

ADVICE FOR UNDERGRADUATES BEGINNING RESEARCH

BAYLOR FOX-KEMPER

ABSTRACT. Some tips and resources to get you started!

1. CONTACTS

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Closely related faculty:

ECF: <https://ecf.brown.edu/>, DEEPS: <https://deeps.brown.edu/>, Fluids at Brown: <https://fluids.brown.edu/>, Institute at Brown for Environment and Society: <https://ibes.brown.edu/>, Brown Theoretical Physics Center: <https://btpc.brown.edu>

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, if you are working during the academic year.

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 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. EXPECTATIONS

3.1. Baylor's Responsibilities.

- (1) Advice on research, such as this document and lots of conversations about your direction, opportunities, and available resources.
- (2) Being supportive of who you are, what you are trying to accomplish, and who you are trying to become. This applies to teaching, research, administration, and other aspects of university life.
- (3) Pursuing funding for you and your research needs, including undergraduate research opportunities (UROPs, UTRAs, SURFs, REUs), travel, conference fees, specialized computing, etc.

Date: July 31, 2024.

3.2. What Baylor expects from you.

- (1) Getting involved! Come to lab meetings, ask questions, read papers distributed to the group, and look for opportunities to participate.
- (2) Mentoring and collaborating with other students in the group
- (3) Taking initiative to find time to do research, which might be an independent study, a summer or academic year internship, a senior thesis, etc.
- (4) Trying to reflect your present understanding accurately—you are learning to be just enough confident, neither overconfident nor unappreciative of your potential and present knowledge.
- (5) Reporting your progress for others. This might be as simple as a lab notebook, jupyter notebook, conference poster or slides, or commented piece of code or dataset uploaded to Baylor’s google drive or the Brown Digital Repository (<https://repository.library.brown.edu>), or as sophisticated as an undergraduate thesis or a published paper (<https://fox-kemper.com/pubs>), but your time in the lab will be limited. We want to build on your successes, not lose them when you go!

4. GENERAL COMMENTS: WHAT IS RESEARCH?

This may be your first experience with doing 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.

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.

A “Scitoon” produced at Brown on this topic can be found here: <https://www.youtube.com/watch?v=mV0bUQpz468>.

4.1. 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 event 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 a 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**.

4.2. 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 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 almost anything academic you’ve done so far, 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. 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 doable by someone at your level only if it is clear that the answer can be gotten using tools you know. After you are done with the research, you’ll be able to go back with hindsight and construct a multi-stage question or theoretical structure, but you don’t need one to get started! Research questions almost always require more training en route and lots of dead ends or roadblocks to be avoided.

4.3. Do I work for Baylor, or is he teaching me? Technically, it depends on your role. If you have an UTRA or are funded by a grant, you work for Baylor. If you are writing a thesis, 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 if you are funded to do research as an undergrad, the expectation is primarily that your training is more likely than significant results from such a short 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.

4.4. 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?

Senior Undergraduate Student

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.

4.4.1. *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 ..."
- (7) Follow up with an email shortly afterward, "Here is my written understanding of exactly what we agreed, 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.

4.4.2. *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).

Deciding whether an authorship or an acknowledgement is appropriate can be hard, and hurt feelings are common in this department. If you are in doubt, discuss with Baylor. It is possible, though rare, that you can poison a research relationship by making a bad decision either way (including an author who doesn't deserve it aggravates other partners and not including a collaborator who thinks they deserve to be are both trouble). The Vancouver criteria established by the International Committee of Medical Journal Editors is a useful reference of standards for authorship (<http://www.icmje.org>).

The ICMJE recommends that authorship be based on the following 4 criteria: 1. Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND 2. Drafting the work or revising it critically for important intellectual content; AND 3. Final approval of the version to be published; AND 4. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

In our field, 'maybe' cases of qualification 1 frequently result from a co-author sharing code or results that are not publicly available. Here, if in doubt ask the code contributor, because development of code is a thankless task that is not presently credited by academic bodies correctly. They may be comfortable with an acknowledgement or have a specific paper they'd like to you cite in the model description instead of a co-authorship. Point 2 is hard to assess in advance, but it should trigger a co-author to at least respond to your emails. Point 3 can significantly delay submission, so I recommend an 'opt out' rather than an 'opt in' email: i.e., "If I don't hear from you by Friday, I will take it to mean that you are OK with the submission of the paper." Point 4 is thus implied, but it, too, can be tricky if you undergo major revisions in the later stage of publications. You should always share your response to reviewers documents and a `latexdiff` or track changes version of the revisions with your co-authors if possible before resubmitting any major revisions. These documents can be helpful to reviewers as well, so it is good practice to learn how to create them in your typesetting software. You should always email the submitted & accepted versions to all co-authors (and other interested parties, e.g., your thesis committee, grant co-investigators, and Baylor if he's not a co-author).

4.4.3. *How should I address collaborators and professors?* There are enormous regional variations in formality of address. Some places might require "Herren Professor Doctor X" in an email or even the classroom! You may have been raised or trained in such a place. Science in the US and at Brown is generally less formal, and you can always refer to Baylor by his first name. However, writing an email to a collaborator or editor that you don't know well does benefit from some formality to begin. You can then respond in later correspondences based on however they sign off on their responses to you. You are far from an expert at this stage, so do not expect everyone to treat you as an equal—they have earned the formalities if they choose to hear them.

4.5. Using Your Faculty and Your Group. As an undergraduate student, you have relationships with a wide group of faculty, concentration advisors, research advisors (me and possibly also in your home department), and possibly a thesis committee. These are 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 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 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. If your email just says, "Can we meet this week?", no preparation will occur.

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.

4.6. 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>.

4.7. Am I Wasting My Time? Being comfortable with muddling about a bit 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. If you're stuck, you might find reading a report on new directions in oceans and climate (Goddard et al., 2013; Griffies et al., 2010; Fox-Kemper et al., 2018, 2021), or writing something easy that can be included in other students' work later (a description of code you've written, summaries of papers you've read, etc.) a way to break out of your rut.

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.

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.

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.

4.8. 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. The emotional goal of an undergraduate research project is to experience a cycle of 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. This emotional cycle is what is really important about an "undergraduate research experience," often more important than any scientific results or skills you may acquire during the project.

In fact, the American philosopher Peirce (1877) notes that feelings of doubt are required as a motivator for inquiry and the quest for truth rather than unfounded beliefs.

The irritation of doubt is the only immediate motive for the struggle to attain belief. It is certainly best for us that our beliefs should be such as may truly guide our actions so as to satisfy our desires; and this reflection will make us reject any belief which does not seem to have been so formed as to insure this result. But it will only do so by creating a doubt

in the place of that belief. With the doubt, therefore, the struggle begins, and with the cessation of doubt it ends. Hence, the sole object of inquiry is the settlement of opinion. We may fancy that this is not enough for us, and that we seek, not merely an opinion, but a true opinion. But put this fancy to the test, and it proves groundless; for as soon as a firm belief is reached we are entirely satisfied, whether the belief be true or false. And it is clear that nothing out of the sphere of our knowledge can be our object, for nothing which does not affect the mind can be the motive for a mental effort. The most that can be maintained is, that we seek for a belief that we shall think to be true. But we think each one of our beliefs to be true, and, indeed, it is mere tautology to say so.

As a scientist you ought to lean toward doubting your beliefs, not doubting your doubts!

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. The DEEPS "Failure Project" tells the story of some DEEPS faculty and how they struggled in the past (<https://drive.google.com/file/d/10g-i6A5Q07WhwE60QgD0kWDKE6rmbn8H/view?usp=sharing>). If you feel like you want to see how far you can go from where you are now, you can read Baylor's undergraduate senior thesis here (<https://fox-kemper.com/pubs/pdfs/Fox-KemperReedThesis96.pdf>). You can also talk to Baylor or seek counseling, in both cases earlier is better!

4.9. 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!

4.10. When Should I Expect Praise? One topic that frequently comes up in discussions of department climate and student satisfaction is feeling overwhelmed by criticism instead of noticing the aspects of your science that have worked. Science is critical and sometimes antagonistic, deliberately, so that the truth comes out and missteps are revealed. However, science is also hard and requires effort, so good work should be noted and honored.

I try hard to point out the good aspects along with critiques, especially with students. Preserving the good, e.g., during paper revisions, is as important as removing the bad. One standard approach from counseling and mentoring that I like is to provide a "compliment sandwich". Start and end a conversation or email where critiques will be made with positive notes. Every meeting with me and every comment from me should contain both positive and critical comments. If you feel that's out of balance, let me know. It may be reflective of a needed change, possibly in your research direction but more likely in our working relationship.

However, that is oftentimes not enough when you are stuck or receive a bad review or grade. It can be good to check in with a friend, explicitly ask Baylor why he is optimistic about your research direction, or review your past successes that have led you to be here. It may surprise you, but I had to train myself to think gratefully while filling out annual reports or updating my CV, so I use these documents to recharge me. I frequently need the boost of confidence or reassurance to take on a difficult or irritating task.

You may be accustomed to getting excellent grades—you did get into Brown or into a working relationship with Baylor! However, you are not yet an accomplished scientist and you have much to learn. This fact is not to say that you will not one day become an excellent and independent scientist, but it is not expected of you yet. So, the work that might earn you an A in a class is probably not ready for a peer-reviewed publication. Although the ideas in it might be, the standards of proof are much more complete than anything you have probably encountered before. That's not to say they are out of your reach, they are not, it just will take more work and revisions passing drafts back and forth with collaborators to finalize. Presentations on your work, e.g., posters and conference talks, may be more readily accessible to you, but you should plan to create a draft early and review it with Baylor and the group. There are lots of little tricks that make for good presentation, but are not at all obvious to discover on your own.

4.11. 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!

4.12. 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.

4.13. Applying to Grad. School, Job Searches, 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.

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. One purpose of this document is to give you better idea of what Baylor thinks about and writes in his letters.

4.14. Clothing and Appearance. You are in control of many aspects of your budding reputation as a researcher, and what you choose to wear is one aspect over which you have enormous control. As you know, scientists are frequently oddballs, and groups of scientists are definitely a 'mixed bag of nuts'. Unlike in the bad old days where dress codes were formalized and scientists were homogenous in gender and background, modern clothing choices require more thought. Scientists these days tend to be informal: I have heard earth scientists' clothing described as "ready at any moment to go hiking".

However, clothing can easily be productive or counterproductive. Good examples of productive clothing choices are: wearing clothes that are appropriate for the activity level (i.e., don't dress for swimming when going to a conference), show respect through an appropriate level of formality (e.g., job interviews and conference presentations should be a bit above the ordinary, but probably not the same as a wedding), and wearing clothes that make you recognizable. This last point is sometimes overlooked, especially by men, but I have heard many stories of scientists tracking down young scientists they don't know later at a conference based on a 'signature' item worn during their presentation (a scarf, a cheerful shirt or sweater, etc.). On the other hand, you don't want to stand out in a counterproductive way. You don't want to be wearing clothes that signal disrespect ("I really don't care, do u?"), or signal sexual availability more than scientific prowess, or are unpleasant or distracting to be around because they are dirty, smelly, or make everyone comment that you have dressed for the wrong weather.

There is also a lot of cultural baggage surrounding clothing, which may lead some scientists to wrong or uninformed conclusions. For example, consider the discussion of politicians needing ‘gravitas’, or being ‘likeable’ or ‘articulate’ to be electable. These are poll-tested code words that trigger misogynistic and racial stereotypes. I *am not* suggesting that you must give in to such stereotypes by diminishing who you are. I am suggesting you claim a degree of control in how you choose to operate given these conditions, which might actually be an appearance of protest if that is what suits you.

You may not know what to choose or choose inappropriately. Rest assured that this is a welcoming society, so it’s probably OK no matter what, but if you feel uncomfortable or don’t know what to choose do discuss with a friend you trust.

4.15. 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.

Although undergrads rarely participate directly in peer-reviewed research publications, their contributions are often featured in these publications later. You may also be working on a thesis or written project with Baylor, which is a reviewed publication, just one reviewed by professors instead of scientific peer review as a journal article would be. Baylor thinks it is very important to credit undergrads when this is so, with co-authorship, acknowledgments, etc. There are often opportunities for undergrads to present their research, 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 undergrad, 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.

4.16. What Does a Good Undergraduate Research Outcome Look Like? It depends, largely on the basis of how much time you have to spend on the project.

For a summer or semester independent study, a good outcome 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 (poster, paper, powerpoint slides, webpage, set of figures, data, calculations, or computer code with explanation, or a copy of a lab notebook). The audience for these documents may vary, but the primary ones are Baylor, his group, and students in your position who might pick up where you left off.

For a project lasting a year or multiple semesters, a thesis or at least one research paper is expected at the end. The goals and audience are the same as for the shorter study documenting results, but some more polishing is possible with this amount of time. This writing will improve your results as well; read

the previous section if you don't see why. Baylor will post your written report along with Master's and Ph.D. theses (<http://fox-kemper.com/pubs> under Student Publications). It is a good idea for you to check out the preceding ones as you are preparing yours, for formatting and inspiration. Just as you are writing for future students' benefit, you are exactly the audience they had in mind!

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.

5. RESOURCES

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

5.1. Writing. Baylor posts and collects sets of detailed instructions on scientific and other writing. Here is one example (<http://bit.ly/1JKVY2Y>). See also books like Turabian (2013); Schimel (2012); Glasman-Deal (2010).

5.2. 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/1Nk1JNw>).

Times may come when you need to read a particular paper extremely deeply, but do not expect to do this with every paper! Also, do not feel shy about stating that you have not read a paper that closely, it is important for others to not assume you grasped more than you did when discussing with you about a particular paper. You might come away from the conversation needing to go back and read more deeply, or you might learn that paper has little to do with where you are going and a superficial understanding is fine for now.

5.2.1. 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.

5.3. 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/107kZdQ>). Mathematica online (<http://bit.ly/1VHUduQ>) and Wolfram Alpha (<http://www.wolframalpha.com>) are excellent resources, and wikipedia is not bad either!

5.4. 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 and pasting it into google!

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