ADVICE FOR GRADUATE STUDENTS BEGINNING RESEARCH

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Abstract. Some tips and resources to get you started!

1. Contacts

Your research supervisor:
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Your research group:
Offices: GeoChem Rooms 134, 137
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Closely related faculty:
DEEPS: http://bit.ly/1HUkNIR, Fluids at Brown: http://bit.ly/1DxYeaS, Institute at Brown for Environment and Society: http://bit.ly/1Qj2BxP

2. Getting Help!

I am almost always available by email. You can make an appointment to meeting in person or by google hangout other times. Just check my calendar at http://fox-kemper.com/contact and suggest an open time that works for you.

I will be contacting you to schedule group meeting times, and I expect for you to come to group meeting if possible. I will schedule it to avoid your classes.

The lab group is also available to you for questions, advice, and support. They are already highly trained in science, and part of what they are learning now is how to advise. They need to learn to talk to you as much as you need to learn from them! To put it another way, a post-doctoral scientist is only about 2 years away from being a professor, and a senior graduate student is only 5 years away, so now is a great chance to get advice and learn how they think. You will be attending group meetings regularly: Speak Up and Ask Questions!

3. General Comments: What is Research?

This may be your first experience with doing multi-year independent research. This opportunity can be formative, changing your life for the better and leading to your true passion! Or, it can be a letdown–not every conversation you'll have or article you read will blow your mind, and there is enormous frustration involved in the practice of research.

Many, many graduate students experience a slump or vertigo in their second or third year, when they realize that getting good grades in classes doesn't automatically give them all of the preparation they need for research. Some never regain their equilibrium, and end up dropping out of school regardless of their scientific potential otherwise. I want you to be as happy and productive as you can be during grad school, and avoiding or minimizing this slump is the reason for this document.

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Think about the work "research." It means searching repeatedly. This thought is a good way to approach research. Just as "fishing" is not the same as "catching," we should not confuse research with the much more rare discoveries and breakthroughs that drive the process.

3.1. **The Scientific Method.** We all learned the basic scientific method in school–hypothesis, prediction, experiment, theory–but real research is quite a bit more fluid and free-form (even though we often write a revisionist chronology of what happened in the lab to fit the method and this re-evaluation is critically important in finding errors and building a logical framework). There are, however, major pitfalls which can occur in the more unstructured process. I include a quotation from Popper (1998), who spent his life analyzing the difference between science and pseudoscience.

> These considerations led me in the winter of 1919-1920 to conclusions which I may now reformulate as follows:
>
> (1) It is easy to obtain confirmations, or verifications, for nearly every theory–if we look for confirmations.
> (2) Confirmations should count only if they are the result of risky predictions; that is to say, if, unenlightened by the theory in question, we should have expected an event which was incompatible with the theory–an even which would have refuted the theory.
> (3) Every good scientific theory is a prohibition: it forbids certain things to happen. The more a theory forbids, the better it is.
> (4) A theory which is not refutable by any conceivable event is non-scientific. Irrefutability is not a virtue of a theory (as people often think) but a vice.
> (5) Every genuine test of a theory is an attempt to falsify it, or to refute it. Testability is falsifiability; but there are degrees of testability: some theories are more testable, more exposed to refutation, than others; they take, as it were, greater risks.
> (6) Confirming evidence should not count except when it is the result of a genuine test of the theory; and this means that it can be presented as a serious but unsuccessful attempt to falsify the theory. (I now speak in such cases of corroborating evidence.)
> (7) Some genuinely testable theories, when found to be false, are still upheld by their admirers–for example by introducing ad hoc some auxiliary assumption, or by re-interpreting the theory ad hoc in such a way that it escapes refutation. Such a procedure is always possible, but it rescues the theory from refutation only at the price of destroying, or at least lowering, its scientific status. (I later described such as rescuing operation as a conventionalist twist or a conventionalist stratagem.)
>
> One can sum up all this by saying that the criterion of the scientific status of a theory is its falsifiability, or refutability, or testability.

Another take on the scientific method comes from Stewart et al. (2010):

> Pioneered by ancient Greeks, developed by medieval Muslims, systematized in the Renaissance, perfected in the Enlightenment and patented by the Dupont Corporation, **the scientific method** improved on man's previous tradition: making shit up. The scientific method added the crucial step of **experimentation**, using real-world data to test a **hypothesis** that, if proven, would be accepted by scientists as a **theory**, which could then be used to get a **grant**, or in some cases, **tenure**.

3.2. **How Research Differs from Coursework.** You have already received lots of training in fundamentals that will be of use to you in research. You probably have solved lots of problems and answered many questions while doing homework and exams. Many were probably harder than those you will encounter in your early research.

However, you will be learning a new skill–*the ability to formulate your own questions that need answers.* A major aspect of research that is confusing is that most of the time doing research is not spent answering questions, it's spent figuring out what the right questions to ask are.

What makes for a good question? 1) *It should be something for which you are prepared* (e.g., it might involve adapting a method you learned in classwork to a different problem), or at least you know how to become prepared (e.g., another lab member might know the method and can teach you, or you might have a paper or textbook describing it, or you might have inherited some computer code that solves a similar problem). 2) *It should be interesting to you.* You will work harder on this than anything academic you've done so far, and there will be times when progress is elusive and you will be frustrated, so don't start a project unless it piques your curiosity. 3) *The solution to the problem should be useful to others.* Baylor and the lab group can help you out here. Basically, if they are interested, you are good to go. You will have opportunities at conferences to further hone your audience and direction, by seeing the larger community and sensing what of your work interests them. 4) *It should seem, at first glance, to be far too short and easy.* Good research problems start small, with a simple question that can be clearly posed. If you do solve it in a day, then *awesome*! You can generalize your question to make it harder! If it's too hard to begin with, then you're stuck with zilch. Typically, a short research question opens many unexpected doors. Multi-stage questions, like those you get on homework assignments, are usually realized in hindsight after years of trying, recalibrating, and strategizing! Research questions almost always require more training en route and avoiding lots of dead ends and roadblocks.

3.3. **Do I work for Baylor, or is he teaching me?** Both. You are funded by a grant that was proposed by Baylor to address a particular science question, or you have a fellowship that was obtained premised on working with Baylor, so you work for Baylor. However, you are getting a degree, taking classes, building a career, and writing a thesis, so you are being taught. However, such bureaucratic distinctions are pretty meaningless, since Baylor is often teaching you because your topic relates to something else he is working on, and even if you are funded to do research, the expectation is that your training is in the field and future potential is equal to your significant results from this project.

The best thing you can do is just get engaged with the project and the group. This will constitute both your job and your education. Getting engaged requires showing up, asking questions, actually reading the things that are suggested, and thinking about what they mean and if they are relevant. If you ask someone a question, it is on you to make sure you understand the answer: ask follow-ups later, see if you can reproduce the result, etc. Don't be too worried about where this kind of work is going at first, you will need to muddle around to collect the tools and ideas to get somewhere.

3.4. **Collaborating.** One of the most important ways for you to develop your career is to build a collaboration network. These are scientists whom you respect and who respect you. They can write letters for your applications, co-author papers, give you data or code that will save you time, cite your papers, etc. Importantly, they will become your friends and community as you develop as a scientist. They will support you on a personal level, have meals with you at conferences, have running jokes, and generally make the process of doing research more fun and less lonely. How do you go about making these connections? Like making friends in the rest of your life, part of it is having shared interests, part is personal chemistry, part is having and acknowledging mutual respect, and part is not taking unfair advantage of that person's time, position, or research results.

Each interaction you have with your collaborators is important in building the relationship. One example is when you add them as a co-author or a conference abstract or paper. Here is a sample email you might send to them if you haven't met them yet.

```
Dear Prof. ???,  (or Dr. ??? if they are a post-doc or researcher)
  I am working with Baylor on a project related to your past collaborations with him.
I intend to present in February at the 2016 Ocean Sciences on this work, and I'd like
to acknowledge your contributions with a co-authorship.  Please find the title, proposed
session, author list, and draft abstract below.  Any suggestions you have are most
welcome!
  Thanks,
    ?Your first name?
```

```
?Your full name?
Graduate Student (or PhD Candidate (if you have passed your prelims but not defended))
Brown University
Dept. of Earth, Environmental, and Planetary Sciences

(Paste the following all in plain text)
Title:
Author List:
Proposed Session Link:
Abstract:
```

Another example is acknowledging their work through offering co-authorships on papers or acknowledgments at the end of papers. I find it better to ask collaborators if they want to be co-authors if in doubt. If they refuse, or if their contributions were long ago or short-lived, then an acknowledgment is appropriate. Acknowledgments also *must* include a detailed list of funding sources for all authors. Often, using a computing center or other facility should be acknowledged, and if so they often give a preferred format on their webpage. Here is a (long) example from Haney et al. (2015) illustrating many of the types of credit:

> Acknowledgments. The authors thank Prof. Gregory Chini for insightful discussions of interactions between symmetric instability and Langmuir circulations, Prof. Eric D'Asaro for suggesting that the submesoscale instabilities of the boundary layer including Stokes forces be explored, and Dr. Peter Sullivan for help with the NCAR LES model. BFK, KJ, AW, and SH were partially supported by NASA NNX09AF38G and NSF OCE 0934737. This work utilized the Janus supercomputer, which is supported by the National Science Foundation (award number CNS-0821794) and the University of Colorado Boulder. The Janus supercomputer is a joint effort of the University of Colorado Boulder, the University of Colorado Denver and the National Center for Atmospheric Research.

3.4.1. *Planning a Meeting.* Every meeting is an opportunity for you to either waste everyone's time or make real progress and potentially have a eureka moment. Knowing how to set a meeting is an important skill. The convener or chair of the meeting is in charge of setting the agenda. It is important to make an agenda, especially so when there are many people coming to the meeting. For a few minutes of the convener's time, 5 or 10 person-hours can be saved!

Here is a basic outline for a half-hour meeting:

(1) Briefly review mood, function, status (1 min), e.g., "Suffering", "Gangbusters", "Stuck"
(2) Bridge discussion from previous session with the current session (2 min), e.g., "Last time, we did . . . and decided . . . "
(3) Set the agenda for the current session, and prioritize the items (2 min), "Today I want to . . . "
(4) Review any homework/action items given in the previous session (5 min), "I completed . . . , but am still working on . . . "
(5) Discuss agenda items and set up new homework/actions (15 min): this is the main point.
(6) Summarize the meeting and exchange feedback (5 min), "OK, we agree that . . . You'll do . . . , and I'll do . . . Here is my written understanding of exactly what that means, . . . We'll meet again on . . . "

For longer meetings, multiply the times accordingly. If the meeting is a hour or longer, you should plan this agenda in advance and include it in your email invitation. You don't have to prepare slides or a handout, but these can be very useful if you have lots of technical details that need to be right (e.g., figures of data, equations).

For academic committee meetings, annual reports, or other rare events, it is important to remember the "big picture." Make sure to address all of academics, research, service, and teaching. It is important to produce slides for the meeting or a handout. You should email a copy of these to all participants in advance of the meeting or shortly afterward. Include both what has happened ever in your life (briefly, i.e., 1 slide for all, e.g., Degree in . . . , High School . . . , From . . . , First Language . . . , Year in Program . . .), and what has happened since your last meeting with most of the group participants (1 slide academics, 1 slide research). Then follow the rough outline above to address your specific goals for this meeting.

3.4.2. *Authorship of Papers:* The first principle of authorship in my group is that students and postdoctoral scientists should almost always lead the writing of the papers they participate in, which is officially encouraged by our department at Brown and my previous affiliations at the University of Colorado. This experience is critical for group member development, and they are often best at detailing the simulations they have run. First authorship indicates who is in charge of "seeing it through," but substantial ideas and input are required from all authors (including myself, of course!). To help a reader identify credit in papers, on my curriculum vitae I indicate special authors with underlines, over-lines, and italics to distinguish senior group members, junior group members, undergraduate researchers, supported graduate students, postdoctoral scientists, and graduate students from other groups.

In climate modeling, it is common to collaborate with scientists at modeling centers or collecting observations. Many authors become involved in papers through contributions to the coding or experimental design. In 2015, *Ocean Modelling* has had fewer than 15% single-author papers, and *Journal of Climate* has had fewer than 5% with one author. Our papers usually have myself or a junior group member as lead, and then an alphabetical list of contributors afterward (e.g., Fox-Kemper et al., 2011; Fox-Kemper et al., 2013; Li et al., 2016). Similarly, when I consult on a graduate student's research in a significant way, but not as primary doctoral advisor, I am usually listed near the end of the author list (e.g., Reckinger et al., 2012; Grooms et al., 2011; Qazi et al., 2014). Collaborative papers with equal partners are alphabetical (Boccaletti et al., 2007; Bates et al., 2012; Cavaleri et al., 2012). In cases where one author contributed significantly more effort, they are first author, then ordering is alphabetical (Jochum et al., 2009; Haney et al., 2012) or by significance of contribution (Belcher et al., 2012; McWilliams and Fox-Kemper, 2013). In some cases, the acknowledgment section of the paper explicitly details each author's contribution (D'Asaro et al., 2014).

3.5. **Using Your Committees and Your Group.** As a graduate student, you will have an advisory committee, a preliminary examination committee, and a thesis committee all composed of faculty and experts relevant to your research topic. Some of them will be potential collaborators, sharing very similar research interests, and some are chosen for breadth of science. Some members may be outside of Climate & Environment, outside of DEEPS, or even outside of Brown. It is important for you to maintain contact with these faculty about your work. They are in the ideal position to offer specific and general advice about your research direction and development as a scientist. You should have a committee meeting *every semester*. You should also send emails to them as significant developments occur, such as submitting a paper, winning an award, getting a model running, etc. You do not need to have a specific reason for them to reply, but they may surprise you with useful advice at such times. Importantly, you need to have such regular communication so that when you do need their advice your collaborative relationship is already healthy and functional (see the surrounding sections).

Do not hesitate to schedule meetings far in advance, faculty are much more receptive when they know why you want to meet and when. Dropping by their office once or twice a year, and expecting spontaneous, yet brilliant advice is ridiculous. Send update emails regularly with no expectation of a response to keep them in the loop. If you need to request a meeting, do it in advance if possible and with an agenda specified in the request. It doesn't need to be formal, but "I'd like to talk to you about difficulties I'm having describing my model results in my thesis" and "I'd like to talk to you about my recent violent trauma" are both appropriate topics for meeting with a faculty advisor. Obviously, however, they require different preparation on the part of the faculty member and such preparation is necessary for an optimal outcome.

You should also interact regularly and spontaneously with other group members, keeping in mind (of course) that they are busy, too. They will get to know your work well over time, and may be in a good position to help out with specific ideas and tips. I love for multiple group members and alums to be authors on papers; it signifies a successful internal model of collaboration.

3.6. **Integrity, Ethics, and Politics.** One of the most important ways that you can gain productive collaborations is through building of trust. You and I will be building trust through our work together, and this is true for any other collaboration as well. What does my trust in my scientific collaborators derive from?

- **A belief in their abilities and thoroughness**: I do not think they cut corners or approximate unduly or in unacknowledged ways.
- **A belief in their scientific integrity**: I do not think they are trying to deceive me or the readers of our papers. I do not think they are trying to claim credit for work that is not their own. I do not think they are trying to cast unfounded doubt on their competitors.
- **A belief in their scientific ethics**: I do not think they are likely to use our work together in ways that I would not approve of without discussion with me, such as encouraging destruction of the environment or development of weapons.
- **A belief in their willingness to report problems**: I trust them to tell me if they perceive a problem in my work, my students' work, or my collaborators' work. Even though such information may be inconvenient for me, I will act on it accordingly and not blame the messenger.
- **A belief that their politics do not trump their science**: In climate work, this can be a problem. It is important to understand when politically sensitive studies are occurring (e.g., our new result implies that the oceans are warming faster/slower than previous studies). On these kinds of projects, it is particularly important to mind scientific integrity, abilities, and thoroughness and to be as sure as humanly possible that these concerns override any political leanings members of the group may have.

You should be aware that I am working to hold myself to the highest standards on these fronts, and that I am evaluating you and our collaborators the same way. When you show me data, I expect you to accurately portray how thoroughly vetted it is. If it is likely to change under a different analysis, or you think there may be a bug, say so. If you have double-checked and triple-checked, but the results still are confusing or unexpected, say so! That may be a sign of the importance of the result. When you write a paper, it is often the case that details must be shortened or left out, and certain poorly understood exceptions must be handled. Interactions with peer reviewers often bring up such concerns. It is acceptable to reduce detail for the purpose of clarity (i.e., they are unneeded), it is not acceptable to reduce detail to cover up weaknesses of the approach or results.

I realize that you are still learning to navigate these waters, and may make unintentional mistakes with ethical or integrity consequences: no problem. However, if I learn that you (or any group member or collaborator) is intentionally falsifying results or hiding data that show disagreement, I will take direct action. This may include termination of my collaboration or your position, and will certainly include mention in any future opportunities that arise (recommendation letters, conversations at meetings, etc.).

You may find the National Academies report on integrity in science helpful: `http://www.nap.edu/21896`.

3.7. **Am I Wasting My Time?** Being comfortable with muddling about a bit, or staring into the void of the unknown, is part of being good at research. However, many people lose track of time, run up too close to deadlines, get overwhelmed by self-doubt or feelings of inadequate progress, etc. So, here are some things to be on the lookout for, which can help you identify when you may be drifting from the winding path to progress to the path to missed opportunities.

Do you feel like avoiding Baylor or the group until you make more progress? This feeling is a key sign that you should do the opposite, and seek help immediately. Often, just talking through your issues will clear the way, or give you the strength to make another push.

Have you checked anything off of your research list this week? If not, you probably have bitten off too much in one bite. Come talk to Baylor, or make a list with smaller, more achievable goals. If you don't have a list, make one and put "make research checklist" as the first item. That way, you get one goal checked off right away! Some weeks, especially those with exams, illness, travel, vacations, etc., will be less productive. That's okay, but two in a row is a problem, and a month is a major issue. If you go a month without checking something off of your research list, you are REQUIRED to meet with Baylor ASAP. If you're stuck on research, do other productive work to get over the frustration: read the grad school handbooks (`http://bit.ly/1ISyNln`, `http://bit.ly/1hP0HZP`), or a book on careers (Fiske and Fiske, 2001; Vick et al., 2008) or writing (Turabian, 2013; Schimel, 2012; Glasman-Deal, 2010), or a report on new directions in oceans and climate (Goddard et al., 2013; Griffies et al., 2010), or write something easy that can be included in other work later (a description of code you've written, summaries of papers you've read, etc.).

Have you charted out your deadlines? It is a good idea to find out early when a thesis draft is due, when you have to register for a class or a conference, etc. It is the worst kind of research failing to forget a form after all of the hard work of getting results is done. Also, making self-imposed deadlines in advance (Chp. 1 by this month, Chp. 2 by next) is a great way to reduce panic if you are working on a thesis. Ask Baylor about overall formatting, etc., to help in this process.

When did you last practice your elevator speech (i.e., 2 minute version of what you're working on)? This practice is part of our group meetings, but it is also part of your continual re-assessment of what you are doing and why it is important. As a scientist and educator, you need to be able to sell your ideas on the spot in person and in writing. Giving your elevator speech to diverse audiences is good practice at linguistic and conceptual gymnastics, and good career practice, too.

Do you feel like you are constantly worrying about research progress, but your schedule is just too full with ...? This feeling is a different version of the avoidance behavior mentioned above. Procrastination or overscheduling yourself with fun or coursework or other non-research can be a sign that something isn't right about your research topic or approach. Group meetings, regular meetings with Baylor, and checklists with small, achievable goals are there precisely to catch these lapses and to help realign.

3.8. **Research Brings Up Lots of Feelings.** Most of the people I know who drop out of research do it because they have *emotional* issues with research, not trouble with skills, talent, or cleverness. You will not like everything you do in research. Some research tasks are frustrating, boring, smelly, nauseating, hard, and even painful. Researchers are usually rife with self-doubt, frustration, injury from perceived slights by colleagues, and the loneliness of working hard on something you can't explain to anyone. *Having these feelings is totally normal*, especially when you first begin research. You will experience at least three emotional lifecycles of graduate research project feelings: curiosity, then some discomfort, then the effort of pushing through, then a eureka! moment or two when something works, and finally to feel what it is like to be clever at *getting things done* and to be acknowledged for it. Getting comfortable with this emotional cycle, and celebrating the good, is part of what you are learning.

Piled Higher and Deeper (`http://www.phdcomics.com`) and Randall Munroe's xkcd comic (`http://xkcd.com`) are good ways to help laugh through the tears research sometimes brings. You can also talk to Baylor or seek counseling, in both cases earlier is better!

3.9. **Do I Like this Work?** The feelings just described are what research feels like for your whole career. Later, you will be more comfortable with the discomfort, and optimize how to seize and celebrate the joys, but research is never easy all the time. When your project or support window is completed, think about whether you feel like the good outweighs the bad. If it does, then go for it! If not, consider how your next project or chapter might be better–less modeling? more fieldwork or observations? more/less statistics? more/less analysis? Just because one project within your research oeuvre wasn't a good fit with you doesn't mean you don't like research as a whole.

3.10. **I Identify with a Group/Gender/Culture/Religion/Sexuality that is Uncommon in Science. Is It for Me?** Yes! You are just what is needed! Take a minute to think of all the ways your unique background will give you a different perspective and strengths as a scientist. These will help you to ask questions or find answers that no one else can!

However, some scientists and professors are socially incompetent and culturally ignorant. There have been studies showing that even well-meaning scientists who consider themselves allies and those who are themselves from underrepresented groups sometimes make decisions or judgments that are biased. This problem is not unique to the sciences. There may be times when you feel particularly wronged or need support. I am here to help. It might be through finding a relatable mentor, or utilizing resources from groups I work with such as `http://mpowir.org` and the Broader Impacts group of the Brown Science Center. It is my goal to build a more diverse scientific community, and supporting early-career students is critical.

Scientists being scientists, many scientists and science administrators are becoming convinced by the evidence from these studies. For this reason, there are increasing opportunities and a desire among scientists to expand the representation of underrepresented groups in the sciences. You can take advantage of these opportunities, and help to bring balance and the improved environment of a diverse workplace to the sciences. I have worked in more and less diverse labs, and diverse ones are the best!

3.11. **I have a Family/Personal/Learning Disability/Trauma/Health Issue that Affects My Schedule, Progress, Public Speaking, Writing, Etc.** No problem–it happens all the time. Just make a plan with Baylor about accommodations–early in the research relationship is better. Normally, you do not need to share any more details than you are comfortable with, and there is lots of flexibility in research that makes adaptation and mitigation easy.

3.12. **Applying to Postdocs, Job Searches, Preliminary Exams, and Thesis Defenses Bring Up Lots of Feelings.** Many of your feelings of self-doubt and anxiety just described are exacerbated when career decisions and evaluations are on the line. They can easily lead to procrastination; sleeplessness; drinking, drugs, and eating problems; writer's block; and whiffing interviews and examinations. The way to avoid this is to seek sympathy and empathy from family, friends, group members and colleagues, to be sure to celebrate with them what is going well, and to keep exercise, eating, sleeping, and partying under control. It is a good idea to start early and small in preparing for these processes, talk to Baylor about how to begin.

The preliminary examination is often a source of excessive worry for grad students. The key is to get *some* research results early and in a form that can be used. If you are experiencing anxiety, use it to study by solving problems from textbooks (Vallis, 2006; Cushman-Roisin and Beckers, 2010; Drazin and Reid, 2004). That will help you become more broadly prepared for all of your career!

Don't be afraid to ask Baylor for recommendation letters after or during your project. You may be feeling unsure about how good the letter will be. Check out the next three sections for a better idea of what Baylor thinks about and writes in his letters.

3.13. **Publish or Perish.** Academia really has only two goals: education and research. Plus, much of the university is engaged in seeing the results of these through to benefit the world. You are already aware of the education part, and probably also realize that academic degrees are the way that education is signified. Grades and transcripts play a much smaller role. Likewise, research is signified by the publication and dissemination of results. The gold standard is peer-reviewed articles or books, but conference presentations, theses, and other publications are also ways to establish a result on a firm footing where it can be communicated, shared, reproduced, and built upon.

Grad students must participate directly in peer-reviewed research publications, and their contributions are often featured in these publications. You may also be working on projects with Baylor or other group members as lead. Baylor thinks it is very important to credit grad students when this is so, with co-authorship, acknowledgments, etc. You will be given as much responsibility and credit as you appear capable of handling. There are often opportunities for you to present this collaborative research or your own work, through posters or other meetings, etc., which you can seek out and discuss with Baylor.

Why do we still do these things in the age of the internet? Can't we just tweet or blog every new formula as they come? No, because writing an article, or presenting at a conference requires a re-evaluation of the logic, techniques, flaws, and implications of research. This re-evaluation is as important in understanding a result as the result itself, and often only comes when things are written out.

If you stay in research, you will be judged on the basis of your publications. No one criterion will be dominant, but number, significance, skill, clarity, and drawing the attention of other scientists are all part of it. Even as an grad student, you might feel pressure to write a report particularly well to incite good recommendation letters, etc. This pressure makes many people panic, causing writer's block, procrastination, etc.

To reduce the panic, try not to focus on what the writing says about you, but what it says about your research. Is this the best way to make your argument? Is there a clearer or simpler way to state your hypotheses? Who will read it? What do they need to know? If they want to reproduce your work, can they? If another student picks up where you left off, have you given them the tools, references, and details that were so hard won by you? Remember, the real reason why we publish is to present our results, not to promote ourselves. If you focus on getting and presenting results, the judging of you as a scientist will come naturally.

3.14. **What Does a Good Graduate Research Outcome Look Like?** I like to structure a graduate career in three stages, which might result in one or more publications each. You will also have ample opportunities to present each at conferences.

Your first project will begin with a structure provided to you by me. I will give you suggestions of interesting hypotheses and tasks (often directly from a proposal or ongoing collaboration effort), provide you with tools (models, software, papers, notes), work closely with you on interpretation of results, and help you through the writing, submission, and revision process. Generally this paper will be strucutred to be straightforward, laying the groundwork of tools, models, etc., for your later work. There are many potential pitfalls just in getting through the process, and it is really helpful to get one in the bag to build experience and confidence. This stage generally results in one paper and one thesis chapter, plus a large fraction of the reading and background work that goes into the thesis introduction.

Your second project will be considerably more your own. You will develop the hypotheses and questions, although the topic is usually related to your first project (since you already have tools and are familiar with the background literature by this point). You will be able to see deeply into the topic at this point, and may see connections and opportunities that would not have been possible before taking on the first project. This stage may involve multiple papers or thesis chapters.

You will generally do your preliminary examination after submitting and revising the first paper, your project writeup will also include preliminary results and ideas for completing the second project. Rather than waiting until the second project is complete, it is much better to have the examination as soon as you are ready with this material.

The third project is entirely up to you to design and execute. Some past students have continued along the course of the first two projects, some have done multiple smaller projects, and some have done a big project only loosely related to the rest of the thesis. This stage may involve multiple papers or thesis chapters.

A good outcome in one project involves: a clear statement of what you are trying to do (hypotheses and research questions), a list of the tools and references you found useful (bibliography), some tasks being completed (results), and some form of communication of these (paper or thesis chapter, possibly augmented with presentations, slides, webpages, data, or computer code). Projects that have culminated in a paper are generally a coherent story, with sufficient quantity and quality of results to stand on its own. The audience for a paper or thesis chapter is twofold: scientists in the field (e.g., those who are most interested at conferences), and a student such as yourself before you began the project. The audience for the other documents may vary, but the primary ones are Baylor, his group, and students in your position who might pick up where you left off.

3.14.1. *Papers and Thesis Chapters.* You may wonder about how papers that are submitted for peer review are considered in thesis work. I have a simple system, which avoids issues of multiple-authorship (if you are only one of many authors, which part of the paper was yours, so that you can use it in the thesis?), copyright and self-plagiarism (you can't really re-use words and figures from a paper as a separate work), and writing. The system is that the chapters of a thesis are arranged by intellectual content, so that there is an overarching narrative of the whole work. Any papers you have written will be included as appendices within the thesis. Chapters that draw on the papers can be much shorter and less detailed, as you do not need to rehash the technical sections such as model descriptions or derivations, instead you just summarize the pieces that fit into the overall narrative. There is no need to have one chapter per paper–whatever makes the most convenient, logical ordering of chapters is best. Chapters that draw on material not yet submitted as papers can be just written simply, and adapted to paper form after the defense, etc. Generally, theses are not published as books, but I will permanently provide a copy from my webpage (as you can, too). You can see how students have organized their theses by looking at `http://fox-kemper.com/pubs` under Student Publications.

Being a good colleague and collaborator is also an important part of the research experience. This means coming to group meetings and recommended research seminars, asking questions, participating in discussions, offering advice if you have it, and seeking out opportunities to learn, improve your research, and broaden your interests.

Collegiality also means behaving or learning to behave in a manner that leads to everyone being happy and productive. Pay attention to cues from group members: Are they too stressed to chat? Are you being too aggressive in critiquing their research? Just as bad, are you being too flattering, obsequious, or fawning instead of offering constructive criticism when they need it? Science, including our group, is a place for oddballs with weird behavior, interests, and unique tastes in clothing. Most importantly, discrimination, bullying, teasing, and prejudice are not tolerated. On the other hand, make yourself easy to be around in the lab. Don't wear stinky gym clothes or too much cologne. Be aware of how a messy workspace, messy eating, making too much noise, unplugging equipment, or failing to be on time is negatively affecting your interactions with the group. We have a fun, exciting, and casual work environment, but only because we all bring our best selves.

4. Resources

Baylor has lots of experience teaching scientific reading, writing, and research and can get you started.

4.1. **Writing.** Baylor posts and collects sets of detailed instructions on scientific and other writing. Here is one example (`http://bit.ly/1JKVY2Y`). Lots of other great books are out there, too (Turabian, 2013; Schimel, 2012; Glasman-Deal, 2010).

4.2. **Reading.** The joke is "hours of time in the library were avoided by months in the lab." Seriously, there is excellent science written up out there with you as the intended audience! It is easily found through google scholar (`http://scholar.google.com`), the bibliographies of other papers or textbooks, or by asking other group members. If Baylor or group members advise you to read a paper, do it and you'll learn!

As a rule of thumb, you should scan at least one new paper related to your research a week. Scientific reading is not the same as reading a novel or magazine article start to finish, because the style is intentionally formulaic for fast skimming. After you practice it will go quickly, just as reading the newspaper does. Baylor posts and collects sets of detailed instructions on scientific reading techniques. Here is one example (`http://bit.ly/1NklJNw`).

4.2.1. *Libraries.* You have access to a wide variety of online science when you are on the on-campus network. If you are off-campus, you can access the same resources by searching through `http://library.brown.edu/libweb/proxy.php`. You can also search for textbooks `http://josiah.brown.edu` or borrow them from Baylor. Please don't keep his books forever; while he writes down who has what in a notebook, some of them still disappear.

4.3. **Math.** Lots of the research topics in the group are highly mathematical. Some good references are Boas (2006), Arfken et al. (2013), and Bender and Orszag (1999). Some of these have electronic versions (see bibliography). Baylor's notes are also helpful (http://bit.ly/1O7kZdQ). Mathematica online (http://bit.ly/1VHUduQ) and Wolfram Alpha (http://www.wolframalpha.com) are excellent resources, and wikipedia is not bad either!

4.4. **Coding.** There is lots of coding in the group–FORTRAN, c++, Matlab, Mathematica, python, xcel, etc. We use various numerical models as well, on local machines, local clusters, and remote supercomputers. It's a good idea to ask around and figure out who is working on a similar platform or with a similar model right away. It is also amazing how much you can figure out by cutting the text of an error into google!

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