

Syllabus for COMP 105, Programming Languages (Information Every Student Must Know)

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*Hard work is great but working smarter is even better.
At times, you have to take a break, back off, and use
your time efficiently.*

— Bill Belichick

Introduction and Welcome

Welcome to COMP 105! Here you will learn to write code from scratch, in a language you have never seen before, in a way that sails through code review.

COMP 105 serves as the fourth course in our required programming sequence. In this sequence, it is the only 100-level course. It is the most technically deep, the most intellectually challenging, and the one in which you'll develop the most diverse and highest-level thinking skills. You will think hard, stretch beyond the skills you have grown comfortable with, and emerge with a permanently higher level of skill.

COMP 105 introduces you—through extensive practice—to ideas and techniques that are found everywhere in today's programming languages. These ideas and techniques infuse many languages you have not yet seen, and they will continue to infuse the programming languages of the future. Foremost among these ideas are functions, types, and objects. COMP 105 also introduces you to the mathematical foundations needed to talk precisely about languages and about programs: abstract syntax, formal semantics, type systems, and lambda calculus. Mathematics helps you recognize ideas and techniques that you have seen before, even when they are disguised.

To provide a sane and sensible context in which to learn, COMP 105 immerses you in case studies, conducted using tiny languages that are designed to help you learn. In any given case study, you may act as a practitioner (by writing code in a language), as an implementor (by working on an interpreter for the language), as a designer (by inventing semantics for a related language), or as a scholar (by proving mathematical properties of the language).

COMP 105 develops high-level, flexible programming skills that you can transfer. For example, you will find you can apply your skills to projects written in older languages such as Perl or Java, in currently popular languages such as Python, Ruby, Scala, and Swift, and in weird languages that might be important in the future, such as Haskell, Rust, Agda, Coq, and who knows what else. No matter what language you work in, when you finish 105, you'll be writing more powerful programs using less code. In a profession where complexity is the enemy, your 105 skills will equip you to tackle the most demanding jobs—and succeed.

What will the experience be like?

COMP 105 is as difficult as any course in our program, and it's a difficulty of a *kind* you are not used to encountering. I want

every student to succeed, and you are more likely to succeed if you know what to expect.

How does 105 compare with 40?

For most students, COMP 105 is as difficult as COMP 40. Some students find 105 a little easier, and some find 105 a little more difficult.

If you know 40, you know that your feeling of accomplishment comes primarily from building the projects. The 40 projects are easy to talk about: they look big, and many of them sound impressive, like “I built an image compressor.” Most important, the 40 projects require that you apply the same skills that you learned in 11 and 15, just to a greater degree. In brief, 40 yields to force.

COMP 105 also has a couple of projects that look big and sound impressive, like “I built a type inferencer.” But overall, 105 is much more about finding a small, elegant, precise solution to a small problem—usually a programming problem, but sometimes a math problem. As a result, compared with COMP 40,

- COMP 105 presents more intellectual challenges.
- COMP 105 gives you many more opportunities to make a satisfying breakthrough, often by an “aha moment.”
- In COMP 105, you spend much more time feeling lost.

But even though 105 is quite different from 40, there are lots of skills that transfer. If you have taken COMP 40, then

- You know how to read a long assignment and how to work away at it gradually.
- You have practice building modules with specifications, and you have practice testing against specifications.
- You have some experience translating some challenging concepts into code.

But you must also be aware that some of not all of your habits in COMP 40 will necessarily transfer to COMP 105:

- COMP 40 may fool you into believing that every hour spent at the keyboard represents progress toward your goals. In 105, it is all too easy to spend hours going nowhere. You *must* learn to pause, step back, and think about where you are going.
- In COMP 40, you can succeed without having much insight into algorithms, linked data structures (think lists and trees), or recursion. In COMP 105, you will need insight into all of those things.
- COMP 40 may fool you into believing that you can complete any difficult course if you just grind away doggedly. In 40, this approach works: it may not be much fun, but you'll finish. And grinding away constantly has another benefit: when you're grinding, you don't feel bad and you don't feel lost.

In 105, this approach works badly or not at all. If you are always grinding, you will never have that quiet moment that gives you the *insight* you need to solve a problem. You can't brute-force 105. Instead, you should deliberately break up your work sessions with *frequent pauses*. Such pauses will help you a lot. Stop, get up and move, and let problems percolate in your brain. You will probably feel lost or uncomfortable for a short time, but in the longer run, you'll finish faster, and then you'll feel great.

Why do I feel lost?

To succeed in 105, you must understand that it is *normal* to feel lost. There is nothing wrong with you, and there is nothing wrong with the course—feeling lost is a consequence of the situation: where you're coming from and where you're going.

Where you're coming from is most likely 11, 15, and possibly 40. All of these courses use a single programming paradigm, and they use almost the same language: imperative programming with unsafe pointers and explicit memory management, close to the machine. Even the syntax and the data are the same—compared to what you can see in the world, and to what you are introduced to in 105, differences between C and C++ barely matter. If you've completed 40, you're going to feel like an expert. And rightly so! You *are* an expert. But you're a *narrow* expert, and 105 introduces you to the demands of a wider world.

The most important way in which 11, 15, and 40 are narrow is that their programming model is a thin veneer over the machine model. These courses don't rely heavily on functions or types, and they do not commit deeply to objects. (While C++ makes it possible to commit strongly to types and to objects, it imposes such staggering complexity that these techniques cannot be taught in introductory courses.) Your inexperience with functions, types, and objects makes you a beginner again. And beginners often feel lost.

The other factor that comes into play is that when you learn challenging new material, you feel bad. Here's the neuroscience:¹

Many labs have observed that these critical brain regions increase in activity when people perform difficult tasks, whether the effort is physical or mental. . . . [The road is difficult], though, because these brain regions have another intriguing property: When they increase in activity, you tend to feel pretty bad—tired, stymied, frustrated. Think about the last time you grappled with a math problem or pushed yourself to your physical limits. Hard work makes you feel bad in the moment.

What should I do about it?

When a successful student suddenly feels lost and confused, it's discouraging. To keep up your courage, I recommend two steps:

¹Lisa Feldman Barrett, "How to Become a 'Superager'", *New York Times*, Dec. 31, 2016

- First, recognize that unpleasant feelings are a normal part of a learning process. Our job as professors is to set you problems that are more challenging than you think you can handle. . . and to support you as learn you can handle them. This learning process requires hard work, attention to detail, and a leap of faith. But if you persist, your unpleasant feelings of confusion will be replaced by satisfying feelings of mastery.
- Second, ask questions. "Is it normal that I'm confused here?" "Are you confused here?" "If I'm confused but I still want to make progress, what skill do I need, or what technique should I practice?" "If you're not confused, what skill are you using? What technique are you applying?"

Both these steps will help you feel better.

You will also need to learn to proceed with your work *despite* feelings of confusion, uncertainty, or anxiety. To help with that, you need support.

What tactics do and don't work?

In 105, the slow approach is the fastest one. Effective 105 students stop, think, pause frequently, and work in short sessions. These tactics can be hard to put into practice, especially if you have used other tactics to succeed in other courses. But the work tactics often preferred by beginners do not promote success in 105. I paraphrase Garth Flint:

[Talented students] are very resistant to [a systematic, thoughtful, slow] approach. They do not want to plan; they want to do trial and error at the keyboard. They have not learned an important axiom of programming: "three hours of trial-and-error coding will save fifteen minutes of planning." (I wish I knew who came up with that. They deserve an award.) [Students] want to hammer keys [in Halligan for hours on end and] then complain [that the course is too much work].

If you approach 105 by hammering away at the keyboard, *be aware how the approach is working for you*. If the course starts taking too much time, you can adjust your tactics—but only if you are mindful of them.

If you have already learned systematic tactics for program design and implementation, you should be able to apply them to COMP 105. If you have not had to learn a systematic approach, which is common after early courses, you will easily master a nine-step design process described in *Seven Lessons in Program Design*.

How does the class support my success?

To help you navigate the learning process successfully, we have built a variety of support structures into COMP 105.

- Early in the course, *homework* is structured as a large collection of small problems. When the going is most difficult, this

structure makes your progress visible, even when progress is incremental.

- Every homework begins with some *comprehension questions* about the reading. These questions guide you toward reading those parts of the book that are most valuable for completing the homework. The comprehension questions focus your attention on the most relevant parts of the very long book.

Comprehension questions are short, and if you understand the reading, you should be able to answer all the questions in just a few minutes. To achieve that understanding, however, substantial reading may be required.

- Weekly *recitation* sections give you supervised practice working on problems that resemble the homework problems. Most recitations are scheduled when a new homework is just starting, so you can get off early, on the right foot. Recitations are small, which makes recitation an ideal place to ask questions, including the questions above. If you have a question, others in your recitation probably have a similar question. *Recitations are mandatory*, and they count toward your course grade.
- Face-to-face interactions are invaluable. COMP 105 provides extensive *office hours*, conducted primarily by students who know the course and who know how to succeed. We spend a significant fraction of the course budget providing face-to-face office hours, so take advantage of this resource!

Every student is expected to go to the instructor's office hours at least once, for at least five minutes.

- After every homework, we distribute *model solutions*. These solutions model the best work of an expert in the field.
- This *syllabus* contains a heavy helping of advice.
- On the first day of class, we provide tips from the instructor, and we also provide advice from successful students.

How can I use office hours effectively?

COMP 105 office hours are organized around physical space.² The primary help point is in the upstairs kitchen in Halligan, and it is equipped with these accessories:

- A whiteboard, next to the refrigerator, where you can write your name and your question or topic for help
- Large photographs of TAs who are on duty, with their names
- Any other course-related things that are timely

When you want help, go to the primary help point. Add your name *and your topic or question* to the queue written on the board. Your TAs have been instructed to prioritize *groups* of students

²We've learned that Halligan Helper leads to unacceptable wait times and unhappy students, so we no longer use it.

who want to talk about similar issues, or who have similar questions. These groups are called *affinity groups*. You can also get help as an individual, but you may have to wait longer than when you are part of an affinity group. (The TAs on duty will help you form affinity groups.)

The 105 help points can get crowded, and not all students thrive in crowds. You are always justified in telling a TA, "I would like to go somewhere quiet to talk about this." Your TAs have been instructed to ask. (They have also been instructed to ask, politely, if other students can join the quiet discussion.)

When the kitchen gets crowded, the 105 TAs have been instructed to walk the second floor every 20 minutes, checking to see if there are students who want to talk about COMP 105.

What can I expect from teaching assistants?

In COMP 105, the TAs have been instructed to use a model that may be a little different from what you are accustomed to. The TAs are not there to help you debug your homework. They are there to help you learn. And the TAs who provide the best help and who help students learn the most are the ones who guide students with questions.

The questions that TAs ask are meant to be timeless and to apply to many problems. Eventually, you will be able to use the questions yourself, to help your own progress. Questions range from the technical ("what algebraic laws apply to this function?") to the conceptual ("in your own words, what is meant by $\Gamma \vdash e : \tau$?") to the procedural ("how much of your 105 time is spent working alone?"). Expect questions about your work, your understanding, and your study practices.

Here are some other things you can and cannot expect from TAs:

- TAs will conduct themselves professionally—this is their job. You can expect them to treat you with professionalism and respect.
- TAs will be committed not just to your material success but to your well-being—I have told them that your well-being is our top priority.
- When it's your turn to be helped, TAs will always be willing to help you in a quiet place, or in private. I hope they will remember to ask you, but if not, a TA will always agree to help you in private.
- TAs will ask you a lot of questions. You can expect them to be framed with good will and with the intention of getting you on track to succeed. Many questions have been designed before the course starts, for use by the entire staff. When you need help with code, expect questions based on our nine-step design process.
- TAs will tell you when they don't know or aren't sure. They can't know everything, but they know what they don't know.

- TAs will push you to interact with other students who are working on similar problems, trying to understand similar topics, or confused by similar issues.
- TAs will push you to take responsibility for your own learning. You can expect them to want to understand what you are doing to study, what you are doing to prepare, and what you are doing on the homework problems themselves. You can expect TAs to ask about your study practices and to help you improve them.
- TAs will prioritize affinity groups over individual help.
- TAs will help individuals on a first-come, first-served basis. You cannot expect them to jump you to the head of a queue just because your question is short. If you think you need help fast, form an affinity group.

- Talk about the homework problems with your friends and classmates. Some classmates may become new friends.
- Join a study group.
- Don't work alone in your room. When you can, work in Halligan.
- Take advantage of office hours.
- If the going gets tough, have another look at this syllabus.
- *Read* the handouts that describe experiences of top students in past classes and the instructor's tips.
- Build a "105-free zone" into your weekly schedule. Honor the zone even if you get behind, so that at least once a week you are sure to get a break from 105. (Because a homework is due every week, there are no structural breaks built into the course.)
- Again, finally, and most important, do not allow yourself to become socially, emotionally, or intellectually isolated.

What if I need special support?

Tufts University values the diversity of our students, staff, and faculty; Tufts recognizes the important contribution each student makes to our unique community. Tufts is committed to providing equal access and support to all qualified students through the provision of reasonable accommodations so that each student may fully participate in the Tufts experience. If you have a disability that requires reasonable accommodations, please contact the Student Accessibility Services office at Accessibility@tufts.edu or call 617-627-4539 to make an appointment with a representative who will help determine appropriate accommodations.

Accommodations cannot be enacted retroactively; if you need an accommodation, you must ask for it in advance.

How must I support my own success?

Everyone on the course staff is committed to your success. But as we do our part, you must do your part. Take advantage of the resources we offer. Read the syllabus. Most important, *do not allow yourself to become socially, emotionally, or intellectually isolated*. To prevent isolation, I recommend that you join a study group, and that when you can, you work in Halligan. The informal support network in Halligan is strong; participating in Halligan culture is one of the unique advantages of getting your computer-science education at Tufts. Don't miss out.

As you will see throughout this syllabus, there is more you can and should do:

- Go to lecture. Using a pen, pencil, or stylus, take notes.
- Go to recitation. Read the homework first.
- Don't try to swallow the textbook. To guide your reading, use the comprehension questions and other recommendations on the homework.
- Look at the homework problems as soon as they come out. Think about them a little bit every day.

105 is a 100-level course. What does that mean?

Unlike 11, 15, and 40, COMP 105 is numbered above 100. Formally, this means only that unlike 11, 15, and 40, 105 counts for graduate credit. But informally, a 100-level course carries additional expectations:

- *It's not just code; it's math.* All required 100-level CS courses have both code and math; the combination of code and math is the essence of the field. 105 is mostly code, but it still has lots of math; 160 is less code and more math; and 170 is almost all math.
- *You are responsible for your own learning.* You can't learn everything you need to know just by showing up at lecture. Lecture will give you the keys to the hard parts, but you need to tackle the book, and you need to fill in gaps on your own.³
- *Junior standing is recommended.* 105 requires a degree of maturity that is not usually expected of freshmen and sophomores. Many students do take 105 as second-semester sophomores, but unless they are also strong in math, these students often struggle. It is reasonable to postpone 105 until your junior year.

What will we learn?

COMP 105 is built around two sets of skills:

- *Programming skills* that exploit the best of the best programming-language features
- *Mathematical reasoning* about code

³"On your own" means "with the help of your classmates and your teaching assistants."

The programming skills contribute to your professional practice, getting you ready to code from scratch in a language you've never seen before. The math contributes to several outcomes:

- Math helps you communicate clearly about languages, language design, and language features.
- Math is a way of seeing patterns in the world. When you're confronted with a language you've never seen before, your mathematical experience will help you know what questions to ask, and it will help you recognize and identify the elements that you *have* seen before.
- Math is an ideal way to specify what programs do: it's clearer and more precise than informal English, and it's cleaner and more streamlined than a reference implementation.
- Experience with programming-language math will help you evaluate future claims about languages (for example, claims about security).

Here are some of the detailed skills you will develop:

- Read and write *precise specifications* of how languages work
- Understand how it is possible to *prove universal truths* that apply to *any* program written in a given language
- Design code using *algebraic laws*
- Write and reason about *recursive functions*
- Capture common patterns of recursion in *higher-order functions*
- Recognize and exploit common higher-order *list-processing functions*
- Program with first-class *functions as data*
- *Prove correctness* of code-improving transformations
- Express rich control structures using functions as *continuations*
- Design and implement *polymorphic* functions, methods, and data structures
- Understand the merits of *polymorphism* in programming
- Use *types* to guide the construction of code
- Understand in detail what are the merits of *type checking* and how type checking works, including polymorphic type checking
- Understand in detail what are the merits of *type inference* and how type inference works, including polymorphic type inference
- Describe computations using the *lambda calculus*
- Hide information using *abstract data types, modules, and interfaces*

- Hide information using *objects* and *protocols*
- Reuse code using *inheritance*

What topics will we study?

You will develop the skills above by studying these topics:

I. Functions

- Recursion revisited: design by algebraic laws
- Abstract syntax & (big-step) operational semantics
- First-class, higher-order functions
- Functions as continuations

II. Types

- Core ML
- Typing rules (monomorphic and polymorphic)
- Type checking
- Type inference

III. Theory

- Lambda calculus & small-step operational semantics
- Recursion and fixed-point operators

IV. Data abstraction

- Abstract data types, modules, and interfaces
- Objects, classes, and protocols
- Inheritance and the design of class hierarchies

How heavy is the workload?

The workload in 105 is heavy; it counts for 5 semester hours of credit. Expect a demanding homework assignment almost every week, plus two challenging examinations. Most students say 105 demands as much time and effort as 40.

What does the workload consist of?

The work is mostly programming assignments. These assignments are significantly more challenging than the assignments in COMP 15 and COMP 40, but most of them are also much smaller: many solutions take 10 to 40 lines of code. Many of the assignments use software that comes with the text by Ramsey.

The homework also has a significant theory component. You will prove theorems using existing theory, and you will also develop new theory of your own, which will describe how a language feature might work. Early assignments are either “mostly programming” or “mostly theory;” later assignments mix programming and theory; and some assignments ask you to apply theory to write code.

The course also has two exams: a midterm and a final.

How does my work affect my grades?

Your course grade is based on *my judgment of the quality of your work* and the degree of mastery you demonstrate. My judgment is influenced by your written work, by your class participation, and by your examination scores, but I give heavy consideration to written work, as indicated by this approximate system of weights:

| | |
|--|-----|
| Homework assignments | 58% |
| Recitations | 10% |
| Midterm exam | 7% |
| Final exam | 15% |
| Participation in other class activities | 5% |
| Office-hour visit to the course instructor | 5% |

The weights may be adjusted at my discretion.

What do my homework grades mean?

Your homework grades are based on the course staff's judgement of the quality of your work and your mastery of the material. Grades are assigned a coarse five-point scale:⁴

- **Excellent** work is outstanding in all respects. To be ranked Excellent, the work must truly excel; that is, it must exceed expectations in some way.⁵

Excellent *documentation* addresses exactly the key issues, and degree of detail is exactly appropriate.

Excellent *code* is very well thought out and implemented. Excellent code shows mastery of new language features and idioms. On the rare larger assignments, Excellent code shows evidence of thorough attention to abstraction and modularity. **Excellent code is so simple that it obviously has no faults.** Instructors will see no obvious ways to make excellent code shorter or simpler. Excellent code is laid out consistently and uses scarce vertical space well. Excellent code is of such high quality that the course staff would be happy to maintain it.

- **Very Good** work is of high quality in nearly all respects. An assignment that does everything asked for, and does it well, earns a grade of Very Good.

Very Good *documentation* addresses most key issues, with a good amount of detail.

Very Good *code* shows correct, idiomatic use of new language features. On the rare larger assignments, Very Good code shows that some attention has been paid to abstraction and modularity, although one or two opportunities may have been overlooked. Very Good code contains well-chosen

⁴It is the same scale used by the National Science Foundation and by Consumer Reports.

⁵By definition, it is not possible for the entire class to excel. The normal top grade is Very Good, and students who consistently produce Very Good work earn A's. Grades of Excellent are awarded only in cases of true distinction. This means, for example, that if everyone in the class turns in a perfect solution, all those perfect solutions are judged Very Good.

names for functions and their parameters, so that it is easy to guess what functions do. Instructors may see one or two ways to make Very Good code shorter or simpler. Layout is consistent and uses scarce vertical space well. Small errors may be evident from reading the code.

- **Good** work demonstrates quality and significant learning.

Good *documentation* covers some key issues, but significant issues may have been overlooked or may be covered with insufficient detail. Vague generalities may appear where precise specifics are expected.

In Good *code*, individual functions are well organized and readable. Most names are well chosen, but there may be some exceptions. On the rare larger assignments, opportunities for abstraction and modularity probably have been overlooked. Good code gets the job done, but possibly in a way that could be shorter or simpler. Layout may be inconsistent in a few places. Errors may be evident from reading the code, but instructors will believe that code could be made correct with only modest changes.

- **Fair** work is lacking in one or more aspects; key issues need to be addressed. "Fair" is the lowest satisfactory grade.

Fair *documentation* shows evidence of effort, but the degree of coverage and detail is significantly short of what the course staff believe is needed to foster success.

Fair *code* contains significant faults. Instructors may not be able to figure out what all functions do. Layout may be inconsistent or waste scarce vertical space (e.g., every other line may be blank). Fair code may show evidence of a 'clone and modify' approach to program construction. Names may be poorly chosen. Possibly a Fair program could be replaced by code half its size. Given Fair code, instructors may believe major changes would be required to make the code correct, or instructors may be unable to understand *why* the code might be correct.

- **Poor** work shows little evidence of effort or has other serious deficiencies. "Poor" is an unsatisfactory grade.

Poor *documentation* may fail to address key issues or may address them perfunctorily.

Poor *code* may be undocumented or inappropriately documented (e.g., overcommented). Poor code is often lengthy, out of proportion to the problem being solved. Poor code may be laid out on the page in a way that is hard to read. Poor code often shows evidence of its history: extra copies of functions, unused logic left lying around, **old code commented out**, and so on. **Poor code may be so complex that it has no obvious faults.**

- **No Credit** is received for work not turned in, for parts that are incomplete, or for work that is non-functional or appears to bear no relation to the problems assigned.

No Credit is received for work that is deemed to be plagiarized. Code submitted for Comp 105 may be examined for potential plagiarism using automated heuristics. Plagiarism is a form of academic fraud, which is unacceptable at Tufts. If academic fraud is suspected, appropriate steps will be taken. Submitting someone else's work as your own is likely to lead to suspension or expulsion. It has happened to others. **No Credit is received for work that you cannot explain.**

In a typical class, a consistent record of Very Good homework, together with commensurate examination grades, will lead to a course grade in the A range. If some work goes "above and beyond" and is rated Excellent, a grade of A+ is possible. Work rated Good corresponds to a wide range of passing grades centered roughly around B. Work rated Fair will lead to low but satisfactory course grades; if a significant fraction of your work is Poor, you can expect an unsatisfactory grade (D or F).

No Credit is a disaster. If 10% to 15% of your work is awarded No Credit, it is likely to cost you something like one full letter grade. Any grade, even Poor, is dramatically better than No Credit. Why? Because the worst thing you can do is to skip problems. Every problem you attempt will teach you something; when you skip a problem, you learn nothing.

What is a "minor deduction"?

Sometimes there is a fault in your code that needs to be corrected, but that does not warrant dragging a grade down from Very Good to Good or from Good to Fair. That sort of fault typically receives a "minor deduction." Here's the prototypical example:

```
It is never correct to write if P then true else  
false. Clean code always says just P.
```

A minor deduction is the rough equivalent of a "point off" out of 100 points.

What about final letter grades?

Final course grades are meant to reflect a consistent standard, consistently applied. The standard is an absolute standard; COMP 105 is *not* graded on a curve. Anyone who achieves strong results can earn an A.

Here are some details about the standard:

- **Fair** is the lowest passing grade and is anchored at a C-minus.
- **Good** typically marks the border between a high B and a low B-minus.
- **Very Good** typically marks a high A, **Excellent** an A-plus, and **Poor** an F.
- As grades get lower, the grading scale spreads out. Excellent, Very Good and Good are all equidistant. For example, 10% Good and 10% Excellent average out to the same as 20% Very Good.

The distance between Fair and Good is bigger than the distance between Very Good and Good, and the distance between Poor and Fair is likewise bigger. For example, 15% Very Good and 10% Fair average out to the same as 25% Good.

No Credit is as far distant from Poor as Poor is from Excellent. For example, 10% No Credit and 26% Very Good average out to a just-passing grade (36% Fair).

- Exam scores will be characterized as Fair, Good, Very Good, and so on, but on an exam, the meanings of these labels are elastic—what counts toward your final grade is the number of points earned.

The standard is a guideline, not a decision procedure. To the degree possible, I adjust the border between letter grades so that different grades reflect significant differences in students' performance. For example, in any given semester, the line between B and B-minus will be *near* a 100% Good record, but in a place where there is a meaningful gap in students' achievement. This place might be above or below 100% Good. Where no meaningful gaps in achievement can be found, the line is drawn to minimize pluses and minuses; for example, many students earn A grades, but relatively few earn A-minus or A-plus.

What if my homework is graded incorrectly?

If we make a mistake in grading your homework assignment, you have *seven days* after the return of the assignment to call the mistake to our attention. File a request using the form at <https://www.cs.tufts.edu/comp/105/regrade>. We reserve the right to reassess your *entire* assignment and assign a new grade. The new grade may be higher or lower than the original grade.

What should I expect from exams?

To understand your exam grades, you must understand what I believe an exam is for. An examination should test not only your mastery of familiar material but also your ability to apply your knowledge to unfamiliar situations. To do well on my exams, you must

- *Remember* the material
- *Understand* the material
- *Apply* your understanding to new problems

When you take one of my exams, **expect not to know all the answers.**

Each exam consists of multiple problems; some problems will ask you to read and write code. Each problem is worth a certain number of points; the number depends on how hard I think the problem is and how long it takes to complete the problem. Most problems are divided into multiple parts of varying difficulty:

- There is usually a basic part that is not too difficult and is worth a few points.

- There is a middle part that is quite difficult and is worth most of the points.
- There is often a “stretch part” that is meant to extend your reach and is worth a couple of points.

It is very rare for an answer to earn *all* points available on a problem.

Every exam is unique, but typical raw scores are much lower than you may be accustomed to. For example, it is almost unheard of for a student to earn 90% of the available points on a COMP 105 exam. Typically, if you earn **two-thirds** of the available points, your grade will probably be Good or Very Good. And if I botch the exam by making it more difficult than I intend, it’s possible that earning only 50% of the points will still result in a high grade.

How are the exams administered?

The final exam is administered during final-examination period as part of the usual Tufts system of two-hour final exams. It is a closed-book exam, but you may take with you one standard US letter page of notes written on both sides. I strongly encourage you to create such page and to write your notes by hand; preparing the notes is a very effective way to study.

The administration of the midterm examination is more complicated. The midterm is designed as a 75-minute in-class exam. But because classes are held two days a week, there is no good time to schedule the exam—our regularly scheduled lectures always fall within one day of a homework deadline. To create flexibility in scheduling, the midterm exam is administered over a period of about 48 hours:

- You can pick up the exam at any time during the availability period, but *you must return it within two hours*. This gives you 45 additional minutes: ample time to collect the exam, get to a quiet place, unpack, pack up, get back to Halligan, and turn in your exam.
- If you have an accommodation that allows extra time on exams, the extra time applies only to the 75-minute portion, not to the administrative time. So for example if you are accommodated by having time and a half on exams, you will have 113 minutes for the exam itself and 45 minutes of administrative time. You will have to return the exam two hours and 38 minutes after you pick it up.
- Pickup and dropoff are available only during business hours. We will try to make it possible for you to drop off your exam as late as 6:00 PM.
- The exam will be available on a Friday and on the following Monday and Tuesday. To guarantee that you have a window of time available to complete the exam, there will be no lecture on that Monday.
- You must complete your midterm by yourself. You may not consult with others, and you may not consult sources on the Internet. You may, if you wish, consult the textbook or

the lecture notes. But I encourage you to prepare for the midterm as you would prepare for the final, with one page of your own notes.

- Once the midterm is available, you must not discuss it with any student who has not yet turned it in. This restriction applies even if you have not seen the exam yet.
- If you have turned your midterm in, you may discuss it with other students who have also turned their midterms in. But such discussion must take place in *private*, where there is no possibility that someone else might overhear you.

How am I graded in recitation?

COMP 105 requires you to learn many new ideas and techniques. Before you can make progress on the homework, you need to understand the ideas and techniques. Recitation helps; each week, you get a third look at ideas and techniques, and you get practice working relevant exercises. Each recitation is graded on a three-point scale:

- **Very Good** recitation participation means *you contributed* a question, answer, idea, or solution, and also *engaged your classmates* to help them contribute. Your recitation leader will model for you what this means. **Very Good** recitation participation also requires that you come to recitation having looked at the homework and that you are prepared to talk about the reading-comprehension questions.
- **Good** recitation participation means you contributed, but you did not engage your classmates. Perhaps you spoke too much and didn’t leave room for others to contribute, or perhaps you simply behaved as if others weren’t there. Perhaps you had little idea of what was actually on the homework or you couldn’t say anything about the reading.
- **Fair** recitation participation means only that you showed up.

We drop the two lowest recitation grades, so if you have one or two bad days, it won’t affect your final course grades. This policy also enables you to miss up to two recitations without penalty. If you need to miss more than two recitations, explain the situation to your academic dean, and have your dean make contact with me.

How is my participation graded?

A portion of your grade is based on your participation in the class. This phrase encompasses a variety of activities that demonstrate you are *engaged actively in managing your own learning, developing new skills, and understanding new ways of programming and problem-solving*. To earn high grades for class participation, you must show that you are so engaged. You can show this engagement in a variety of ways:

- Asking appropriate questions in class
- Answering questions when called on in class

- Contributing photographs of the blackboard from class
- Asking appropriate questions on Piazza
- Answering questions well on Piazza
- Organizing study groups
- Working out ideas with teaching assistants
- Helping other 105 students in Halligan
- Participating in the *in-class midterm course evaluation*
- Submitting evidence that you *wrote online end-of-term course evaluations*
- Submitting evidence that you *evaluated your recitation leaders*

Nobody has to do *all* of these things; you can earn top grades for class participation by doing just a few things well. In particular, nobody is required to speak in class—but everybody should be prepared to answer questions if called upon. What questions are appropriate? Any question about programming languages. However, it may not be appropriate to insist that every question be tracked to its lair and answered. If a question becomes inappropriate during class, I will let you know.

How should I interact with people?

Engineering is not a solitary profession. To maximize your chances of success in 105 and beyond, I have designed some interactive experiences into the class.

- *Discussions with classmates.* Programming is a creative process. To help you think creatively, understand what the homework problems are asking, and discover paths to solutions, I encourage you to discuss the questions with friends and colleagues. You will do much better in the course, and at Tufts, if you find people with whom you regularly discuss problems.

Once you reach the coding stage, however, discussions are no longer appropriate. *Each program, unless explicitly assigned as a pair problem or a recitation problem, must be entirely your own work.*

- *Practice work with classmates.* Recitation will give you practice working out problems with the help of your classmates, under the supervision of a recitation leader. Your recitation leader will model and identify appropriate ways of talking about problems.
- *Deep work with one classmate.* Much of the programming in 105 is about your individual understanding of new language features and new ideas, and to develop this understanding, you will tackle most programming problems on your own. In the real world, however, substantial artifacts are seldom built by individuals working alone. COMP 105 will therefore provide you with some opportunities to build something substantial by working deeply with one classmate, not just on the ideas, but on the code itself. This is *pair programming* (more at Wikipedia).

In COMP 105, pair programming is always an opportunity, never an obligation. You are not required to work in pairs. If you do choose to work in a pair—which I recommend—know that *no single pair may work together on more than three assignments*. If you need help finding a partner, advertise on Piazza.

- *Interaction with faculty during lecture.* A particularly useful form of interaction is the question asked in class. Questions are always welcome; if you have a question, chances are other people in class have a similar question. Ask it! One question that is always legitimate is “why are we doing this?”
- *Interaction with faculty outside of lecture.* One of your jobs as a student is to get to know some of the faculty. To help you with this part of your education, I count up to five minutes of office-hour visits as part of your course grade. Each minute you spend in conversation with me during my office hours will earn one percent of your overall course grade, up to a possible total of five percent. To earn your five percent, you must come to my office hours *before Spring break*. While you may find it helpful to talk about homework, class, engineering, or Tufts overall, any mutually agreeable topic of conversation is acceptable.

Office-hour visits after Spring break still count toward your course grade, but not for the full five percent.

- *Interaction online.* At any time of day or night, you can post a comment or question to Piazza. *If your question contains any of your code or your algebraic laws, you **must** make it private.* Otherwise, questions on Piazza should be suitable for public consumption. If your question contains no code or algebraic laws, please make it visible to everyone, so you get participation credit for asking it, and your classmates have a chance to help you by answering it. (By helping to answer your question, your classmates improve their own grades for class participation. Similarly, you can improve your grades by answering other people’s questions—but *your answers must not contain any code you have developed for the assignment*. Do as you would be done by, and everyone wins.)

I will use information in SIS to enroll most of you in Piazza. But if you are not enrolled, you can enroll yourself using the COMP 105 signup page.

We make every effort to answer posted questions in a timely fashion. But if you have posted a question to Piazza and have not gotten a timely response, many questions are appropriate to post to Stackoverflow, which can respond very quickly indeed. If you use Stackoverflow, please follow our guidelines, which are online.

Questions that include code you are working on (or code you have written) are OK for Piazza, but *they must be “private.”*

Please don’t send questions directly to the course staff using their personal email addresses. If, in a rare case, you have

an issue that is not appropriate for the whole course staff to see, please send email to my personal account.

- *Interaction with course staff in real life.* The course staff are here to enhance your learning; it is part of their job. Please interact with course staff using the same professional manners and standards you would use in any workplace. Please also recognize that COMP 105 is only *part* of anyone's job: a member of the course staff may be present but not actually available to talk about 105.
- *Interaction on holidays.* We do not guarantee to hold office hours on university holidays. To know whether office hours will be held, consult Piazza.

How much interaction is too much?

Interactions and discussions with classmates must take place in human language, at a high level. You must not discuss code, and you must not exchange human language, pseudocode, or other information that is expressed at the level of code. If you start communicating in code or at the level of code, including algebraic laws, you're breaking the rules.

- While I encourage shared work at the whiteboard or in notebooks, if your shared work is so detailed or low-level that there is only one reasonable translation into code, you are collaborating too closely.
- Unless you are working with another student as part of a programming pair, *it is not acceptable to permit that student to see any part of your program, and it is not acceptable to permit yourself to see any part of that other student's program.* In particular, you may not test or debug another student's code, nor may you have another student test or debug your code. (If you can't get code to work, consult a TA or the instructor.) Using another's code in any form *or writing code for use by another* violates the University's academic regulations.
- *Algebraic laws have the same status as code:* only you and your programming partner (and the course staff) may see your algebraic laws.
- *Do not, under any circumstances, post a public question to Piazza that contains any part of your code or your algebraic laws.* Such questions must be private.

Suspected violations will be reported to the University's Director of Community Standards, who will investigate, decide if a violation has taken place, and if so, recommend an appropriate penalty. Be careful! As described in the university's academic-integrity policy, the penalties for violation can be severe. A single bad decision made in a moment of weakness could lead to a permanent blot on your academic record.

The same standards apply to all homework assignments; work you submit under your name must be entirely your own work. *Always acknowledge those with whom you discuss problems!*

So can I post my code on github?

Code in a github repository is visible to other students. So *no, you may not post your code to a github repository*—unless you are very careful to make the repository private. It is certainly convenient to use github for backup and to share your work with potential employers. But it **must** be private. It is against course policy for you to put your homework in a public github repository—and because a public github repository can facilitate misbehavior by others, it is considered a violation of academic integrity.

How do pair-programming interactions work?

In pair programming, you work with a partner under the following constraints:

- When work is being done on the program, *both partners are present at the computer.* One partner holds the keyboard; the other watches the screen. Both partners talk, and the keyboard should change hands occasionally.

If you are in the middle of a pair-programming project and your partner has to travel for a day or two, it is permissible for you to continue working together using a tool like TeamViewer, provided that you also maintain a real-time audio connection. (TeamViewer allows two programmers to work on one computer by enabling one computer to “control” another.)

- *You submit a single program under both your names.* That work gets one grade, which you both receive.

While we strongly encourage both discussion and pair programming, we are also charged with guarding Tufts's standards of academic integrity. The following policies help ensure that these standards are upheld:

- If circumstances, such as scheduling difficulties, make it impossible for you to work as part of a pair, you may *ask the course staff for permission* to divide an assignment into parts and to do some parts as a member of a pair and other parts as an individual. Such parts must appear in different files, and **each file must be clearly identified as the work of an individual or the work of a pair.** Work done jointly by the pair should be submitted by *both* members of the pair. **Files containing joint work must be identical.** If you as an individual modify a file containing joint work, and you submit the modified file, that act will be considered a violation of academic integrity.
- **It is never acceptable** to divide an assignment into parts and have some parts done by one partner and other parts done by the other. Submitting work done by someone else as your own will be considered an **egregious violation** of academic integrity. **Submitting individual work as the product of pair programming** is also a violation of academic integrity.

What if pair programming doesn't work for me?

In COMP 105, you are never required to pair program. About 20% of students routinely opt not to pair program.

If you try pair programming and find it is not working, or if your programming partner disappears in mid-project, proceed as follows:

- Notify your partner that you wish to discontinue the pairing. You needn't explain yourself; a simple wish to stop is reason enough.
- Submit the work done in partnership at that point, even if it is incomplete or broken. That work is "community property" and both students may submit it.
- If you wish, follow up with an additional submission of whatever you complete on your own.

How does the course staff monitor pair programming?

To try to ensure a good pair-programming experience for everyone, the course staff will choose a random sample of students to ask these questions:

- How did you form your partnership?
- Briefly describe your experience working with this partner.
- How do you feel about the experience?

The course staff will use this information to try to improve students' pair-programming experience and to try to prevent disappointing experiences from getting worse.

Do I have a right to pair program?

Pair programming is a privilege, not a right. If you foul up and don't fix it, I may revoke your pair-programming privileges. Foul-up consists in any of the following *unacceptable behavior*:

- Repeatedly failing to keep appointments with your partner
- Lying to your partner about what you have done
- A pattern of violating academic integrity
- Other similarly egregious offenses

If I revoke your pair-programming privileges and you believe I have done so unfairly, you may appeal to the department chair.

What is expected of my homework?

In this class, *you will learn most of the material as you complete the homework assignments*. The importance of homework is reflected in the weight it is assigned. Most homework for this course involves short programming assignments. Many of them are based on the text by Ramsey. There are also some larger programming assignments. And there is some theory homework, involving more proving and less programming.

As in most classes, it helps to start the homework early. But in 105, *starting early seems to produce unusually good benefits*. Many students report that if they start early, even if they don't appear to make much progress, a solution will "come to them" while they are doing something else.

Another reason to start early is that *if you get stuck, early help is a lot better than late help*. 105 is a big course, and your difficulties could be overlooked until they get out of control. Keep an eye on yourself, and remember that a short conversation during office hours or recitation can save hours of aimless frustration.

If you complete and understand all the homework assignments, you are almost certain to do well on the exams and earn a high grade. If you miss assignments or don't really understand the homework, it will be difficult for you to earn a satisfactory grade.

How should my homework be submitted?

Homework for each assignment is submitted using a course-specific *submit script*, with a name like `submit105-impcore`. The submit script checks to be sure you have files with the right names, and so on.⁶ On most assignments, there are some additional checks:

- Code you submit must be accepted by the appropriate compiler or interpreter *without any warning or error messages*.
- Unit tests submitted as part of your solution must pass, and the entire file must load, including testing, in at most 250 CPU milliseconds. *If you have created long-running test cases, place them in a separate file.*

And the submit script may ask for other information:

- The submit script for the first assignment should ask you how we should pronounce your name. A COMP 105 instructor might answer "kaeth-LEEN FIH-shur" or "NORE-muhn RAM-zee."
- Every submit script should ask you approximately how many hours you have spent completing the assignment.

Before running a submit script, `cd` to the directory in which you have placed your solutions. If the submission script complains, fix the problems and resubmit. You may submit and resubmit the same assignment as many times as you like. I encourage you to *submit work early and often, even if it is incomplete*, so that you have may have an independent check that what you plan to submit is what the submit script is expecting.

How do I get access to the submit scripts?

We provide a submission script for each assignment. To get access to those scripts, you need to execute

```
use comp105
```

⁶We hope one day to get provide to take care of these checks for us, but we're not there yet. Please don't submit homework using provide.

to ensure that these scripts are on your execution path. This use command should also give you access to interpreters for `impcore`, `uscheme`, and so on.

It is very convenient to put the use line in your `.cshrc` or `.profile` file, but to work around a misfeature in use you will need the line

```
use -q comp105
```

Without the `-q` option you may have difficulties with `scp`, `ssh`, `git`, `VNC`, or `rsync`.

A submission script is named `submit105-name`, so for example the submission script for the first assignment is called `submit105-impcore`.

How should my homework be formatted?

Whether it is digital or analog, your written work must bear your name, and it must be neat and well organized. Clear English expression is required; *grammar and spelling count*. The same requirements apply to exams.

Every assignment should include a README file that describes the work. This description must

- Identify you by name
- Identify what aspects of the work have been correctly implemented and what have not.
- *Identify anyone with whom you have collaborated* or discussed the assignment.

How should my code be written?

Your code should conform to our coding-style guidelines, which are online. Pay special attention to the *offside rule*. These guidelines will help your solution be understood and modified by others. Your code is graded its conformance to these guidelines, on your *explanation* of what you are doing, and on your code's functional correctness.

You will notice that the code from the book does not conform to all of the guidelines in the handout—especially the guidelines on layout. That's because the book code is written as a literate program. If you wish to submit your own code as a literate program, you may. And you may choose whether you wish to work with the bare or the commented versions of the code in the book.

How will the structure of my code be evaluated?

The structure and organization of your code is evaluated according to our general coding rubric, which is online.

How will the correctness of my code be evaluated?

Submitted code is typically evaluated by automated testing. Our test scripts aim to explain why you got the grade you did, and if you made a mistake, what it was. On most assignments, you can expect grades to be assigned according to the following criteria:

- To earn a Very Good grade, code must show no faults. (In rare cases, we may assign Very Good grades to code with faults. In such cases, faultless code often earns Excellent grades.)
- To earn a Good grade, code must show faults only in particular corner cases which course staff will have identified as compatible with quality and significant learning.
- To earn a Fair grade, code may have faults, but it must have no grave faults. Grave faults that might disqualify code from earning a Fair grade include misuse of standard output, or such run-time errors such as using an undefined name or calling a function with the wrong number of arguments.
- To earn a Poor grade, code must show significant progress toward solving a problem, even if the solution is substantially incomplete.

In summary, Very Good code is expected to be faultless. Faulty code normally earns a Fair grade, but if the faults are very minor, it might earn a Good grade, and if the faults are grave, it might earn a Poor grade.

Code that writes to standard output or standard error, unless such output is called for in the problem specification, is at risk of earning No Credit. Use `print` and `println` at your peril!

Should I use LaTeX to write theory homework?

No. LaTeX and the `mathpartir` package do make it possible to typeset clear, legible inference rules, derivations, and proofs. That makes it easy for the course staff to read your work. But unless you already have experience using LaTeX to typeset mathematics, I recommend against using it. LaTeX is a power tool, but it's hard to learn, and it provides terrible error messages. In COMP 105, you will be learning plenty of other power tools; learn LaTeX some other time.

If, however, you already know LaTeX, you may benefit by emulating our LaTeX source code for a simple proof system or Sam Guyer's LaTeX source code for typesetting operational semantics.

Then how should theory homework be written?

Use pencil and paper. (Microsoft Word, Open Office, and that ilk are even worse choices than LaTeX—they aren't set up to handle even simple math, let alone inference rules.) Of course, you need to submit PDF. Here are two ways to get it:

- The big copier in the CS office has a document feeder and a Scan button. The scan is formulated as PDF and is sent to an email address you designate.
- If you have a smartphone with a decent camera, there are many scanning apps. I recommend Scanbot, which is free for both Android and iOS.

Any PDFs you submit will be emailed back to you automatically. Use the automated email to confirm that the PDF was correctly transferred to the homework server, that it opens, and that it displays your work as you expect.

How may I use the library?

You may look in the library (including the Internet, etc.) for ideas on how to solve homework problems, just as you may discuss problems with your classmates. But using the library is never required; everything you need to know can be found in lecture, in recitation, on the course web site, or in one of the books.

Some students rely heavily on the library. Although this behavior is permissible, I discourage it. I assign homework problems not because I want to know the answers, but because *doing* homework is the best way for *you* to learn. While library skills are important in our profession, the homework in this course is designed to develop other skills that are even more important. Remember, you will not have the library with you when you write your exams or go on job interviews!

If you do use the library, the Internet, or other outside sources, *your homework must acknowledge the use of these sources*, even if you find little or nothing useful.

So how may I use code downloaded from the Internet?

Any code that is posted to the official Tufts COMP 105 web site is permissible for you to use. You **must not** download any other code from the Internet. You certainly may not submit it as part of a homework assignment.

May I use code from the book?

Absolutely! Any code from either of the books is fair game for you to use. Most of this code is provided in machine-readable form in `/comp/105/build-prove-compare`. Help yourself!

Several of the later homework assignments—especially around type systems—are feasible only with the support of code from the book.

How should I use Wikipedia?

Don't. *Wikipedia is a terrible source of information on programming languages*. Many of the entries are just plain wrong, and Wikipedia's rules make it nearly impossible for experts to correct

bad articles. You don't yet have enough experience to identify bad information, so *don't use Wikipedia for 105*.

What does an extra-credit problem mean?

Most homework assignments will offer opportunities to earn extra credit. *I use extra credit to adjust final letter grades*. For example, if your grade average falls in the borderline between A- and B+, I will assign you the higher grade at my discretion if you have done significant extra-credit work. *I will also mention extra credit if I write you a letter of recommendation*. Extra credit is just that: extra. *You can earn an A or A+ without doing any extra credit*.

What if I can't get my homework in on time?

Homework is typically due at 11:59 PM on a Tuesday. We will grant an automatic extension of fifteen minutes at no cost to you. If you plan on submitting your work at midnight, you will have fourteen minutes for last-minute changes.

We expect your homework to be submitted on time. But we recognize that the exigencies of college life occasionally interfere. If you have difficulty, you have several options:

- For ordinary difficulties, each student is automatically issued *seven* "extension tokens." By expending an extension token, you get a 24-hour extension on *all* deadlines associated with a single assignment. It happens automatically; when you turn in any piece of work more than fifteen minutes late, the course software charges you one extension token.

Expenditure of extension tokens is governed by these rules:

- *At most one extension token* may be expended on any single assignment.
- *When you are out of tokens, late homework will no longer be accepted*. It will be returned ungraded, and you will receive No Credit for the work.
- If an illness affects your ability to complete homework on time, your first step is to report the illness using SIS. This step alerts us about your illness. We will then make suitable arrangements.
- If you experience extraordinary difficulties, such as bereavement, family emergencies, or similarly unpleasant events, please begin by making contact with your associate dean for undergraduate education. Please take this step *before the assignment is due*. Ask your dean to drop me an email or give me a call, and we will make special arrangements that are suited to your circumstances. "Special arrangements" might include a longer extension, but more commonly, we will try to find a way for you to skip portions of the homework.

After the 24-hour extension deadline has passed, model solutions will be available on the Web or distributed as hard copy in class.

What if my partner is out of extension tokens?

If you are pair programming with another student, and you need to submit work a day late, *both* partners are charged an extension token. If your partner is out of extension tokens, your only choices are to submit on time or to get a “no-fault divorce” and submit separately. After the divorce, both students have equal rights to all common work, but only the student who still has tokens can submit late. At submission time, *both submissions must be identified as individual work* (list nobody as the programming partner). Submitting as a partnership is likely to harm one or both grades. The true situation should be explained in the README file.

What if I can't finish all the problems?

If you can't finish every problem, act tactically to maximize your grade:

- *Start* every problem. Turn in, if you can, a partial solution, or at least an analysis. Incomplete work might still earn a grade of Poor, or possibly even Fair.

If you turn in nothing for a problem, you get nothing for it. “No Credit” means *zero*. That's very bad for your grade. If you have to choose between two problems of equal weight, it is slightly better to get two Poor grades than to get one No Credit and one Very Good. You can't just scribble down anything and expect to receive a Poor grade—the course staff have to be able to find some substance. But if you document some progress, the outcome will be good for you.

105 is very cumulative, so if you can't finish every problem, you'll also want to act strategically to maximize the chances that you can do better on the next assignment. Your best strategic choice depends on the details of the assignment, so ask the course staff.

What is expected in lecture?

In lecture, I expect you to maximize your own learning and to eliminate distractions that might interfere with other students' learning. *Attendance at lecture is a privilege, not a right or an obligation*. If the course staff thinks your activities might be distracting other students, that privilege will be revoked.

Should I take notes? How?

To maximize your own learning, I recommend that you *take notes, sketches, and diagrams by hand*. Paper is good, with a pen or pencil. If you have a large touch screen and can take notes with a stylus, that works, too. I recommend *against* using a keyboard with a standard laptop or word-processing software:

- The neuroscience is quite clear that note-taking with pen or pencil activates most of the brain. Note-taking using a keyboard activates a much smaller region.
- Word-processing software is terrible for note-taking. Your notes should be about highlights and connections: good

notes connect more recent material with material from earlier in the lecture; good notes contain diagrams; good notes contain arrows and boxes. Good notes are highly non-linear. A word processor is designed to produce polished final documents, not to take notes. Use the superior tool: pencil and paper.

You never need to copy the instructor's notes or slides; they are available online. Use your own notes to make connections and to highlight points that you find difficult or that you want to remember.

What distractions must I avoid?

During class, *please put your cell phone on vibrate*. If you must take a call, please leave the classroom and do not return until you have finished your call.

The ultimate distraction machine is the laptop computer. Please refrain from any computer-based activity that is visible from a nearby seat and that might distract another student. Such activities include, but are not limited to

- Visible images or videos
- Anything involving continual movement on the screen
- Anything involving sound
- Conversations by text message or chat
- Games

If you cannot resist such activities, put your computer away at the start of class.

What is expected in recitation?

Recitation helps deepen your knowledge of the course material, and it helps you learn to work in a way that promotes insight and defends you against overwork and exhaustion. Recitation is structured around *practice* on problems related to current homework assignments.

- Before your recitation, you are expected to have looked at the current homework assignment, and you are expected to have read enough to talk about the comprehension questions on the homework.
- During recitation, you will discuss and tackle problems. You are expected to contribute, to engage your classmates, and to make sure your classmates have room to contribute.

Recitation is mandatory, and your participation is graded.

Which recitation do I attend?

You should have received a recitation assignment by email. This email should authorize you to adjust your record in SIS so that you are duly signed up for the recitation you have been assigned. If you signed up for a different recitation using SIS,

your SIS sign-up may not be honored. To get access to a recitation, you *must* have an email from the department, which will authorize you for your recitation.

(In order to create a small-group learning environment, we cap the enrollment of each recitation section. We use software to place each student into a recitation section that works for them, maximizing the number of students who get a top preference. Unfortunately, the registrar is not able to do this work for us or to enter your assignment into SIS on your behalf.)

If you did not receive an email authorizing you for a recitation, or if you need to change recitations, please post immediately to Piazza.

What logistics and policies affect my homework?

Here is a summary of relevant information that is distributed throughout this syllabus:

- Homework must be submitted using a submit script.
- You can get *one* automatic 24-hour extension by expending one “extension token.” You have a total of seven such tokens. On any given assignment, you can expend at most one token.
- Code must compile or load with no errors or warnings, and it must do so within 250 CPU milliseconds.
- Except when you are pair programming, another student must never see your code or your algebraic laws.
- Any homework question can be posted publically to Piazza, *unless* that homework question contains code, an algebraic law, an inference rule, or another part of the solution. Any question that discloses your work must be posted privately.
- If needed, you have 7 days to request a regrade, which you do via a Web form located at <https://www.cs.tufts.edu/comp/105/regrade>.

I’m not required to take 105. Should I take it anyway?

COMP 105 is required for Computer Science majors. If you’re not a Computer Science major, find the paragraph that applies to you below.

If you’re getting a *Computer Science minor*, or if you’re just *interested in computing*, you should take 105 if you want an intense experience that will broaden and deepen your programming skills. (Unless you have a professional or recreational interest in mathematics or logic, some of the theory parts of the course may be less interesting to you.)

If you’re a *postbac student* or a *master’s student*, you also should take 105 if you want an intense experience that will broaden and

deepen your programming skills. Many of our postbac students, in particular, report that 105 was a highlight of their certificate program. Postbac students and master’s students do need to be aware that as part of Tufts’s commitment to residential learning, the course is designed to serve undergraduate students who are on campus during the day.

If you’re a *doctoral student* or *MS/PhD student*, the value of 105 depends on what you are trying to accomplish.

- If your research is going to depend on your ability to design, write, and evolve good software, take 105.
- If you’re curious about programming languages as a potential area of research, consider taking 105. Just keep in mind that 105 is designed to be required of all undergraduate students. That makes it light on research and heavy on practice.
- If you know you’re interested in programming languages and you want to study core programming-language topics at a graduate level, 105 is going to disappoint you—it’s not operating at the right level. 105 is a *first* course in the field. As such, it just touches on the rudiments of theory, and it omits many other interesting topics, including logical relations, denotational semantics, garbage collection, and logic programming.
- If what you want is to meet the proficiency requirement for the PhD qualifying examination (“functional programming and object-oriented programming with inheritance”), 105 is one of several options. The proficiency requirement is minimal, and 105 presents a broad and deep view of programming languages that goes beyond minimal proficiency. If that’s what you’re looking for, great! But it’s an intense experience that may take time away from your research.

What skills must I have already?

COMP 105 is the final course in our required programming sequence, and it calls on a broad and deep array of skills you are expected to have developed in earlier courses.

What basic skills do I need?

You must grasp basic algorithms, data structures, and good programming practice.

What Unix skills do I need?

You must understand the basics of files, directories, creating and editing files, printing, compiling and loading programs, and using `make`. You will be much, much happier if you also can write a simple shell script (`sh`) and use `Awk` and `grep` effectively. You can learn about such things from Kernighan and Pike.

What file-transfer skills do I need?

If, as we recommend, you do your theory homework on paper, you need to know how to convert it to PDF and to get the PDF onto a departmental Linux machine.

- If you use the copier in the CS office, you will be emailed a PDF attachment.
- If you use the Scanbot app on a smartphone, you can get Scanbot to upload to a service like Google Drive, from which you can then download to the servers.
- If you use some other means of creating the PDF, getting it to the servers is up to you. Various students report good results with Swift File Transfer from Android devices and scp (from the OpenSSH suite) from computers.

What theory skills do I need?

You must be comfortable with basic discrete mathematics. You must be able to prove theorems, *especially by induction*.

You must have taken Discrete Math (Math 61 or COMP 61). If you have not, you must produce some other evidence that you can reason precisely about computational objects.

You must be able to *write an informal mathematical proof*. For example, you should be able to prove that a sort function returns the same set of elements that it was passed.

You must be comfortable using basic mathematical formulas with “forall” (\forall) and “exists” (\exists) quantifiers, i.e., the propositional and predicate calculi.

You must know basic set theory, e.g., the mathematical definition of functions as sets of ordered pairs.

You must be *comfortable reading and writing formal mathematical notation*, or at least be able to look at it without running screaming from the room.

What programming skills do I need?

You must have substantial programming experience. If you don't, you will have difficulty keeping up with the homework.

A few homework assignments require some proficiency in C. If you have a strong background in C++, some details will be different, but your background should be sufficient.

Your programming experience should include work with dynamically allocated data structures and with recursive functions. You must be *comfortable writing recursive functions* in the language of your choice, as well as *proving that such functions terminate*.

You must have implemented some of the basic data structures and algorithms used in computer science, like stacks, queues, lists, tables, search trees, standard sorts (quick, insertion, merge, heap), topological sort, and graph algorithms. These topics are well covered in COMP 15 at Tufts. Prior exposure to exhaustive search (backtracking) will also be helpful.

What other programming skills might help?

This course uses unusual programming paradigms, and it really helps to have some facility with systematic software design. Our recommended nine-step design process is a solid starting point, but if you have practice with additional design methods, you will prosper. Many of the most effective design methods are grounded in formal reasoning about programs, including the following intellectual tools:

- *Loop invariants and termination conditions* as they apply to imperative programs
- *Contracts* for functions, including *preconditions and post-conditions*
- *Termination conditions* for recursive functions⁷
- *Representation invariants and abstraction functions* for abstract data types

You can brush up on this material by looking at the article by Bentley on the reading list. Chapter 4 of Liskov and Guttag has a nice tutorial on reasoning about data, which you will find helpful in several assignments.

What is the most important skill of all?

The most valuable skill you can have for COMP 105 is the skill of managing yourself. To do well in 105 or in any other course that involves programming, develop these habits:

- Think carefully about a problem *before* you begin to write code.
- *When having difficulty* writing code, stand up, *walk away from your computer*, and think about the difficulty. Enlist the whiteboard as your ally.
- Never be satisfied with a “working program,” but strive for *the simplest, clearest, most elegant implementation*.

If you have these habits, the other prerequisites are almost irrelevant. If you don't, you can expect difficulty no matter what other background you have.

What books do I need?

You absolutely, positively have to have the book *Programming Languages: Build, Prove, and Compare* by Norman Ramsey. You can buy the book in the Computer Science office in Halligan. When you buy the book, nobody profits: the intellectual property is donated; the copies are printed by the University printing office; and the department sells the book for a sum just sufficient to cover the cost of printing.

⁷When writing recursive functions, try to develop your understanding of the deep connections between recursion and loops; the ideas of invariants and termination conditions apply to both.

The short booklet *Seven Lessons in Program Design* is available online, and hard copy is distributed on the first day of class.

The book *Elements of ML Programming* by Jeff Ullman is very useful, but just for a few assignments. If need be, you can get by without it; we have assembled an extensive ML learning guide that uses entirely free resources. We recommend Ullman's book anyway, because we think that spending the extra money will save you enough time to be a good tradeoff. If you do buy the book, be sure you get the ML'97 edition. It is available in the University bookstore, but you can probably get it more cheaply elsewhere.

What computers can I use?

The class is set up to run on Red Hat Enterprise 64-bit Linux, as installed on the departmental homework server and in the laboratories in Halligan 116, 118, and 120. For remote access use `homework.cs.tufts.edu`. The software from the book will be installed on these machines, but you can also grab the software and compile it on your own computer; try `git clone homework.cs.tufts.edu:/comp/105/build-prove-compare`.

If you need an account for CS machines, please send email to `staff@cs.tufts.edu`. I recommend that you ask for `bash` or `fish` as your login shell.

What software can smooth my path?

I recommend a wonderful program called `ledit`, which is extremely handy for interacting with our interpreters. Try typing, e.g., `ledit impcore`, and you will be able to get an interactive editing loop with the `impcore` interpreter. The `ledit` program is already installed on the departmental servers, and it can also be downloaded from INRIA and installed on your own machine.

I also recommend using a “programmer’s editor” such as `vim` or `emacs`. A most valuable feature of such editors is the ability to jump directly to the source location of an error. For `vim` you will need to learn the `:make` command, and you will probably need to set `makeprg`. For `emacs` you will need to learn the `M-x compile` command.

How about Emacs tricks?

If you do use `emacs`, you will find your code much easier to manage if you enable `paren-mode`, which you can do by placing these lines in your `.emacs` file:

```
(require 'paren)
(show-paren-mode)
(setq show-paren-style 'expression)
```

I also recommend using the `M-x customize-face` command with face `show-paren-match` to set the screen to bright yellow on parenthesis match.

You can use the Emacs TRAMP facility to edit files directly on the remote server, by using file names like `/nr@homework.cs.tufts.edu:/comp/105/www/syllabus.md`. This allows you to edit on your own local machine, but every time you save the file, it is automatically sent to the homework server, where you can compile or run it.

What if campus closes unexpectedly?

At least every other year, there is a snowstorm so disruptive that we cannot hold classes on campus. In these cases, following guidelines developed for the School of Arts, Sciences, and Engineering, we will conduct class or recitation electronically. Educational Technologies has a web page explaining what to do when campus is closed. We will announce details on Piazza.

Office hours present a greater challenge. When we can do so safely, we'll try to have boots on the ground in Halligan. But also, we will pay extra attention to Piazza, and some TAs may hold office hours electronically.

What may I do with solutions?

I provide solutions to all homework and exam questions. Being able to examine master solutions helps you learn. But I provide solutions for your private use *only*. Please do not share them with other students, and please make sure they do not find their way into public places, archives, and so on.

Copying solutions, whether from me or from another student, is a serious violation of academic integrity. *Providing* solutions to be copied is equally serious. For either violation, the usual penalty is a year's suspension.

What if I am repeating the course?

If you are repeating the course, we expect you to abide by the following policies.

- There is no acceptable use of model solutions from prior semesters. If you have kept any model solutions, destroy them.
- If you have written your own solutions for past semesters, it is acceptable to consult them for ideas, and it is acceptable to submit parts verbatim. Such use must be acknowledged.
- In every homework, your README file must note what work is new, what work is based on work from a prior semester, and what work is submitted verbatim from a prior semester. Even if *nothing* is from a prior semester, your README file must disclose this information.

(README files are anonymized, but PDFs are not. If you wish to preserve your privacy from graders, you should consider not removing your name from any PDFs you submit.)

- In every homework, you must cite collaboration with every partner with whom you worked on the assignment in a past semester—even if none of that partner work survives.

What else do I need to know about academic integrity?

The course operates under the university's academic-integrity policy, which you must know. In addition, you must know that in COMP 105, *seeing another student's code* is an integrity violation, and so is *allowing another student to see your code*. I am mandated to report even the suspicion of an integrity violation.

I'm different. Am I really welcome here?

Yes! We strive to create a learning environment that welcomes students of *all* backgrounds. If you feel unwelcome for any reason, please let us know so we can work to make things better. Talk to anyone on the teaching staff, or if that feels uncomfortable, try your academic advisor, our department chair, or your dean.

COMP 105 can be especially difficult for first-generation college students and for members of underrepresented groups, who may not have the family or social support that helps them develop their skills in "how to be a college student." If you are a first-generation college student or a member of an underrepresented group, I encourage you to have your "five minutes with the professor" visit early in the term, and we can talk about your support system.

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