Notes for SOCS undergraduates considering graduate school in computer science

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1 Why obtain a graduate degree in computer science?

There are two kinds of graduate degrees in computer science: the M.Sc. and the Ph.D.. Some students obtain just one of these. Others obtain both. Here are some reasons why you might (or might not want) to obtain one of these degrees.

- *to broaden your knowledge of CS and/or acquire a specialization which you can apply when apply for a tech job*

  On the one hand, this makes sense. Graduate level courses that are taught by professors who are involved in a particular research area. Such courses introduce students to advanced topics in these areas. The courses typically reflect the prof's particular expertise which means you can learn about the cutting edge of that topic. If that's the topic you want to learn about, great.

  On the other hand, you might end up having to take some advanced courses on topics which you are not so interested in. This can happen because of scheduling constraints or because the courses you want to take are just not offered the year you want to take them. Taking advanced courses on topics that don't really interest you in a waste of time.

- *to have a more advanced degree to distinguish your CV;*

  A graduate degree – whether its an M.Sc. or Ph.D. – is respected and valued by many companies. As such, it gives your CV an edge. Even if the particular area of concentration of your graduate work has little to do with the job you apply for afterward, successfully completing the degree means that you have acquired skills that a B.Sc. typically does not have, and you will have demonstrated your competance. If you have written a thesis, then you will have a different type of experience which requires you to develop further organization skills, written and oral communication skills, maturity, and (some) independence.

- *for fun; to satisfy your intellectual hunger;*

  You enjoy the intellectual life of the university. You enjoy studying and learning material at an advanced level. As a ugrad, you have proven yourself to be good at it with your high grades. You are not yet prepared to give up this life yet, for a 9 to 5 job. You don't know what you hope to achieve in graduate school in computer science, but you figure it could be interesting.

- *to learn what research is;*

Many students go to graduate school because they think they might enjoy research. A B.Sc. degree does not prepare you to do research. That's not what the Bachelor curriculum is designed for. Undergraduate courses typically offer a well-defined package of concepts, facts, and tools which are bundled in a very structured form (hopefully). You are evaluated by how well you process these packages. Such courses are effective for structured learning, but the process and skills you acquire there do not prepare you for research. Not at all. To learn how to do research, you need go on to graduate school. You need to learn to specialize (grad level courses) and you need to go into depth where our knowledge is *unstructured*. If you do a PhD then you also need to pose and to solve problems *on your own*

A research career in computer science typically follows one of two paths. One is academics, namely as a professor in a college or university. It is nearly impossible to become a professor without a Ph.D.. Think of a Ph.D. as a license that you need to apply for a professor position.

The second path is a career in industry. Large tech companies typically have Research and Development labs world-wide which employ hundreds of computer scientists as researchers. These jobs are challenging, exciting, competitive, and well paid. Many of the research breakthroughs in computer science have come out of such research labs. Such positions require proven research experience - at least an M.Sc., but more typically a Ph.D..

There are also many government labs that hire researchers (although less common in CS).

Assuming you have the qualification (namely you are an above average student) and you are interested in doing a graduate degree, why would you *not* want to do it? There are a few obvious reasons, and they are real:

- *opportunity cost;*

  It will take a few years to get an M.Sc. degree and much more than that to get a Ph.D. You could have gained many other experiences during that time. You could have earned money.

- *you might not enjoy it;*

  I'll say more about this in coming pages but here are a few examples. Graduate level classes can be very specialized and might not be useful or interesting. You depend heavily on your supervisor and you often don't know in advance how that relationship is going to work. Research is very difficult, and slow.

- *it may make you overqualified;*

  This is more an issue with PhD than MSc. Because your job expectations will be higher with a PhD than a BSc, there may be many (entry level) jobs where employers are looking for someone with a BSc who they can mould rather than someone with PhD. It could be a bit awkward to be 30 years old with a PhD and to have a Project Manager who is 25 years old and has a BSc.

2 Research life in computer science (Ph.D. and beyond)

This section is for those who go to graduate school and are considering a career in research. It is less relevant for those who are looking for an M.Sc. as a way to improve their skills for the general computer science workforce. (In the latter case, proceed to Sec. 3).

The purpose of research is to create knowledge. In computer science, this means creating new algorithms, programming language concepts and constructs, hardware tools, theorems about how hard certain problems are or what is the best way to solve them, etc. There are certain aspects of *research life*, however, that you might not appreciate until you become involved in it:

- *Researchers belong to a community.*

  The specific problem you are working on often is being addressed by only a small number of people in the world. This means that any progress you do make on the problem will be of great interest to these people. These includes those in your own laboratory – your supervisor and fellow graduate students – as well as those in other laboratories in the world whom you meet at conferences where you and they present research results. As you continue in your career, exploring a wider range of research problems, this network of colleagues becomes larger and you find yourself a member of a research community. This community becomes a source of professional support, e.g. job opportunities down the road.

  That all sounds warm and fuzzy, but keep in mind that these people are also your competitors. This means that they might not share their ideas with you as openly as you would like and vice-versa. It also means that you will review each other's papers and grant applications. There are political and ethical issues here, and some people don't play fair and it can be frustrating. This is as true in academic research as in any field.

- *Researchers become identified with their work.*

  When you publish a significant new result, the publication has your name on it and you become identified with it. You are the person who wrote paper X that showed Y is true or showed how to Z. Having your work identified with you personally can be very satisfying.

  I find it interesting that science works like this. There's no reason it *should* since, unlike say music or literature, the point of science is to discover something which already exists and that is independent of the person who discovered it. Presumably this system of getting credited with discoveries evolved because it is effective for motivating many people to do this sort of work. Would you toil for years trying to solve a problem if, in the end, no one knew or cared that it was you who solved it?

- *Research is a slow process. But that is part of what makes it worth doing.*

  Before you can discover or invent something, you need to know what has been done before. Getting up to speed on a problem requires months and often years of reading the literature, stewing your thoughts, talking to experts in the field, re-reading the literature, more stewing, etc. Then, once you understand the problem and its history, you need to reformulate it and solve it in a way no one has done before. This process requires patience, focus, and intellectual stamina. It is not for everyone. But those who choose research careers do love the challenge, and get tremendous satisfaction from solving a problem that they have worked on for so long, and that no one else in the world has been able to solve, and to get credit for it.

- *As a researcher, you are your own boss. You work on problems that you choose to work on.*

  As a university professor in computer science, you can do research on whatever area of computer science (or related fields) that you like. Also in industry, where you may have to work on problems that have relevance to your company's products, you are often still left some time to pursue your own research interests. Companies have to provide some flexibility, otherwise their best researchers will look for jobs elsewhere.

3 Graduate degrees: M.Sc. vs. Ph.D.

3.1 M.Sc.

There are two types of M.Sc. programs: those that are "terminal" and consist mostly of coursework and perhaps a small project, and those that are research oriented and consist of a combination of courses and a research thesis. Both types of M.Sc. typically take one to two years.

One example of a terminal M.Sc. is for students who begin an M.Sc. with the intention of carrying out research but who subsequently decide that research is not for them. Such students may be allowed to take extra courses and/or do a small project rather than write a thesis. McGill has such an option, for example.[1] Note that such a terminal M.Sc. is a perfectly valid M.Sc. degree. For many jobs in industry, having the degree is all that matters.

Another example of a terminal M.Sc. is offered by many U.S. universities, either for employees of high tech firms or for students who want to get a graduate degree for whatever reason. The tuition fees for such programs tend to be very high. Often they are paid for by the student's employer. Or the student might come from a foreign country and want a credential or experience in the U.S. to stay and eventually work.

The second type of M.Sc. program is the more common one that SOCS undergraduates pursue. This M.Sc. requires research and a thesis.[2] The thesis takes about a year. It is not required to contain original or publishable research. Instead, it can be an implementation or verification of a previously published method. It can even be a large literature survey. However, for those who wish to continue on in research beyond the M.Sc., it is better to try to carry out original work. Such research could lead to a publication and publications are viewed highly as research credentials. (Note: *where* you publish is important too. Some confererences and journals are much more competitive than others.) Another issue is your independence in the thesis research. An M.Sc. thesis is not required to be independent work. Many students rely heavily on their supervisor for directing them throughout their M.Sc. thesis research.

Besides the content of an M.Sc. thesis, the thesis is a good exercise in organization and writing. Even if your thesis topic is on a specialized subject that has nothing to do with the industry job you eventually apply for, writing a thesis forces you to organize a large body of work and present it in written form. The M.Sc. thesis is read and evaluated by your supervisor, and typically by an external examiner as well.

[1] At McGill, it is called the Project Option.

[2] At McGill, it is called the Thesis Option.

3.2 Ph.D.

A Ph.D. is quite different from an M.Sc.. A Ph.D. is the most advanced academic degree you can get. It is focused on doing original independent research. A Ph.D. typically takes about five years. The first year or two are spent on courses or exams. The remaining years are spent on a research project that is written up in a document (Ph.D. thesis) and defended orally.

The Ph.D. thesis must contain significant original work. Replicating the experimental findings of others is not enough. Moreover, the majority of the original ideas in the research are expected to come from you the student rather than from your supervisor or committee members. As such, Ph.D. students are expected to work much more independently on their research than M.Sc. students.

One final note about the Ph.D. concerns the duration. Many people are impressed when there hear that person X took only three years to a Ph.D.. While this is impressive, keep in mind that a Ph.D. that takes six years and makes a major breakthrough is considered to be much more valuable than one that takes three years but which makes no impact. The goal is to do a thorough job and to break new ground on a novel problem. The goal is not to graduate as fast as you can. Really, people don't care if you took 3 years as opposed to 6; there may be many reasons for taking 6 years: you had a baby, your wife had a baby, you got sick; you changed topics in midstream; you had to take care of your parents, etc. There are so many of these reasons that *no one asks*.

4 Graduate programs: Canada vs. U.S.

Most SOCS undergraduates who are considering graduate school will choose either Canada or the U.S.. A few pursue graduate studies in other countries (England, France, Germany, Australia, ...) but I restrict MY discussion to Canada and the U.S. because they are the most common choice.

There are significant differences between Canadian and U.S. graduate school programs in computer science. The tradition is that Canadian schools require you to apply to the M.Sc. program prior to applying to the Ph.D. program, whereas U.S. schools typically require you to apply straight into the Ph.D. program.[3] Thus in Canada, you focus on the M.Sc. from the start and keep your Ph.D. options open whereas in the U.S. you focus on the Ph.D. from the start.

Canada

Even if you had a solid and successful research experience as an undergrad – such as a full summer project in a lab and some parttime work during the year – you might still be hesitant to go directly into a Ph.D. program. For example, you still may be unsure of your abilities. Doing well as an undergraduate at McGill is something to be proud of. But how would you do in graduate school where your peers *all* had high GPA's as undergraduates and all come from good schools? You may also be unsure how much you would enjoy research. Or, you may simply wish to stay in Canada because you like it here.

Staying in Canada for an M.Sc. allows you to test the water. It gives you a taste for research and a chance to prove yourself within a research area. With this experience and an M.Sc. under

[3] Added in 2011: There is a recent trend, though, for Canadian schools to accepts ugrads directly into the Ph.D. program. U of Toronto does this, for example.

your belt, you would be in better position to choose a Ph.D. at a place that is right *for you* - whether in Canada, the U.S. or elsewhere.

To be accepted into an M.Sc. program in Canada, you typically do *not* require research experience as an undergraduate, nor do you require a detailed research proposal. You can be accepted based on a high GPA alone. You do need letters of recommendation for your M.Sc. application, but if your GPA is high enough[4] (say 3.7+) then these letters are merely a formality.

There is no cutoff GPA for entry into the M.Sc. program. The grades that committees expect vary from school to school and from year to year. McGill, the University of Toronto, and the University of British Columbia are widely recognized as among the top Canadian CS departments for graduate studies and research, so these tend to admit applicants with higher GPAs than most other Canadian programs. Factors such as whether your grades improved from year to year, and whether you did well in upper level courses matter more than just the raw GPA number. Also, if you have some research experience and your research supervisor can write a strong letter for you, then this helps considerably. There have been several cases of students with GPAs in B range who have made it into McGill's M.Sc. programs, just because they did well in their 500 level courses or because they could show evidence of research skills.

McGill vs. other Canadian schools

Should a SOCS undergraduate apply to the SOCS M.Sc. program? There are advantages and disadvantages to staying at McGill. One big advantage is that you may already know professors here and maybe have started a research project with one (*e.g.* COMP 400) which you would like to extend into an M.Sc. thesis. Such students tend to get through the M.Sc. program quite quickly, often in 16 months total with a solid publication to show for it. (There is also the combined BSc/MSc program. This is a way to do an MSc in just one year. Have a look on our web page for more info.)

One big disadvantage of staying at McGill for an M.Sc. is that you limit your exposure to the academic world. Switching universities introduces you to new professors, a new university environment, and a new city. Many of you who come from Montreal hope to stay in this city forever. You may be reluctant to move to other places in Canada because of certain pre-conceptions about life there or because it too far from home. Those of you who feel this way might benefit the most from leaving.

U.S.

Because Canadian Ph.D. programs require an M.Sc. whereas U.S programs do not, you could obtain your Ph.D. sooner by going straight to the U.S.. This might be more attractive for those of you who have research experience as undergraduates, who know what area of computer science you wish to work in, and who have a particular supervisor or research group in mind. Top U.S. Universities have a high concentration of outstanding professors and students. The intellectual level and professional opportunities at these places is amazing. If you can do a reasonably good Ph.D. thesis at one of these top places, the credential alone would carry you a long way in your career.

[4]For students who did ugrads during covid, grades might matter less because of grade inflation during covid.

Another advantage of going to a top U.S. school is that students have an opportunity in the summer to do internships in the private sector, at places like Microsoft and Google. (This can be arranged if you are at a graduate student at a Canadian school too, but this is not part of the culture. In the U.S. it *is* very much part of the culture.) These experiences are eye openers in many ways for people, and they provide you with contacts that you will have throughout your career.

If going straight into a Ph.D. program at a top U.S. school appeals to you, you should nevertheless be aware that things can go wrong. Here are a few ways how. (Note: some of these things can happen anywhere, not just at top U.S. schools.) First, while it is great to work in a lab of a famous professor at a top U.S. school, you might find that you spend little one-on-one time with this professor. Perhaps the professor is heavily involved in academic administration, or is heavily involved in a company, or has ten other Ph.D. students who want his/her ear. Second, these schools are very competitive and this can have negative consequences. Fellow graduate students, especially those working for other professors in other labs, may be hesitant to discuss their research ideas openly for fear of them being stolen. You may find yourself having the same fear. Third, students who are funded by a professor's grant that promises to do X and who do not do X (because they don't find X as interesting as Y) risk having pressure put on them, which can be unpleasant. Fourth, being a graduate student at many top U.S. schools is not as prestigious as you might imagine. These schools sometimes pamper undergraduate students[5] but leave graduate students to fend for themselves. So, before you sign up, *speak to people who are students at these schools and with the prof you want to work with, and find out if these are issues.*

What about funding? Nearly all Ph.D. students in the U.S. get funding in the form of a Teaching Assistantship or a Research Assistantship. If you get accepted into U.S. school but they don't offer you significant funding, then don't go. No money means they are not committed to you.

5 Fellowships: why getting your own funding matters

Regardless of which program you are applying to, it is always better if you get your own funding. Having your own fellowship has significant advantages, and no disadvantages. First, you are a more attractive student since obviously you were good enough to get your own money. Second, you have more control over your graduate experience, namely you will be more free to choose your supervisor and research topic. Professors often fund students from their grants but these grants are associated with specific research projects. Third, you do not have to work as a Teaching Assistant to supplement your income. Fourth, many schools offer "top-ups" to these fellowships, which means that you can earn decent money and get a graduate degree at the same time.

Fellowships for funding grad studies are available both from the federal (NSERC) and Quebec (FQRNT) governments. The application deadlines for these two fellowships are early October (of your U3 year). The Application includes a Personal Statement/Research Proposal, as well as Letters of Recommendation. These are *very important* parts of your file. Do not assume you can coast to a fellowship based on your GPA alone.

These fellowships are available only to Canadian citizens or Permanent Residents of Canada. Yes, in certain cases, the fellowships can be taken outside of Canada.

[5] who pay astronomical tuition fees and often donate large piles of money to their *alma mater* after they graduate

For more information, see this link.

6 General preparation for graduate school

There are certain basic steps you should take to prepare yourself for graduate school. These steps are especially important if you are applying to go to a Ph.D. program in the U.S. or if you are applying for an NSERC or FQRNT fellowship.

- *take 400 and 500 level courses as early as possible in your SOCS ugrad program;*

  If you apply during your U3 year[6], then you need to know at that time which area you wish to work in for your graduate research. This means you should be taking advanced courses (400 level or above) in this area in the Winter semester of U2 or the Fall semester of U3. Doing well in such advanced courses indicates (to your evaluators) that you can do well in graduate school.

- *spend your U2 summer doing research*

  Find a professor to supervise you on a project for a few months in the summer (e.g. COMP 396). Such an experience will orient you to what research is about. It will also give you contact with a professor and with graduate students, who can help you along the way with letters of recommendation and advice. It might also lead to a publication.

  NSERC offers undergraduate scholarships (called USRA) for summer research. The application deadline is early in the Winter semester.

- *try to get started early on Project Courses (COMP 396/400).*

  Start thinking about a COMP 400 project in the summer following your U2 year. Although you would register for the course in the U3 year, having a head start on the project would inevitably lessen your burden in the U3 year. It would also give you a chance to get to know a particular professor and show him or her how keen are capable you are, so that this professor could write a letter of recommendation for you.

  Note: COMP 400 is intended for Honours students, but it is not restricted to Honours students. If you are a CS Major student with a GPA of 3.5 or more, then you are a candidate for graduate school and so you should seriously consider taking COMP 400.

The following two steps apply only to those who are applying to U.S. Ph.D. programs:

- *Write the GRE exam.*

- *Contact the professor you would like to work with, after having done your homework.*

  Typically, a department will not accept a student into its Ph.D. program unless some professor there has shown an interest in the student's file. If you wish to work with a professor, then it is expected that you contact that professor to let him/her know. (See Sec. 7 for some advice on contacting professors about possible supervision.)

[6] as opposed to after you graduate

7 Approaching professors

Applying to graduate school means that you need to approach professors and ask for their involvement in your life. This can be as small as writing a letter of recommendation, or more significant as in supervising a summer research or a technical project (COMP 396/400), or even bigger as in supervising a M.Sc. or Ph.D. thesis.

You may be shy to approach professors. You may not know what is expected from you or how to proceed. I suspect many students end up not going to graduate school because they are hesitant to approach professors (sometimes until it is too late), or they fail to get into the graduate school they want because they make mistakes in how they approach professors.

Here are a few tips for the various cases.

Letter of Recommendation

In most cases, professors are happy to write Letters of Recommendation. If you did well in a course and you had some interaction with the professor during the course e.g. by asking questions, then the professor will probably know you by name and have a sense of who you are. In this case, the professor will appreciate how much work you did to get your `A`, and will try to help you out. Letter of recommendation forms for M.Sc. programs in Canada take very little time to fill out.

Writing Letters of Recommendation is not part of the professor's job, and a professor is allowed to decline to write a letter. But generally professors don't decline if the request is a reasonable one. No prof became a prof without others writing letters for him/her, so we all understand the importance of the process.

The most effective letter of recommendation for graduate school comes from an established professor (preferably at the Associate or Full Prof level i.e. tenured), someone with whom you have worked, and who is recommending you to work in a field in which he/she has a solid reputation. A strong letter from a top person is worth as much as straight A's in all your courses.

Avoid getting letters from non-academics, unless they themselves have Ph.D. degrees in computer science. For example, if the spent the summer working in a company, you may be tempted to ask your boss to write a letter. I would strongly advise against this. Such letters will be disregarded (unless the person can state in the letter why they are recommending you for something – i.e. research in graduate school – that they little experience with and know very little about).

Inevitably, you will also need letters from people whom you do not know so well. For these, make sure you:

- Give them a copy of your CV and a Personal Statement. Ask them for comments and suggestions. It takes a professor 10-30 minutes to read this information and give some basic feedback. Your application will be competing against other students who *did* get such feedback, so if you choose not to get such feedback then you will be at a disadvantage. Also, the feedback helps the professor to get to know you and presumably this can only help the letter.

- Don't wait until the last minute. It makes you look disorganized. Why should a professor spend time to carefully think through a letter for you, if you yourself do a rush job?

Supervision of Summer Research or COMP 400

The most useful research experiences are those in which you have some freedom to show your stuff. Pick a computer science area that interests you and ask a professor if they could suggest topics and books or papers to look at. Be explicit about your intentions, namely that you are thinking of pursuing this topic in COMP 400 and possibly in graduate school. Then, read the books; read the papers; ask questions; get into the professor's head.

For your project, be wary of getting involved in an implementation that involves lots of programming but not much theory or creative room. Programming expertise does *not* get you into graduate school and it does *not* prepare you for research. Rather it prepares you for more programming. If you demonstrate that programming is what you like to do and this is what you are good at, then this is what your Letters of Recommendation will indicate. And this is not what top graduate schools are looking for.

Potential graduate supervisor

For a M.Sc. program at a Canadian university, there is often no need to contact a professor about possible supervision of your M.Sc. thesis. Often you are asked to indicate a research area. Professors in that area then review the file and recommend whether they think you should be accepted.

The Ph.D. is a typically a different story. A Ph.D. means that you will work with a specific professor for a period of several years, and typically this professor needs to commit to supervising you from day 1. So, a professor will typically be more careful in committing to supervise a student and similarly, you should be careful in committing to work with a professor. (Again, make sure you speak to other students who are/have worked with this person.)

Given the above, it should be no surprise that your chances of being accepted into a top Ph.D. program are much higher if you are being recommended by someone who has contacts in that program. If this is not the case, then you will just have to introduce yourself. However, you should do your homework beforehand. Do not send out emails to a professor after having spent just a few minutes looking at his/her web page or research articles. Professors receive hundreds of such emails every year, and treat such emails as spam.

Instead, you should carefully read at least a few of that person's recent research papers, and email intelligent comments/questions about them. *It is very rare for students to do this, and so if you do it, then you will have an edge. You will also get a sense of whether you want to work with the person based on how/if they respond.*

8 Personal Statement

There are plenty of articles available on the web that advise on how to write personal statements or statements of research interest. See for example p. 11 of this document by this link. Prof. Mor Harchol-Balter at CMU. She has a few examples – **The grade regurgitator** and **The boy genius** – which you should definitely try to avoid. Here are a few other *don'ts* that you should resist:

- Don't try to shock the reader into attention. You are not a professional writer and so such special effects typically come across as amateurish. Instead, just be serious and honest and play it straight.

- Don't be boastful of your accomplishments. Let the professors writing your Letters of Recommendation tell about your abilities.
- Don't be too specific about your plans, because you may come across as being narrow minded. Try to find a balance between having a plausible plan based on your experiences, and being open to new ideas.
- Don't stress what a good programmer you are and how many programming languages or systems you know or what software you have written. This may be relevant for certain industry jobs, but not for research. Specifying these details shows that you *don't* know what research is about.
- The probability that a person reads what you write is inversely proportional to the length of what you write, so you need to tradeoff information for conciseness. Try getting it all into one page.

One final point: Letter of Recommendation forms typically ask professors to rate the students maturity, judgment, and ability to communicate. You would be surprised at how many students rank poorly on these categories because of how they behave in brief interactions with a professor: Particularly annoying are:

- hastily or carelessly written emails that require clarification;
- asking questions that indicate you have made little effort on your own to find the answers.

Other Resources

- "Applying to Ph.D. Programs in Computer Science" (Prof. Mor Harchol-Balter at CMU) (PDF)
- Our professional and personal lives are defined both by our successes and our failures. Have you ever considered writing a failure resume which outlines what you tried and failed?
- "Advice for profs writing letters of recommendation" (Prof. Shriram Krishnamurthi at Brown U.) (PDF)

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