I strongly believe that doing research is the best -- really, the only -- way to learn true science. By "true science", I mean science as a lens through which you view the world, a way of interacting with your environment. This definition of "science" is much more inclusive (and more powerful) than a set of facts or principles, and it can only be experienced by doing.

I am unabashedly selective in choosing student research colleagues. I base my choices on my judgement of the *attitude* and the *aptitude* that individual students display, and my choices may not have much to do with GPA or classroom performance, even though I may ask for a copy of your academic record. I generally give preference to students who are early in their Denison careers, and I generally give preference to students who are considering a career in research. Rising seniors whose main objective is to become a physician may have to prove to me that research *in itself* matters to them. I reserve the right to be cagey and not commit to taking any students until mid-January of the year in which their research will begin, but once I commit to you, you can be assured that I will do everything in my power to provide you with a top-notch research experience and to make myself available to you as a resource in the lab, the classroom, and life outside of Denison. In short, I view this as a serious, and mutual, commitment.

Because science, for me, is a way of life, I have high expectations for what constitutes meaningful scientific research. And because I see science as a process rather than a body of information, my expectations are those of process; I do not judge research as "good" or "bad" on the basis of the results, but rather on how it was conducted.

1. I expect, first and foremost, that you will take emotional and intellectual ownership of your research project. This is YOUR project. I expect you to become the world's foremost expert on its inner details and rationale. To do that, you must be invested in it, you must apply yourself to the experimental work, and you must be curious about it. You must care. I know that emotional and intellectual investment in a research project is subtle and cannot be measured in terms of the number of hours that you spend working on it. Thus, I will *not* ask you to keep track of hours or become upset if I don't see you spending X, Y, or Z hours at the bench or at the computer or in the library. But experience tells me that your level of investment will show, and I do ask you to regard this research as a serious commitment. For senior research, it would be reasonable for you to expect to spend at least 12 hrs per week, with about 8 hrs/week in lab and at least 4 hrs/week in the library (see points #2 and 12). During the summer, forty-ish hours per week is a reasonable target, again divided between the lab and the library.

2. To satisfy your curiosity in your project, you must read. Scientific research does not occur in a vacuum; *it is only in relation to the work of others that our individual efforts have meaning and justification*. Therefore we must know what others are doing. To do that, we devour the literature. Expect to read at least one paper per week during the school year; during the summer a better target would be one a day. Of course, consuming data is only productive when you can place the new information into some conceptual framework. For that reason, it is important to stop frequently in your reading and ask yourself how it all fits together. When you can't answer that question, be sure to stop reading and come discuss it with me or with someone else before you try to acquire any more information!

3. In order for you to learn the most, for me to be of greatest use to you, and for your research to be successful, you must be honest with yourself and with me. If you are uncertain about something, don't be ashamed of your ignorance; ask for help! If I ask you a question and you don't know or can't remember the answer, there's no shame in that; just tell me so! If you have set up an experiment and you realize part way through that you've done something wrong, don't try to cover it up; stop what you're doing, record the error in your notebook, and start over. Or stop what you're doing, record the error in your notebook, and decide what you can learn by doing the experiment in spite of its flaw(s). In all cases, recognize the situation and deal with it openly.

4. When it comes to results, I hold your work to the same standards that I apply to my own. Clearly, I don't expect you to know what a grad student or post-doc would know, and I don't expect you to be as fluid or comfortable in the lab as a more experienced lab rat. I don't expect you to be able to get techniques to work the first time, or to get them to work *every* time. But when your experiments do work, and when they seem to be giving us meaningful information, then I will treat your data just like I would treat data generated by a Ph.D. scientist. That is to say, I will insist that your results be *reproducible*, that they be *statistically significant*, that they be meticulously *documented*, and that they be generated in a *well-controlled* experimental context. In short, they must be rigorously defensible in the court of scientific opinion. If your work meets my standards in this regard, then it is world-class -- and I will have no qualms about publishing it and telling my professional peers about it at every opportunity.

5. Your head should have a deeper understanding than your hands. You'll probably use a wide variety of lab procedures in the course of your research. Many of these will be things you've never heard of before, and may never cover in one of your classes. As noted above, I'll never expect you to get everything right the first time down a new experimental path, and by the same token I don't expect you to know the reason for every step in every procedure you do. But I *do* expect that you'll take the initiative to learn everything you can about procedures you use so that you can clearly and carefully explain the techniques employed in your research (as always, if you have questions, ask me!). You are training to be neither a technician nor a piece of equipment; as a scientist, you should know *why* you do what you do.

6. You are part of a research team. I expect you to treat your co-workers (including me) with respect -- in your one-on-one interactions, in group meetings, and in your use of group resources and space. Please bear in mind also that the team you have joined is an ongoing entity that existed before you came on board and will exist after you leave. Therefore it is imperative that you leave group resources in good shape for those who follow you in this research program, and it is critically important that you carefully document your research so that your work can be replicated and built upon after you leave Denison. I will check your notes from time to time (especially as the need arises for me to incorporate your results into what I am writing or telling someone else) and give you feedback on your lab documentation practices. And as a general rule, I ask that you never take your lab notebooks out of the building unless you have made special arrangements with me in advance. A few pointers on lab notebooks and digital datafiles:

- Please use a bound lab notebook. I don't care specifically what kind you use; suitable ones are available in the campus bookstore.
- I don't care what exact format you choose for your notebook entries, but I'll be happy to show you options for both.
- Your notebook entries *must* be readable by another member of the lab.
- They must also be clearly laid out, and your logic and language must be accessible to anyone else in the lab who needs to learn from your notes, either tomorrow or ten years from now.
- Each entry must include
    - the date
    - what you did (in enough detail for you or someone else to reproduce your work based solely on what is written there; references to protocols written somewhere else should be clear and unambiguous)
    - what you found -- including observations on what happened along the way ("tube number ten looked a little cloudy") as well as notes, pictures, data tables, etc on the final outcome
    - what it means -- what can you conclude from this experiment? what can you do next? what other questions do the data raise? these notes should be started before you discuss your results with anyone else, and should be completed before you begin to lay out the next experiment
- All entries should be in pen, and should represent your original notes. If you need to recopy something for purposes of clarification or legibility, *add* the new text; *never* eliminate the original!

- ***It is very important that you keep a copy of EVERY original digital datafile resulting from your research*** (images of gels, automated sequencing files, etc), even those corresponding to experiments that "didn't work". Original data files and all files derived from them should be named systematically according to the following convention. This may feel cumbersome at first, but I assure you that it will save you, and those who come after you, considerable grief in the long run.
  - **your family name** followed by **the date of the experiment** followed by **an underscore** followed by **the type of experiment** followed by **any additional information**. I'd prefer that you use a numerical format for the dates with four digits for the year, two digits for the month, and two digits for the day. For instance, if on May 3rd of 2007, I take a picture of an agarose gel of a PCR experiment, and then I later modify the image file to change the contrast and trim off unused lanes, I should have two saved files:
    Kuhlman20070503_PCRgel
    Kuhlman20070503_PCRgel_trim&pretty
- Because I regard your lab records as part of the long-term resouces of this research group, I'll happily get you the tools you need to keep your records. If you need a notebook, or a set of colored pens, or a flash storage drive, let me know; I'll pay for it.

If you have any questions about good lab documentation, *please ask me!*

7. My effectiveness as an advisor is limited by your willingness to use me. You are a high priority to me. If you have a question or need advice or need reagents or need me to take over an experiment while you run off to do something urgent, do not hesitate to ask me, even if I appear to be busy. That is *my* side of the high expectation coin -- I expect that I will do everything that I can to be available to you when you need me. But you have to let me know that I am needed.

8. I expect you to tell me to bug out when I get in your way. I will be very eager to know your experimental results and interpretations, often before you know them yourself. When that irritates you, or when you want to learn how to do something without me hovering over you, please tell me so. My interest and eagerness to help with and participate in your work won't be diminished, but I will try to respect your wishes.

9. Please use equipment and reagents responsibly. With the help of Denison University, I endeavor to provide you with high-quality tools for your research. In exchange, I ask that you

- keep common-use areas scrupulously clean
- put reagents back where they are kept immediately after you are done using them
- treat equipment with informed care (this means that you will *read instruction manuals* and will ask me if you have any questions about proper use of any instrument)
- order (or ask me to order) refills on reagents *well before* we run out of the current batch (this means that you must be aware of the state of your reagents beyond simply sticking a pipet into the tube -- you *must* think ahead. Occasional slip-ups are probably unavoidable, but they are costly, both in terms of time and money, so you should take pains to avoid them.)
- for your safety, you should ***never*** work alone without making arrangements with me ***in advance***

10. I expect you to use only those reagents and supplies that you need, but also, not to use less. There is virtue neither in wasteful excess, nor in miserly corner-cutting that compromises your ability to design effective experiments. See Dudes' Rules #3, 5, 7, and 11. Enough said.

11. Our research meetings only benefit us if we both come to them well-prepared. In preparation for our meetings, I will make every effort to stay current with your experimental status, stay in touch with the relevant research literature, and accomplish the tasks that I agree to undertake for you. In turn, I expect you to come to meetings ready to tell me about what you have done at the bench (at times, in extreme detail) and what you have read *and what you think that it all means*. And I expect you to ask me for information and clarification and help and ...! as appropriate. Please make a point of bringing your notebook to all research meetings.

12. Writing and talking about your work are two of the best ways to see its meaning more clearly. As the end of your research period nears, I expect that you will compose your data and reflective thoughts in a concise, scholarly, authoritative written report. I will bend over backwards to help you in this process, but I strongly encourage you to begin the writing *now*, at the beginning, by reading and thinking and talking and writing in your notebook at every step of the way. Also, as your work progresses, I will work with you to seek out opportunities for you to tell the larger scientific community about all the cool stuff you are discovering. That is a great way to reflect on your work, to put it in context, and to understand its rationale well enough to explain it to others. Perhaps most importantly, by discussing your work with others, you gain the opportunity to see *your* work through *their* eyes. Invaluable.

13. Take the *Dudes' Rules* to heart -- think about your research, be honest, be careful, do it right -- and enjoy the search for knowledge.

Some notes on procedure and assessment…

1. I will typically request that you submit an informal (but nevertheless detailed) report of what you have done at a point about halfway through the research period (i.e., in late December for academic-year research, or around week 5 for summer research). This Interim Report will provide context for a one-on-one discussion of your research progress, and will help inform the direction of your research for the second half of the research period. It is an invaluable opportunity to look back at what you've done and ask why you did it and what you've learned. It is especially important for Senior Research students, both for informing your work and for shaping my assessment of your work. Together with a detailed literature review (in late November), the Interim Report will form the basis for my evaluation of whether Senior Research projects can be converted to Honors Research projects (more on that below).

Most research projects will also end with a more formal report -- typically a poster presentation for summer students, and typically a written report for academic-year students, though those aren't firm requirements. More comments on that below.

2. Our department has set up guidelines to ensure that students doing Senior/Honors research are progressing at a pace that should enrich the learning benefits of the research experience. In consultation with me and your secondary research advisor, you will have a chance to review and revise the departmental timetable to suit your assessment of your needs. For students doing research before their senior year, I think that this process of setting achievement and timing goals is a useful one as well. And in all cases, setting up a timetable of goals and objectives provides a convenient framework for periodic discussions of your and my assessments of your research progress.

2. Some students doing Senior Research choose to hold their work to a higher standard and convert their research to Honors Project status. This involves some paperwork and a review of the student's research aptitude by the faculty in the department. In most cases, the departmental review hinges on the research advisor's evaluation of the student's work to date. As noted above, my evaluation is based heavily on two pieces of written work -- a detailed literature review, completed by late November (that can be used as the core of the Introduction section of your final paper), and a thorough and introspective Interim Report on your progress-to-date (including any previous summer work, etc; this can be used as the core of your Results section). In addition to these pieces of writing, I review your interactions with me over your research period so far, and ask how well you are meeting the expectations (especially #1~6) laid out above. Throughout, I look for *evidence of independent initiative and independent design* of the research program -- some bit of *you* in the work -- which is, to me, what really sets an Honors Project apart from other Senior Research projects.

For students doing Honors projects, the main hurdle always appears to be the deadline date for submission of the Honors Thesis. I take pains to remind you that your Senior Research experience continues *after* that Honors Thesis is submitted. This mirrors the professional research world -- a line of investigation rarely stops just because the results have been submitted for publication. Thus loose ends and unfinished experiments should be brought to a close, and it is of ***critical*** importance that you spend some real time organizing your notes and reagents in preparation for your departure from Denison. As noted in #7 above, your research is part of an on-going, team effort. You will benefit from the work of your predecessors, and your work can inform the efforts of those who come into this lab after you. For that system to work, you and I will need to get together to go over the disposition of your notes and reagents. Finally, I ask any student who has been involved in the development of an assay or experimental procedure to submit an up-to-date, fully commented description of the procedure before leaving the lab. Distilling your acquired wisdom for posterity can be a very gratifying experience. Relish what you've accomplished!

3. Grading of academic-year research projects:

Overall: As noted above, I judge research by how it is conducted, not by what data it does or does not produce. That is, I care most about your intellectual development, and not about your productivity *per se*. Of course, productivity is often a good indication of your commitment of time and energy to the project, and so I am aware of it, but that is not the primary criterion on which I will evaluate you. More importantly, I want to see evidence that you are learning to think like a scientist -- to see the larger context of your personal experimental work, to design good experiments and interpret them conservatively, and to show the imprint of your personal intellectual engagement in the project.

Some specific questions I ask in evaluation are:

- how well are you meeting the expectations laid out above? I take these seriously; you should, too.
- are you showing evidence of intellectual ownership and growing in scientific maturity?
- do you come to our regular research meetings well prepared to discuss your findings and your questions? do you ask good questions and have good ideas?
- do your Interim Report and your final Research Report (or Honors Thesis) give evidence of articulate, introspective, honest analysis of your work? Can you place your work in the appropriate scientific context? Have you read enough to know how your work relates to the work of other scientists around the world and over the decades?
- do you have high personal standards for your finished work -- is it grammatically and esthetically clean, well thought out and well executed?
- were you responsible about finishing up the research period? Did you clean up your area, hand in your notebooks, label the reagents I want to keep and throw the rest away? Are your notes in a state that will help the next person who works on your project start easily, or will they require hours of deciphering?
- if you have produced a significant research accomplishment -- something that you feel should be counted in your favor in your grade assessment -- is it reproducible? Did you give me a protocol that I can follow to completion?

If you are ever curious about how I currently rate your work, do not hesitate to ask!

Generally, I grade research students on a simple A, B, C… scale (that is, without "+"s or "-"s). I have never given a 'D' to a research student, and hope never to do so; this grade would indicate personal investment at a minimal and superficial level and a gross failure to take responsibility for the project. I have rarely given a 'C', a grade that reflects my assessment that the student has taken neither the initiative to make a personal impact on the project, nor the time to achieve project goals, learn the scientific context of their work, or speak about the work in a scientifically mature voice. I will award a 'B' to students who I feel are conscientious in their attention to the lab work and lab environment, and who do some reading, but who have not really become involved enough in the project to take the initiative on seeing it advance. They are working, in other words, on *my* project rather than on *their* project. An 'A', then, is an indication that I feel you have met or exceeded the expectations laid out above, that *you* are the owner of your project both physically and intellectually,

that you are reading, thinking, discussing, and driving your work forward. That you are, in short, a scientist.

The Project Report: A major part of your final research grade will come from my evaluation of your final Research Report. Fundamentally, your paper is an opportunity to hone your ability to communicate scientific results and insights in a mature voice. I hope that you will also approach it as an excellent opportunity to reflect upon the intellectual context of your project and thus develop a more sophisticated understanding of why you were doing what you were doing (see point #11 above).

Your paper should take the general format and tone of the sort of research paper that you find in any scholarly biochemical journal. The Introduction should set up the scientific problem you are tackling; the Materials&Methods should detail *how* you are doing it; the Results will show *what* you found; the Discussion will present your perspective on *what it means*, *why* it is significant, and what should be done next.

I am frequently asked to tell students what level they should shoot for in terms of the technical sophistication of their content and language. Clearly, I don't expect a publication-ready manuscript. Indeed, for Honors Theses, this would be inappropriate, because at least one of your readers will be a faculty member with little or no formal training in biochemistry. Accordingly, it will be desirable for you to start your introduction from a more elementary and comprehensive perspective than you find in most papers. And I will insist that you use less technical jargon than the average scientific paper, or at least that you carefully explain the terms you use. In general, I think that a reasonable level to target is that of a second-semester junior Biochem major -- someone who knows some molecular biology, some organic chemistry, and some biochemistry, but may have no specific knowledge of your particular research area. Some students want their family or friends to be able to read about their research and so they've chosen to include an appendix that will bring a well-educated non-scientist up to speed enough to read the rest of the paper. I'll be happy to show you examples of effective writing from past students.

I look for writing that is fluid and accessible but written in a scientifically mature voice. I place a high value on the presentation of your work in its historical context and its definition in terms of the importance of the central question(s). Relevant published work from our research group and other groups around the world should be exhaustively reviewed, concisely summarized, and interpreted from your perspective and in your voice (your "literature review" due in November is an opportunity for you to get a good start on this). Data should be presented clearly, explicated lucidly, and analyzed critically. Experimental difficulties should be presented honestly and discussed in the context of what was done, what could have been done, and how your controls inform the interpretation of problematic data. Even if little "progress" was made on the project, I look for a clear sense that you know where you'd like the study to go if you were continuing to work on it, both in terms of overcoming the short-term obstacles and in terms of the questions you'd like the investigation to address in the long term.

Feedback along the way: To make sure that we are on the same page with regards to assessing your progress, I would like to spend one or two of our regular weekly meetings each semester in a frank discussion of how well each of us is meeting expectations for our respective roles in your research project. In addition, I will certainly be happy to give you as much feedback as you want on issues of experimental design and interpretation, and on draft versions of sections of your paper. A few notes on timing:

- different people work at different rates; some are very effectively motivated by deadlines while others do their best work well in advance of the due date. I will endeavor to help you set up a timetable that will make your research and your writing as productive as possible for you, keeping in mind that…
- Honors Project Reports are typically due in early April, so my attentions will be primarily devoted to any Honors students that I am supervising for the last few weeks before Honors Projects are due.
- all Senior Research projects (Honors or not) wrap up in what is probably the busiest time of the academic year, so I am almost certainly going to be distracted by competing concerns after the middle of March. Please be patient with me, and plan your use of me accordingly.
- I have found that for my past students as well as for myself, some of our best thinking about our projects happens in the closing stages of writing about the work. Accordingly, I *strongly* encourage you to plan to have your paper done (and that means *completely* done) one week before the due date. This will give us both a week to review your results and your interpretation and perhaps come to new insights about the meaning of your data and about fruitful future directions. And to catch typos and stuff, too.