The Pharmacology Graduate Group (PGG) at the University of Pennsylvania is a collaborative and interdisciplinary Ph.D. program that brings together over 95 faculty from 25 academic departments in the Schools of Arts and Sciences, Dental Medicine, Engineering, Medicine, and Veterinary Medicine at the University of Pennsylvania and in the associated Children's Hospital of Philadelphia. The PGG is part of an umbrella organization called Biomedical Graduate Studies (BGS), which provides financial support and administrative oversight.

Coursework: Every PGG student is required to take four Core courses that introduce the broad basis of modern pharmacology:

1. Cell Biology (Fall, Year 1)
2. Fundamentals of Pharmacology (Fall, Year 1)
3. Biological Data Analysis (Spring, Year 1)
4. Medical Pharmacology (Fall, Year 2)
5. Medical Physiology (Fall, Year 2)

The first 1.5-2 years of study are devoted to classes and laboratory rotations. For most students, this period begins with the Fall semester of the first year and ends with the Spring semester of the second year upon completion of the Candidacy (qualifying) examination.

A total of 20 credit units are required prior to officially beginning thesis research; students take 4 credits each semester. Most classes are worth one credit unit; exceptions are Medical Pharmacology (PHRM 600) and the laboratory rotations. PGG students also take 1–3 elective courses, chosen from all relevant, graduate-level courses offered across campus; one elective must be a “topics” course involving discussion of primary literature. Courses offered by other departments or programs can be taken with permission from the Academic Advising and Curriculum Chair.

Laboratory Rotations: Students complete three rotations during their first and second years in the program. Each rotation is chosen by the student, under the guidance of the Academic Review Committee. Rotations provide students with opportunities to learn a wide range of modern laboratory techniques and gain first-hand experiences that will aid in the selection of a thesis laboratory. Lab rotations are graded and end with a peer reviewed oral presentation.

Candidacy Exam: The Exam taken by PhD students in the spring of their second year, consists of a written Proposal (in the format of an NRSA application) and an oral Defense. Both must reflect a substantial depth of knowledge in the topics covered by the proposed thesis research and an understanding of the broader significance of the work. Preparation includes a Candidacy Exam Workshop, a 10-session scientific writing/proposal development course run by experienced faculty, with input from past students and the Chair of both the PGG and the Chair of the Department of Systems Pharmacology and Translational Therapeutics (SPATT).

Seminars and retreats: All students attend a weekly Pharmacology year-long seminar series sponsored by SPATT. Fall features outside speakers and Spring PGG graduate students. While all graduate students present their work in informal lab meeting settings, the Spring Student Seminar series forces them to present their work in a manner that is understandable and interesting to those outside their research “comfort zone”. Students are also encouraged to attend other relevant seminars throughout the University. Students participate in retreats occurring throughout the academic year, including an annual student run Symposium.

Journal clubs: All students participate in the Pharmacology Journal Club. Third-year students organize the assignment of topics and each student gives a presentation at least once per semester.
Research and Dissertation. The most important element of the Ph.D. is the generation of a body of original research, completed during the research phase. Students work with their Thesis Advisor and the student-selected Thesis Committee toward the execution of original research. The PGG expects at least one to two first authored manuscripts towards completion of the Ph.D. thesis; however, the thesis committee ultimately

determines whether the student has met this requirement. An oral defense of the document, to the Thesis Committee and an additional outside judge, completes the Ph.D.

The average (median) time to degree in our program over the past 10 years is 5.5 years but can vary for a program as large as ours (currently 65 students): the interquartile range for the past 10 years is 5.3 – 6.9 years.

This F31 applicant (INSERT NAME HERE) is currently a (INSERT YEAR HERE) year student in the program. Thus, HE/SHE has completed ... indicate what courses you have completed and any other educational opportunities/training opportunities ...

Progress: Formal monitoring and evaluation occurs via three primary mechanisms:

1. The Academic Review Committee (ARC) provides advising, monitoring, and evaluation of all students in their first and second years. The ARC consists of five faculty who meet with students individually, twice a year. The ARC reviews and addresses any concerns from the student's performance from the previous semester and helps finalize upcoming plans, including coursework, laboratory rotations, and the dissertation. The student is required to provide and be prepared to discuss an updated Individual Development Plan (IDP) which includes two distinct sections: i) "Skills and Motivations," which helps the ARC get to know the student better, and ii) "Plans/Goals for the Coming Year," which includes written lists of specific courses and laboratory rotations that are planned. Additionally, first and second year students are assigned to one faculty member of the ARC, who serves as their individual advisor. The completed form is reviewed by the PGG Chair and ARC Chair. The ARC also reviews the overall performance of all junior and senior PGG students on a yearly basis and is available to consult on any other academic-related issues for dissertation-level students.

2. The Candidacy Exam evaluates and provides feedback for students as they transition to their Thesis work. Feedback is provided via a written evaluation of both the Written Proposal and Defense, which is immediately shared with the student. Possible outcomes are i) Unconditional pass, allowing the student to begin his or her Thesis work; ii) Conditional pass, which is assigned if the Committee feels that the student would benefit by, for example, re-writing and/or re-defending part or all aspects of the proposal, which typically must be completed within 1–3 months following the initial Exam; or iii) Fail, in which case the student is told why in the most specific terms possible and is a candidate for dismissal from the PGG. The PGG and ARC Chairs review all of these evaluations and provide additional feedback, as needed, including possible dismissal following failed Exams.

3. The Thesis Committee meets with Thesis-level students every 6–12 months. At each meeting, the student is required to provide: i) a written progress report describing current progress and future plans; ii) a copy of the previous Thesis Committee Report, reminding the Committee of their progress; iii) organized, well-managed lab notebooks used since the previous meeting; iv) an up-to-date copy of the student's CV; and v) an IDP, that includes sections on "Skills and Motivations and Career Planning," "Achievements and Plans/Goals," and "Skills to Improve." The IDP and a Thesis Committee Report, which is filled out by the Committee Chair and shared with the student at the end of the meeting which is reviewed annually by the PGG and ARC Chairs, who provide additional feedback and guidance as necessary.

Professional Development Activities within BGS and PGG:
Biomedical Graduate Studies (BGS) utilizes a variety of methods to promote student professional development, defined as *i*) training in skills apart from those of scientific endeavor that engender success in the workplace, whether it be academia or other, and *ii*) providing opportunities to students to evaluate career paths for which PhD training in the biomedical sciences provides a strong competitive advantage. Professional development for BGS is coordinated by Dr. David R. Manning, Director of Training Support and Career Development.

A key resource for both students and faculty is the **BGS Career Development website https://bgscareerdevelopment.com/**

The website comprises five sections. *Core Competencies* provides descriptions of the skills acquired and cultivated through PhD training in the biomedical sciences and the roles these skills play in assorted professions. *Career Descriptions* discusses the types of careers for which PhD training in the biomedical sciences can be particularly useful in terms of entry and success. The write-ups for each of about two-dozen careers include

a detailed description of the career, advantage of the advanced degree, key competencies, on-campus student organizations, first steps, alumni videos, alumni networks, and resources. The *Career Blog* provides an up-to-date schedule of seminars, workshops, and other events relevant to career exploration and development, with cross-referencing to other sections of the website via categories and tags. *Resources* contain what are considered the most useful resources, both at Penn and elsewhere, relating to career exploration. *Alumni Outcomes* provides detailed data on career paths for alumni of BGS.

Certificate programs offer students opportunities to pursue specialized scientific and professional interests. These programs generally consist of 3–4 courses, many together with a seminar series and capstone project. Several certificate programs are closely aligned, through design, with the standards and educational mission of BGS. These are Graduate Training in Medical Science, Public Health, and Environmental Health Sciences. Other certificate programs, i.e. those elsewhere within the Perelman School of Medicine, the University, and in some cases other institutions, can be relevant as well. For example, students have expressed interest in, and BGS supports, the Wharton School's Certificate in Business Foundations Skills, the Law School's Certificate in Law, and the Institute of Translational Medicine and Therapeutics' Certificate Programs in Translational, Entrepreneurial, and Regulatory Sciences.

Learn to Lead. With a supplement to the NIGMS T32GM008076 the PGG was able to support this seminar series that presents talks and panel sessions with individuals from various science based careers. In the past the seminars have covered biotechnology, pharmaceuticals, consulting, entrepreneurship, government and university laboratories, teaching at primarily undergraduate institutions, medical writing, patent law, policy, public health, publishing, regulatory affairs, and science policy and tenure track academic positions.

Students in the Pharmacology Graduate Group have also organized an outreach and professional development group **Pharmacology Graduate Opportunities for Outreach and Development (Pharm4GOOD)** whose mission is to create a community for pharmacology graduate students to develop personally and professionally. Training as doctoral students is enhanced by volunteering, community outreach, and teaching principles of pharmacology to the broader community.

BGS maintains a close relationship with **Penn's Office of Career Services**. This office conducts an annual Biomedical Career Fair, various workshops and panel sessions, and one-on-one advising through 'Walk-in Wednesdays at BGS'. It provides, as well, a variety of high-level on-line resources that include The Versatile PhD, Carpe Careers, and Handshake.

Individual development plans (IDPs) https://www.med.upenn.edu/bgs/idp.shtml
The purpose of an IDP is to provide to students the opportunity to articulate their range of career interests and to put into place short- and long-term support and resources to explore these interests. The IDP forms are split into five sections: coursework/rotations, pre-thesis research, or thesis research. IDPs evaluate research skills; professional development; achievements; and an action plan. *They are required of the students annually*. Each IDP requires the input of the mentor or advisory committee, who following the discussion helps the student craft the last section, the action plan. As noted from the section titles, the IDP formally addresses both progress in scientific training and professional development. The duality of the intent is important, as rigorous scientific training is key to the advantages students have in securing access to, and success within, careers on which they eventually set their sights.

Synopsis of BGS Activities Related to Rigorous Experimental Design and Transparency to Enhance Reproducibility (Referred to as Scientific Rigor and Reproducibility, or SRR)

Coursework relating to experimental design and interpretation. All students are required in their first year to take a course in statistics as it relates to experimental design and interpretation. For most students, the course is BIOM 611, *Statistical Methods in for Design and Analysis of Experiments*. This course provides students with instruction in premise, design, and analysis from a statistical perspective. It comprises a mix of lectures (21 h) and computer laboratory sessions (21 h). Specific topics include scientific method; comparisons of means and proportions between and among groups, including analysis of paired data, analysis of variance (ANOVA), correlation, and linear regression; and both parametric and nonparametric approaches to inference. An important goal of the course is to enable students to fit statistics to any form of work going forward. To this end, students

are provided considerable instruction in R and R-based statistical packages. Should a student enter BGS with a substantial background in statistics, he or she may elect to take a more advanced course, however coursework in statistics in the first year is mandatory.

Workshop in Reagent Authentication and Transparency. Students in their second year attend a 1-hr, graduate group-specific workshop in reagent authentication and transparency. For most graduate groups, the workshop is led by Dr. Manning, wherein the topics are *i*) authentication of cell lines, antibodies, genetically modified animals, and specialty chemicals, *ii*) best practices in keeping laboratory notebooks as related to transparency and reproducibility, and *iii*) responsibilities inherent to publication. The topics of authentication and transparency for the Epidemiology & Biostatistics and Genomics & Computational Biology graduate groups are sufficiently different as to require workshops led by their own faculty.

****Workshops relating to concepts of experimental design.*** A series of workshops covering experimental design at a conceptual level are being designed for incoming students to take place during orientation, i.e. the week prior to the start of classes. The workshops are linked with BIOM 600, a first-semester course taken by almost all BGS students in which experimental design is emphasized in lectures, assigned readings, and examinations. Currently envisioned are three 1.5-hr graduate group-specific sessions that cover premise, framing of experimental questions, validation of experimental systems, experimental controls, types of replication, and model induction. Guidance in coverage of these topics will be provided by *Experimental Design for Biologists* by David J. Glass.

*, **These workshops were in a "beta testing phase" from September 2017 – May 2018, and will start officially in September 2018, thus upper year students will be encouraged to attend to ensure exposure for all BGS students. Eventually these workshops will be geared for first and second year students.

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