How to think about science and becoming a scientist

By Jake Seliger and a friend

A lot of students want to know whether they should major in the humanities, business, or science, which is a hard choice because most of them have no idea whatsoever about what real science (or being a scientist) is like, and they won't learn it from introductory lectures and lab classes. So freshmen and sophomores who are picking majors don't, and can't, really understand what they're selecting—or so I've been told by a lot of grad students and youngish professors who are scientists.

One former student recently wrote me to say, "I **was** a biochemistry major with a dream of being a publisher and long story short, **I am no longer a biochem major** and I am going full force in getting into the publishing field right now" (emphasis added). I discouraged her from going "into" publishing, given that I'm not even convinced there is going to be a conventional publishing industry in five years, and forwarded her e-mail to a friend who was a biochemistry major. My friend's response started as a letter about how to decide if you want to become a scientist but turned into a meditation on how to face the time in your life when you feel like you have to decide what, if anything, you want to become.

The thing about being "interested" in science is that the undergraduate survey classes rarely confirm if you really are. They're boring. Rote. Dull. I credit my Bio 101 teacher with making the delicate, complicated mysteries of carbon based life as engaging as listening to my Cousin "M" discuss the subtle differences among protein powder supplements. I spent most of class surfing Wikipedia on my laptop. The next semester I weaseled my way into an advanced cell bio class that was fast and deep and intellectually stimulating, thanks to an eccentric teacher with a keen mind and a weird tendency to act out enzymatic reactions in a sort of bastardized interpretive dance. I dropped Bio 102, which didn't cripple my ability to keep up with advanced cell bio in any way (showing that survey classes can be unnecessary, boring, and confusing—confusing primarily because they leave out the details that are supposed to be too "advanced" but in fact clarify what the hell is going on), and got an unpaid research position in a faculty lab that eventually turned into a paid gig. By the way: there is significant pressure to dumb survey courses down and virtually no pressure on professors to teach them well; there are still good ones, but don't let the bad ones dissuade you.

If any field of scientific inquiry interests you, if you have the impulse to ask your own questions and are excited by the idea that you can go find the answers yourself and use what you've discovered to tinker and build and ask new questions—which is to say, if you like the idea of research—you've got a much better chance of figuring out if you want to be a scientist. How? Go and be one. Or, at least, play at being a scientist by finding a lab that will train you at doing the work until you wake up one day and realize that you are teaching a new undergrad how to program the PCR machine and your input is being used to develop experiments.

I was a biochemistry undergrad major, and I absolutely deplored the labs that were required by classes, but it turned out I loved the *actual* work of being in a lab. Classes lacked the creativity that makes science so appealing; they feel designed to discourage interest in science. In class, we had 50 minutes to purify a protein and learn to use the mass spectrometer. Big deal. Can I go now? But put me in front of the PCR machine with a purpose? I'd learn how to use it in an afternoon because doing so meant that I was one step closer to solving a problem no one had solved before. You don't find that kind of motivation in most classrooms. And you don't need a Ph.D. to contribute to the field. All you need is intellectual appetite. (For an exception to the "class is boring" rule, check out Richard Feynman's intro to physics lectures.)

So: I didn't like glossing over information, memorizing for tests, and being told I had till the end of class to identify how many hydrogen ions were in compound X. I wasn't excited by my major, but I was excited by my subject—and the longer I spent working in a real lab with a professor who saw that I was there every day and willing to learn (he eventually gave me a pet project), the more engaged I became with biochemistry. Sure, the day-to-day involved a lot of pipetting and making nutrient-agar plates to grow bacteria on, but I was working towards something larger than a grade.

I was splicing the DNA of glucose galactose binding protein and green fluorescent protein to try to make a unique gene that could express a protein which fluoresced when binding to glucose. In essence, a protein flare. Then I built it into an e-coli plasmid so it would self-replicate, while a lab in Japan was trying to get the gene expressed into what effectively turned into glow-under-blacklight-just-add-sugarwater mice. The goal was to get the gene expressed in diabetic people who could wear a fluorimeter watch and check how brightly the genetically engineered freckle on their wrist glowed, in lieu of pricking their finger to check their blood glucose.

Do you have any idea how awesome it was to describe my research at parties? I left out the parts where I had to evacuate the whole lab for four hours after accidentally creating a chlorine cloud and especially the parts where I spent an entire day making 250 yeast-agar plates and went home with "nutrient powder" in my hair and lungs. But even with the accidents and drudgery, the bigger goal was motivating. Being part of the real scientific conversation gave my work purpose that a grade did not. I dreamed of building nanobots and splicing the DNA together to build biological machines. It sure as hell beat memorizing the Kreb's cycle in return for a 4.0 GPA and med school.

That is what I love about science: you get to build something, you get to dream it up and ask questions and see if it works and even if you fail you learn something. What I loved was a long way from the dreary crap that characterizes so many undergrad classes. To be fair, the day-to-day isn't all that whiz bang, but it's rarely Dilbert-esque and I really liked the day-to-day challenges. There was something zen about turning on music and pipetting for three hours. That was right for me. It might not be for you; if you're trying to be a scientist or get a feel for what science is like (more on that below), don't be afraid to expose yourself to multiple labs if the first doesn't work out for you.

My own heart will always be that of a splice-n-dicer. I'll always love fiddling with DNA more than purifying compounds over a bunsen burner. But you don't know what day-to-day tasks will give you the most pleasure. You don't yet know that you might find zen at 3 a.m. setting up DNA assays, your mind clear, the fluid motion of your hand pulling you into a state of flow. You find out by doing, and you might be surprised—especially because classes don't give you a good sense of what the life of a scientist is like. It also doesn't introduce you to the graduate students, the post-doctorates and the assistant professors who show you what kind of struggle comes from love, which in turn generates internal motivation. It doesn't take you away from your university into summer programs that show you how amazing it is to be in a lab with real money and the resources to make your crazy ideas possible.

Which brings me to choosing a field: If you like science, but don't know what kind, pick the most substantive one that interests you, with as much math as you're willing to handle, and just get started (math is handy because it applies virtually everywhere in the sciences). Chemistry, biochem and biology overlap to such a degree that I was working in a biochem lab on a genetics project with the goal of creating a protein, and biology labs worked with us in tandem. When you get into the real work, the lines between fields blur. You can major in biochem and get a Ph.D. in neuroscience, study organic chemistry and work for a physical chemistry / research firm. Other scientists don't care about what classes you took or what your degree says—they care about what you know and what you can do and if what you can do can be applied in a useful way. When in doubt, focus on developing technical skills more than the words on your degree.

One summer I applied to the Mayo Clinic Summer Undergraduate Research Fellowship (something I recommend anyone interested in science do—there are "SURF" programs at almost every major university and research center and they will give you a stipend, housing and exposure to a new lab. It can do amazing things for your CV, your career and your relationship to the larger scientific community. In math and some other fields, your best bet is the NSF's Research Experiences for Undergraduates (REU) Program). But I didn't get the job. I had six months in a lab at that point. I had a 3.96 GPA. I had a pretty great "why me" essay. Still, nothing.

A year later I applied again. By that time I'd been in the lab for a year and a half. I knew how to handle most of our major equipment. My CV described the tasks I could perform unsupervised, the problems I tackled by myself, and solutions I'd found. My advisor explained my role and the amount of autonomy I had been given. This time I got the job.

When I met with the director of my summer lab in person he made it clear that there were many fine applicants with stellar GPAs. I'd never even worked with radioactive iodine tagged proteins. They picked me because they knew undergrads only had three months to get substantive research done, and they simply didn't have time to train someone (especially someone who might turn out to lack tenacity). They needed someone who knew how to work in the lab and could adapt quickly. They needed someone who knew how to work the machines my college lab used, and someone who knew how to work with e-coli plasmids. I could do that.

So pick whatever you think you like best, start with that, find a lab, and learn how to be adept at as many basic lab skills as possible. Delve more deeply into the ones associated with your research. Be ready to work when the right opportunity and research lab come along. The new lab will always ask what skills you have and whether they can be applied to the questions their lab is trying to solve, even if you've never asked similar questions. A chemistry major could therefore be what a certain biology lab needs at a given time.

A lot of what is frustrating and off-putting about science at first, including working in the research lab, is the same thing that's frustrating and off-putting about math: to really enter the conversation you have to have the vocabulary, so there's a lot of memorizing when you start. Which is just obnoxious. But it doesn't take too long, and if you start interning in a lab early, then the memorizing feels justifiable and pertinent, even if you feel initially more frustrated at a) not knowing the information and b) not knowing how to apply it. If you don't get into a lab, however, it's just hard and pointlessly so (even though it isn't).

(Virtually all fields have this learning curve, whether you realize it or not; one of Jake's pet books is Daniel T. Willingham's *Why Don't Students Like School: A Cognitive Scientist Answers Questions About How the Mind Works and What It Means for the Classroom*, which describes how people move from no knowledge to shallow knowledge to deep knowledge. It's bewildering and disorienting to start with no knowledge on a subject, but you have to endure and transcend that state if you're going to move to deep knowledge. He says that he's climbed that mountain with regard to writing, which makes writing way more rewarding than it used to be.)

Once you have the language and are able to think about, say, protein folding, the way you would a paragraph of prose, or the rhythm in a popular song, science takes on a whole new life, like Frankenstein's Monster but without the self-loathing or murder. You start to think about what questions you can ask, what you can build, and what you can do—as opposed to what you can regurgitate. The questions you pose to people in your lab will lead to larger conversations. Feeling like an insider is nice, not only because it's nice to belong, but because you'll realize that even being a small part of the conversation means you're still part of the larger discussion.

Science is exciting, but not until you find a way to break through the barriers and into the real thing, so don't give up prematurely. Like most things, however, your experience depends on whether you have or make the right opportunities. I went to medical school after a grad school detour. How I feel about that decision is an entirely different essay, and one I'll post later. I ended up specializing in Emergency Medicine because I had enthusiastic ER docs teaching me. Before residency, I thought I'd do anesthesia, but the profs were boring and it seemed like awful work. I'm on a fabulous anesthesia rotation right now, the medical equivalent of a Riviera cruise, and am thinking, "Hey! Maybe I should have done this." Same with rehab medicine. It's a perfect fit for me, but I had two boring weeks of it in a non-representative place and so wasn't about to sign myself over to a whole career without having any more to base my opinion on.

Some days I think that if I'd had a different lab, which exposed me to different things, if my Mayo summer had given me different connections, I would be pipetting merrily away at Cold Spring Harbor research center, building a nanobot that would deliver the next big cancer treatment on a cellular level. Or maybe I would be a disgruntled post-doc, wishing that I could finally have a lab of my own. Or working for Pfizer. Anything could have changed my path. And just because you choose to study something you love doesn't mean you'll succeed.

But not choosing to study something you love is even worse. Point is, most choices in life are luck and chance, but you shouldn't discard viable options—especially ones in science—based on a couple of survey courses designed to move the meat. Universities do view freshmen as piggybanks whose tuition dollars fund professors' salaries and research, which is why they cram 1,000 of you into lecture halls and deliver an industrial-grade product that's every bit as pleasant as industrial-grade mystery meat. Unfortunately, those classes are often the only real way to know if you like something and to be exposed to it unless you seek out more real-world representative opportunities. Most universities won't go out of their way to shunt you into those opportunities. You have to want them and seek them out. So if you think you like biology? Or physics? Read *The Elegant Universe**. The greatest show on earth. The history of the polio vaccine. See if it stirs you.

That being said, if you don't like science, you don't like it; I'm just warning you that what you think you don't like might simply be due to not quite knowing enough or having negative exposures. Still, you can have all the best intentions, follow my advice, find a great lab, try out different opportunities if the first or second don't work out, and decide it's just not for you. You probably can't force it to be your passion, but you probably also underestimate the extent to which you, like most people, have a range of possible passions. I only caution you to make sure that you aren't basing your choice on one bad class or a crappy lab advisor. This is good advice in any field.

Here's an example of possible premature optimization: I received an email from Jake's former student, saying she was thinking about being a judge as a "backup," in case a career in publishing didn't work out. Being a judge, that's a life goal. A big one. And law does not make good on its promise of a comfortable income the way it once did. For more on that, see the Slate.com article "A Case of Supply v. Demand: Law schools are manufacturing more lawyers than America needs, and law students aren't happy about it," which points out that there are too many certified and credentialed "lawyers" for the amount of legal work available. Plus, while society needs a certain number of lawyers to function well, too many lawyers leads to diminishing returns as lawyers waste time ginning up work by suing each other over trivialities or chasing ambulances.

By contrast, an excess of scientists and engineers means more people who will build the stuff that lawyers then litigate over. **Scientists and engineers expand the size of the economic pie; lawyers mostly work to divide it up differently**. Whenever possible, work to be a person who creates things, instead of a person who tries to take stuff created by someone else. There is an infinite amount of work in science because the universe is big and we don't really understand it and we probably never will. New answers to questions in science yields more questions. More lawsuits launched by lawyers just yields fighting over scraps.

Another personal example: I wasn't just queen of the lab nerds. Sure, I tie-dyed my lab coat and dated a man who liked to hear me read aloud from organic chemistry textbook, but I also wanted to write: not academic papers and book chapters, but novels and essays. I'd always been dual-minded and never bought the "Two Cultures" idea one scientific and one humanistic, described in C.P. Snow's eponymous book. This bifurcation is, to speak bluntly, bullshit. As a kid I spent as much time trying to win the science fair as I did submitting poetry to *Highlights*. May 1994's Grumpy Dog issue was my first publication. You may have read it and enjoyed the story of "Sarah, the new puppy." Or, you may not have been born yet. That was me as a kid. As an adult, I'm not confined to science either—and neither is any other scientist.

I imagine many of you reading this post who are struggling with whether or not to be a scientist are, fundamentally, not struggling with what you want to major in, but what you want to be and how your decisions in college influence your options. Many of you are likely creatively-minded, as scientific types often are, despite how "poindexter" characters are portrayed in popular T.V. Staying close to your passions outside the test tube gives you the creative spark that makes your scientific thinking unique and fresh. So you don't have to pick science and say, "That's it, I'm a scientist and only a scientist." You become a scientist and say: Now what do I want to build/ask/figure out?

Jake again:

So what should you do *now* to get into science? Here's a list that I, Jake Seliger the non-scientist, wrote, based on the experiences described by friends in the sciences:

0) Look for profs in your department. Look for ones who are doing research in an area in or adjacent to what you might be interested in doing.

1) Read a couple of their recent papers. You probably won't understand them fully, but you should try to at least get a vague sense of what they're doing. You may want to prepare a couple of questions you can ask in advance; some profs will try to weed out people who are merely firing off random e-mails or appearing in the office hours to beg.

2) Look for a website related to their lab or work, and try to get a sense of whether you might be interested in their work. Chances are you won't be able to tell in advance. You should also figure out who their grad students are—most science profs will have somewhere between one and dozens of students working under them.

3) Go meet with said prof (or grad students) and say, "I'm interested in X, I've read papers W, Y, and Z, and I'd like to work in your lab." Volunteer, since you probably won't get paid at first.

4) They might say no. It's probably not personal (rejection is rarely personal in dating, either, but it takes many people years or decades to figure this out). If the prof says no, go work on the grad students some, or generally make yourself a pest.

5) Try other labs.

6) Don't give up. This is a persistent theme in this essay for good reason.

7) Keep reading papers in the area you're interested in, even if you don't understand them. Papers aren't a substitute for research, but you'll at least show that you're interested and learn some of the lingo. Don't underestimate the value of knowing a field's jargon. Knowing the jargon can also be satisfying in its own right.

8) Take a computer science course or, even better, computer science cours**es**. Almost all science labs have programming tasks no one wants to do, and your willingness to do

scutwork will make you much more valuable. Simple but tedious programming tasks are the modern lab equivalent of sweeping the floor.

If you don't have bench research experience, you probably won't get into grad school, or into a good grad school. You might have to pay for an MA or something like that to get in, which is bad. If you're thinking about grad school, read Louis Menand's *The Marketplace of Ideas* as soon as possible. See also Penelope Trunk's Don't Try to Dodge the Recession with Grad School and Philip Greenspun's Women in Science. Ignore the questionable gender comments Greenspun makes and attend to his discussion of what grad school in the sciences is like, especially this, his main point: "Adjusted for IQ, quantitative skills, and working hours, jobs in science are the lowest paid in the United States."

Another: Alex Tabarrok points out in his book *Launching The Innovation Renaissance: A New Path to Bring Smart Ideas to Market Fast* that we appear to have too few people working in technical fields and too many majoring in business and dubious arts majors (notice that he doesn't deal with graduate school, which is where he diverges from Greenspun). In his blog post "College has been oversold," Tabarrok points out that student participation in fields that pay well and are likely "to create the kinds of innovations that drive economic growth" is flat. On an anecdotal level, virtually everyone I know who majored in the hard sciences and engineering is employed. Many of those who, like me, majored in English, aren't.

According to a study discussed in the *New York Times*, people apparently leave engineering because it's hard: "The typical engineering major today spends 18.5 hours per week studying. The typical social sciences major, by contrast, spends about 14.6 hours." And:

So maybe students intending to major in STEM fields are changing their minds because those curriculums require more work, or because they're scared off by the lower grades, or a combination of the two. Either way, it's sort of discouraging when you consider that these requirements are intimidating enough to persuade students to forgo the additional earnings they are likely to get as engineers.

There’s another way to read these findings, though. Perhaps the higher wages earned by engineers reflect not only what they learn but also which students are likely to choose those majors in the first place and stay with them.

Don't be scared by low grades. Yes, it's discouraging to take classes where the exam average is 60, but keep taking them anyway. Low grades might be an indication that the field is more intellectually honest than one with easy, high grades.

In the process of writing and editing this essay, the usual panoply of articles is about topics like "science majors are more likely to get jobs" have been published. You've probably read these articles. They're mostly correct. The smattering linked to here are just ones that happened to catch my attention.

Science grads may not get jobs just because science inherently makes you more employable—it may be that more tenacious, hard-working, and thus employable people are inclined to major in the sciences. But that means you should want to signal that you're one of them. And healthier countries in general tend to focus on science, respect science, and product scientists; hence the story about the opposite in "Why the Arabic World Turned Away from Science."

If you're leaving science because the intro courses are too hard and your friends majoring in business are having more fun at parties, you're probably doing yourself a tremendous disservice that you won't even realize until years later. If you're leaving science because of a genuine, passionate interest in some other field, you might have a better reason, but it still seems like you'd be better off double majoring or minoring in that other field.

My friend again, adding to what I said above:

As someone who was going to do the science PhD thing before deciding on medical school I agree with most of what Jake says. Let me emphasize: you *will* have to volunteer at first because you don't have the skills to be hired in a lab for a job that will teach you something. Being hired without previous experience usually means the job doesn't require the skills you want to learn, and so you won't learn them. So you don't want that job.

I had a paying job in a lab, so you can get them eventually—but I only started getting paid after I'd worked in it for a year, even then the pay was more like a nice boost because the money just happened to show up and they thought, "What the heck, she's been helpful." Think of this time as paying your way into graduate school, because if you don't have lab work, despite how good your grades are, you will not get into a good graduate school with funding.

Here's why: You have a limited amount of time in graduate school and are not just there to do independent research and learn. You're there to do research *with* the department, and they need you to start immediately. If you already have years of bench research experience, the departments and the professors in that department know you can—and there is no substitute for experience.

The place where you really learn how to work in a lab and develop your skills is in one, not in the lab classes where you learn, at best, some rote things (plus, you need to know if you like the basic, day-to-day experience of working in a lab and the kind of culture you'll find yourself in; not everyone does). Even if you do learn the tools you need for a certain lab, it doesn't demonstrate that you're actually interested in research.

The only thing that demonstrates an interest in research, which is all graduate school really cares about, is working in a lab and doing real research. I can't stress that enough, which is why I've repeated it several times in this paragraph. A 4.0 means you can study. It doesn't mean you can do research. People on grad school committees get an endless number of recommendation letters that say, "This candidate did well in class and got an 'A.'" Those count for almost nothing. People on grad school committees want letters that say, "This candidate did X, Y, and Z in my lab."

I recommend starting with your professors—the ones whose classes you've liked and who know you from office hours. Hit them up first. Tell them your goal is to be a scientist and that, while academics are nice, you want to start being a scientist *now*. If they don't have space for you, tell them to point you in the direction of someone who does. Keep an open mind. Ask *everybody*. I was interested in nanobots, gene work, molecular what-nots, etc.

I started by asking my orgo ["organic chemistry" to laymen] teacher. Nothing. I asked my Biochem ["biological chemistry" or "biochemistry"] professor and was welcomed with open arms. Point is, if the labs you want have no space, go to another. Don't give up. Be relentlessly resourceful. Be tenacious—and these aren't qualities uniquely useful to scientists.

The skills I ended up with in the biochem lab turned out to be almost 100% on point with what I wanted to do later, even though the research was different. The kind of research you end up doing usually springs from the lab skills you have, and it's much harder to decide what you want and try to find a lab that will give you those skills. So instead of trying to anticipate what research you'll want to do from a position where you can't know, just learn some research skills. Any skills are better than none. Then you have something to offer the lab you want when space / funding becomes available. I took what I learned in that biochem lab and spent a summer doing research on protein folding—it wasn't like my initial research, but the prof needed someone who knew how to do X, Y and Z, which I did, and he was willing to train me on the rest.

You'll face other decisions. For example, in many fields you'll have to decide: do you want wet-lab research (this does not refer to adult entertainment) or do you want more clinical research? "Wet lab" means that you're mucking with chemicals, or big machines, and stuff like. Clinical research means you're dealing more with humans, or asking people questions, or something along those lines. I would suggest the wet lab if you think you may be even slightly interested (sort of like how you should experiment with lovers when you're in college if you think you're even slightly interested in different sorts of things). In fact, I'd suggest wet-lab work or some sort of computational lab in general, because clinical research skills can be extrapolated from wet lab—but not vice versa.

You can show that you can think if you're in a clinical lab, but in a wet-lab you need to be able to think **and** use a pipette. Or that you can use modeling software, if you're interested in the computer side of things. That's where the programming comes in handy if you're capable of doing it; if not, then I feel less strongly than Jake about programming, because often labs need someone with serious computer training, like a post doc, if their research revolves around modeling. But it could come in handy for you, anyway, and certainly couldn't hurt, so if you're interested it could be an extra perk.

Once you're in the lab, if you want to learn skills outside what you're working with. Ask. Ask everyone. Ask the computer guy, ask the woman on the other project. Get whatever you can get get good at it, then put it on you C.V. and make sure you can explain it clearly when someone asks, even if you're not an expert, just be able to play on on T.V.

As for #3, about figuring out who their grad students are: I also find that less important. You need to talk to the primary investigator, the guy who runs the lab. If he's not interested in you, it's not worth going through grad student channels to convince him to take you. Someone is going to want you, and it's best to go there in both science and love. Don't fall for the false lead of the pretty girl in the alluring dress who disappears as soon as you get close. You can always try alternate channels later if you really want to get back into lab #1.

Think of it this way: if you're struggling just to get a foot in the door, you're going to struggle to get any research done. Not that the research will feel meaningful at first: you'll be doing tasks assigned to you. But you should feel like this gets better, that you get more independence. And if that's the not the ethos of the lab to start with, it never will be. As I mentioned before, if I'd gotten into that orgo lab, I'd have been a scut monkey for years.

As Jake said: read your professors' papers. You probably won't have any idea what's going on. I still have no idea what's going on half the time, but read 'em anyway. Shows you're worth the effort, especially when you ask for that lab spot. Jake's 100% right about ways to get your professors attention.

Don't give up. Just don't give up. Take "no" for an answer and kiss grad school (at least a *good* PhD program with full funding, which is what you want: don't pay for this **under any circumstances**) goodbye. Scientists are distinguished by their tenacity, whether they're in grad school or not. And make sure you know what you're giving up **before** you do.

What kind of research are you interested in? What gets you going? Even if you're not sure there are a certain number of fundamental things that, I believe, if you're familiar with, will get you into whatever lab you want because they are used in most labs and shows you're trainable for the other stuff. And you'll know what science is like, which you simply don't right now. Giving up on it based on some bad grades as a freshman or sophomore is folly.

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* Although a different friend observed, "Books are a step above classes, but in my experience, many aspiring theoretical physicists are really people who like reading popular science books more than they like doing math."