CS107, Lecture 1
Welcome to CS107!

reading:

General Information handout

Bryant & O'Hallaron, Ch. 1 (skim)

Honor Code and Collaboration Page

Plan For Today

- Introduction
- CS107 Course Policies
- Unix and the Command Line
- Getting Started With C

CS107 on Zoom

- You are encouraged to share video!
- Post questions/comments/follow-ups on the discussion forum thread for that day's lecture. We'll take periodic "question breaks" to address them.
- In today's lecture, we ~~won't~~ will use Zoom chat.
- Everyone is muted by default.

Join: https://edstem.org/us/join/md5VrY

Today's thread:
https://edstem.org/us/courses/3085/discussion/204279

Plan For Today

- **Introduction**
- CS107 Course Policies
- Unix and the Command Line
- Getting Started With C

What is CS107?

The CS106 series:

- Taught you how to solve problems as a programmer
- Many times, CS106 instructors had to say, “just don’t worry about that,” or “it probably doesn’t make sense why that happens, but ignore it for now”

CS107 finally takes you **behind the scenes**:

- Not quite down to hardware or physics/electromagnetism (that’s for later...)
- It’s how things work **inside C++/Python/Java**, and how your programs map onto the components of computer systems
- Not only does it just feel good to know how these work, it can also inform projects you work on in the future.

What is CS107?

Computer Organization and Systems

- How languages like C++ and Java **represent data** under the hood
- How programming structures are encoded in **bits and bytes**
- How to efficiently **manipulate and manage memory**
- How computers **compile** programs
- Uses the **C** programming language
- Programming **style** and software development practices

CS107 Learning Goals

The goals for CS107 are for students to gain **mastery** of

- writing C programs with complex use of memory and pointers
- an accurate model of the address space and compile/runtime behavior of C programs

to achieve **competence** in

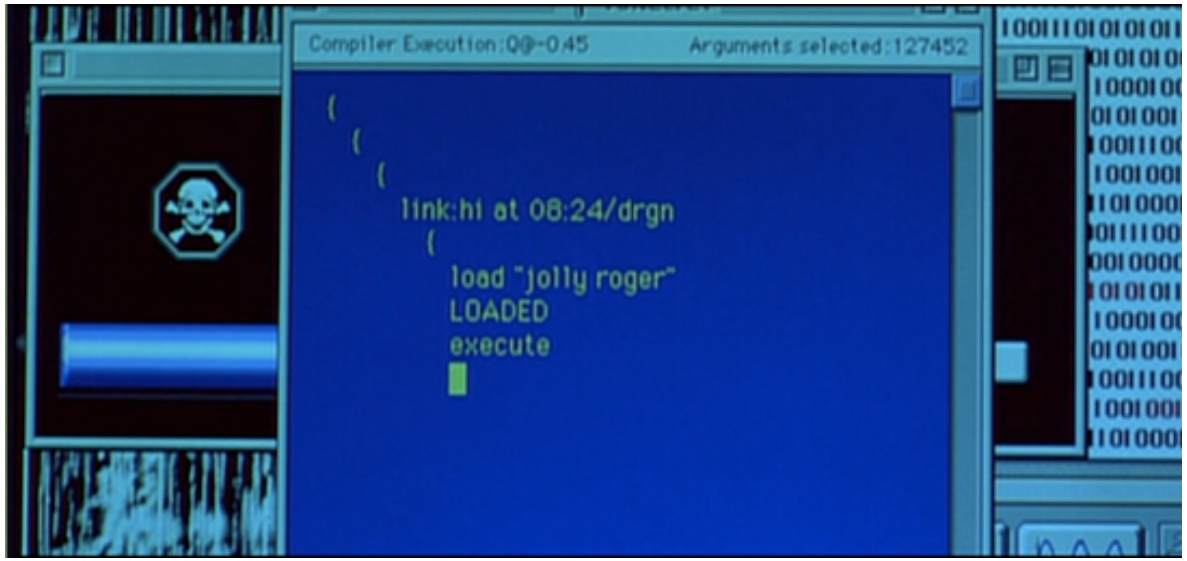
- translating C to/from assembly
- writing programs that respect the limitations of computer arithmetic
- identifying bottlenecks and improving runtime performance
- working effectively in a Unix development environment

and have **exposure** to

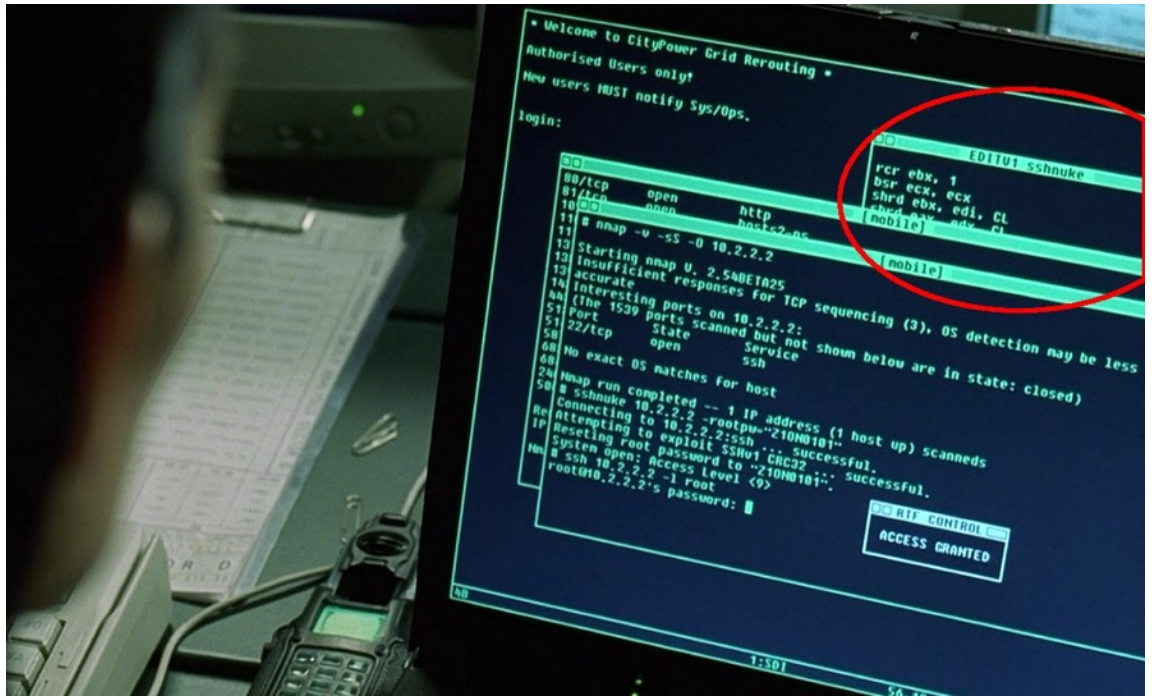
- a working understanding of the basics of computer architecture

CS107 Learning Goals

(also learn to identify legitimate programmer scenes in old movies)



Jeff Goldblum's character saving the world by uploading a virus to the alien mothership
Independence Day, 1996



Trinity saving the world by hacking into the power grid using Nmap Network Scanning
The Matrix Reloaded, 2003

Course Overview

1. **Bits and Bytes -** *How can a computer represent integer numbers?*
2. **Chars and C-Strings -** *How can a computer represent and manipulate more complex data like text?*
3. **Pointers, Stack and Heap –** *How can we effectively manage all types of memory in our programs?*
4. **Generics -** *How can we use our knowledge of memory and data representation to write code that works with any data type?*
5. **Assembly -** *How does a computer interpret and execute C programs?*
6. **Heap Allocators -** *How do core memory-allocation operations like malloc and free work?*

CS107 Online

- This quarter, we have made many adjustments and changes to make CS107 the best it can be in an online format.
- We are working to emphasize community and connection.
- We understand the unprecedented situation this quarter presents for everyone involved.
- We will constantly evaluate and listen to ensure the class is going as smoothly as possible for everyone.
- Please communicate with us if any personal circumstances or issues arise! We are here to support you.

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Teaching Team


Lisa Yan


Aditi Gaur


Brynne Hurst


Matthew Trost


Ricardo Iglesias


Sanket Gupte


Cem Gokmen


Lucas Soffer


Makena Low


Soham Gadgil


Nick Troccoli

- About Lisa Yan (yanlisa@stanford.edu):
  - Stanford MS, 2015, studied computer networks
  - Stanford PhD, 2019, researched tools for improving CS classrooms
  - Systems has played a key part in my discovery of CS. I hope it will for you too ☺

Companion Class: CS107A

- **CS107A** is an extra 1-unit "Pathfinders" or "ACE" section with additional course support, practice and instruction.
- Meets for an additional weekly section and has additional review sessions
- Entry by application – see the FAQ on the course website for details

- Email adbenson@stanford.edu for Zoom info this week

Andrew Benson

Question Break!

Plan For Today

- Introduction
- **CS107 Course Policies**
- Unix and the Command Line
- Getting Started With C

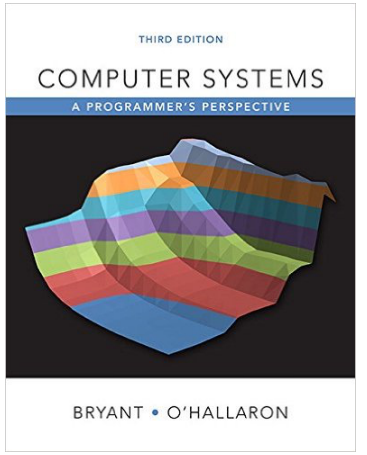
Course Website

cs107.stanford.edu

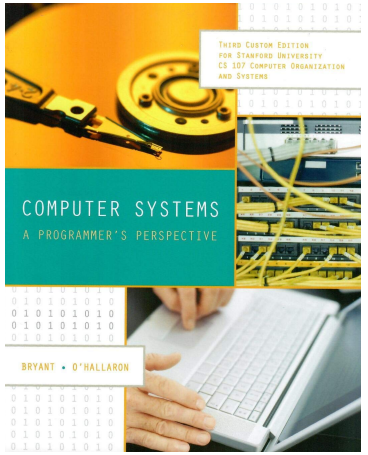
*lecture videos on Canvas

Textbook(s)

- *Computer Systems: A Programmer's Perspective* by Bryant & O'Hallaron, **3rd Edition**
  - **3rd edition matters** – important updates to content
  - Stanford Library has generously scanned **all** readings for CS107 under "fair use" (private study, scholarship, research). [**Canvas -> Files**]. Please do not distribute.
  - If you want more context, or if you plan to continue onto CS110, you may want to purchase a full copy
- A C programming reference of your choice
  - *The C Programming Language* by Kernighan and Ritchie (free link on course website Resources page)
  - Other C programming books, websites, or reference sheets



Full textbook



CS107 full chapters

canvas CS107-specific readings

The textbook (and C programming references) are **very** good resources in this course, especially post-midterm!

Course Structure

- Lectures*: understand concepts, see demos
- Assignments: build programming skills, synthesize lecture/lab content
- Labs: learn tools, study code, discuss with peers

Great preview of homework!

	Monday	Tues-Thurs	Friday
Week N			Lecture: part A
Week N+1	Lecture: part B assignN released	Lab	

- **assign0**: out later today, due next Monday (covers today's lecture)

*Lectures are "flipped" (pre-recorded) on Canvas; live lecture is optional review and Q&A

Grading

*****	45%	Assignments
**	20%	Final Project
*	10%	Mid-quarter Assessment
**	15%	Lab Participation
*	10%	Lecture Check-in Quizzes

Read our full course policies document:
https://cs107.stanford.edu/syllabus.html

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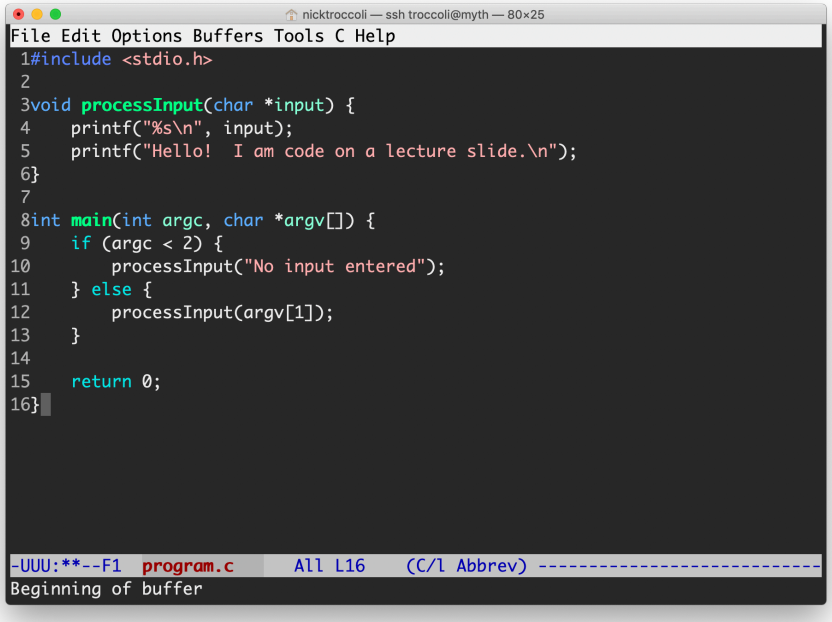
Assignments

- 6 programming assignments completed individually using **Unix command line tools**
  - Free software, pre-installed on Myth machines / available on course website
  - We will give out starter projects for each assignment
- Graded on **functionality** (behavior) and **style** (elegance)
  - Functionality graded using *automated tools,* given as point score
  - Style graded via *automated tests* and TA code review, given as bucket score
  - Grades returned via course website



The Style Bucket System

+	An outstanding job; could be used as course example code for good style.
ok	A good job; solid effort, but also opportunities for improvement.
-	Shows some effort and understanding but has larger problems that should be focused on.
- -	Shows many significant issues and does not represent passing work.
0	No work submitted, or barely any changes from the starter assignment.

Late Policy

- **Start out with 5 "free late days"**: each late day allows you to submit an assignment up to 24 additional hours late without penalty. ~~(No late days permitted for final project)~~ Max two late days permitted for final project
- **Hard deadline 48 hours** after original due date
- Penalty per day after late days are exhausted (1 day: 80% cap; 2 days: 60% cap)
- Late days are "pre-granted extensions" – additional extensions for exceptional circumstances must be approved by the **instructor**. Please communicate with us! We are here to accommodate you as much as possible.

Grading

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Final Project

- The final project has you implement your own “heap allocator” – a fundamental component of many of the programs we will write this quarter.
- We first use it as clients, and then we implement it!
- Capstone project that sums up topics from throughout the quarter.
- **You must do the final project in order to pass the class.**

Question Break!

Grading

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Mid-Quarter Assessment

- Available from Wed. 2/24 – Fri 2/26
- Open-book, timed assessment; you can choose when to start
- We aim for a lower-stakes assessment instead of a traditional midterm:
  - Weighted 10%
  - Flexible timing
  - Assessment will be written to minimize time pressure
  - Primary goal: reinforce concepts learned to that point
- Covers material from assign1-4

Question Break!

Grading

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Lab Sections

- Weekly 1 hour 30-minute labs led by a CA, starting *next* week, offered on Tuesdays, Wednesdays and Thursdays.
- Hands-on practice in small groups with lecture material and course concepts.
- Graded on attendance + participation (verified by submitting work at the end)
- Short pre-lab exercise to do in advance of showing up for each lab
- Lab preference submissions open **Tuesday 1/12 at 5PM PST** and **are not first-come first-serve**. You may submit your preferences anytime until **Saturday 9/19 at 5PM PST**. Sign up on the labs page of the course website.

Grading

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**|	15%	Lab Participation
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Lecture Check-in Quizzes

- Main lecture material is **pre-recorded** in short video "bytes" (get it?) and posted in advance of live lecture.
- Short "lecture check-in quizzes" after each ~1-2 videos, permitting multiple attempts, due by that live lecture.
- Each day's worth of lecture quizzes are weighted the same in aggregate.

Nick Troccoli

CS107 instructor
Spring/ Fall
2020

canvas

- **Live lecture** times will be 30-45 minutes max, and we instead review concepts further, answer questions, and do additional exercises.
- You can submit questions in advance of the live lectures or bring questions!

Lisa Yan

Grading

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Note: C- or above required for an S.

Question Break!

Read our full course policies document:
https://cs107.stanford.edu/syllabus.html

Getting Help

- Post on the **Discussion Forum**
  - Online discussion forum for students; post questions, answer other students' questions
  - Best for course material discussions, course policy questions or general assignment questions (DON'T POST ASSIGNMENT CODE!)
- Visit **Helper Hours**
  - 24/7 open community where you can chat about course topics or just hang out
  - Using Nooks (more info to come soon!)
  - Work anytime with other students or come at scheduled times for TA help; schedule will be posted on course website tomorrow.
  - Best for **group work**, **coding/debugging questions (with TAs only!)** or **longer course material discussions**
- **Email** the Course Staff
  - cs107@cs.stanford.edu – please do not email CAs individually
  - Best for **private matters** (e.g. grading questions, OAE accommodations).

Stanford Honor Code

- The **Honor Code** is an undertaking of the students, individually and collectively:
  - that they will not give or receive aid in examinations; that they will not give or receive unpermitted aid in class work, in the preparation of reports, or in any other work that is to be used by the instructor as the basis of grading;
  - that they will do their share and take an active part in seeing to it that others as well as themselves uphold the spirit and letter of the Honor Code.

- The faculty on its part manifests its confidence in the honor of its students by refraining from proctoring examinations and from taking unusual and unreasonable precautions to prevent the forms of dishonesty mentioned above. The faculty will also avoid, as far as practicable, academic procedures that create temptations to violate the Honor Code.

- While the faculty alone has the right and obligation to set academic requirements, the students and faculty will work together to establish optimal conditions for honorable academic work.

see also: http://honorcode.stanford.edu/

It is your responsibility to ensure you have read and are familiar with the honor code guidelines posted on the main page of the CS107 course website. Please read them and come talk to us if you have any questions or concerns.

Honor Code and CS107

- Please help us ensure academic integrity:
  - Indicate any assistance received on HW (books, friends, etc.).
  - Do not look at other people's solution code or answers
  - Do not give your solutions to others or post them on the web or our Ed forum.
  - Report any inappropriate activity you see performed by others.
- Assignments are checked regularly for similarity with help of software tools.
- If you need help, please contact us and we will help you.
  - We do not want you to feel any pressure to violate the Honor Code in order to succeed in this course.
  - If you realize that you have made a mistake, you may retract your submission to any assignment at any time, no questions asked.

https://cs107.stanford.edu/collaboration

OAE Accommodations

- Please email the course staff (cs107@cs.stanford.edu) as soon as possible with any accommodations you may need for the course.
- We are eager to do everything we can to support you and make you successful in CS107!

Question Break!

Plan For Today

- Introduction
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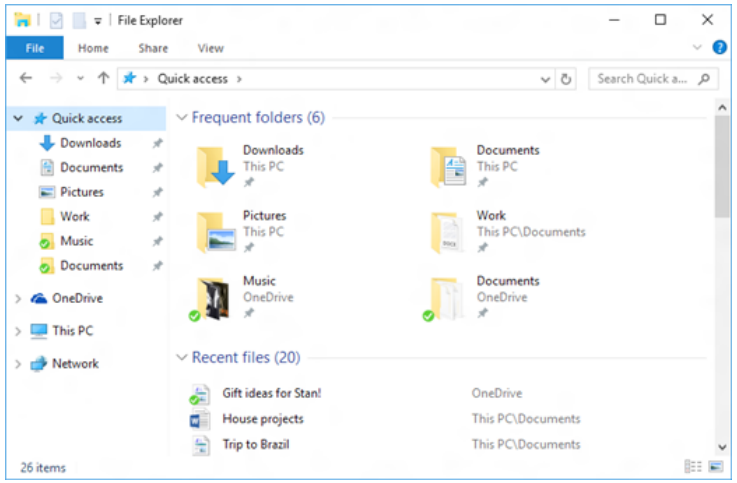
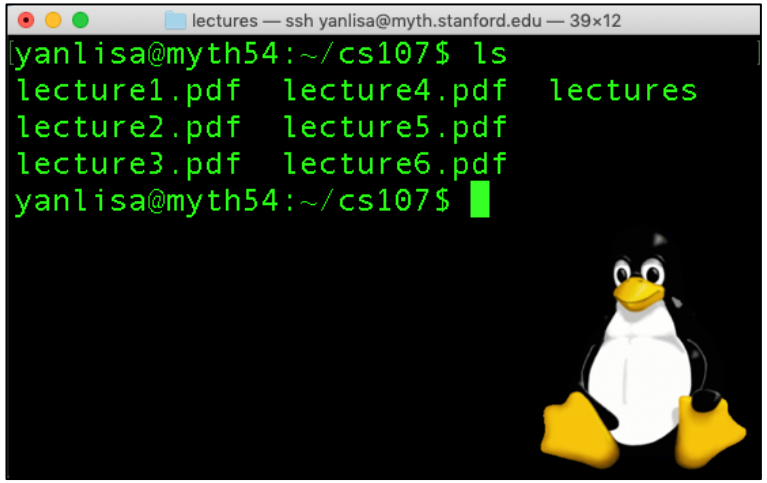
What is Unix?

- Which of the following is a **Unix** system? (select all that apply)

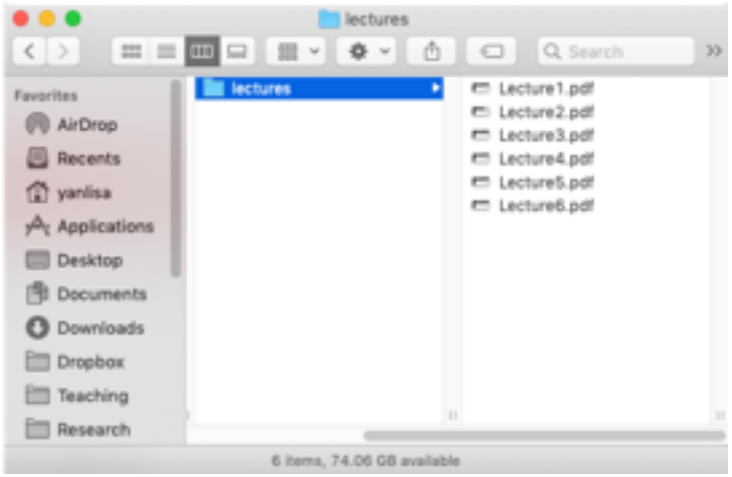
A. Windows



B. Linux



C. Mac OS X

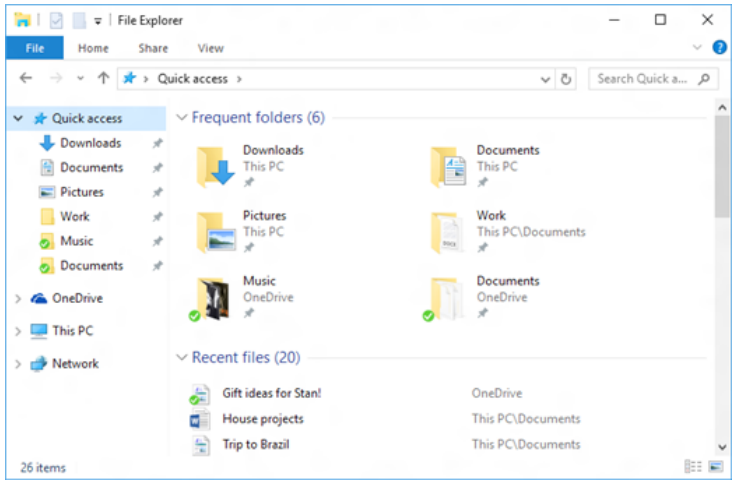


In Zoom chat: Type your answer and WAIT to press enter.
(we'll wait 30 seconds)

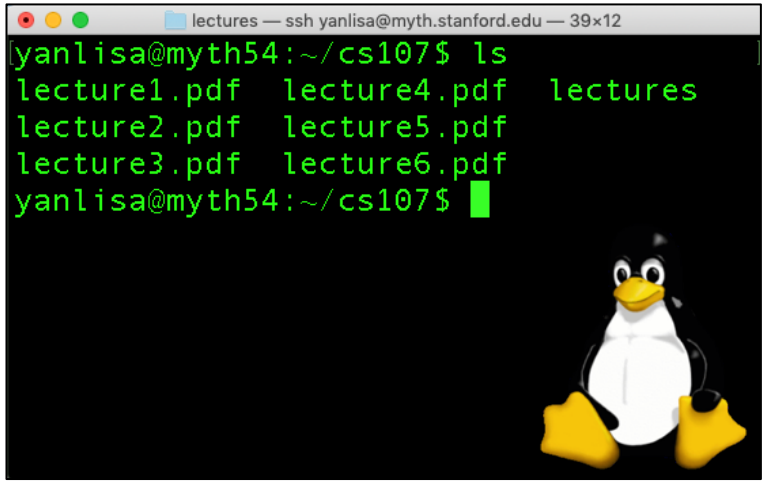
What is Unix?

- Which of the following is a **Unix** system? (select all that apply)

A. Windows



B. Linux



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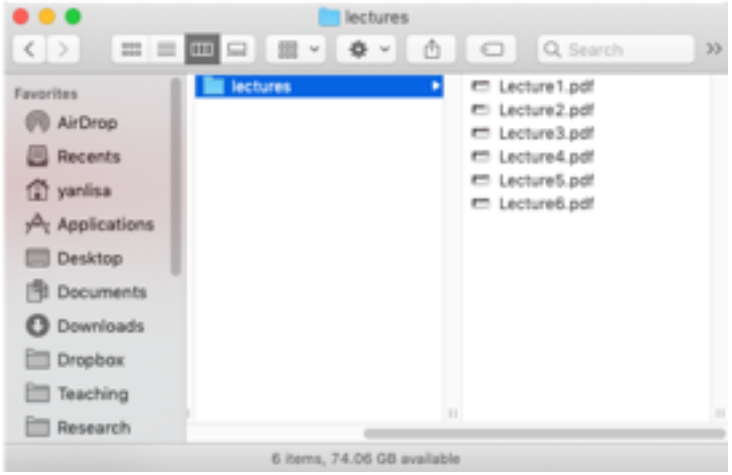
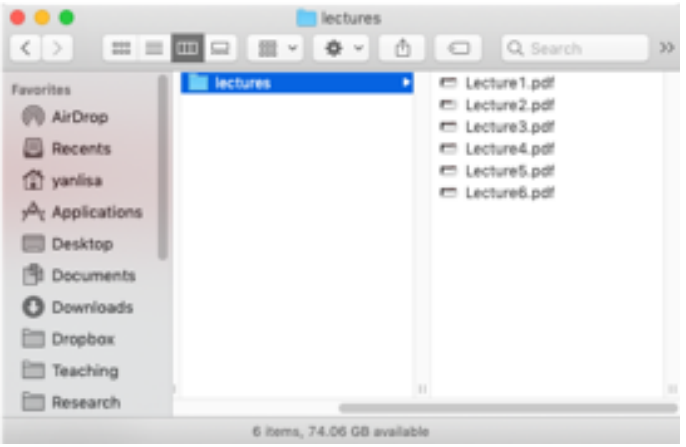


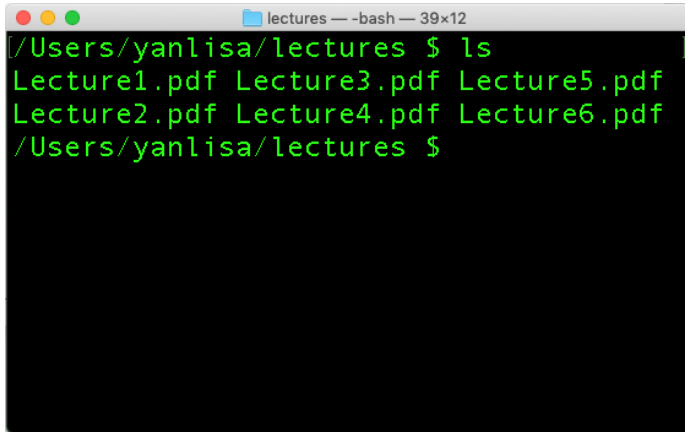
- **Unix:** a set of standards and tools commonly used in software development.
  - **Mac OS X** and **Linux** are operating systems built on top of Unix
- You can navigate a Unix system using the **command line** ("terminal")
- Every Unix system works with the same tools and commands

What is the Command Line?

- The **command-line** is a text-based interface (i.e., **terminal** interface) to navigate a computer, instead of a Graphical User Interface (GUI).
- Just like a GUI file explorer interface, a terminal interface can:
  - show you a **specific place** on your computer at any given time.
  - let you go **into folders** and **out of folders**.
  - let you **create new** files and **edit** them.
  - let you **execute programs**.



Graphical User Interface GUI



CLI

Text-based interface ~~TBI~~

Why Use Unix / the Command Line?

The Matrix (1999)

Why Use Unix / the Command Line?

- You can navigate almost any device using the same tools and commands:
  - Servers
  - Laptops and desktops
  - Embedded devices (Raspberry Pi, etc.)
  - Mobile Devices (Android, etc.)
- Used frequently by software engineers:
  - **Web development**: running servers and web tools on servers
  - **Machine learning**: processing data on servers, running algorithms
  - **Systems**: writing operating systems, networking code and embedded software
  - **Mobile Development**: running tools, managing libraries
  - And more…
- We'll use Unix and the command line to implement and execute our programs.

Demo: Using Unix and the Command Line

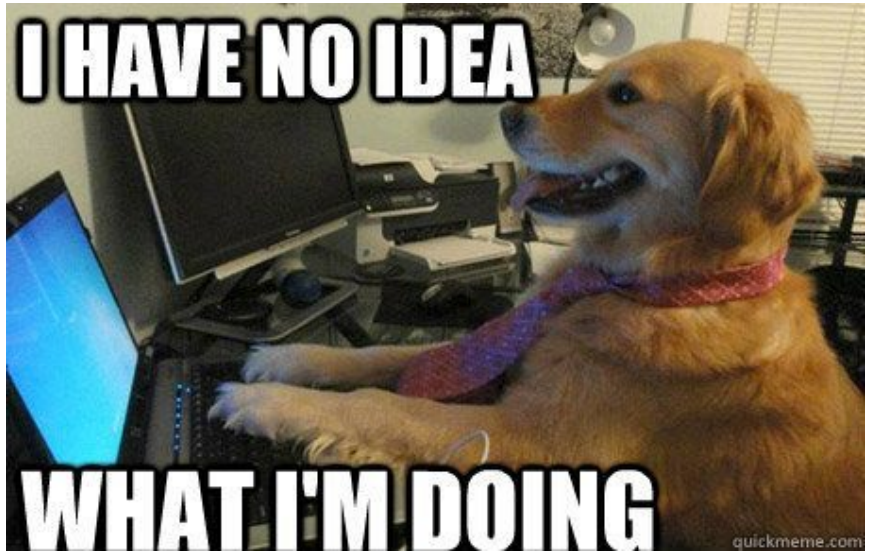
Unix Commands Recap

- **cd** – change directories (..)
- **ls** – list directory contents
- **mkdir** – make directory
- **emacs** – open text editor (or **vim**)
- **rm** – remove file or folder
- **man** – view manual pages

See the Resources page of the course website for more commands and a complete reference.

Practice builds confidence

- Using Unix and the command line can be intimidating at first:
  - It looks really retro!
  - How do I know what to type?
- It's like learning a new language:
  - At the beginning, you might constantly have to look things up (**Resources** page on course website)
  - It's important you spend as much time as you can (during lab and assignments) building muscle memory with the tools.
- We'll continue to work on your Unix while we introduce C.



Question Break!

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- **Getting Started With C**

The C Language

C was created around 1970 to make writing Unix and Unix tools easier.

- Part of the C/C++/Java family of languages (C++ and Java were created later)
- Design principles:
  - Small, simple abstractions of hardware
  - Minimalist aesthetic
  - Prioritizes efficiency and minimalism over safety and high-level abstractions

C vs. C++ and Java

They all share:

- Syntax
- Basic data types
- Arithmetic, relational, and logical operators

C limitations:

- No advanced features like operator overloading, default arguments, pass by reference, classes and objects, ADTs, etc.
- No extensive libraries (no graphics, networking, etc.). Small language footprint means not much to learn ☺
- Weak compiler and almost no runtime checks (this may cause security vulnerabilities!)

Programming Language Philosophies

C is procedural: you write functions, rather than define new variable types with classes and call methods on objects. **C is small, fast and efficient.**

C++ is procedural, with objects: you write functions, and define new variable types with classes, and call methods on objects.

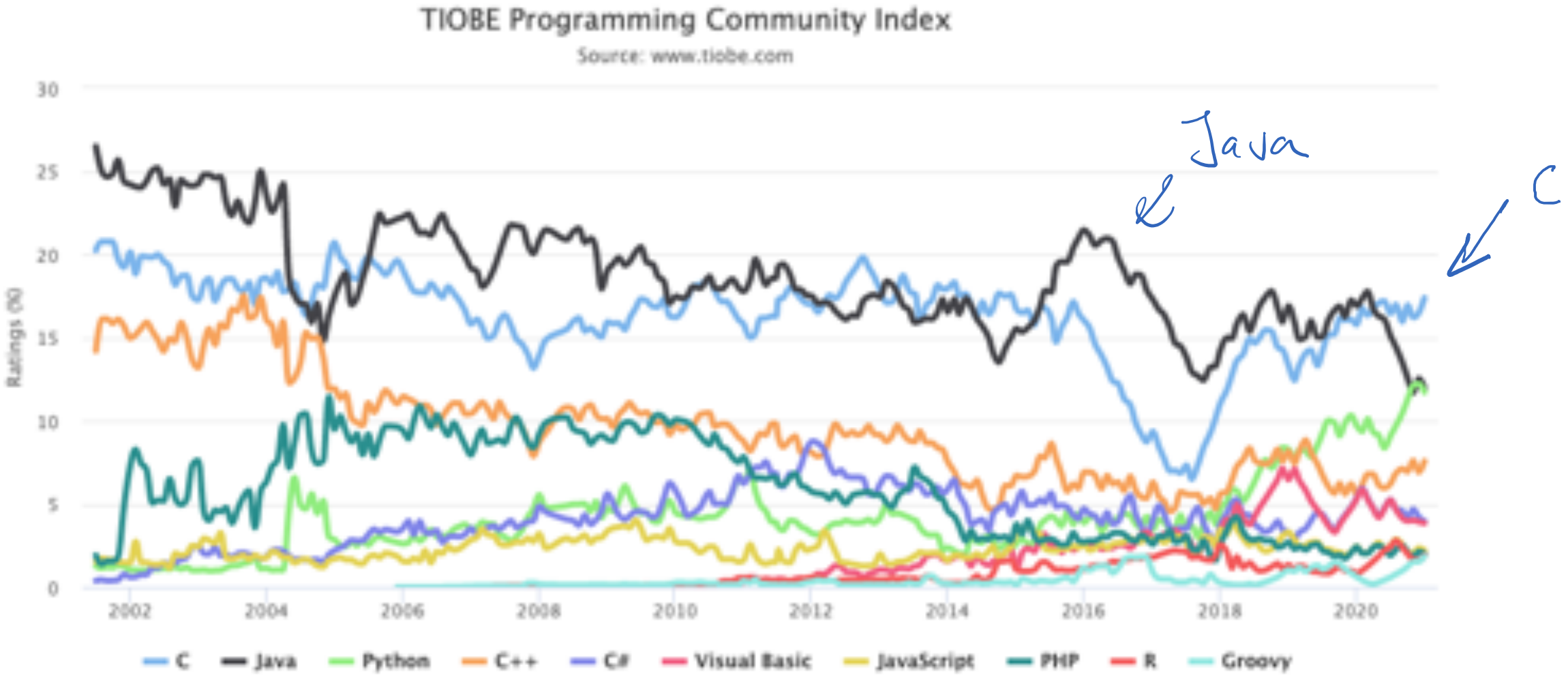
Python is also procedural, but dynamically typed: you still write functions and call methods on objects, but the development process is very different.

Java is object-oriented: virtually everything is an object, and everything you write needs to conform to the object-oriented design pattern.

Why C?

- Many tools (and even other languages, like Python!) are built with C.
- C is the language of choice for fast, highly efficient programs.
- C is popular for systems programming (operating systems, networking, etc.)
- C lets you work at a lower level to manipulate and understand the underlying system.

Programming Language Popularity



https://www.tiobe.com/tiobe-index/

Our First C Program

```c
/*
 * hello.c
 * This program prints a welcome message
 * to the user.
 */
#include <stdio.h>   // for printf

int main(int argc, char *argv[]) {
    printf("Hello, world!\n");
    return 0;
}
```

Our First C Program

```c
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 * hello.c
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#include <stdio.h>   // for printf

int main(int argc, char *argv[]) {
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}
```

Program comments
You can write block or inline comments.

Our First C Program

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    return 0;
}
```

Import statements

C libraries are written with angle brackets.

Local libraries have quotes:

```
#include "lib.h"
```

Our First C Program

```c
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#include <stdio.h>   // for printf

int main(int argc, char *argv[]) {
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    return 0;
}
```

`main` function – entry point for the program
Should always return an integer (0 = success)

Our First C Program

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#include <stdio.h>   // for printf

int main(int argc, char *argv[]) {
    printf("Hello, world!\n");
    return 0;
}
```

main parameters – **main** takes two parameters, both relating to the *command line arguments* used to execute the program.

argc is the *number* of arguments in **argv**
argv is an *array of arguments* ***(char * is C string)***

Our First C Program

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}
```

printf – prints output to the screen

Console Output: printf

Format: `printf(text, arg1, arg2, arg3);`

`printf` makes it easy to print out the values of variables or expressions.

```
printf("Hello, world!\n");
```

If you include *placeholders* in your printed text, `printf` will replace each placeholder *in order* with the values of the parameters passed after the text.

`%s (string)` `%d (integer)` `%f (double)`

```
char *classPrefix = "CS";
int classNumber = 107;
printf("You are in %s%d", classPrefix, classNumber); // You are in CS107
```

Question Break!

Writing, Compiling, and Debugging

We will use:

- the **emacs** or **vim** text editor to write our C programs
- the **make** tool to compile our C programs
- the **gdb** debugger to debug our programs
- the **valgrind** tools to debug memory errors and measure program efficiency

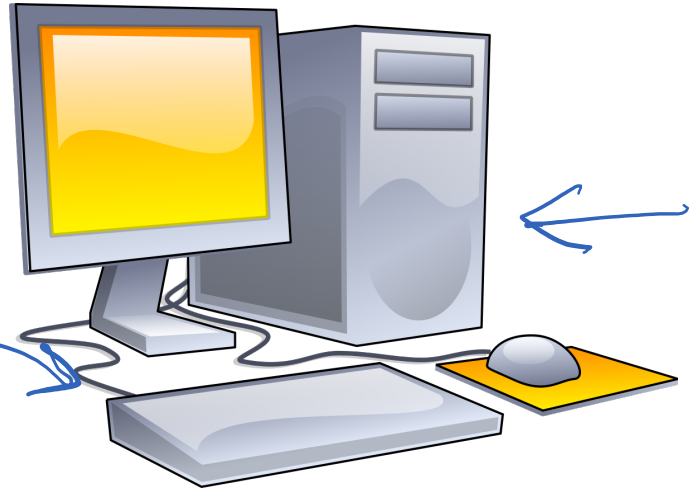
Now

Next week

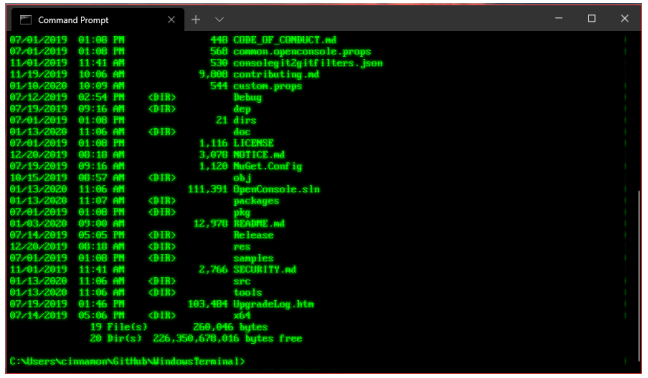
Demo: Compiling And Running A C Program

Where/what is myth??

Interface



Computer



Your local computer
Your location, Earth

SSH (remote access)

Myth cluster
Gates basement,
Stanford, CA

Familiar Syntax

```
int x = 42 + 7 * -5;                    // variables, types
double pi = 3.14159;
char c = 'Q';


for (int i = 0; i < 10; i++) {          // for loops
    if (i % 2 == 0) {                   // if statements
        x += i;
    }
}

while (x > 0 && c == 'Q' || b) {        // while loops, logic
    x = x / 2;
    if (x == 42) { return 0; }
}

binky(x, 17, c);                        // function call
```

bool?

Boolean Variables?

To declare Booleans, (e.g. `bool b = ____`), you must include `stdbool.h`:

```
#include <stdio.h>      // for printf
#include <stdbool.h>    // for bool

int main(int argc, char *argv[]) {
    bool truth = 5 > 2 && binky(argc) > 0;
    if (truth) {
        printf("Hello, world!\n");
    } else {
        printf("Howdy, world!\n");
    }
    return 0;
}
```

This is our first look under the hood!

Why is `bool` ***not*** a built-in C type?

Boolean Variables?

```
1  #include <stdio.h>
2  #include <stdbool.h>
3  int main(int argc, char *argv[]) {
4    _______?_______
5    printf("x as an int: %d\n", x);
6    if (x) {
7      printf("Hello, world!\n"); // A
8    } else {
9      printf("Howdy, world!\n"); // B
10   }
11   return 0;
12 }
```

What will this print if Line 4 initializes x as

```
    bool x = true;  1 A
    bool x = false; 0 B
1.  int x = 0;
2.  int x = 5;
3.  int x = -3;
```

Boolean Variables?

```
1  #include <stdio.h>
2  #include <stdbool.h>
3  int main(int argc, char *argv[]) {
4    _______?_______
5    printf("x as an int: %d\n", x);
6    if (x) {
7      printf("Hello, world!\n"); // A
8    } else {
9      printf("Howdy, world!\n"); // B
10   }
11   return 0;
12 }
```

What will this print if Line 4 initializes x as

	`bool x = true;`	**A**
	`bool x = false;`	**B**
1.	`int x = 0;`	**B**
2.	`int x = 5;`	**A**
3.	`int x = -3;`	**A**

C treats a nonzero value as true and a zero value as false.

Working On C Programs Recap

- **ssh** – remotely log in to Myth computers
- **Emacs** – text editor to write and edit C programs
  - Use the mouse to position cursor, scroll, and highlight text
  - Ctrl-x Ctrl-s to save, Ctrl-x Ctrl-c to quit
  - In this class we will also support **Vim**, another command-line text editor
- **make** – compile program using provided Makefile
- **./myprogram** – run executable program (optionally with arguments)
- **make clean** – remove executables and other compiler files
- Lecture code is accessible at **/afs/ir/class/cs107/lecture-code/lect[N]**
  - Make your own copy: **cp -r /afs/ir/class/cs107/lecture-code/lect[N] lect[N]**
  - See the Resources page for even more commands, and a complete reference.

Question Break!

assign0

Assignment 0 (Intro to Unix and C) has been released on the course website and is due in one week on **Mon. 1/18 at 11:59PM PST**. (errata: said 1/11 previously)

There are **5** parts to the assignment, which is meant to get you comfortable using the command line, and editing/compiling/running C programs:

- Visit the **Resources** page to become familiar with different Unix commands
- **Clone** the assign0 starter project
- **Answer** several questions in `readme.txt`
- **Compile** a provided C program and **modify** it
- **Submit** the assignment

Lectures 2 and 3

- Complete Lecture 2 quiz by **Friday 1/15 1:00pm**
- Lecture 2 review in-class on Friday

- Complete Lecture 3 quiz by **Tuesday 1/18 1:00pm** (Note Monday MLK holiday)
- Lisa to hold Lecture 3 Helper Hours on Tuesday
- Lecture 3 + 4 review in-class on Friday 1/22

Recap

- CS107 is a programming class in C that teaches you about what goes on under the hood of programming languages and software.
- We'll use Unix and command line tools to write, debug and run our programs.
- Please visit the course website, cs107.stanford.edu, where you can read the General Information Handout, information about the Honor Code in CS107, and more about CS107 course policies and logistics.

We're looking forward to an awesome quarter!

Preview: Next Time

- Make sure to reboot Boeing Dreamliners every 248 days
- Comair/Delta airline had to cancel thousands of flights days before Christmas
- Many operating systems may have issues storing timestamp values beginning on Jan 19, 2038
- Reported vulnerability CVE-2019-3857 in libssh2 may allow a hacker to remotely execute code

Next time: *How can a computer represent integer numbers? What are the limitations?*