Crook Lab Mission Statement

Overview

The Crook Lab uses genetic engineering to help others. We are interested in both application-agnostic platform technologies as well as application-specific solutions. We disseminate our accomplishments through publications, licensing of intellectual property, and presentations. We believe in open science, and make every effort to make our technologies and data freely available to the research community. We also believe in mentorship, and enthusiastically and patiently train others, just as we were mentored.

Culture

Our laboratory is committed to cultivate an environment of efficiency and mutual respect within the laboratory. The Crook Lab strives to be:

- Helpful. We offer our advice, assistance, and/or mentorship enthusiastically, proactively, and unconditionally. We respect that time is limited, and we are correspondingly grateful for the help that others provide.
- Brave. We are not afraid to take intellectual risks, dive into a difficult project, do the moonshot experiment, or dream of changing the world. We take pride in the fruits of our labor, and we also respect and celebrate the bravery of others.
- Playful. Life follows a set of rules, and it is fun to figure out what they are, see if they can be bent, and exploit their loopholes. Playing with others (e.g. collaboration) makes the game even more fun.
- Skeptical. We challenge our assumptions, pressure-test our technologies, and let go of ideas that weigh us down. We approach others' data with the same skepticism that we approach ours, and expect that others will do the same to us.
- Responsible. We are good stewards of the knowledge, funding, materials, equipment, space, and time we have been provided.
- Direct. We strive to be clear and honest in our communications with members of our lab, other scientists, and the general public.

Onboarding/Offboarding

New Lab member expectations from Nathan

Hello new lab members!

Welcome to the Crook Lab! I'm excited to have you with us. This note formalizes the expectations I have for all my graduate students. The purpose of formally listing these expectations is to 1) provide standardization and 2) reduce confusion regarding graduation requirements across my advisees. These expectations are structured to make my advisees competitive for industry jobs and postdocs following graduation.

1) Conduct research safely. Get enough sleep before working. Bug me for safety protocols, and if you are nervous about doing something, ask me about it and we will figure out another way.
2) Be professional and courteous to your labmates. If a conflict arises that cannot be resolved amongst the affected individuals, let me know and I will provide guidance.
3) Stay up to date with current literature.
4) Publish 3-5 "Primary research outputs" (defined below) in ~5 years (if you are a graduate student) or 2-3 "primary research outputs" total if you are a postdoc. I do understand that unexpected research roadblocks occur, and I have structured this range accordingly. If you are co-advised, outputs with your co-mentor do count toward this total. Primary research outputs include:
    a) First- or co-first author research articles. If you are the nth author on a paper, it counts as 1/n for "article counting" purposes.
    b) Patent applications
    c) Completed industrial sponsored research projects (if not published or patented otherwise - this is intended to incentivize these types of projects since they are valuable insights into industry).
5) Publish 1-2 review articles, usually when our lab is invited to do so by a journal.
6) Present oral presentations on your research 2-3 times at national meetings (i.e. AiChE, ACS, SEED, or Gordon-esque style smaller conferences).
7) Apply for individual fellowships as they arise.
8) Write one full grant application on any project. This includes identifying a funding source (internal, public, or private), making a budget, writing the research proposal, and working with me to get the grant submitted on time through the university's grant submission office. Sorry, individual fellowships don't count for this one.
9) Generate individual sections of grant applications I write (upon request by me).
10) Follow other departmental graduation requirements (e.g. classes, qualifying/prelim exams, TA requirements, etc.) You are responsible for keeping up to date with these departmental requirements, as they can sometimes change.

What follows are the general policies for working in the lab.

1) All experimental work and generated material (including strains, plasmids, and samples) must be recorded on Benchling, with sufficient detail to permit a future lab member to understand and reproduce your work.
2) Group meetings are comprised of two general types:
    a) Research update. One person presents their research progress each week in either a powerpoint or chalk talk format. These presentations should be self-contained, containing enough background and experimental detail for someone in our field (not just our lab) to understand. Presentations should be ~40 minutes in length to permit discussion of results. Group discussion of current issues or problems is strongly encouraged.
    b) Paper intro. This is a presentation that is just focused on background – what is known about your research area and what other work has been done? Can you perform a back-of-the-envelope calculation to estimate feasibility? This will help you understand better how to strategically plan your experiments, identify collaborators/competitors, and explain your topic to others.
    c) 5-minute update. This is a very short "snippet" of your recent work. It could be a successful experiment, a failed experiment, a problem you are having posed to the group, or something interesting that is research-related. The goal of this is to get quick feedback on things if needed.
    d) Thought experiments – these are meetings led by me on various topics. Come with an open mind!
3) I do not require certain work hours, but I am usually working on campus from 9am to 4pm and overlapping with me will make discussions with me and troubleshooting much easier.
4) I don't keep track of vacation time, but so I (and other group members) know how to get in contact with you (and when to leave you alone), you must put when you are gone on the lab calendar.
5) If you are sick/contagious, please stay home and send a quick email to me and/or the lab so we don't pester you with emails while you are gone.

Finally, be sure to check the lab manual to get to know the general operating procedures for placing orders, setting up printers, handling lab chores, accessing forms and passwords, etc.

Offboarding

1. Update and exam the Crook Lab Master Stocks. Follow the rules in the first "Readme" sheet and carefully make the sheet and stocks as described. And discard all the other frozen stocks you think wouldn't help others or future projects.
2. Put your project specific reagents and chemicals in common store locations. Update the chemical inventory, especially your project specific reagents.
3. Toss the primers you think wouldn't help others and keep the primers that can be used in the future (example: 16s Primers for certain types of strains) and compile a google sheet for that.
4. Cleanup and organize your bench and spaces in 4C and -20C

5. For people who are out of the lab, move all files from your lab computer onto the Crook Lab shared drive. Export all flow cytometry files as .fcs for ease of sharing.

Research

Performing quality research advances the core mission of the Crook Lab. Researchers are expected to thoughtfully plan experiments with appropriate controls, maintain a detailed, up-to-date, and accurate lab notebook, perform the experiments with care, and analyze results impartially.

Before Your Experiment

When planning experiments, researchers should review the following checklist:

1. Define your hypothesis and think about various possibilities for the results you might see, and what those would mean.
2. Design experiments to test your hypothesis, including appropriate controls.
3. Write the experimental protocol following Crook Lab general protocols, information found in the literature, and consulting lab members (when applicable).
4. Book necessary equipment on the appropriate Google Calendar.
5. Check for necessary materials (reagents, consumables, media, etc).
6. Review the safety procedures relevant to these chemicals and protocols. Email the group and discuss with Dr. Crook if an especially hazardous procedure is planned.

See the Crook Lab Protocols repository in Benchling here.

Reproducibility/During Your Experiment

1. Update your lab notebook at least daily.
2. Treat shared equipment with respect. Book the equipment in advance, update the booking if your plans change so that others may use it, and be sure to follow defined operating and operating procedures. Export your data immediately.
3. Clean your bench and common lab space before and after (like your kitchen!)
4. Return common equipment, reagents, and consumables in a timely manner. In general, prepare individual aliquots of commonly used reagents to avoid cross contamination of the lab supply (ie Zyppy Wash Buffer). Make your own aliquots of PCR reagents and other -20C/-80C reagents to prevent repeated freeze-thaw cycling induced degradation.
5. Make glycerol stocks of all strains generated over the course of your experiments. Stocks should be labeled on the cap with your stock number (“xx001”). The side of the tube should be labeled with the stock number and colony (“xx001-1”), plasmid description with *at least* the selection markers, parental strain (“5-alpha”), and date stocked. The colony number should be used to reference corresponding sequencing data.

6. When taking strains from someone else, make your own copy for your own racks by scraping from the glycerol stock, spotting on a plate, and scraping the cell mass into glycerol. This will help minimize genetic drift from repeated passaging of single colonies.
7. There should be a “master” and “working” stock of all "kit" or commonly-used plasmids. Master and working copies are in two separate freezers. “Master” stocks are never used unless to replenish the working stock.

Recordkeeping/After Your Experiment

Maintaining an accurate record of your experiments is critical. We use Benchling as our electronic laboratory notebook platform, which allows for open access across the group, efficient cloning design, and streamlined record keeping. The following are tips for optimizing your lab notebook for clear record keeping and accessibility:

1. Build a project overview page for every major project (work that would contribute to 1 paper). Keeping this up to date will make writing the paper significantly easier. The following sections are recommended, but may be customized as needed:
    a. Overview/Background/Motivation (can become the backbone of your Introduction)
    b. Key papers (beginning of your References section)
    c. Project phases (hyperlinks to individual notebook entries) (sub-sections of your Results section & Materials and Methods)
    d. Strains used/generated (hyperlinks to each) (Supplemental Information & Materials and Methods)
    e. Key results (short summary/figure from each project phase) (Results section)
    f. Discussion - think about what your results “mean” in a broader context. For example, do they agree or disagree with prior literature? Has anyone observed similar results before? Can you use your quantitative data to provide a back-of-the-envelope estimate of feasibility for a certain industrial process?
    g. ~50% of your paper is already written and completed before you’ve forgotten all of the details!
2. Create notebook entries for each segment of a project (for example: “Cloning XYZ Plasmids”, “Growth Curves on XYZ Substrates”). These can span multiple days. Include necessary information to replicate results, hyperlink to specific protocols used, and include raw results (i.e. gel images, sequencing results, growth curves, flow cytometry plots).
    a. Make sure to export data from lab computers immediately. Lab computers are not meant for data storage and results should be recorded and analyzed in a timely fashion.
    b. Where possible, attach all raw and analyzed data that is relevant to your hypothesis and results. If it is not possible to attach data due to the size of the files (e.g., large raw sequencing reads), put a link to or reference the location of the file.
    c. Make sure that your notebook entry names are unique! An easy way to do this is prefix it with a date (e.g., 2023-01-10: My experiment). This makes experiments

easier to search through and reference in Benchling for you and current/future colleagues.

3. Protocols for common lab procedures should include a list of reagents needed, detailed steps and citations where appropriate (for example: “Sb Chemical Transformation”, “Gel Extraction”).
4. When designing plasmids in Benchling it is recommended to indicate whether or not the plasmid has been successfully created. Use the notation “xx001 Assembly” for any plasmid that has not yet been cloned. After validating the sequence and making glycerol stocks, remove “Assembly” and ensure that the name of your plasmid is consistent with your Stocks Google Sheet. Your Stocks Google Sheet (which is also imported into the group database) should at a minimum contain the following information:
    a. Stock Name (“xx001”), Bacterial/Yeast Strain (“5-alpha”, “Sc BY4741”), Plasmid Description (include all operational units on the plasmid: “Con2, pGAL1, TcdB GTD, tSSA1, Con3, HIS3, CEN6/ARS4, KanR-ColE1”), Date Constructed/Stocked, **Freezer Box #**, Bacterial Resistance(s), Yeast Resistance(s)/Selection Marker(s)

Data analysis and Graphics

1. Excel: free from NCSU. Useful for data manipulation, but care should be taken when preparing figures in Excel to give them a polished look. Consider exporting data into another software for making figures.
2. FloJo/Floreada: Floreada is a free application for visualizing and analyzing flow cytometry data (link). You can download Floreada or use the website application. They have a guide on the website for using the tool, can be used to generate some basic statistics and can generate some good curves. Flojo has more functions than Floreada and can do compensation calculations. You need a license to run FloJo on your computer. Ask Dr. Kueng for permission to borrow a dongle license from his lab and reserve it every time you need to use it on the calendar.
3. Graphpad Prism: individual academic subscription, cost may be reimbursed. Excellent for figure making and certain data analyses are built in (binding kinetics, curve fitting, statistical analyses, etc.). Prism has an excellent user guide, though switching from Excel will require some effort.
4. Custom scripts (R, Matlab, python): Matlab is available through NCSU, and the others are free. These are typically adapted from other bioinformatics pipelines to suit your specific needs, and can be used to generate figures if desired. (Bioconductor - Rstudio packages, manuals, etc.)
5. ImageJ: open source from NIH. Useful for analyzing biological images (gels, microscope images, etc.). There are tutorials online for everything.
6. To go deeper with data analysis and graphics, check out the Data & Visualization offerings from NCSU Libraries - they often have workshops throughout the academic year.
7. We have a lab biorender! There are 4 dedicated seats - priority on those is for students close to defending.

8. The BRC Cluster is our preferred cluster for bioinformatics. Email someone for access and cc Nathan.

Group Meetings

The purpose of our group meetings is to foster collaboration, communication, and shared progress within our lab. We normally start the meeting by discussing Talking Points (Crook Lab Group Meeting - Talking Points) and then go to the topic/presentation. Nathan will also put together a schedule of who will be presenting and what presentations will be held during each week's group meeting (Crook Lab Group Meeting Schedule).

1. Attendance is expected, so do not plan experiments during the group meeting. If you are running late or have something unavoidable, communicate this with Dr. Crook.
2. It is everyone's responsibility to regularly check the schedule of the group meeting and come prepared. Group meeting topics are usually finalized at least a month in advance.
3. Engage in the discussion by asking questions and expressing your opinions. There are no right or wrong answers; the key is active participation.

In our group meetings, we have structured our discussions into four distinct formats to ensure effective communication and collaboration.

Paper Introduction

This is a presentation that provides background information about your project, presenting the research question and goals for that project (hypothesis, tool generation, problem to solve, etc.). Be sure to include a brief overview of other approaches/techniques and explain the rationale for your project in the context of the field. This should be treated as preparation for writing the introduction section of the research article/review that you will eventually submit for publication. The more work you do during this presentation will make it easier to write.

Main Update

This presentation is the primary presentation for you to practice presenting your research. The topic and level of detail is up to you as you will have different presentation requirements during your PhD journey (preliminary presentations, conference/seminar presentations, thesis defense, etc.). The effort put into making a clear, cohesive, and engaging presentation will yield dividends - don't throw this together the day of. It also is a great way for people to get a better understanding of your work's bigger picture compared with the quick 5-minute updates.

This presentation should include any significant progress or developments that have occurred (ie, key updates, achievements, or milestones) as well as providing an overview of the

project's current status and direction. Like the 5-minute presentations, feel free to ask questions or present work that you are unsure of to solicit feedback and start conversations!

5-Minute Update

This is a quick update for whatever you would like to talk about and is structured to foster connection between lab members, understand each other's projects and share cool research ideas/concepts. This means you could present a lab result, what you have learned/accomplished in the past few weeks or even cool ideas that you want to share/discuss with the group. It also is a great time to ask for feedback from others, present terrible results or present an issue that you are having in the lab related to your research. We all love to hear and celebrate the great results but we all love to help each other out even more!

Please be courteous and keep your update to **5 minutes**. It does not have to be and should not be an exhaustive update from the past few weeks.

Thought Experiments

These group meetings will not be an individual presentation and is a group discussion. Nathan will direct and lead the discussion around the specific topics. The topics are designed for the group to explore hypothetical scenarios or conceptual situations and prompt creative thinking/critical analysis. Check the meeting schedule for the topics.

Science Communication

We strive to disseminate our research findings to a large audience by publishing quality peer-reviewed articles, giving presentations at conferences, interacting with the media, through licensing IP with key partners, forming startup companies, and outreach.

Publications

The primary written output from our research findings. Researchers are expected to design experiments towards a cohesive article, collect findings and prepare research articles for publication.

Authorship:

Our lab encourages an inclusive approach to designating authorship. It is important to discuss authorship expectations at the beginning of the project and prior to drafting the publication. This is especially important for interdisciplinary projects with many contributors.

1. What are the expected contributions towards the project? Use this as a preliminary guide for assigning authorship.
2. Will there be more than one first author? How will the author order be decided?
    a. Author order should be discussed among researchers and if a disagreement is found, Dr. Crook is happy to mediate a discussion to decide on authorship order.

    b. For a lighthearted take on this problem, see here and here
3. The PIs will have their own version of this discussion to decide on “corresponding author”.

Follow these guidelines for drafting and publishing a research article:

1. Build an outline/story for the paper. Make a list of the results sub-sections and corresponding figures. It is important to discuss this with Dr. Crook and co-authors prior to drafting the manuscript.
    a. Decide on the target journal and backup journals for submission. This will help guide the structure of your manuscript.
2. Draft the manuscript with co-authors. It is helpful to step back and approach the introduction and discussion sections with care. What message do you want to convey in the paper? Inject opinion, commentary, forward-looking thoughts.
    a. Figures should convey the message of the paper independently of the text, so spend time accordingly. We typically use BioRender for graphics and Prism/Python/R/Matlab/Excel for data figures. Make sure figures are color-blind accessible (try using one of these palettes). Lab members are an excellent resource for figure advice and critiques.
3. Seek revisions from lab members, co-authors, and Dr. Crook.
4. Once all authors have thoroughly reviewed the manuscript and agree, submit it to the target journal (handled by the corresponding author, who will also provide a cover letter and recommended reviewers (though the main authors can certainly help!)).
5. Address revisions from reviewers by discussing textual edits and follow up experiments with co-authors.

Conferences

A platform for sharing recent results and interacting with the broader scientific community. Researchers will typically give oral and/or poster presentations, speak with other attendees, and visit sponsor booths. Oral presentations usually encompass one or nearly one paper’s worth of information. Poster presentations and flash talks are popular choices for junior scientists. Posters are also a great way to have insightful discussions with other researchers that often lead to new ideas and collaborations. And please record the conference you attend in the google excel sheet here.

Conferences are an excellent opportunity for students. Ask for permission prior to submitting abstracts. Costs may be covered by grants and/or travel awards. Whenever possible, apply for travel awards (CBE, GGA, the conference organizers etc.), split rooms if comfortable, and find cheap transportation.

Here is a list of conferences we have attended in the past:

1. American Institute of Chemical Engineers Annual Meeting (AIChE): typically held in the fall with a focus on academic institutions

2. American Chemical Society Annual Meeting (ACS), Biochemical technology section (BIOT): typically held in the spring (the fall meeting does not include BIOT) with substantial industry presence
3. North Carolina Microbiome Symposium: a local (RTP) 1-day symposium featuring microbiome-related talks from academia and industry.
4. The Society for Industrial Microbiology and Biotechnology (SIMB) annual meeting: typically held at the end of summer with a focus on industrial wise perspective. Most of the oral talks are presented by professors and directors from bio-companies. Posters are presented by graduate students and researchers.
5. @everyone please add

Media

Allows us to share our work with the public through interviews and articles with local and national news organizations. Remember your audience is the general public, and adjust accordingly. Focus on the bigger picture and limitations of the work.

Patents

Allow us to apply our findings beyond the lab through licensing and commercialization. We work closely with the NCSU Office of Research Commercialization for IP related concerns.
Co-authors who have made substantial intellectual contributions to the IP will be included as inventors and we strive to divide ownership evenly when applying for patents. When in doubt, speak with Dr. Crook and co-authors before sharing sensitive information in presentations (peptide/protein sequences, genotypes/strains, etc.).

Mentorship/Development

Mentorship

Mentorship plays an important and sometimes outsized role in a successful PhD/postdoc. Therefore, we at the Crook lab will strive to make opportunities for mentorship available equally to all lab personnel. Below we define expectations and best practices surrounding the mentor-mentee relationships within the Crook lab.

PI-Mentee Relationship

Dr. Crook's has several roles in the PI-mentee relationship:

- Funding: provide adequate funding for PhD students and inform students of new, relevant funding opportunities to pursue themselves.
- Project Management: understand project load among graduates/post-docs and disseminate available projects accordingly.

- Information Repository: provide guidance on concepts or techniques that are relevant to the foci of the Crook lab. This is especially relevant for newer lab members or those starting on new-to-them projects. Guide new students to repositories of information such as the Crook Lab Manual or the Crook Lab Protocol repository on Benchling. If known, refer students to other students with knowledge of or experience with certain techniques.
- Direct Feedback: provide fair, firm, and direct feedback regarding projects, conduct, and research outputs.
- Expectations: While general expectations for all members of the Crook lab are listed in the New Lab Member section, individual expectations may shift based on the nature of the project or other things; it is important that Dr. Crook set these expectations where possible.
- Opportunities: Dr. Crook will disseminate opportunities that are relevant to members of the lab.

1-on-1 Meetings

1-on-1 meetings are critical for a mentee to keep Dr. Crook apprised of project progress as well as to receive more direct feedback in terms of projects, PhD milestones, funding, professional development, career trajectory, and other guidance. These meetings initially occur on a weekly basis, but can be made less frequent at the trainee's request as they become more independent. As there are many projects that Dr. Crook must be aware of at a high-level, it is of critical importance for the mentee to structure their 1-on-1 meetings to provide enough context for Dr. Crook to provide direct feedback. This means establishing an agenda beforehand and taking good notes during the meeting. It is useful to have a consistent outline that you can add to over the week, instead of just coming up with an agenda 15 minutes before the meeting (which none of us have ever done before, certainly!) An example agenda is below:

Projects: information relevant to the project(s) you are working on.

- Progress since last update: any progress made on the project since last update to help keep Nathan informed.
- Questions: any questions you have for Nathan on concepts, techniques etc.
- Notes: any pieces of information that arise during the 1-on-1 that are worthy of writing down.
- Next steps: a reminder for you of how to proceed with this project after the 1-on-1.

Logistical/other: points to bring up about outages, concerns, or bring up any interesting ideas, questions about papers, etc. Anything not pertinent to an ongoing project.

Graduate Student Mentor-Mentee Relationship

When incoming graduate students first join the lab, they will be matched up with a more senior graduate student whose project is most similar to theirs (depending on the makeup of the lab, "senior" could mean just one year above the incoming student). This matchmaking process should be performed by Dr. Crook in conjunction with the graduate student mentor once new lab members are established. General expectations for the graduate student mentors and mentees are below.

Graduate Student Mentor

- Be a good steward of the Crook lab: embody the traits and values listed in the Culture, Communication, and General Conduct sections; lead by example.
- Set expectations early on: To avoid miscommunications regarding level of time and effort for projects, have an initial meeting to discuss your expectations for what your mentee should be doing.
- Be generous with authorship: If your mentee, in the process of learning the lab and their project, contributes intellectually to a piece of your (the mentor's) project, include them on the publication.

Graduate Student Mentee

- Be communicative: everyone in the lab is at a different point in their academic, professional, and personal lives; some of us are new to the country, or have families, or otherwise have constraints that others may not be aware of. Communication regarding time availability is essential for a good graduate student mentee.
- Establish good laboratory practices early:
    - Learn the ins and outs of Benchling and take really good notes when your mentor is instructing you.
    - Set up your stocks and strains list if relevant to your project
- Be proactive in making shared reagents: includes plates, 1x TAE for gels, 10% glycerol stocks, etc.

Development

Development opportunities in the Crook lab are expected to be primarily self-driven. However, Dr. Crook will share opportunities from various sources, e.g., University competitions, funding opportunities, internships, professional development courses, etc. It is the responsibility of the mentee to express interest in these types of opportunities, usually within the scope of 1-on-1 meetings. Don't be shy about sharing your longer-term (e.g. post Crook-Lab) plans with Dr. Crook! It will help him identify/suggest opportunities that might be of interest to you.

Individual Development Plans

The CBE department is beginning to require an Individual Development Plan (IDP) to be completed for each graduate student. This is in response to the NSF requiring IDPs for each NSF-funded graduate student and postdoc. IDPs are a structured way for a trainee to think about their long-term career goals, and what steps they need to take to achieve them. IDPs are more useful for some people than others - they are particularly useful for those that already have a strong idea of what they want to do after they leave the Crook Lab. However, for those that don't have a good idea, IDP creation is a good opportunity to consider what sorts of careers suit their interests.

Dr. Crook recommends myIDP to create an IDP and track progress:

https://myidp.sciencecareers.org/

External Development Resources

Several professional development resources are available within the CBE department and some also align with research going on in the Crook lab.

- Professional Development Programs (The Graduate School) - programs offered through the graduate school, optionally receive a certificate upon completion.
- Professional Development Workshops (The Graduate School) - a calendar of professional development-related events
- Interdisciplinary Professional Development Workshop Series (Genetics and Genomics Academy) - a workshop series hosted by the GGA
- Professional Development Opportunities (Plant Sciences Initiative) - Events and resources for PSI-related projects

Milestones/Requirements

Requirements

These are the “checkboxes” that a student has to complete before they graduate. They are certainly important, but should not be seen as the entire point of a PhD.

- Check with your specific graduate program for your graduation requirements (usually some combination of required classes, a qualifying exam, a prelim exam, a defense, and TAing a few classes)
- See the Onboarding section for Crook Lab-specific graduation requirements.

Milestones

- Some programs require a “qualifying exam”. This is a way to ensure that the student meets some minimum level of understanding of domain-specific knowledge, prior to commencing their research in earnest. At NCSU CBE, the “qualifying exam” consists of:
    - Satisfactory grades in graduate level core CBE classes,
    - The ability to understand and critically evaluate domain literature (i.e. CHE 701), and
    - The ability to put forth (and explain) a coherent plan of research (i.e. CHE 702). In contrast to the “preliminary exam”, for CHE 702 this plan of research is usually taken from one of Dr. Crook’s grant applications and put into the student’s own words.
- All programs require a “preliminary exam”, which is a more in-depth research proposal document plus an oral exam, evaluated by a faculty committee of the student’s choosing (subject to some requirements related to which departments the committee members come from).

- In some departments, this research proposal should accurately reflect what the student intends to study during the rest of their PhD, and is therefore largely the product of the student's prior research in the group, their interests, and their own self reflection.
- In other departments, this proposal is not related to the student's actual research. It may be in a similar area, but the hypotheses/goals are different. This type of proposal tests the student's breadth of knowledge and intellectual flexibility.
- The written document should be polished, with minimal grammatical errors, a clear and concise description of the prior literature, a clear scientific or engineering goal, and a logical plan of work. The student will likely need to generate figures containing their preliminary data and schematics for their planned experiments. Aim for a document that could be submitted to a funding agency with minimal edits.
- Schedule the oral exam well in advance (approx 4 months is a good rule) to allow for travel schedules. Schedule a 2 hour block of time.
- The oral presentation itself should be no more than 30 minutes in length to allow time for questions. The content of this talk is largely reflective of the written document, though it can also contain one slide about courses taken/planned, as well as one slide about publications or presentations the student has made thus far. Do not worry about correct grammar or word usage here - the goal of this presentation is to communicate visually and verbally what you have previously communicated in a written format.
- A well-fed committee member is a happy committee member :)
- Many students stress about the questions they will be asked during the prelim. These often fall into one of several categories. You can have backup slides with extra data that you don't have time to cover in the main presentation
    - Clarification: something was unclear, for example what technique you will use, what controls will be performed, etc. These only require simple answers.
    - Fact-check: Maybe the committee member knows something about your system that conflicts with what you said. For these, you can point to the reference you used, clarify the context in which your fact is valid, or acknowledge that you may not know the whole picture. Beyond whether or not you were right, it is important to communicate to the committee how that fact relates to your broader research aims.
    - Fundamentals: Sometimes a committee member can see your project as relating to something you were taught in your core classes. Concepts like enzyme kinetics, transport, thermodynamics, math, metabolism, etc all play into what we do, so the goal of these questions is to evaluate whether you can put your project into these sorts of terms. It's ok if you can't remember specific terms, but it is important to show the committee your thought process when you are answering. Talk them through it and they can help you when you get stuck.

        - Logistical: Can you realistically accomplish what you have proposed? Maybe you have over-proposed, maybe not. You can provide some indication of your proficiency with the methods you propose, but also be realistic in that roadblocks may occur. Be able to communicate a contingency plan in case one of your experiments does not work.
        - Forward-looking: Your project may have real-world applications. How might your research be applied in the real world? What quantitative metrics must your system have in order to be better than the state-of-the-art? How close are you to achieving those? What limitations still have to be overcome?
        - Public interest: Sometimes a committee member is just interested in your general area, like the microbiome, microplastics, etc. They may ask a question that isn't pertinent to your specific project, but is more tangentially related. For example, "I heard that autism is related to the microbiome", or "I heard we eat a credit card's worth of plastic every year". There are no wrong answers to these questions, but you get extra "points" if you can inject a critical perspective, showing that you can cut through the hype in your particular area.
- Committee Meetings. These should be scheduled approximately once per year to update committee members on your research progress and get high-level feedback. In CBE, yearly committee meetings are a requirement. In other departments, they are strongly recommended. These should be at least 90 minutes in length, budgeting around 30-45 minutes for your presentation. Unlike the other meetings with your committee, these are not exams - the committee will try to help you! Some advice:
    - Celebrate your achievements, but highlight where the committee's advice is needed.
    - Listen to your committee's advice, and act on it! They will expect you to have at least tried their suggestions during your next meeting.
- The thesis is the culmination of your PhD work! Schedule this one at least 6 months in advance, and be aware of graduate school deadlines, formatting requirements, etc. If the final document is not approved by the graduate school by the deadline, you may not be able to graduate that semester, so plan ahead! It is recommended to reserve at least 2 months of time to prepare the written and oral materials. Also, be sure to **embargo** your thesis as it likely contains intellectual property that we may wish to protect.
    - The thesis (ETD) should adhere to the guidelines from the Graduate School, found here. Students should be aware of the deadlines for their thesis submission and oral defense, as well as class registration requirements. You can view past students' theses here.
    - The written document generally has the following sections:
        - Title and Table of contents
        - Acknowledgments
        - Introduction (can be cut and pasted from a review paper you have written, but make sure that it introduces the various topics in the main body of your thesis). You may have to add one or two sections to a previously

written review paper. Do a good job of bringing the committee (who is not an expert in your area) into your field, lead them through the work that has been done, and end with the key knowledge gaps your work will fill.
        - Results chapters can be cut-and-paste from your published work. For work that is soon-to-be-published, use this opportunity to generate a near-complete draft of your paper. It will save you effort in the future. For work that is unlikely to be published due to unsatisfactory results, Dr. Crook recommends that you include a writeup to demonstrate this effort to your committee. However, this is not required.
        - The conclusion section is brief (a couple of pages at most), as most of the discussion should be in your individual chapters. You may want to use this opportunity to take a broader view of the impact your work has on the field, or to put forth some provocative ideas. Since your thesis will be publicly accessible (but not peer reviewed) this is one of the few opportunities you will have to disseminate these types of opinions.
    - For the oral defense, all of the comments related to the prelim still apply here. However, one important thing that the committee looks for at this stage is being able to converse with you about your research topic as a colleague, rather than a teacher. For example, can you have a stimulating conversation with them about your research? Do you have well-reasoned opinions about your field, and where it is heading?
- For PhD students and postdocs, there are other milestones that **may** be relevant to you as you progress through your training:
    - Research: Can you perform experiments under the guidance of a more senior member of the lab? Can you design your own experiments that allow you to advance toward a more long-term goal? Can you identify new research directions that you are well-equipped to tackle? PhD students and postdocs should be able to say “yes” to all of these questions by the time they leave the lab.
    - Communication: Can you clearly communicate the results of experiment(s) in both written and visual forms? Can you assemble a body of work into a coherent and logical narrative? Can you clearly communicate what is novel about these results, and/or how they fit in with what is already known in other areas of science? Can you do these things without substantial editing by a mentor? PhD students and postdocs should be able to say “yes” to all of these questions by the time they leave the lab.
    - Mentorship: can you teach someone else the techniques that are pertinent to your research area? Can you effectively manage one or several others in the pursuit of a common goal? Can you lead your mentees such that they are able to perform research independently? Employers often want to know the extent of your mentorship experience so that they can judge whether or not you are suitable for a research leadership role.
    - Collaboration: Can you effectively and seamlessly work as part of a team to divide roles/responsibilities toward the pursuit of a common goal? Do you have a

working understanding of the techniques and experiments being performed by your collaborators? Can you learn to manage disputes over project direction/ownership? Are you gracious with your time in assisting others to learn techniques that you are familiar with? Team-based work is increasing in frequency in both academic and industrial settings.

- Teaching: Most trainees are able to grade quantitative work. Can you design effective rubrics for both qualitative and quantitative work which effectively distribute partial credit where appropriate? Can you effectively explain concepts to struggling students during office hours? Can you assemble previously-written homework/exam problems in a new way to effectively test what has been taught? Can you formulate new homework/exam problems that are doable, yet challenging, and which expose students to the broad applications of the techniques they are learning? Can you assemble one or several lectures to teach new material to students, while ensuring that students remain engaged during the lecture? Can you put together a new course, including defining learning objectives and structuring lectures/assignments to meet those objectives? These skills are most relevant for those who wish to move into a career involving teaching, but also have some relevance to others.
- Service: Do you contribute to activities in the group/department/field that are not directly related to your research, such as recruitment, student governance, departmental socials, and conference organization? Can you be effectively led by another person to ensure the success of those activities? Can you lead others to accomplish those activities? Most jobs will expect some amount of work that falls outside your specific job description. Service also increases your visibility within and outside your organization, and can lead to new collaborations/opportunities.
- Outreach: Do you participate or lead activities that engage non-scientists with your work? This can overlap with “service”, and is important to build your ability to distill your research in a way that non-scientists can understand. Most members of the general public are aware of the general problems you are working on, but may not be aware of the details of the techniques you are using to work on them.
- Entrepreneurship: Can you recognize a commercial opportunity based on your work? Can you engage with potential customers to understand whether your product or service will be competitive? Do you know how big your market is? Do you know the regulatory requirements surrounding your product? Can you identify trusted colleagues to support you as you start your company? Do you understand how intellectual property and equity affect financial matters at the company? Starting companies based on university research is a lot of work, but can be very rewarding.

Collaboration Philosophy

Collaboration involves individuals working together collectively to address a shared idea or challenge. The Crook Lab welcomes collaboration in various forms, whether it's among students within the lab, between different labs within the same institution, across labs in different institutions, or even among institutions across countries.

We strive to follow the following guidelines to maintain a positive relationship with collaborators to ensure thorough, ethical and transparent research:

1. Establishing open communication to relay research breakthroughs, new results and observations, potential experiments and planning with collaborators so that everyone is on the same page.
2. Making sure samples from outside the lab are stored under the correct conditions and maintained appropriately.
3. Having an open dialogue about giving credit to collaborators and having transparent discussions for authorship in papers to make sure credit is apportioned accordingly.
    a. Dr. Crook recommends that the trainees try to decide amongst themselves how they want authorship to be shared, and involve the PIs in this discussion if there is a disagreement.
4. Respecting the ideas and opinions of everyone involved in the project.
5. Record your research so that it is accessible to everyone involved in the project.
6. Keeping confidential information safe.