of being covered under another health care plan which is equivalent to the Penn State plan. Students on assistantships/fellowships are automatically enrolled in the medical, dental and vision plans. Insurance premiums are deducted monthly from the assistantship stipend. Penn State will pay 80% of insurance coverage and the student is responsible for 20%. Students who are not on assistantships/fellowships must pre-pay for health care coverage.

The insurance subsidy for eligible dependents is 75% of the annual premium expense for spouse, domestic partner OR children; 76% of the annual premium expense for family.

Detailed information on health insurance, including the health insurance booklet, enrollment deadlines and table of monthly payroll deductions is available at: http://studentaffairs.psu.edu/health/services/insurance/.

It is each student's responsibility to notify the department, payroll office, and the international office (if applicable) if there is a change of address during your stay at Penn State. Please change the information on LionPath and more importantly, on ESSIC (Employee Self-Service Information Center). https://essic.ohr.psu.edu The ESSIC system is available for students who are on a paid assistantship or fellowship.

Selecting an Academic Advisory Committee

Upon entering the program, a student, along with his/her adviser, will select an academic advisory committee, consisting of three members of the IDGP in Bioengineering Graduate Faculty (including the adviser).

- All students (Masters, IUG and Ph.D.) will assemble an academic advisory committee to help select courses and assess progress on research. New students should contact their adviser prior to the beginning of the semester for help setting up an advisory committee and for class selection. Existing students should meet with their advisory committee each fall.
    - Committee will meet at least once a year and in time to help student select courses (generally late Spring or August)

- For every yearly meeting, students will create 1 page document summarizing the hypothesis (or goals) and specific aims of the project, a 10 minute PowerPoint presentation and current resume.
    - Committee will complete progress report form and a completed audit form, and attach to aims page and hard copy of presentation slides. All documents should be given to the graduate staff assistant to be placed in student's academic folder.
- For IUG and Master's students, the academic advisory committee will generally serve as their thesis reading committee.
- For Ph.D. students, the Doctoral Committee will replace the academic advisory committee after completion of the second year of the Ph.D. and before registering for the comprehensive exam.

Training in the Responsible Conduct of Research (RCR)

During the first year of study, all graduate students studying for the M.S. and/or Ph.D. in Bioengineering are required to complete the free online Scholarship and Research Integrity (SARI) training provided by the Collaborative Institutional Training Initiative (CITI). This may be completed during BIOE 591. http://www.research.psu.edu/training/sari/about-sari. Upon completing the training, participants are issued a certificate of completion. Email or photocopy the certificate and submit it to the Program's Graduate Secretary prior to the end of their second semester of study. All graduate students admitted to candidacy for the Ph.D. degree, shall participate in five hours of discussion based Responsible Conduct of Research (RCR) education. This requirement is considered a prerequisite for scheduling of the comprehensive exam and may be satisfied by enrollment in BIOE 591, Bioengineering Ethics and Professional Development, or IBIOS 591, Ethics in the Life Science if located in Hershey. Please register for the ethics course during your first or second semester.

Code of Conduct

The Penn State Intercollege Graduate Degree Program (IGDP) in Bioengineering has adopted the same Code of Conduct as The Graduate School. Please refer to the links below regarding the code policies.

http://www.gradsch.psu.edu/policies/student.html

Bioengineering Colloquium

The Bioengineering Colloquium (BIOE 590) is held every week during the Fall and Spring semesters. All graduate students must register for BIOE 590 (1 credit) each semester in attendance. Ph.D. students must register for BIOE 590 (1 credit) until they have passed their comprehensive exam. Attendance is mandatory.

III. Ph.D. Degree Requirements

Completing a Ph.D. in Bioengineering consists of satisfying minimum course requirements, passing two formal exams (candidacy exam and comprehensive exam), and completing and defending a dissertation (final exam). The Ph.D. is a research-focused degree and research is expected to be the focus of students' energies with coursework providing depth of understanding and developing the breadth of knowledge expected of a doctoral candidate. Students are expected to begin their research work upon entering the program, and course requirements are set up with the expectation that during the first two years of study students spend at least half of their time carrying out research with the remainder devoted to coursework. Later years are devoted entirely to research activities. While the number of publications resulting from doctoral research varies, the general expectation is that Ph.D. students should publish at least three first-author publications prior to completing their dissertation. It is permissible to use content from the student's first-authored papers in the dissertation.

The policies described here apply to the Ph.D. degree in Bioengineering. Official Graduate School policies covering all Ph.D. degrees at Penn State can be found at:
http://bulletins.psu.edu/graduate/degreerequirements/degreeReq1

Ph.D. Course Requirements

Upon entering the Ph.D. program, the student, along with his/her research adviser, will select an academic advisory committee, consisting of three members of the IDGP in Bioengineering Graduate Faculty (including the adviser). Working with this committee, the student will select courses appropriate to their research and professional goals. In preparation for selecting proper courses for the first semester, the advisory committee must be selected and meet with the student before the start of classes (normally late August).

The minimum credit requirements for a Ph.D. in Bioengineering are as follows:

- Total minimum number of course credits is 29.
- 20 credits must be earned at a Penn State Campus and recognized by the Graduate School.
- 6 credits of Bioengineering; 6 credits Life Science; 6 credits Technical/Quantitative/Bioengineering Electives. 12 of these credits must be lecture or laboratory-based and at the 500 level. The other 6 credits can be 400 or 500-level lecture-based courses and cannot include the ethics course or colloquium.
- 6 additional credits at the 500 level in courses relevant to their research.
- At least 6 credits of BIOE 600 (Thesis Research).
- Ph.D. students must attend colloquium every semester until they have passed their comprehensive exam.
- 1 credit Bioengineering Ethics and Professional Development, BIOE 591
- Completion of online training in Responsible Conduct of Research (RCR) see the following website for details: http://www.research.psu.edu/training/sari/program*
- Any other courses as determined by student's adviser and/or academic advisory committee.

*All Ph.D. students admitted to candidacy must participate in five hours of discussion-based education on Responsible Conduct of Research, which will be satisfied by attaining a passing grade in BIOE 591 Bioengineering Ethics and Professional Development, in addition to taking the on-line training in RCR (see p. 6).

Students who enter the Ph.D. program with a Master's degree will work with his/her advisory committee to determine the suitability of substitutions for courses already taken. For each course substitution a Graduate Course Substitution Form (included in the appendix) must be filled out and signed by the Chair of the Graduate Program. Note that for Ph.D. coursework requirements, official credit transfers from other institutions are not used and this substitution form is used instead. These forms are included with Academic Advisory Committee Meeting summaries in the student's file.

Example Timeline for Bioengineering Ph.D. Degree

Semester 1

- In August, set up academic advisory committee and define course plan for year 1
- Take two 3-credit courses
- Take 1 credit BIOE 591 (Bioengineering Ethics and Professional Development) and 1 credit BIOE 590 Colloquium
- Register for BIOE 600 research credits up to at least 12 total credits
- Take online Training in the Responsible Conduct of Research

Semester 2

- Take two 3-credit courses
- Take 1 credit BIOE 590 Colloquium
- Register for BIOE 600 research credits up to 12 total credits

Summer

- Take candidacy exam

Semester 3

- Present yearly update to advisory committee and plan courses for Year 2 (before classes begin)
- Take two 3-credit courses
- Take 1 credit BIOE 590 Colloquium
- Register for BIOE 600 research credits up to 12 total credits

Semester 4

- Take two 3-credit courses
- Take 1 credit BIOE 590 Colloquium
- Register for BIOE 600 research credits up to 12 total credits

Year 3

- Present yearly update to advisory committee and plan courses for Year 3 (before classes begin)
- Take any classes suggested by advisory committee
- Take 1 credit BIOE 590 Colloquium until passing comprehensive exam
- Form doctoral committee
- Take comprehensive exam
- Register for BIOE 600 research credits up to 12 total credits until passing comprehensive exam and register for BIOE 601 after.

Years 4 and 5

- Carry out full-time research
- Meet with doctoral committee at least once per year
- Complete and defend dissertation

Note: Ph.D. students are expected to carry out research full-time during all summers. In rare cases when appropriate courses are offered, students also take coursework during summer terms.

English Proficiency Exam

A candidate for the degree of Doctor of Philosophy is required to demonstrate a high level of competence in use of the English language, including reading, writing, and speaking, as part of the language and communication requirements for the Ph.D. (Note: this is separate from teaching assistant testing.)

To fulfill this requirement, the English proficiency of each doctoral student in Bioengineering will be evaluated based upon the written and oral portions of the candidacy exam. Verbal communication skills will be assessed during the oral portion of the candidacy exam. The candidate's communication skills will be examined by the Candidacy Committee and a judgment of acceptability will be made or a recommendation for remedial course work in English will be made.

Competence in English must be formally certified by all graduate programs before the doctoral **comprehensive exam** is scheduled. (International students should note that passage of the minimal TOEFL requirement does not demonstrate the level of competence expected of a Ph.D. from Penn State.) It is the responsibility of the student to meet these requirements by taking whatever remedial steps are necessary to demonstrate an acceptable command of the English language.

All international students who are planning to be (or hope to be) a teaching assistant must take the American Oral English Communication Proficiency Test (AEOCPT) which evaluates American English speaking skills.

IV. Ph.D. Candidacy Exam

The candidacy exam is the first of three formal exams required for a Ph.D. The exam is taken at the end of the first year of study, typically at the start of summer following Spring semester. The exam is also given at the end of Fall semester. The purpose of the candidacy exam is to ensure that students possess the qualifications expected of a Ph.D. student and have the potential to perform at the high level expected of a Ph.D.bioengineer upon completion of the degree. The format of the exam is a written proposal on a research topic different from the student's dissertation project, followed by an oral defense.

The focus of the exam is to provide convincing evidence that the candidate has the creativity, maturity and confidence to carry out Ph.D. level bioengineering research. Candidates are evaluated on the following criteria:

(1) Demonstration of a mastery of the course work undertaken during the current graduate program and prior undergraduate and/or graduate academic programs. This coursework includes engineering, mathematics, the physical and chemical sciences, and biology at the molecular, cellular, and systems levels.

(2) A well-defined and superior ability to approach the solution of new problems by the methodical and logical application of sound scientific methods based upon fundamental principles of engineering and the physical sciences.

(3) The ability to write a coherent and rigorous proposal and present it orally to the committee.

(4) An ability to demonstrate extensive general knowledge of a traditional engineering or physical science discipline in which the candidate possesses a major and readily recognizable strength. Normally this discipline overlaps with the candidate's thesis research and the topic of their candidacy proposal. Examples include biomaterials, imaging, cellular/molecular bioengineering, fluid mechanics, drug delivery, etc.). Students must have a minimum 3.0 GPA to take the exam.

Candidacy Exam Proposal Topic

The student is responsible defining the topic of his/her proposal. Advisers and others may be consulted to refine the research topic. The proposal must be on new research (not problems that have already been solved). The topic can be broadly related to the student's research area, but the proposal must outline research that is distinct from the student's research project, different from other research being carried out in the lab, and not overlapping with any past grant proposals written by the student's adviser. Proposals can cover either hypothesis-based or design-directed research. Proposals must combine tools/topics from both the biological sciences and engineering, and students should make an effort to integrate engineering tools and quantitative analysis into their proposals. Statistical tests to assess significance should be described, and if animal studies are proposed, the necessary institutional approvals should be described.

Applying for the Candidacy Exam

The student will submit an application to take the candidacy exam by noon on the last day of classes for the semester. The application (see Appendix) consists of a title and 250 word summary of the proposal. Applications are reviewed by the candidacy exam committee as to their suitability for an exam topic, and are either approved or returned with suggestions for modifications of the proposal. Approvals are given one week after submission, on the last day of finals for the semester. The student will be given four weeks to complete the proposal. Oral defenses will be scheduled in the 1-2 weeks following submission of the written proposal. Students are expected to be available and on campus for scheduling the oral defense.

Written Proposal Format

The student will prepare a research proposal, suitable for a Ph.D. level research project. The proposal will be in the form of an NIH R01 research grant consisting of a title page, summary page, specific aims page, research plan, and full reference list.

Researching the literature will be the primary tool for developing the proposal. The student may solicit technical advice and consult with experts on campus and in the department as a way to learn about critical techniques, instruments and key experiments. Otherwise, the adviser and other faculty should not be consulted to read and critique rough drafts of the proposal beyond the specific aims. Students are encouraged to solicit critiques on writing and presentation from fellow students. Students should not carry out research to generate preliminary data for their candidacy exam.

The format of the research proposal will consist of the following sections, with recommended page limitations:

I. Title Page (see Appendix)
(a) Provide a succinct title for the proposal and the estimated starting and ending dates of the research.
(b) Name of the student.
(c) Name of dissertation adviser.

II. Summary (1/2 page)
State the proposal's broad, long-term objectives and specific aims, making reference to the health or biology relatedness of the project. Describe concisely the research design and methods for achieving these goals. Avoid summaries of past accomplishments and the use of the first person. This abstract is meant to serve as a succinct and accurate description of the proposed work when separated from the proposal. Do not exceed the ½ page limit. Make page separate from title page and specific aims.

III. Specific Aims (1 page limit)
State concisely the goals of the proposed research and summarize the expected outcome(s), including the impact that the results of the proposed research will exert on the research field(s) involved. List succinctly the specific objectives of the research proposed, e.g., to test a stated hypothesis, create a novel design, solve a specific problem, challenge an existing paradigm or clinical practice, address a critical barrier to progress in the field, or develop new technology. A figure on the specific aims page is allowed.

IV. Research Strategy (12 pages)
Significance (2-4 pages):
Explain the importance of the problem or critical barrier to progress in the field that the proposed project addresses. Describe the scientific premise for the proposed project, including consideration of the strengths and weaknesses of published research or preliminary data crucial to the support of your application. Explain how the proposed project will improve scientific knowledge, technical capability, and/or clinical practice in one or more broad fields. Describe how the concepts, methods, technologies, treatments, services, or preventative interventions that drive this field will be changed if the proposed aims are achieved.

Innovation (up to 1 page):
Explain how the application challenges and seeks to shift current research or clinical practice paradigms. Describe any novel theoretical concepts, approaches or methodologies, instrumentation or interventions to be developed or used, and any advantage over existing methodologies, instrumentation, or interventions. Explain any refinements, improvements, or new applications of theoretical concepts, approaches or methodologies, instrumentation, or interventions.

Approach (the remainder of the 12 pages):
Describe the overall strategy, methodology, and analyses to be used to accomplish the specific aims of the project. Describe the experimental design and methods proposed and how they will achieve robust and unbiased results. Discuss potential problems, alternative strategies, and benchmarks for success anticipated to achieve the aims. If the project is in the early stages of development, describe any strategy to establish feasibility, and address the management of any high risk aspects of the proposed work. Provide a tentative sequence and time table for the investigation.

V. Bibliography
Provide a list of all references cited in the above sections that is in the format of articles written for major journals, such as the American Journal of Physiology or Journal of Biomechanics. Citations within the text may be made by either author (year) or by number. Provide the full citation in the bibliography, i.e. authors, title, journal, volume, page numbers and year. The student is expected to have critically read and understood the publications that provide the foundation of their proposal. Limit the number of references to a maximum of 40. The use of EndNote, Mendeley, or equivalent bibliographic software is strongly recommended.

All text should be typed single space and a <u>minimum font size of 11 points</u> should be used. <u>A minimum 3/4 inch margin</u> should be maintained on the top, bottom and sides of each page. Each page should be numbered at the bottom. Figures should all have legends, and images taken from the literature should be properly referenced.

More information on the format of the R01 grant can be found on the NIH website:
https://grants.nih.gov/grants/how-to-apply-application-guide.htm
Sample R01 grants can be found at:
https://www.niaid.nih.gov/researchfunding/grant/pages/appsamples.aspx

Students submit a hard copy and pdf file of the completed proposal by noon on the Friday the proposal is due to the Graduate Staff Assistant, Jenna Sieber (jns5431@engr.psu.edu). She will coordinate with the student and committee to select a time for the oral defense of the proposal.

Candidacy Oral Defense and Evaluation

A two hour oral exam will be scheduled approximately one week following submission of the written proposal. During the oral exam, the student will present a 10 minute (maximum) overview of the proposal, which will be followed by a period of questions and answers from the committee. Students should bring a hard copy of the proposal to the exam and are allowed written notes, but PowerPoint slides and overheads are prohibited – this is a “chalk talk.” Student will have use of the blackboard and the committee will have the written proposal, so the student can refer the committee to specific figures in the proposal. The committee will be charged with the task of evaluating the proposal and any questionable areas established by the student’s academic record. Students are expected to be particularly well grounded in technical areas closely related to the proposal.

A standing candidacy exam committee, made up of at least four Bioengineering IDGP Faculty plus the student’s adviser, will administer the exam. The adviser should attend, but cannot participate in exam scoring. The committee will grade the written and oral components in areas using a five point scale with 1.0 being the best and 5.0 being the lowest. See the Appendix for a copy of the Candidacy Exam Evaluation.

Scores from all committee members are averaged and in each category a score of 3.0 or better is defined as passing. To receive a passing grade for the candidacy exam, a student must receive a score of 3.0 or better on at least six of these seven categories. If a student’s performance is unsatisfactory in two areas, they may take the exam once again in the next semester and must then pass all seven areas. Unsatisfactory performance in three or more areas will constitute failure of the candidacy exam and the student may not continue with the Ph.D. In this case, the student may obtain a Master’s degree upon completion of the requirements for that degree.

Students will be notified of the outcome of their exam within one week of the oral defense. Upon passing the candidacy exam, the student is classified as a Ph.D. Candidate in Bioengineering.

V. Ph.D. Comprehensive Exam

Doctoral Committee

In preparation for the comprehensive exam, students, together with their adviser, must form a doctoral committee. The doctoral committee consists of a minimum of four members of the Graduate Faculty including the adviser, who serves as the chair. The adviser must be a member of the Intercollege Graduate Degree Program (IGDP) in Bioengineering. At least three committee members must be members of the IGDP in Bioengineering. The committee must also include an “Outside Field Member” who is not a member of the IGDP in Bioengineering. Finally, at least one member of the doctoral committee must have his/her primary appointment outside the administrative unit in which the adviser’s primary appointment is held. The Graduate School will appoint the committee and notify all persons.

Please note if a committee member is added or dropped from the committee any time before the final exam is taken, it is the responsibility of the graduate student to notify the graduate staff assistant, as new paperwork needs to be completed and processed by the Graduate School.

Comprehensive Exam Policies

The next step toward the Ph.D. degree is the comprehensive exam, which is given when the candidate has completed all required course work. The comprehensive exam is generally given between the end of the second year and the end of the third year of the Ph.D. program and must take place at least one year prior to the PhD dissertation defense (final exam). The exam is intended to evaluate the candidate's mastery of the major (and if appropriate, minor) field. The Bioengineering Program uses the comprehensive exam as an opportunity to evaluate the Ph.D. student's dissertation proposal. In preparation for the exam, the student must form a doctoral committee, schedule an exam time, and prepare a detailed Ph.D. dissertation proposal according to departmental guidelines.

A candidate for the Ph.D. must have satisfied the English competence and the communication requirement before taking the comprehensive exam. This requirement is fulfilled during the oral candidacy exam. All candidates are required to have a minimum grade-point average of 3.00 for work done at the University at the time the comprehensive exam is given, and may not have deferred or missing grades. The student must be registered for the semester in which the comprehensive exam is taken. Student can be registered for BIOE 600 to satisfy requirement. The student must have the committee signatory page signed and approved by the Graduate School before comprehensive exam can be given.

The exam is scheduled and announced officially by the Office of Graduate Enrollment Services upon recommendation of the Biomedical Engineering Department Head. **Three weeks' notice is required by the Office of Graduate Enrollment Services for scheduling this exam.** The exam is given and evaluated by the entire doctoral committee. A favorable vote of at least two-thirds of the members of the committee is required for passing. In case of failure, it is the responsibility of the doctoral committee to determine whether the candidate may take another exam. The results are reported to the Office of Graduate Enrollment Services.

The dissertation adviser, as well as the chair of the doctoral committee (can be the same person), along with additional members of the committee to total a minimum of three (3), must by physically present at the comprehensive exam. The graduate student must be physically present at the exam. (Thus for a five-person committee, two could participate via distance.) No more than one member may participate via telephone; a second member could participate via PicTel or other video conferencing modality. The exam request and a request for exceptions must be submitted to the director of Graduate Enrollment Services for approval at least two weeks prior to the date of the exam. Special arrangements, i.e., requirements for meeting participation via distance, should be communicated to the student and the doctoral committee members well in advance of the exam.

When a period of more than six years has elapsed between the passing of the comprehensive exam and the completion of the program, the student is required to pass a second comprehensive exam before the final oral exam will be scheduled.

Format of the Comprehensive Exam

As part of the comprehensive exam, Ph.D. candidates are required to submit a written dissertation proposal to their doctoral committee. **Hard copies and pdf versions of the written proposal must be submitted to the Graduate Staff Assistant, Jenna Sieber and all committee members at least one week prior to the exam.** Failure to meet this deadline will result in postponement of the exam.

The written version should be read by the primary adviser and revised by the student prior to submitting it to the doctoral committee.

The oral component of the comprehensive exam is a two hour closed-door session in which the candidate prepares a 30 minute PowerPoint presentation (roughly 25 slides) based on their work to date and content of their proposal. The committee will ask questions and evaluate the student's mastery of coursework, broad knowledge of their field, and specific details of their proposal.

The objective of the dissertation proposal is three-fold. First, the proposal itself serves to outline the course of the student's proposed research program with sufficient detail so that the student's adviser and members of the doctoral committee may provide useful guidance and input into design and execution of the proposed research plan. Secondly, the act of writing the proposal enables the student to map out a clear course of research activities that are logical and methodical. Third, writing the proposal serves as a training exercise that will be of use to the student in the preparation of future applications for research funding. Where applicable, this document can be submitted as training grant proposal to the NIH or other funding agencies.

Format of the Ph.D. Dissertation Proposal

The format of the proposal will be similar in style to an NIH R21 proposal. Examples of NIH proposals can be found online at: http://www.niaid.nih.gov/researchfunding/grant/pages/appsamples.aspx. The proposal should contain the following sections:

I. Title Page (see Appendix)

II. Summary (1/2 page)
State the proposal's broad, long-term objectives and specific aims, making reference to the health or biology relatedness of the project. Describe concisely the research design and methods for achieving these goals. Avoid summaries of past accomplishments and the use of the first person. This abstract is meant to serve as a succinct and accurate description of the proposed work when separated from the proposal. Do not exceed the ½ page limit. Make page separate from title page and specific aims.

III. Specific Aims (1 page limit)
State concisely the goals of the proposed research and summarize the expected outcome(s), including the impact that the results of the proposed research will exert on the research field(s) involved. List succinctly the specific objectives of the research proposed, e.g., to test a stated hypothesis, create a novel design, solve a specific problem, challenge an existing paradigm or clinical practice, address a critical barrier to progress in the field, or develop new technology. A figure on the specific aims page is allowed.

IV. Research Strategy (6 pages)
Significance (max. 2 pages):
Explain the importance of the problem or critical barrier to progress in the field that the proposed project addresses. Describe the scientific premise for the proposed project, including consideration of the strengths and weaknesses of published research or preliminary data crucial to the support of your application. Explain how the proposed project will improve scientific knowledge, technical capability, and/or clinical practice in one or more broad fields. Describe how the concepts, methods, technologies, treatments, services, or preventative interventions that drive this field will be changed if the proposed aims are achieved.

Innovation (max. ½ page):
Explain how the application challenges and seeks to shift current research or clinical practice paradigms. Describe any novel theoretical concepts, approaches or methodologies, instrumentation or interventions to be developed or used, and any advantage over existing methodologies, instrumentation, or interventions. Explain any refinements, improvements, or new applications of theoretical concepts, approaches or methodologies, instrumentation, or interventions.

Approach (the remainder of the 6 pages):
Describe the overall strategy, methodology, and analyses to be used to accomplish the specific aims of the project. Describe the experimental design and methods proposed and how they will achieve robust and unbiased results. Discuss potential problems, alternative strategies, and benchmarks for success anticipated to achieve the aims. If the project is in the early stages of development, describe any strategy to establish feasibility, and address the management of any high risk aspects of the proposed work. Provide a tentative sequence and time table for the investigation.

V. Bibliography
Provide a list of all references cited in the above sections that is in the format of articles written for major journals, such as the American Journal of Physiology or Journal of Biomechanics. Citations within the text may be made by either author (year) or by number. Provide the full citation in the bibliography, i.e. authors, title, journal, volume, page numbers and year. The student is expected to have critically read and understood the publications that provide the foundation of their proposal. There is no limit to the number of references for the thesis proposal. The use of EndNote, Mendeley, or equivalent bibliographic software is strongly recommended.

VI. Appendix
The student should include as an appendix any manuscripts on which he/she is first or middle author and which have been published, accepted, or submitted to date as part of their doctoral studies. The committee will use these manuscripts along with preliminary data in the proposal to evaluate the student's progress to date. There is no page limit or format requirements for the appendix.

All text in the proposal (not including the appendix) should be typed single space and a <u>minimum font size of 11 points</u> should be used. <u>A minimum 3/4 inch margin</u> should be maintained on the top, bottom and sides of each page. Each page should be numbered at the bottom. Figures should all have legends, and images taken from the literature should be properly referenced.

Approvals

The dissertation proposal must be approved by the dissertation adviser and all members of the student's doctoral committee. In addition, program approval by the Bioengineering Program Chair is also required. The Bioengineering Program Chair will review the proposal to ensure conformity to these guidelines and Graduate School regulations, and to ensure that adequate facilities and Program commitments are available to facilitate completion of the proposed studies.

VI. Final Dissertation Defense

The doctoral candidate who has satisfied all other requirements for the degree will be scheduled by the Office of Graduate Enrollment Services, on the recommendation of the Bioengineering Program Chair, to take a final exam. Three weeks' notice is required by the Office of Graduate Enrollment Services for scheduling this exam. According to Bioengineering Program policy, the final oral exam may not be scheduled until at least one year after the comprehensive exam was passed. **It is the responsibility of the doctoral candidate to provide a copy of the dissertation to each member of the doctoral committee and Program Chair at least two weeks before the date of the scheduled exam. The copy given to the committee must be complete and have been thoroughly edited by the adviser.** Failure to meet this deadline with a completed thesis will necessitate rescheduling of the final exam.

Candidates must be continuously registered and maintain their student status until they pass the final oral exam and their dissertation is accepted by their doctoral committee. This may be satisfied by registering (fall and spring semesters) for course work; BIOE 601 and BIOE 610 are for Ph.D. dissertation preparation and are full-time, non-credit courses.

Both the dissertation adviser and the student are responsible for ensuring the completion of a draft of the dissertation and for adequate consultation with members of the doctoral committee well in advance of the oral exam. Major revisions to the dissertation should be completed before this exam. The dissertation should be in its final draft, with appropriate notes, bibliography, tables, etc., at the time of the oral exam; both the content and style should be correct and polished by the time the final draft of the dissertation is in the hands of the committee.

The final exam of the doctoral candidate is an oral exam administered and evaluated by the entire doctoral committee. It consists of an oral presentation of the dissertation by the candidate and a period of questions and responses. These will relate in large part to the dissertation, but may cover the candidate's entire program of study, because a major purpose of the exam is also to assess the general scholarly achievements of the candidate. The portion of the exam in which the dissertation is presented is open to the public. This public session is followed by a closed-door session of the candidate and the committee in which more detailed questions and specific concerns of committee members are addressed. Following this discussion, the candidate is excused from the room, the committee decides on pass or fail, and the candidate is then notified of their status.

The dissertation adviser, as well as the chair of the doctoral committee (which is typically the same individual), along with additional members of the committee to total a minimum of three (3), must by physically present at the comprehensive exam. The graduate student must be physically present at the exam. No more than one member may participate via telephone; a second member can participate via PicTel or equivalent video conferencing modality. The exam request and a request for exceptions must be submitted to the director of Graduate Enrollment Services for approval at least two weeks prior to the date of the exam. Special arrangements, i.e., requirements for meeting participation via distance, should be communicated to the student and the doctoral committee members well in advance of the exam.

A favorable vote of at least two-thirds of the members of the committee is required for passing. The results of the exam are reported to the Office of Graduate Enrollment Services. If a candidate fails, it is the responsibility of the doctoral committee to determine whether another exam may be taken.

If a member of the committee needs to be changed, a new signatory pages needs to be signed and submitted to the Graduate School for approval. Please see graduate staff assistant for assistance.

Doctoral Dissertation Information

How to Submit a Doctoral Dissertation

- Become familiar with the format requirements by reading the Dissertation Guide carefully (http://www.gradsch.psu.edu/current/thesis.html).
- Activate the intent to graduate on LionPath during the semester in which you plan to graduate. Go to http://www.gradsch.psu.edu/current/thesis.html for deadlines.
- Upload a draft of your dissertation for format review to the eTD Web site (http://www.etd.psu.edu) by the format review deadline. Corrections and detailed instructions will be returned to you by email within two weeks. (Note: the format review can be done either before or after the oral defense, as long as the deadline is met.)
- Make any changes required by your committee and Office of Theses and Dissertations. Receive approval from the committee in the form of signatures on the doctoral approval page.
- Review the dissertation one last time to be sure that no further changes are needed. It will not be possible to make corrections after final approval by the Office of Theses and Dissertations. Upload the final dissertation, as a pdf file, to the eTD Web site by the deadline.
- Submit the supporting materials to the Office of Theses and Dissertations (this may be done either before or after you upload your file). Supporting materials are: signed doctoral approval page, ProQuest/UMI Agreement, Survey of Earned Doctorates, and $95 fee (cash or check). All formscan be found at http://www.gradsch.psu.edu/current/thesis.html.
- Await notification of approval (if further changes are required, you will be notified).
- Provide one unbound copy to the department. Check with your adviser to see if he/she wants a bound copy and if so, you must work out the payment arrangements. If you would like personal copies, you can submit copies for binding with a check to cover the cost of binding and shipping to the bioengineering staff assistant in Room 206 Hallowell or you can take your copies to the Multimedia & Print Center on campus. (http://www.multimediaprint.psu.edu)

Thesis Deadlines and Format Review

Every thesis and dissertation at Penn State must be reviewed and approved by the Thesis Office (a division of Graduate Enrollment Services). There are no exceptions.

Thesis deadlines (calendar) for each semester can be found on the Graduate School's Website at: http://www.gradsch.psu.edu/calendar/gradcal.html.

It is the responsibility of the thesis author to be aware of and to meet deadlines for submission. **Failure to meet the specified deadlines will result in the removal of your name from the graduation list.** It is not necessary to submit the thesis for format review a second time if graduation is postponed to a later semester.

The length of time required for review of the thesis or dissertation by the Thesis Office varies according to the number of documents awaiting review at any given time. If you submit early in the semester, you will most likely get it back in less than a week. If you wait until the final deadline, it may take longer. In either case, you will be notified by e-mail when the review is completed.

Intent to Graduate

You must activate the intent to graduate on LionPath during the semester in which you plan to graduate. This will put your name on the graduation list so that a diploma is printed for you. If you fail to meet the other deadlines (e.g., submission of the thesis for format review), your intent to graduate will be removed. It does not carry over to the next semester.

Final Submission, Approval, and Letter of Certification

When the final thesis is uploaded, it is examined once more to make certain that the required revisions have been made and all the pages are present. If everything is in order, the document will be approved and the author will be notified of the approval. The eTD will be available online immediately after the degree conferral date (unless restriction is requested). **Without exception, changes cannot be made to the thesis or dissertation after approval by the Thesis Office, so it is important to carefully proofread the thesis before final submission.**

If you require documentation stating that you have met the requirements for the degree before graduation, you may apply to Graduate Enrollment Services in 114 Kern Building (814-865-1795) for a Letter of Certification. You should apply for this letter at least two weeks before you need it. The letter will be provided only after approval of your final dissertation.

VII. Master's Degree Requirements

Below are degree requirements for the M.S. degree in terms of general requirements as delineated by the Graduate School and specific requirements set by the Bioengineering Program. Course expectations are set up so that coursework during the semester will require up to half of the students' time with research activities taking up the majority of the time. Summers are generally set aside for full-time research. Beyond the specific course requirements listed below, M.S. students are expected to publish at least one first-author paper based on their research. This is not a requirement for graduation, however.

The policies described here apply to the M.S. degree in Bioengineering. Official Graduate School policies covering all M.S. degrees at Penn State can be found at: http://bulletins.psu.edu/graduate/degreerequirements/masters

Minimum Requirements:

- 30 credits that must include the following:
    - At least 24 credits at the 500-level or above
    - 20 credits must be earned at a Penn State Campus and recognized by the Graduate School
    - 6 credits of Bioengineering; 6 credits Life Science; and 6 credits Technical/Quantitative/Bioengineering Electives.
    - At least 12 credits must be lecture- or lab-based (not independent study) and at the 500-level (not including the ethics course or the graduate seminar). Additional 6 (or more) credits are at the 400 or 500-level.
    - At least 6 credits of BIOE 600 (Thesis Research)
    - Students must register for BIOE 590 (BIOE Colloquium) each semester in attendance.
    - 1 credit Bioengineering Ethics and Professional Development, BIOE 591 Completion of online training in Responsible Conduct of Research. See the following website for details: http://www.research.psu.edu/training/sari/program.
- Master's Thesis with oral defense. Each student must follow the Graduate School's guidelines regarding uploading the online submission of their thesis. A hard copy of the final thesis must be submitted to the graduate staff assistant.

Transfer credits

A maximum of 10 graduate credits earned at other accredited institutions may be applied toward the requirements for the master's degree. However, credits cannot have been used for a previous degree. To receive credit for transfer courses, the student must provide a syllabus of the course taken and a completed petition form, available from the bioengineering staff assistant. All courses will be evaluated on a case by case basis.

Integrated Undergraduate/Graduate Degree (IUG) Program

An integrated undergraduate-graduate (IUG) degree program overseen by the Schreyer Honors College combines a Penn State baccalaureate degree with a master's degree as a continuous program of study. It provides the student an opportunity complete both a Bachelor's and Master's degree in 5 years.

IUG Admission Requirements

Students must be in the Schreyer Honors College. Application materials must be filed during the scholar's fifth or sixth semester of study (the Junior year). See the Biomedical Engineering Departmental regulations and Schreyer Honors College regulations for more specific guidelines for applying.

Students should complete the Graduate's School online graduate application at: http://www.gradsch.psu.edu/apply/ In addition, they will need to upload their personal statement and current resume. Their honor adviser and thesis adviser should upload their letters of recommendation. Should the honor adviser and thesis adviser be the same person, then another faculty member should be asked by the student to submit a letter of recommendation. The third letter of recommendation will be provided by the department head. Students do NOT need to supply GRE scores. Once you submit your application, please tell the graduate staff assistant and she will provide the transcripts and updated audit.

The student along with their IUG adviser should complete the plan of study. Once completed and signed by their adviser, it should be given to the graduate staff assistant to be included in the overall graduate application packet.

IUG Degree Requirements

Students in the IUG program must complete the same requirements as normal M.S. students in Bioengineering with the exception that up to 12 credits of coursework are allowed to double count for both undergraduate and graduate requirements. For the M.S. portion of the degree, a minimum of 30 credits and must include the following:

- 6 credits of bioengineering; 6 credits of life science; 6 credits of technical/quantitative/bioengineering electives
- 6 credits of BIOE 600 Thesis Research
- 1 credit of BIOE 591 Ethics
- BIOE 590 Bioengineering Colloquium; students must register for 590 every semester they are in attendance for the IUG program.
- At least 12 credits just be lecture based and at the 500 level, NOT including BIOE 591 or 590.
- 24 credits must be at the 500 level or above
- Up to 12 credits may be double counted for the undergraduate and graduate program. However 6 of these credits must be at the 500 level
- Completion of the online training in Responsible Conduct of Research, which may be included as part of BIOE 591.
- Completion of thesis and oral defense.
- Complete final hard copy of thesis to graduate staff assistant. Upload final version of thesis to Graduate School and Schreyer Honors College.

M.S. Thesis

A thesis is required of all M.S. students. This thesis must be defended orally in front of the student's master's thesis committee, which is composed of the adviser plus two other members. The thesis committee is generally the same as the student's academic advisory committee, but it does not need to be. The co-chairs of the Bioengineering Program (William Hancock-UP and Christopher Siedlecki-HY) will also be required to review and sign the thesis; two original signature pages are required.

The Graduate School Office of Thesis and Publications provides a Thesis Guide, which provides formatting instructions, can be located at on the Penn State Graduate School web site at http://www.gradsch.psu.edu/current/thesis.html.

M.S. Thesis Deadlines

The deadline for submitting the final thesis to the Graduate School is generally 3-4 weeks before the end of the semester. Firm dates are established by the Graduate School and are located at http://www.gradsch.psu.edu/calendar/.

To complete the thesis it is necessary to leave sufficient time for the reading committee to read and critique the thesis and for the student to defend it and incorporate any revisions from the committee into the final version that is submitted to the Graduate School.

Therefore, **the oral thesis defense** must occur no later than **one week** (preferably longer) before the Graduate School thesis submission date. The student must provide each committee member with a hard copy and a pdf version of the thesis **at least one** week before the thesis defense.   Meeting these deadlines will be strictly enforced and is the responsibility of the student. Failure to meet deadlines will result in postponement of graduation until the following semester.

The thesis draft submitted to the committee should be complete, copy edited, spell checked, and thoroughly reviewed by the primary adviser. When submitting the thesis draft to the advisory committee, also provide one hard copy for review by the Program Chair. **Remember: completed theses must be submitted in hard copy and in pdf version to the thesis reading committee and the Program Chair <u>at least one week before the thesis defense and at least two weeks</u> before the Graduate School thesis submission deadline.**

Please provide one hard copy of the final version to the graduate staff assistant Jenna Sieber (jns5431@engr.psu.edu) to have bound and placed in the library.

How to Submit a Master's Thesis

- Become familiar with the format requirements by reading the Thesis Guide carefully
- http://forms.gradsch.psu.edu/thesis/thesisdissertationguide2012.pdf

- Activate the intent to graduate on LionPath during the semester in which you plan to graduate. Go to http://www.gradsch.psu.edu/current/thesis.html for deadline.

- Upload a draft of your thesis for format review (Word of pdf file) to the eTD Web site (http://www.etd.psu.edu) by the specified deadline. Corrections and detailed instructions will be returned to you by e-mail within two weeks.

- Make any changes required by adviser and readers. Receive approval in the form of signatures on the Master's Approval Page.

- Review the thesis one final time to be sure that no further changes are needed. It will not be possible to make corrections after final approval by the Thesis Office. Convert the file to a pdf for eTD submission. If you cannot do this, contact the Thesis Office for assistance.

- Go to the eTD Web site (http://www.etd.psu.edu) and upload the final eTD. Submit supporting materials to the Thesis Office (Note: It doesn't matter if you upload first or submit the materials first). Supporting materials are: signed Master's Approval Page and thesis fee
(cash or a check payable to Penn State; please write your student id number on the check. Please be sure to check the website for current fee.)

- Await notification of thesis approval by e-mail. If changes are required, you will be notified. Your eTD will be accessible on the eTD Web site immediately after graduation unless you have restricted access.

Provide one unbound, single sided copy to the department (Jenna Sieber, Room 206, Hallowell Building; jns5431@engr.psu.edu). Check with your adviser to see if he/she wants a bound copy and if so, you must work out the payment arrangements. Pricing brochures are available in 206 Hallowell or go to the following website for more information. Bring all copies to the Graduate Staff Assistant in 206 Hallowell and she will send them to be bound. (http://www.multimediaprint.psu.edu).

NOTE: It is the student's responsibility to check with the graduate school for any changes or additions the Graduate School may have imposed after the printing of this handbook.

Example Timeline for Bioengineering M.S. Degree

Semester 1

- In August, set up academic advisory committee and define course plan for year 1
- Take two 3-credit courses
- Take 1 credit BIOE 591 (Bioengineering Ethics and Professional Development) and 1 credit BIOE 590 Colloquium
- Register for BIOE 600 research credits up to at least 12 total credits
- Take online Training in the Responsible Conduct of Research

Semester 2

- Take two 3-credit courses
- Take 1 credit BIOE 590 Colloquium
- Register for BIOE 600 research credits up to 12 total credits

Summer

- Carry out research toward thesis

Semester 3

- Present yearly update to advisory committee and plan courses for Year 2 (before classes begin)
- Take two 3-credit courses
- Take 1 credit BIOE 590 Colloquium
- Register for BIOE 600 research credits up to 12 total credits

Semester 4

- Take 1 credit BIOE 590 Colloquium
- Register for BIOE 600 research credits up to 12 total credits
- Write and defend Master’s thesis (can push to summer)

APPENDIX A: Bioengineering Graduate Faculty

James Adair, Ph.D., Professor of Material Science and Engineering, and Biomedical Engineering. Nanoscale materials and phenomena for biological, electronic, optical, and structural applications; property manipulation for designer particles and materials; colloid and interfacial chemistry; material synthesis and chemistry; powder and material characterization; and powder processing.
Reka Albert, Ph.D., Professor of Physics and Biology. Computational systems biology, modeling of signal transduction networks
Harry R. Allcock, Ph.D., Evan Pugh Professor of Chemistry. Application of chemical synthesis to polymer chemistry, materials science, and biomedicine; and the chemical synthesis of new materials to generate useful combinations of properties.
Justin Brown, * Ph.D., Assistant Professor of Biomedical Engineering. Musculoskeletal regenerative engineering.
Peter J. Butler,* Ph.D., Professor of Biomedical Engineering. Membrane biophysics, cell mechanotransduction, vascular physiology; use of quantitative light microscopy to investigate the molecular bases of vascular function.
Francesco Costanzo, Ph.D., Professor of Engineering Science and Mechanics. Clot fracture mechanics with applications in the surgical therapy of acute stroke.
Brent A. Craven, Ph.D**.,** research associate, Applied Research Laboratory. Computational fluid dynamics, fluid-structure interaction, multi-physics modeling, numerical methods, digital image processing, three-dimensional anatomical reconstruction
Wayne R. Curtis, Ph.D., Professor of Chemical Engineering and Biotechnology. Biotechnology, plant biology pharmaceutical production using plants.
Melik C. Demirel, Ph.D., Professor of Engineering Science & Mechanics. Synthesis and fabrication of functional materials, bioinspired engineering, biointerfaces, multi-scale computing for biological systems
Michele Diaz, Ph.D., Associate Professor of Psychology and Linguistics. Director of Human Imaging at the Social, Life, and Engineering Sciences Imaging Center. Using fMRI to understand regions of brain related to speech.
Cheng Dong, * Ph.D., distinguished Professor of Biomedical Engineering, and engineering science and mechanics; department head and chair of the Intercollege Graduate Program in Bioengineering. Biomechanics, cellular mechanics, cell motility, cell deformation and cell adhesion in the microcirculation, computer modeling.
Patrick Drew, Ph.D., Assistant Professor of Engineering Science & Mechanics and Neurosurgery. Neurovascular coupling, vascular development, neurophysiology, neural engineering
Aronold Fontine
Mary I. Frecker, Ph.D., Professor of Mechanical Engineering and Biomedical Engineering. Mechanical design, compliant mechanisms, design optimization, medical devices.
Andris Freivalds, Ph.D., Professor of Industrial Engineering. Industrial ergonomics, cumulative trauma disorders, biomechanics, work physiology.
Bruce J. Gluckman, Ph.D., Associate Professor of Engineering Science & Mechanics, neurosurgery and biomedical engineering. Dynamical and pattern forming systems
Esther W. Gomez, Ph.D., Assistant Professor of Chemical Engineering and Biomedical Engineering. Biomechanics, fibrosis and cancer, tissue engineering, biosensors
Weihua Guan, Ph.D., Assistant Professor of Electrical Engineering and Computer Science. Electro-fluidic and opto-fluidic devices and systems for biosensing and actuation, bioMEMS/NEMS, Lab-on-a-chip, Micro/Nanofluidics, Electrokinetic Phenomena, Point-of-care Testing.
William O. Hancock, * Ph.D., Professor of Biomedical Engineering. Motor proteins, cytoskeletal mechanics, quantitative cell biology.
William E. Higgins, Ph.D., distinguished Professor of electrical engineering and biomedical engineering. 3-D/4-D medical imaging analysis and visualization and virtual endoscopy.
Christine Dolan Keating, Ph.D., Professor of Chemistry. Biological interfaces, experimental models for intracellular organization, biomolecular-nanoparticle conjugates, multiplexed biosensors.
Michael Krane, Ph.D., research associate. Applied Research Laboratory. Experimental studies in unsteady fluid mechanics: fluid-structure interaction, acoustics, speech sound production, sleep apnea, snoring, multiphase flows.
Robert Kunz, Ph.D., Senior Scientist, Applied Research Laboratory and Professor of Aerospace Engineering. CFD algorithm/code development, biomedical engineering and biological system simulation, turbulence modeling and turbulence dispersion**.**
Gregory Lewis, Ph.D., Assistant Professor of Orthopaedics and Rehabilitation. Development and Testing of a Novel Simulation Technology for Fracture Treatment Education
Xiaojun (Lance) Lian, * Assistant Professor of Biomedical Engineering. Directed Differentiation of human pluripotent stem cells to cardiovascular, blood, brain, and pancreatic cell lineages.
Herbert H. Lipowsky, * Ph.D., Professor of Biomedical Engineering and Engineering Science and Mechanics. Pressure and flow relationships in the microcirculation, in vivo rheology of blood flow in sickle-cell disease and other hematological disorders.
Keefe Manning,* Ph.D., Associate Professor of Biomedical Engineering. Hemodynamics, pediatric heart defects, blood rheology and cardiovascular prosthetics.
Costas D. Maranas, Ph.D., Donald B. Broughton Professor of Chemical Engineering. Reconstruction, analysis and redesign of metabolic networks, computational protein design.
Kristina A Neely, Ph.D., Assistant Professor of Kinesiology. Neuroscience, role of central nervous system in decision making, fMRI imaging, neural networks.
Thomas Neuberger, Ph.D., research associate in the Huck Institutes of the Life Sciences and Assistant Professor in biomedical engineering. Imaging techniques of MRI.
Gerson Rosenberg, Ph.D., Jane A. Fetter Professor of Surgery and Biomedical Engineering. Mechanical circulatory assistance, the electric artificial heart, artificial organs.
Jeffrey Schiano, Ph.D., Associate Professor of Electrical Engineering. Control systems and nuclear resonance sensors.

Steven J. Schiff, Ph.D., Brush chair Professor of Engineering; Professor of Neurosurgery and Engineering Science and Mechanics. Understanding the physics of dynamical disease of the nervous system and developing smart prosthetics
Neil A. Sharkey, Ph.D., Professor of Kinesiology, Orthopaedics and Rehabilitation. Human biomechanics.
Christopher A. Siedlecki, Ph.D., Professor of Surgery and Biomedical Engineering. Cardiovascular biomaterials, structure/function, relationships of proteins and surfaces, protein and cellular interactions and implanted biomaterials, surface modification and characterization, scanning probe microscopy.
Margaret Slattery,* Ph.D., Assistant Professor of Biomedical Engineering.
Srinivas Tadigadapa, Ph.D., Professor of Electrical Engineering and Biomedical Engineering. Design, fabrication and characterization of microelectromechanical systems, integration of smart materials into MEMS devices, biological MEMS, inertial MEMS and RF MEMS devices.
Akif Undar, Ph.D., Professor of Pediatrics, Surgery and Biomedical Engineering.
Erwin A. Vogler, Ph.D., Professor of Materials Science and Engineering and Biomedical Engineering. Surfaces and the biological response to materials, the mediating role of water, mechanisms of water wetting, and thin-film phenomena.
Yong Wang, * Ph.D**.,** Associate Professor of Biomedical Engineering. Using synthetic oligonucleotides and polymers to develop antibody-like nanomaterials, programmable protein delivery systems, and tissue-like nanostructured biomaterials.
William Weiss, Ph.D., Professor of Surgery and Biomedical Engineering. Implantable circulatory support devices, electromechanics, transcutaneous energy transmission.
Pak Kin Wong, Ph.D., * Professor of Biomedical Engineering. Advanced biomanufacturing and microfluidics to study collective cell migration, and cancer metastisis. BioMEMS for clinical diagnostics.
Hui Yang, Ph.D., Associate Professor of Industrial and Manufacturing Engineering. Healthcare informatics and signal processing, sensor-based modeling and analysis of complex systems, nonlinear stochastic dynamics.
Qing X. Yang, Ph.D., Professor of Radiology and Biomedical Engineering. Ultra-fast imaging, pulse sequence and k-space sampling method developments; fMRI; high field MRI/NMR (susceptibility effects, dielectric effects); RF coil design.
Jian Yang, * Ph.D**.,** Associate Professor of Biomedical Engineering. Development of novel biodegradable elastomers. Tissue engineering small diameter blood vessels, cardiac tissues and nerve tissue. Cancer imaging, drug delivery and regulation of stem cells via functional polymers.
Sulin Zhang, Ph.D., Associate Professor of Engineering Science & Mechanics and Biomedical Engineering. Mechanics of nanostructured materials, small-scale contacts and nano-bio interfaces, cellular mechanics, biomechanics and multi-scale methods across different length and time scales
Nanyin Zhang,* Ph.D., Associate Professor of Biomedical Engineering. Medical Imaging
Siyang Zheng,* Ph.D., Associate Professor of Biomedical Engineering. Micro/nano technologies for biological and medical applications.

*Biomedical engineering Primary Faculty

APPENDIX B: Bioengineering Graduate Courses:

501 BIOENGINEERING TRANSPORT PHENOMENA (3 cr.) Application of the equations of mass, energy, and momentum conservation to physiological phenomena and to the design of artificial organs.

503 FLUID MECHANICS OF BIOENGINEERING SYSTEMS (3 cr.) Cardiovascular system and blood flow, non-Newtonian fluid description, vessel flows, unsteady flows and wave motion, wind-kessel theory, **TRANSMISSION** line theory.

504 RESEARCH TOPICS (3 cr.) Numerical methods and computational techniques for modeling physiological systems and medical devices. Topics include differentiation equations, finite difference methods and finite element methods. Programming and finite element modeling software will be covered. Examples include physiological systems at the organ and cellular levels, physicochemical analysis of biological systems, and transport phenomena in engineered devices. Computing programming experience is required to be successful in this course.

505 BIOENGINEERING MECHANICS (3 cr.) Application of the principles of continuum mechanics to characterization of the passive and active mechanical properties of soft and hard tissues and their constituent cells. Fundamentals of the description of stress and strain and advanced topics in visco-elasticity are considered to describe the normal and diseased state at the tissue, cellular and molecular level. Prerequisites: EMCH 210, ME 033 or equivalent.

506 MEDICAL IMAGING (3 cr.) Medical diagnostic imaging techniques, including generation and detection of ultrasound, X-ray, and nuclear radiation; instrumentation and biological effects. Prerequisite: PHYS 202.

508 (MATSE 508) BIOMEDICAL MATERIALS (3 cr.) Properties and methods of producing metallic, ceramic, and polymeric materials used for biomedical applications. Prerequisites: None

509 MECHANOBIOLOGY (3 cr) Explore the molecular bases of cell mechanics and the role of mechanics in cell biology.

510 BIO MEMS AND BIONANOTECHNOLOGY (3 cr.) Build basic foundations for understanding electrical, mechanical and chemical transducers in biomedical applications through learning BioMEMS fabrication, design and analysis.

512 CELL AND BIOMOLECULAR ENGINEERING (3 cr.) Graduate level cell and molecular biology course for engineers emphasizing molecular mechanisms.

513 BIOENGINEERING LABORATORY TECHNIQUES (3 cr.) Laboratory techniques in cell molecular biology, protein biochemistry and cell culture with an emphasis on engineering analysis and quantification.

514 QUANTITATIVE MICROSCOPY (3 cr.) Application of advanced microscopy to quantification of cellular and molecular function.

515 CELL MECHANICS AND BIOPHYSICS (3 cr.) Advanced topics and recent developments in cellular engineering; applications of engineering science to cell biology. Prerequisite: BIOE 505

517 (MATSE 517) BIOMATERIALS SURFACE SCIENCE (3 cr.) Special properties of surfaces as an important causative and mediating agent in the biological response to materials. Prerequisite: None.

518 NANOBIOMATERIALS (3 cr.) Foundational course in synthesis, fabrication and characterization of nanobiomaterials and their applications in biomedical engineering.

519 Artificial Organ Design (3 cr.) Basic techniques and principles of a multidiscipline approach to artificial organs design. Prerequisites: None.

552 (**EMCH 552, IE 552) Mechanics of the musculoskeletal System** (3 cr.) Structure and Biomechanics of bone, cartilage, and skeletal muscle; dynamics and control of musculoskeletal system models. Prerequisite: consent of program. Prerequisite or concurrent: BIOL 472

553 (**IE 553**) **Engineering of Human Work** (3 cr.) Physics and physiology of humans at work; models of muscle strength; dynamic movements; neural control; physical work capacity; rest allocation. Prerequisite: BIOL 041 or 472.

576 Bioengineering of the Cardiovascular System (3 cr.) Experimental and analytical studies of network branching patterns, regional blood flow, rheology and mechanics of blood cells and vessels as they affect physiological function. Prerequisite: BIOL 472.

590 Bioengineering Colloquium (1 cr.) Weekly series of seminars by speakers from outside and within Penn State University on new and developing research areas in Bioengineering, and presentations by registered students on their thesis research. All students are required to attend; M.S. degree students must register for four semesters and Ph.D. students must register every semester until comprehensive exam is passed.

591 Bioengineering Ethics and professional development (1 cr) Discussions focused on issues related to medical device development and marketing, responsible conduct of research, and meeting oversight requirements by Institutional review Boards for human studies and IACUC oversight of animal experiments.

596 Individual Studies (1-9 cr.) Opportunity for advanced graduate students to study independently in consultation with a faculty adviser.

597 Special Topics (1-9 cr.) This designation is assigned to new or developing graduate courses covering specialized areas of interest in Bioengineering. Past offerings have focused on topics such as advanced studies of cardiovascular function, advanced topics in artificial organ design and cellular biomechanics.

Some 400-level biomedical engineering courses may be used towards your degree in consultation with your adviser and/or advisory committee. Biomedical engineering courses are denoted by BME and can be found on the Schedule of Courses page at the following: http://soc.our.psu.edu/

APPENDIX C: LIFE SCIENCE ELECTIVE COURSES

Coursework is divided into three categories: Bioengineering Courses, Life Science Electives, and Technical Electives. For technical electives, students can choose courses in engineering, math, physics, chemistry, or other departments. Bioengineering courses can also be used as technical electives. Life science electives are courses that focus on biology and physiology at the molecular, cellular, organ or organism level. Generally, Biology 472 (Human Physiology) is recommended for every student. Courses such as bioinformatics, analytical techniques, and similar technical courses that focus on analytical tools and do not focus on the biology do not count as Life Science Electives. Below is a list of courses that count as Life Science Electives. Students should explore course offerings in other departments and consult with other students and faculty to learn about the most up-to-date course offerings across campus. Each student's advisory committee will be responsible for determining whether specific courses count toward life science or technical elective distributional requirements; the Graduate Curriculum Chair, Dr. Will Hancock will make final decisions on distributional requirements.

BIOL 404 **Cellular Mechanisms in Vertebrate Physiology** (3) This course considers cellular mechanisms governing physiological aspects of vertebrate cell signaling and their adaptation to particular organismal functions.

BIOL 409 **Biology of Aging** (3) Mechanisms of the aging process, with special reference to man. Unfavorable progressive changes in molecules, cells, systems, and organisms. Effective: Summer 1984 Prerequisite: 6 credits in biology

BIOL 411 **Medical Embryology** (3) Develops an understanding of human reproductive physiology, embryological processes, their time frames, and the development of major human body systems. The course emphasizes clinical correlations and the medical consequences of developmental abnormalities.

BIOL 413 **Cell Signaling and Regulation** (3) Introduction to the themes of cellular signaling and regulation through critical review of primary literature.

BIOL 416 **Biology of Cancer** (3) This course intends to illustrate biological basis of cancer development, and discusses aspects on prevention, detection, and treatment of cancer.

BIOL 422 **Advanced Genetics** (3) Chromosomal mechanism of heredity; cytoplasmic and polygenic inheritance, chemical genetics, genomics, and experimental evolution.

BIOL 426 **Developmental Neurobiology** (3) Overview of basic developmental processes as they apply to the central nervous system.

BIOL 430 (B M B 430, ENT 430) **Developmental Biology** (3) Molecular and genetic analyses of mechanisms involved in differentiation and determination in biological systems.

BIOL 432 **Developmental Genetics** (3) An advanced course in developmental biology, focusing on the use of genetics techniques to study fundamental questions of animal development.

BIOL 443 **Evo-devo: Evolution of Developmental Mechanisms** (3) How evolution of animals and plants can be traced to changes in the regulation and/or interactions of genes controlling development.

BIOL 460 (ANTH 460) **Human Genetics** (3) The human genome, its variation, origins, and relation to disease and other traits.

BIOL 465 **General Cytology** (3) Structure and function of organelles of plant and animal cells, mitosis, meiosis, cytological techniques.

BIOL 469 (BB H 469) **Neurobiology** (3) Comprehensive examination of neuroanatomy and physiology designed to integrate the principles of neurochemistry, neuroendocrinology, and molecular biology.

BIOL 470 (BB H 470) **Functional and Integrative Neurosciences** (3) Neurobiological function in motivated behaviors, motor and sensory functions, learning and memory development, sexual differentiation, and pathology.

BIOL 471 **Molecular Neurobiology/Cell Biology Laboratory** (3) Introduction to modern molecular and cellular methodologies. The course is designed to integrate the principles of molecular cell biology with neurochemistry and neuroendocrinology.

BIOL 472 **Mammalian Physiology** (3) Mechanisms concerned with normal animal function, with special emphasis on humans.

BIOL 479 (AN SC 479) **General Endocrinology** (3) Endocrine mechanisms regulating the morphogenesis, homeostasis, and functional integration of animals.

BIOL 497A **Biology of RNA** (3) This course will explore the biological functions that RNA plays in diverse organisms, including transcription, translation, virology, and RNA- interference.

B M B 400 **Molecular Biology of the Gene** (2-3) Biochemistry of genetic phenomena, including the structure, replication and dynamics of genes and chromosomes, their expression and regulation.

B M B 401 **General Biochemistry** (3) Principles of the structure and function of biological molecules, including carbohydrates, lipids, membranes, proteins, and enzymes. Students may not receive credit for both CHEM 476 and B M B 401.

B M B 402 **General Biochemistry** (3) Comprehensive survey of the pathways and regulation of intermediary metabolism.

B M B 406 **Molecular Biology** (3) A discussion of current aspects of cell molecular biology with a laboratory emphasizing current biotechnology techniques.

B M B 432 (MICRB 432, VB SC 432) **Advanced Immunology: Signaling in the Immune System** (3) The study of signaling pathways that regulate the immune response.

MICRB 410 **Principles of Immunology** (3) Theories of immunity; focuses on the basis for the acquired immune response at the organ, cell, and molecular levels.

B M B 442 **Laboratory in Proteins, Nucleic Acids, and Molecular Cloning** (3) Laboratory in enzyme purifications and assay techniques; nucleic acid isolation and characterization, including plasmid preparation.

B M B 443W **Laboratory in Protein Purification and Enzymology** (3) Laboratory in protein isolation methodology, enzyme kinetics, and physico- chemical properties of proteins.

B M B 460 (MICRB 460) **Cell Growth and Differentiation** (3) Mechanisms and regulation of protein trafficking, organelle biosynthesis, cell development, signaling and cell cycle control. Emphasizes experimental design and analysis.

B M B 464 **Molecular Medicine** (3) An exploration of the impact of advances in molecular biology on understanding disease mechanisms, medical diagnosis, and therapeutics.

B M B 465 **Protein Structure and Function** (3) A study of the relationship between structure and function of proteins; internet analysis to predict structure and function is included.

B M B 474 **Analytical Biochemistry** (3) Physical/chemical theory and techniques that emphasize purification and characterization of biological macromolecules, including proteins, lipids and nucleic acids.

B M B 480 (MICRB 480) **Tumor Viruses and Oncogenes** (3) Oncogenes, DNA and RNA tumor viruses, and relevant experimental techniques with emphasis on molecular basis of carcinogenesis and gene regulation.

BIOTC 489 (V SC 489) **Animal Cell Culture Methods** (3) An overview of animal cell culture methodology and its practical application in bioprocess technology.

VB SC 420 **General Animal Pathology** (3) Nature and mechanisms of the disease process including degenerations, growth disturbances, inflammation, host-parasite relationships and neoplasia.

VB SC 448W **Current Topics in Immunology** (3) Study of current approaches and questions driving research in immunology and infectious diseases.

Graduate Level Courses

BMMB 501 **Core Concepts in Biomolecular Science** (5) Introduction to broaden one's understanding of biochemical and biophysical principles and the basic aspects of eukaryotic and prokaryotic cell biology.

BMMB 541 **Molecular Biology of Animal Development** (3) The course emphasizes comparative molecular genetic analyses of developmental gene networks using vertebrate and Drosophila model systems.

BMMB 551 (IBIOS 551) **Genomics** (3) Structure and function of genomes including use of some current web-based tools and resources for studies and research in genomics.

BIOL 571 (PHSIO 571) **Animal Physiology** (3) Mammalian cardiovascular, respiratory, renal, and gastrointestinal systems.

BIOL 572 (PHSIO 572) **Animal Physiology** (3) Mammalian nervous, endocrine, metabolic, and reproductive systems.

VB SC 520 **Pathobiology** (3) The course deals with the mechanism of disease. Topics are: homeostasis, vascular injury, inflammation, neoplasia, genetic disorders, and biochemical toxicology.

VB SC 534 **Current Topics in Cancer Research** (3) A discussion of current cancer research literature with the focus on primary research literature.

Note: Other Life Science courses not listed here can be used with approval of Dr. William Hancock, Chair of the Graduate Curriculum Committee.

APPENDIX D: SAMPLE TITLE PAGE FOR CANDIDACY AND COMPREHENSIVE EXAMS

Penn State Bioengineering Program
Ph.D. Candidacy Exam

Research Proposal

A New Method of Determining Molecular Dimensions

Proposed Start Date: September 1, 1904

Proposed Completion Date: April 1, 1905

Submitted by: Albert A. Einstein

Adviser: Professor I. Dunno

APPENDIX E: Candidacy Exam Evaluation

This form is used by Candidacy Exam Committee members to evaluate candidates in their performance on the exam. The candidate must achieve a score of 3.0 or better on six out of the seven categories to pass the exam.

I. Writing – sentence structure, grammar, organization SCORE:________

1. Excellent, good grammar, no typos, appropriate usage and style, ideas are clear and easy to follow
2. Very good. Some spelling, grammar, style problems, or ideas are unclear in places.
3. Adequate. Writing is acceptable for 1st year PhD student, but needs work on clarity or sentence structure.
4. Poor. Serious writing problems that require remediation.
5. Unacceptable. Concern that student will be unable to write his/her thesis and papers.

II. Oral presentation and English skills SCORE:________

1. Excellent. Very clear and organized. Quality is at the level of a good meeting talk.
2. Very good. Presentation was concise, but some ideas needed clarification or logical connections were lacking.
3. Adequate. The points were made but not clearly and logically.
4. Poor. Very hard to understand points being made, student needs significant work in speaking or English skills.
5. Unacceptable. Serious concerns regarding speaking skills.

III. Overall quality of the proposal including significance of problem, logic, innovation and rationale SCORE:__________

1. Excellent. Send it to the NIH.
2. Very good. A well thought-out proposal on a significant topic.
3. Adequate. Problem is addressed, but was not compelling, aims not supported, and/or problems in study design.
4. Poor. Not persuasive, experiments don't get at problem, lack of innovation, or other significant problem in the proposal.
5. Unacceptable. Student needs to pick another problem and redevelop aims and study.

IV. Physical and mathematical sciences fundamentals SCORE:________

1. Excellent. Student is solid on fundamentals of physics, chemistry and mathematics and can logically apply clear scientific reasoning to solve a new problem.
2. Very good. Student can logically apply first principles of chemistry and physics to the research problem.
3. Adequate. Student thinks logically, but needs to strengthen chemistry, physics or math skills.
4. Poor. Student does not think logically or clearly. Cannot apply existing knowledge from classes to research problem.
5. Unacceptable. Student cannot apply knowledge from basic coursework and cannot think logically through a problem.

V. Engineering fundamentals SCORE:________

1. Excellent. Applies graduate-level engineering to the problem, able to answer questions on engineering background. Accurate in analysis.
2. Very good. Solid engineering but a few weak points.
3. Adequate. Some solid engineering applied to the problem, but some significant weaknesses were identified in knowledge areas where the student has taken relevant courses.
4. Poor. Significant weaknesses in engineering training identified. Potential concern whether student can handle graduate-level engineering. Some course-based remediation may be warranted.
5. Unacceptable. Major weaknesses in engineering that likely cannot be remediated by coursework.

VI. Life science fundamentals SCORE:________

1. Excellent. Solid grasp of principles of molecular/cell biology and systems physiology.
2. Very good. Good foundations of biology at multiple size scales.
3. Adequate. Sufficient for Bioengineering PhD, but room for improvement.
4. Poor. Significant weaknesses in life science fundamentals identified.
5. Unacceptable. Little or no knowledge in life sciences.

VII. Integration of engineering and biology in solving research problem SCORE:________

1. Excellent. Demonstrates high level proficiency to solve novel biological or medical problem with engineering tools.
2. Very good. Identifies important biological / clinical problems, but does not show how engineering is uniquely suited to solve them.
3. Adequate. Able to integrate engineering and life science, but connections need to be strengthened. Integration lacks innovation.
4. Poor. Significant weaknesses connecting engineering and biology/medicine.
5. Unacceptable. Little or no connection between engineering and biology/medicine.

Score Each Category on a scale of 1.0 (Outstanding) to 5.0 (Poor). Passing is 3.0.

APPENDIX F: Tips on writing papers, proposals and theses

Below are some words of wisdom about how to be efficient and effective in your scientific writing. One eternal truth is that writing is hard and to become a better writer, you must work at it and allocate sufficient time for both writing and revising.

Dissertation structure
A dissertation typically consists of an introduction chapter, some number of chapters that make up the various projects carried out and/or papers written during graduate studies, and a concluding chapter that ties everything together. If you have published papers, these can be included as chapters, there is no need to rewrite work that has been published or submitted. The peer-reviewed papers that come out of your work are the most important product of your research.

Getting started:
To start writing a paper or thesis, make an outline. Then fill in the outline with figures and tables that make up the results. Build your outline with successively more detail, and then replace these details with sentences and paragraphs and your written document will take shape. As you develop an outline go through it with your adviser to make sure you are on track.
To write a paper, write the Results first. Then write the Discussion in relation to the Results. Then write the Introduction and link it to the Discussion.

General writing tips:

- Generally getting a first draft is the hardest step. However, good writing requires multiple rounds of revisions. Don't underestimate the time required for revising and tightening text to focus ideas and clarify the presentation.
- Strive for clarity and brevity in your writing. Use first person ("we carried out the experiment" rather than "the experiment was carried out"). Put key action in verbs rather than nouns. Use active verbs. Avoid long introductory phrases or clauses and make subjects of sentences short and concrete.
- Minimize use of acronyms (if you use it 3 times or less, don't use acronym). Minimize use of jargon, and avoid lab jargon – consider renaming reagents, procedures, protocols, etc. for the purpose of writing (which is a different process than the day to day work in the lab).
- In revising text, distill your ideas, distill your sentences, and remove redundant text. Consider that adding more details can dilute your central message and most important points – readers can only take so much in so keep your focus.
- Throughout the thesis help guide your reader by using introductory sentences to paragraphs and transitions between paragraphs. You should strive for flow, and also give your reader signposts along the way to help guide them.
- In the age of spellcheck, there is no excuse for misspelled words and obvious grammar errors. Any thesis given to a committee must be free of spelling and grammar errors. If you feel writing clearly and using correct wording and grammar might be a problem, please have someone else look through the thesis first.
- In a paper, thesis or dissertation, the wording must be your own. No sentences can be derived form anyone else's work; this is plagiarism and any evidence of plagiarism will result in an unacceptable thesis, as well as other consequences.

Figures and legends

- Use figures and diagrams to help your readers navigate the key points.
- Take the time and care to make excellent figures. Think about the best way to plot the data to emphasize the point you are making. Do not use fancy Excel colors and shading. Make axes and labels large and readable. Images should not be pixelated.
- If images are taken from published work say that clearly and include reference number, e.g. "Image adapted from Jones et al (19)" . For theses you do not need permissions from journals to use figures.
- All figures should have a legend that includes figure number, figure title, and a description of every panel in the figure. It is OK if there is redundancy between the text and the figure legends – ideally a reader should be able to go through the document and look at the figures and read the figure legends and get the main points that way.

Abstract

- Write a good abstract. This is the first thing that everyone reads and the only thing that many read. It is important to make a good impression and summarize your work clearly and succintly. ABSTRACT SHOULD BE NO MORE THAN ONE DOUBLE SPACED PAGE FOR MS AND UP TO 2 FOR PHD DISSERTATION.

Introduction Chapter

What to include:

- An overview of your field of study that sets up your key questions and hypotheses
- Transitions between sections to help make the introduction a logical whole
- Clear statement of key questions and hypotheses
- Figures and diagrams to help explain the points you are making.
- A paragraph at the end of the introduction that previews the rest of the thesis for the reader, describes chapters and how they relate to published work, and lays out collaborations involved in the work.

What not to include:

- A list of everything you can think of that might touch on your project

Middle Chapters (and Papers)

- Each chapter can (and ideally should) be a published or planned paper. If it is published make sure you clearly describe how the chapter relates to the published work (Is it the paper word for word? Is it the paper plus some additional data? Is it part of the paper? Be specific).
- At the beginning of each chapter you should set up the question you will be asking. You need to make your audience excited about the hypothesis or design goal - this means they need to understand what the hypothesis or goal is and why it is important.
- In writing a paper, make sure that the first paragraph of the Introduction and the last paragraph of the Discussion are conceptually linked. Conclude the Introduction with a paragraph that previews the results and sets up the rest of the paper.
- Organize the Results section as a series of sub-sections, with each referring to a particular figure or table. Describe fully in the text everything that is contained in the figures. Think of the Results section as describing a logical sequence of experiments, with each sub-section starting with a description of the experimental design, followed by a description of the resulting findings written in the past tense. Stating the question being addressed in each sub-section is a good organizational tool. Remember that the sequence of presentation need not (and generally should not) follow the timeline of the experiments; instead build the best story you can with the data that you have.

- Discussion
- The first paragraph is an important setup of the discussion. Make it a summary of the key results and a roadmap of the rest of the discussion.
- In the Discussion, be sure to describe how the results answer the question(s) you posed in the Introduction.
- Acknowledge limitations and how work agrees or conflicts with other studies.
- Discuss the implication of the work for the field and how it may impact other fields.
- At the end of each chapter you should have some sort of conclusion or wrap up section. What was the answer to your question? Why is it important?
- If you include work of others, make sure to clearly acknowledge their specific contributions in the figure legends.
- Materials and Methods can be included within each chapter (either before Results or after Discussion) or it can make up a separate chapter in the thesis.

Conclusion/Future Directions Chapter

- The goal of the last chapter is to position your work in the field. You should say what you have learned, how this has advanced the general understanding in the field. Include some models to summarize your work. Tie this text into points you raised in your Introduction Chapter 1.
- Point toward the next questions or design iterations and larger questions. Don't just focus on what you would do over the next months if you continued; instead, think in a larger perspective of the field and discipline.

Thesis Timeline

- Get a complete draft to your advisor 1 month before your defense. Ideally, you should go back and forth with your advisor writing and revising chapters that are evolving into papers. Your advisor should have read your thesis that you submit to the committee.
- Get your thesis to your committee 2 weeks before the defense. This should be a fully polished document with all figures, references and sections. Failure to meet the deadline will result in the defense being postponed.

Other writing resources

K.L. Turabian. A manual for writers of research papers, theses and dissertations. Chicago style for students and researchers. 8th edition. University of Chicago Press. – Has sections on research to writing, proper citations, and style.

K. Kelner. Tips for publishing in scientific journals. *Science Careers* (2007). DOI: 10.1126/science.caredit.a0700046

J. M. Samet. Dear Author – advice from a retiring editor. *Am J Epidemiol* **150**:433–436 (1999)

W.A. Wells. Me write pretty one day: how to write a good scientific paper. *J. Cell Biol.* **165**:157-58 (2004).

http://careers.ucsc.edu/grad/get_published.html

APPENDIX G: Forms

MASTER'S APPROVAL PAGE
http://www.gradschool.psu.edu/current-students/etd/mastersapprovalpagepdf/

DOCTORAL APPROVAL PAGE
http://www.gradschool.psu.edu/current-students/etd/doctoralapprovalpagepdf/

GRADUATE ADVISORY COMMITTEE MEETING FORM
http://assets.engr.psu.edu/BME/docs/forms/AAC%20Meeting%20Form.pdf

GRADUATE COURSE SUBSTITUTION PETITION
http://assets.engr.psu.edu/BME/docs/forms/Graduate%20Course%20Substitution%20Petition%20Fillable.pdf

APPLICATION FOR PHD CANDIDACY EXAMINATION
http://assets.engr.psu.edu/BME/docs/forms/Application%20for%20PhD%20Candidacy%20Examination%20Fillable.pdf