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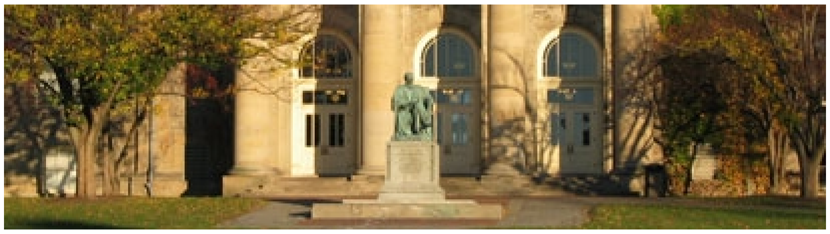

Undergraduation

March 2005

(Parts of this essay began as replies to students who wrote to me with questions.)

Recently I've had several emails from computer science undergrads asking what to do in college. I might not be the best source of advice, because I was a philosophy major in college. But I took so many CS classes that most CS majors thought I was one. I was certainly a hacker, at least.

Hacking

What should you do in college to become a good hacker? There are two main things you can do: become very good at programming, and learn a lot about specific, cool problems. These turn out to be equivalent, because each drives you to do the other.

The way to be good at programming is to work (a) a lot (b) on hard problems. And the way to make yourself work on hard problems is to work on some very engaging project.

Odds are this project won't be a class assignment. My friend Robert learned a lot by writing network software when he was an undergrad. One of his projects was to connect Harvard to the Arpanet; it had been one of the original nodes, but by 1984 the connection had died. [1] Not only was this work not for a class, but because he spent all his time on it and neglected his studies, he was kicked out of school for a year. [2] It all evened out in the end, and now he's a professor at MIT. But you'll probably be happier if you don't go to that extreme; it caused him a lot of worry at the time.

Another way to be good at programming is to find other people who are good at it, and learn what they know. Programmers tend to sort themselves into tribes according to the type of work they do and the tools they use, and some tribes are smarter than others. Look around you and see what the smart people seem to be working on; there's usually a reason.

Some of the smartest people around you are professors. So one way to find interesting work is to volunteer as a research assistant. Professors are especially interested in people who can solve tedious system-administration type problems for them, so that is a way to get a foot in the door. What they fear are flakes and resume padders. It's all too common for an assistant to result in a net increase in work. So you have to make it clear you'll mean a net decrease.

Don't be put off if they say no. Rejection is almost always less personal than the rejectee imagines. Just move on to the next. (This applies to dating too.)

Beware, because although most professors are smart, not all of them work on interesting stuff. Professors have to publish novel results to advance their careers, but there is more competition in more interesting areas of research. So what less ambitious professors do is turn out a series of papers whose conclusions are novel because no one else cares about them. You're better off avoiding these.

I never worked as a research assistant, so I feel a bit dishonest recommending that route. I learned to program by writing stuff of my own, particularly by trying to reverse-engineer Winograd's SHRDLU. I was as obsessed with that program as a mother with a new baby.

Whatever the disadvantages of working by yourself, the advantage is that the project is all your own. You never have to compromise or ask anyone's permission, and if you have a new idea you can just sit down and start implementing it.

In your own projects you don't have to worry about novelty (as professors do) or profitability (as businesses do). All that matters is how hard the project is technically, and that has no correlation to the nature of the application. "Serious" applications like databases are often trivial and dull technically (if you ever suffer from insomnia, try reading the technical literature about databases) while "frivolous" applications like games are often very sophisticated. I'm sure there are game companies out there working on products with more intellectual content than the research at the bottom nine tenths of university CS departments.

If I were in college now I'd probably work on graphics: a network game, for example, or a tool for 3D animation. When I was an undergrad there weren't enough cycles around to make graphics interesting, but it's hard to imagine anything more fun to work on now.

Math

When I was in college, a lot of the professors believed (or at least wished) that computer science was a branch of math. This idea was strongest at Harvard, where there wasn't even a CS major till the 1980s; till then one had to major in applied math. But it was nearly as bad at Cornell. When I told the fearsome Professor Conway that I was interested in AI (a hot topic then), he told me I should major in math. I'm still not sure whether he thought AI required math, or whether he thought AI was nonsense and that majoring in something rigorous would cure me of such stupid ambitions.

In fact, the amount of math you need as a hacker is a lot less than most university departments like to admit. I don't think you need much more than high school math plus a few concepts from the theory of computation. (You have to know what an n^2 algorithm is if you want to avoid writing them.) Unless you're planning to write math applications, of course. Robotics, for example, is all math.

But while you don't literally need math for most kinds of hacking, in the sense of knowing 1001 tricks for differentiating formulas, math is very much worth studying for its own sake. It's a valuable source of metaphors for almost any kind of work.[3] I wish I'd studied more math in college for that reason.

Like a lot of people, I was mathematically abused as a child. I learned to think of math as a collection of formulas that were neither beautiful nor had any relation to my life (despite attempts to translate them into "word problems"), but had to be memorized in order to do well on tests.

One of the most valuable things you could do in college would be to learn what math is really about. This may not be easy, because a lot of good mathematicians are bad teachers. And while there are many popular books on math, few seem good. The best I can think of are W. W. Sawyer's. And of course Euclid. [4]

Everything

Thomas Huxley said "Try to learn something about everything and everything about something." Most universities aim at this ideal.

But what's everything? To me it means, all that people learn in the course of working honestly on hard problems. All such work tends to be related, in that ideas and techniques from one field can often be transplanted successfully to others. Even others that seem quite distant. For example, I write essays the same way I write software: I sit down and blow out a lame version 1 as fast as I can type, then spend several weeks rewriting it.

Working on hard problems is not, by itself, enough. Medieval alchemists were working on a hard problem, but their approach was so bogus that there was little to learn from studying it, except possibly about people's ability to delude themselves. Unfortunately the sort of AI I was trying to learn in college had the same flaw: a very hard problem, blithely approached with hopelessly inadequate techniques. Bold? Closer to fraudulent.

The social sciences are also fairly bogus, because they're so much influenced by intellectual fashions. If a physicist met a colleague from 100 years ago, he could teach him some new things; if a psychologist met a colleague from 100 years ago, they'd just get into an ideological argument. Yes, of course, you'll learn something by taking a psychology class. The point is, you'll learn more by taking a class in another department.

The worthwhile departments, in my opinion, are math, the hard sciences, engineering, history (especially economic and social history, and the history of science), architecture, and the classics. A survey course in art history may be worthwhile. Modern literature is important, but the way to learn about it is just to read. I don't know enough about music to say.

You can skip the social sciences, philosophy, and the various departments created recently in response to political pressures. Many of these fields talk about important problems, certainly. But the way they talk about them is useless. For example, philosophy talks, among other things, about our obligations to one another; but you can learn more about this from a wise grandmother or E. B. White than from an academic philosopher.

I speak here from experience. I should probably have been offended when people laughed at Clinton for saying "It depends on what the meaning of the word 'is' is." I took about five classes in college on what the meaning of "is" is.

Another way to figure out which fields are worth studying is to create the *dropout graph.* For example, I know many people who switched from math to computer science because they found math too hard, and no one who did the opposite. People don't do hard things gratuitously; no one will work on a harder problem unless it is proportionately (or at least log(n)) more rewarding. So probably math is more worth studying than computer science. By similar comparisons you can make a graph of all the departments in a university. At the bottom you'll find the subjects with least intellectual content.

If you use this method, you'll get roughly the same answer I just gave.

Language courses are an anomaly. I think they're better considered as extracurricular activities, like pottery classes. They'd be far more useful when combined with some time living in a country where the language is spoken. On a whim I studied Arabic as a freshman. It was a lot of work, and the only lasting benefits were a weird ability to identify semitic roots and some insights into how people recognize words.

Studio art and creative writing courses are wildcards. Usually you don't get taught much: you just work (or don't work) on whatever you want, and then sit around offering "crits" of one another's creations under the vague supervision of the teacher. But writing and art are both very hard problems that (some) people work honestly at, so they're worth doing, especially if you can find a good teacher.

Jobs

Of course college students have to think about more than just learning. There are also two practical problems to consider: jobs, and graduate school.

In theory a liberal education is not supposed to supply job training. But everyone knows this is a bit of a fib. Hackers at every college learn practical skills, and not by accident.

What you should learn to get a job depends on the kind you want. If you want to work in a big company, learn how to hack Blub on Windows. If you want to work at a cool little company or research lab, you'll do better to learn Ruby on Linux. And if you want to start your own company, which I think will be more and more common, master the most powerful tools you can find, because you're going to be in a race against your competitors, and they'll be your horse.

There is not a direct correlation between the skills you should learn in college and those you'll use in a job. You should aim slightly high in college.

In workouts a football player may bench press 300 pounds, even though he may never have to exert anything like that much force in the course of a game. Likewise, if your professors try to make you learn stuff that's more advanced than you'll need in a job, it may not just be because they're academics, detached from the real world. They may be trying to make you lift weights with your brain.

The programs you write in classes differ in three critical ways from the ones you'll write in the real world: they're small; you get to start from scratch; and the problem is usually artificial and predetermined. In the real world, programs are bigger, tend to involve existing code, and often require you to figure out what the problem is before you can solve it.

You don't have to wait to leave (or even enter) college to learn these skills. If you want to learn how to deal with existing code, for example, you can contribute to open-source projects. The sort of employer you want to work for will be as impressed by that as good grades on class assignments.

In existing open-source projects you don't get much practice at the third skill, deciding what problems to solve. But there's nothing to stop you starting new projects of your own. And good employers will be even more impressed with that.

What sort of problem should you try to solve? One way to answer that is to ask what you need as a user. For example, I stumbled on a good algorithm for spam filtering because I wanted to stop getting spam. Now what I wish I had was a mail reader that somehow prevented my inbox from filling up. I tend to use my inbox as a todo list. But that's like using a screwdriver to open bottles; what one really wants is a bottle opener.

Grad School

What about grad school? Should you go? And how do you get into a good one?

In principle, grad school is professional training in research, and you shouldn't go unless you want to do research as a career. And yet half the people who get PhDs in CS don't go into research. I didn't go to grad school to become a professor. I went because I wanted to learn more.

So if you're mainly interested in hacking and you go to grad school, you'll find a lot of other people who are similarly out of their element. And if half the people around you are out of their element in the same way you are, are you really out of your element?

There's a fundamental problem in "computer science," and it surfaces in situations like this. No one is sure what "research" is supposed to be. A lot of research is hacking that had to be crammed into the form of an academic paper to yield one more quantum of publication.

So it's kind of misleading to ask whether you'll be at home in grad school, because very few people are quite at home in computer science. The whole field is uncomfortable in its own skin. So the fact that you're mainly interested in hacking shouldn't deter you from going to grad school. Just be warned you'll have to do a lot of stuff you don't like.

Number one will be your dissertation. Almost everyone hates their dissertation by the time they're done with it. The process inherently tends to produce an unpleasant result, like a cake made out of whole wheat flour and baked for twelve hours. Few dissertations are read with pleasure, especially by their authors.

But thousands before you have suffered through writing a dissertation. And aside from that, grad school is close to paradise. Many people remember it as the happiest time of their lives. And nearly all the rest, including me, remember it as a period that would have been, if they hadn't had to write a dissertation. [5]

The danger with grad school is that you don't see the scary part upfront. PhD programs start out as college part 2, with several years of classes. So by the time you face the horror of writing a dissertation, you're already several years in. If you quit now, you'll be a grad-school dropout, and you probably won't like that idea. When Robert got kicked out of grad school for writing the Internet worm of 1988, I envied him enormously for finding a way out without the stigma of failure.

On the whole, grad school is probably better than most alternatives. You meet a lot of smart people, and your glum procrastination will at least be a powerful common bond. And of course you have a PhD at the end. I forgot about that. I suppose that's worth something.

The greatest advantage of a PhD (besides being the union card of academia, of course) may be that it gives you some baseline confidence. For example, the Honeywell thermostats in my house have the most atrocious UI. My mother, who has the same model, diligently spent a day reading the user's manual to learn how to operate hers. She assumed the problem was with her. But I can think to myself "If someone with a PhD in computer science can't understand this thermostat, it *must* be badly designed."

If you still want to go to grad school after this equivocal recommendation, I can give you solid advice about how to get in. A lot of my friends are CS professors now, so I have the inside story about admissions. It's quite different from college. At most colleges, admissions officers decide who gets in. For PhD programs, the professors do. And they try to do it well, because the people they admit are going to be working for them.

Apparently only recommendations really matter at the best schools. Standardized tests count for nothing, and grades for little. The essay is mostly an opportunity to disqualify yourself by saying something stupid. The only thing professors trust is recommendations, preferably from people they know. [6]

So if you want to get into a PhD program, the key is to impress your professors. And from my friends who are professors I know what impresses them: not merely trying to impress them. They're not impressed by students who get good grades or want to be their research assistants so they can get into grad school. They're impressed by students who get good grades and want to be their research assistants because they're genuinely interested in the topic.

So the best thing you can do in college, whether you want to get into grad school or just be good at hacking, is figure out what you truly like. It's hard to trick professors into letting you into grad school, and impossible to trick problems into letting you solve them. College is where faking stops working. From this point, unless you want to go work for a big company, which is like reverting to high school, the only way forward is through doing what you love.

Notes

[1] No one seems to have minded, which shows how unimportant the Arpanet (which became the Internet) was as late as 1984.

[2] This is why, when I became an employer, I didn't care about GPAs. In fact, we actively sought out people who'd failed out of school. We once put up posters around Harvard saying "Did you just get kicked out for doing badly in your classes because you spent all your time working on some project of your own? Come work for us!" We managed to find a kid who had been, and he was a great hacker.

When Harvard kicks undergrads out for a year, they have to get jobs. The idea is to show them how awful the real world is, so they'll understand how lucky they are to be in college. This plan backfired with the guy who came to work for us, because he had more fun than he'd had in school, and made more that year from stock options than any of his professors did in salary. So instead of crawling back repentant at the end of the year, he took another year off and went to Europe. He did eventually graduate at about 26.

[3] Eric Raymond says the best metaphors for hackers are in set theory, combinatorics, and graph theory.

Trevor Blackwell reminds you to take math classes intended for math majors. "'Math for engineers' classes sucked mightily. In fact any 'x for engineers' sucks, where x includes math, law, writing and visual design."

[4] Other highly recommended books: *What is Mathematics?*, by Courant and Robbins; *Geometry and the Imagination* by Hilbert and Cohn-Vossen. And for those interested in graphic design, Byrne's Euclid.

[5] If you wanted to have the perfect life, the thing to do would be to go to grad school, secretly write your dissertation in the first year or two, and then just enjoy yourself for the next three years, dribbling out a chapter at a time. This prospect will make grad students' mouths water, but I know of no one who's had the discipline to pull it off.

[6] One professor friend says that 15-20% of the grad students they admit each year are "long shots." But what he means by long shots are people whose applications are perfect in every way, except that no one on the admissions committee knows the professors who wrote the recommendations.

So if you want to get into grad school in the sciences, you need to go to college somewhere with real research professors. Otherwise you'll seem a risky bet to admissions committees, no matter how good you are.

Which implies a surprising but apparently inevitable consequence: little liberal arts colleges are doomed. Most smart high school kids at least consider going into the sciences, even if they ultimately choose not to. Why go to a college that limits their options?

Thanks to Trevor Blackwell, Alex Lewin, Jessica Livingston, Robert Morris, Eric Raymond, and several anonymous CS professors for reading drafts of this, and to the students whose questions began it.

- More Advice for Undergrads
- Joel Spolsky: Advice for Computer Science College Students
- Eric Raymond: How to Become a Hacker