Intro, C refresher
CSE 333

Instructor: Hannah C. Tang

Teaching Assistants:

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Justin Tysdal	Leanna Nguyen	Sayuj Shahi
Wei Wu	Yiqing Wang	Youssef Ben Taleb

Poll Everywhere

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- What have you heard about CSE 333 or Hannah? What do you hope to learn? Do you have any concerns going into the class?

Lecture Outline

- **Course Introduction**
- Course Policies
- C Intro

Introductions: Course Staff

- Instructor: Hannah C. Tang (hctang@cs)
  - UW CSE alumna with 17 years ~~of bugs~~ in industry
- 9 TAs:
  - Deeksha Vatwani, Hannah Jiang, Jennifer Xu, Justin Tysdal, Leanna Nguyen, Sayuj Shahi, Wei Wu, Yiqing Wang, and Youssef ben Taleb
  - Available in section, office hours, and discussion group
  - An invaluable source of information and help
- Get to know us
  - We are here to help you succeed!

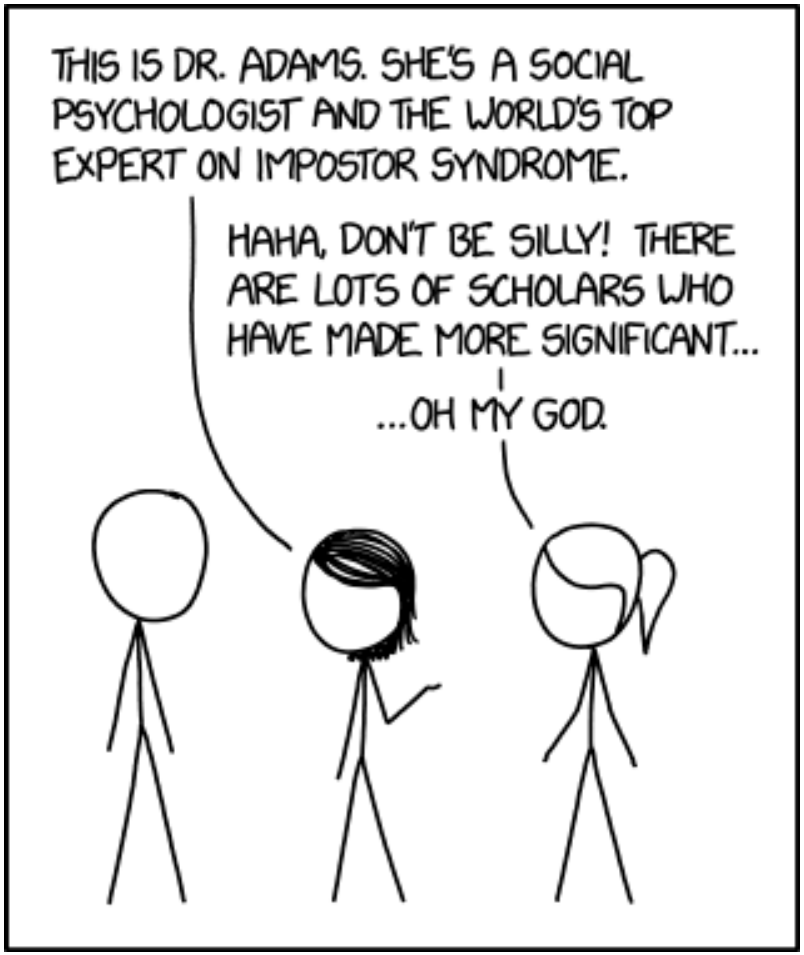
Introductions: Students

- ~185 students this quarter

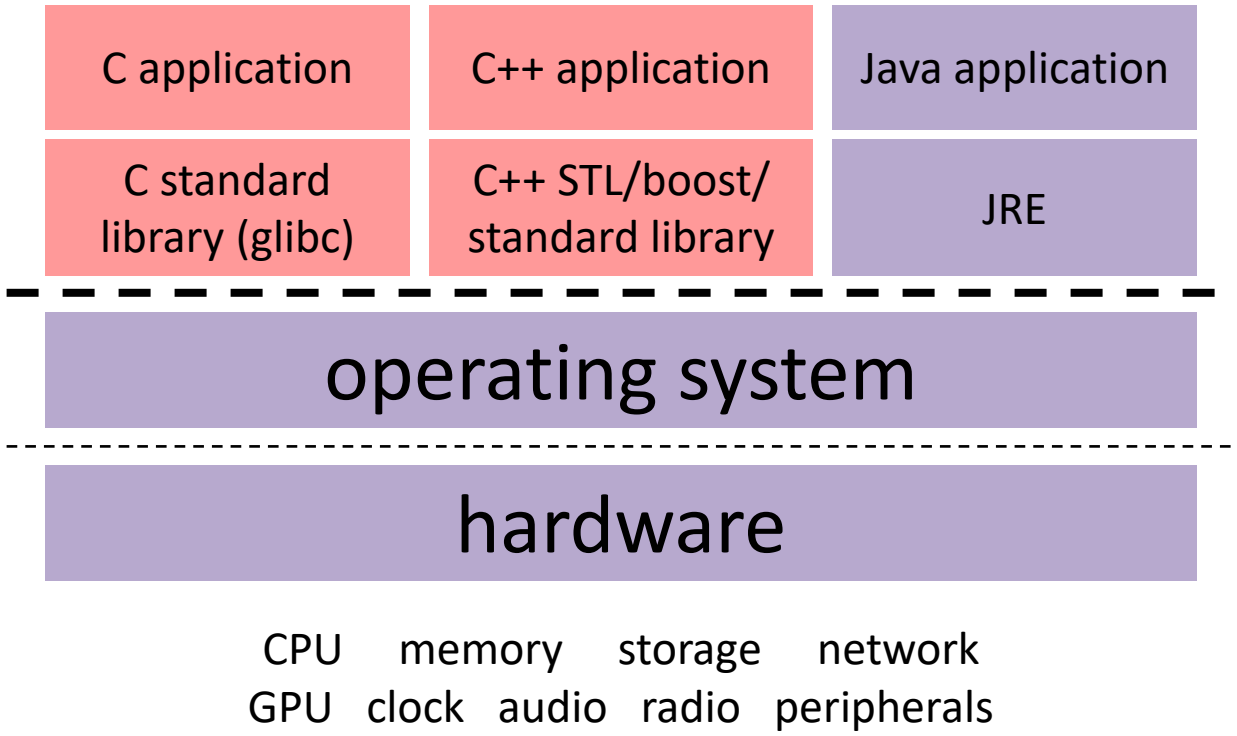
- Expected background
  - **Prereq:** CSE 351 – C, pointers, memory model, linker, system calls
  - CSE 391 or Linux skills needed for CSE 351 assumed

Introductions: Students

- ~185 students this quarter
  - Easier to feel lost, as if everyone is "better" than you
- "Nearly 70% of individuals will experience signs and symptoms of impostor phenomenon at least once in their life."
  - https://en.wikipedia.org/wiki/Impostor_syndrome
- Our course size can be an asset!



Course Map: 100,000 foot view



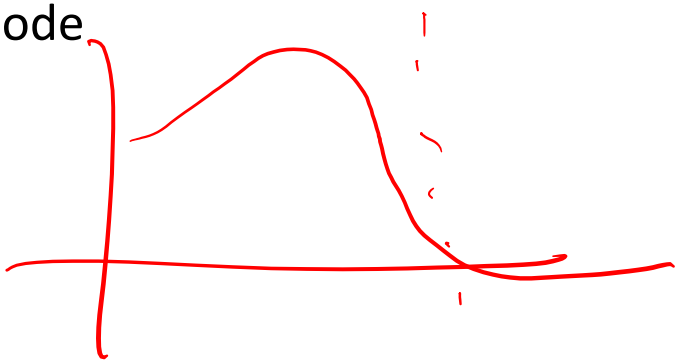
Systems Programming

- The programming skills, knowledge, and engineering discipline you need to build a system
  - **Programming:** C / C++
  - **Knowledge:** long list of interesting topics
    - Concurrency, OS interfaces and semantics, techniques for consistent data management, distributed systems algorithms, …
    - Most important: a deep(er) understanding of the "layer below"
  - **Discipline:** testing, debugging, performance analysis

Discipline?!?

- Cultivate good habits, encourage clean code
  - Coding style conventions
  - Unit testing, code coverage testing, regression testing
  - Documentation (code comments, design docs)
  - Code reviews

- Will take you a lifetime to learn
  - But oh-so-important, especially for systems code
    - Avoid write-once, read-never code



Lecture Outline

- Course Introduction
- **Course Policies**
- C Intro

This is Only an Overview!

- https://courses.cs.washington.edu/courses/cse333/24au/syllabus.html

- This is just the summary/highlights
  - … but you must read the full details online!

Communication

- Website: http://cs.uw.edu/333
  - Schedule, policies, materials, assignments, etc.
- Office Hours: spread throughout the week
  - Schedule posted shortly and will start as soon as we can
- One-on-ones: by appointment
  - Send us a message with your availability in the next 3 days
  - Do **not** expect a response in less than 24 hours!

Communication

- Messages to staff: things unsuitable for Ed chat or Gradescope regrade requests
  - Please send email to cse333-staff@cs.uw.edu. Reaches all staff so the right person can help out quickly, and helps follow up until resolved
  - (***don't*** email to instructor or individual TAs if possible – we can get quick answers for you and coordinate better if it goes to the staff
- Discussion: Ed group linked to course home page
  - Ask and answer questions – staff will monitor and contribute
  - Use private messages for questions about detailed code, etc.
- Announcements: will use broadcast Ed messages to send "things everyone must read and know"

Course Components

- Lectures (~28)
  - Introduce the concepts; take notes!!!
- Sections (10)
  - Applied concepts, important tools and skills for assignments, clarification of lectures, exam review and preparation
- Final exam, but no midterm
  - Goal is to revisit and internalize concepts

GRADED Course Components

- Programming Exercises (~18)
  - Roughly one per lecture, due the morning before the next lecture
  - Coarse-grained grading (check plus/check/check minus = 1, 2, 3, or 4)
- Programming Projects (0+4)
  - Warmup, then 4 "homeworks" that build on each other
- Lecture Activities (huge variance but can assume >50)
  - In-class polls graded on *completion* not *correctness*
  - Must be completed during class time; can miss up to 20% of them

Grading (tentative)

- **Exercises:** ~35%
  - Submitted via Gradescope
  - Evaluated on correctness and code quality, roughly equally
  - We drop the lowest scoring exercise

- **Homeworks:** ~35%
  - Submitted via GitLab; **must tag** the commit that you want graded
  - Evaluated on correctness and code quality, roughly equally
  - Binaries provided if you didn't get previous part working or prefer to start with a known good solution to previous parts

Grading (tentative)

- **Lecture Activities:** ~15%
  - Actively paying attention during lecture is correlated to good grades

Attentive=0	HW (35)	Ex (35)	Final (15)	
Median	33.83	28.08	10.64	3.3
Count	36			
Attentive=1	HW (35)	Ex (35)	Final (15)	
Median	34.34	30.25	12.41	3.5
Count	63			
Attentive=2	HW (35)	Ex (35)	Final (15)	
Median	34.36	30.58	12.25	3.6

  - … as does attending lecture **synchronously**

Timely=0	HW (35)	Ex (35)	Final (15)	
Median	32.98	29.83	11.51	3.4
Count	46			
Timely=1	HW (35)	Ex (35)	Final (15)	
Median	34.34	30.25	12.41	3.6
Count	63			
Timely>=1	HW (35)	Ex (35)	Final (15)	
Median	34.36	30.58	12.25	3.6
Count	88			

- **Final:** ~15%
  - No midterm!

Deadlines and Student Conduct

- Late policies
  - Exercises: no late submissions accepted, due 10 am before class
  - Projects: 4 late days for entire quarter, max 2 per project
  - Need to get things done on time – difficult to catch up!
    - But we will work with you if unusual circumstances / problems

- Academic Integrity (**read** the full policy on the web)
  - This does ***not*** mean suffer in silence – learn from the course staff and peers, talk, share ideas; *but* don't share or copy work that is supposed to be yours

And Off We Go…

- Goal is to figure out setup and computing infrastructure right away so we don't put that off and then have a crunch later in the quarter

- So:
  - First exercise out today, due Monfsy morning **10 am** before class
  - Warmup/logistics for larger projects in sections Thursday
    - HW0 (the warmup project) published tomorrow and gitlab repos created then. OK to ignore details until sections tomorrow and we'll walk through the whole thing, but read up ahead of time and maybe try some of the initial setup before section.
    - Bring a laptop to sections! We may have time to go through some of the initial configuration parts for hw0.

Gadgets (1)

- Gadgets reduce focus and learning
  - Bursts of info (*e.g.* emails, IMs, notifications, etc.) are *addictive*
  - Heavy multitaskers have more trouble focusing and shutting out irrelevant information
    - http://www.npr.org/2016/04/17/474525392/attention-students-put-your-laptops-away
  - Seriously, you will learn more if you use **paper** instead!!!
    - (even compared to note-taking on a tablet, although that is better than a keyboard, and that is way better than just "watching the show")

Gadgets (2)

- So how should we deal with laptops/phones/etc.?
  - Just say no!
  - No open gadgets during class (really!)
    - Unless you're actually using a tablet or something to take notes
  - Urge to search? – ask a question! Everyone benefits!!
  - You may close/turn off non-notetaking electronic devices now
  - Pull out a piece of paper and pen/pencil instead ☺

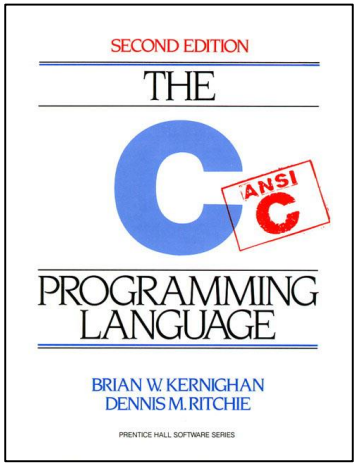
Deep Breath….

- Any questions, comments, observations, before we go on to, uh, some technical stuff?

Lecture Outline

- Course Introduction
- Course Policies
  - https://courses.cs.washington.edu/courses/cse333/24sp/syllabus.html
- **C Intro**
  - **Workflow, Variables, Functions**

C



- Created in 1972 by Dennis Ritchie
  - Designed for creating system software
  - Portable across machine architectures
  - More recently updated in 1999 (C99) and 2011 (C11) and 2017 (C17)

- Characteristics
  - "Low-level" language that allows us to exploit underlying features of the architecture – but easy to fail spectacularly (!)
  - Procedural (not object-oriented)
  - Typed but unsafe (possible to bypass the type system)
  - Small, basic library compared to Java, C++, most others….

Generic C Program Layout

```
#include <system_files>
#include "local_files"

#define macro_name macro_expr

/* declare functions */
/* declare external variables & structs */

int main(int argc, char* argv[]) {
  /* the innards */
}

/* define other functions */
```

C Syntax: `main`

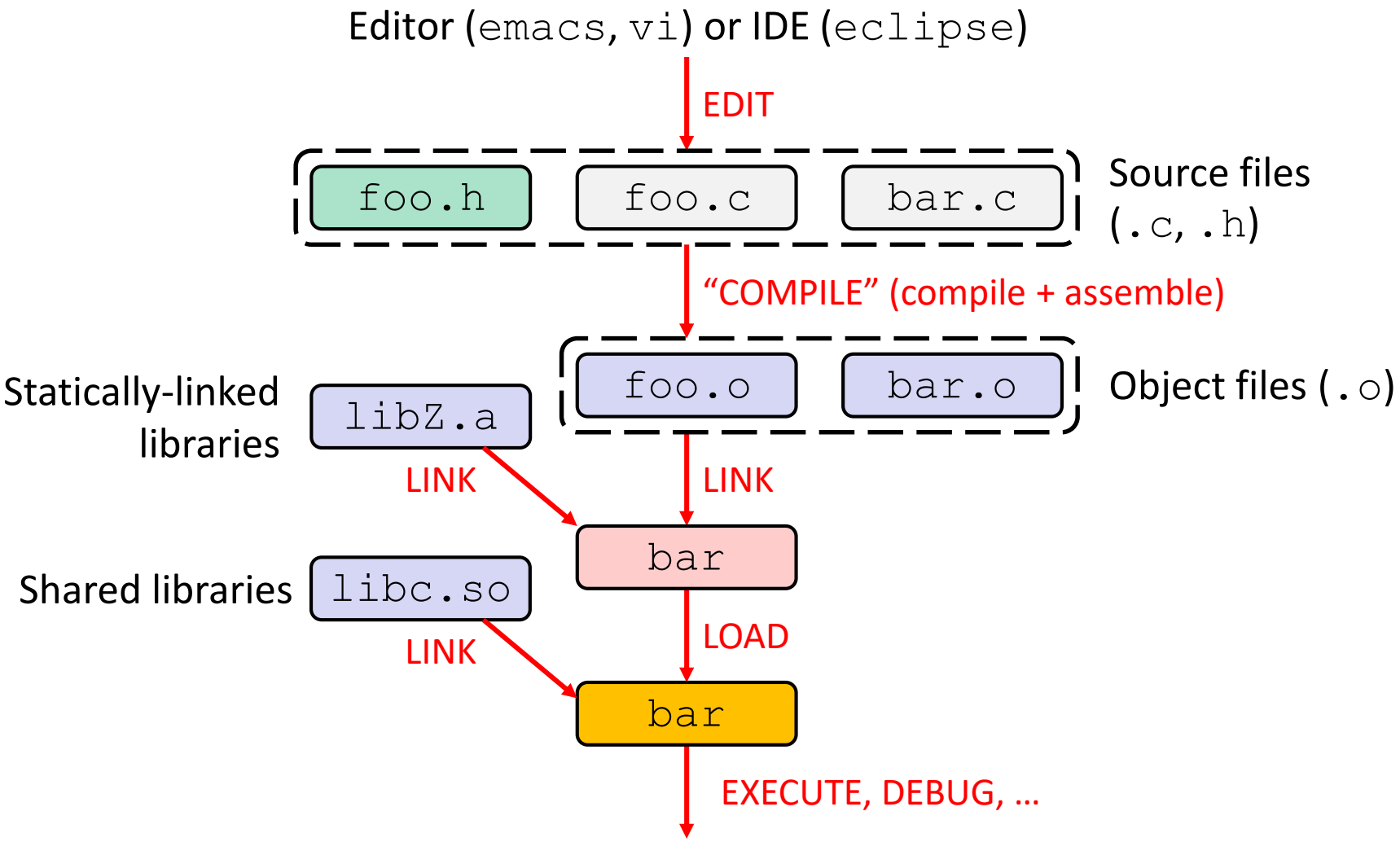
- To get command-line arguments in `main`, use:

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

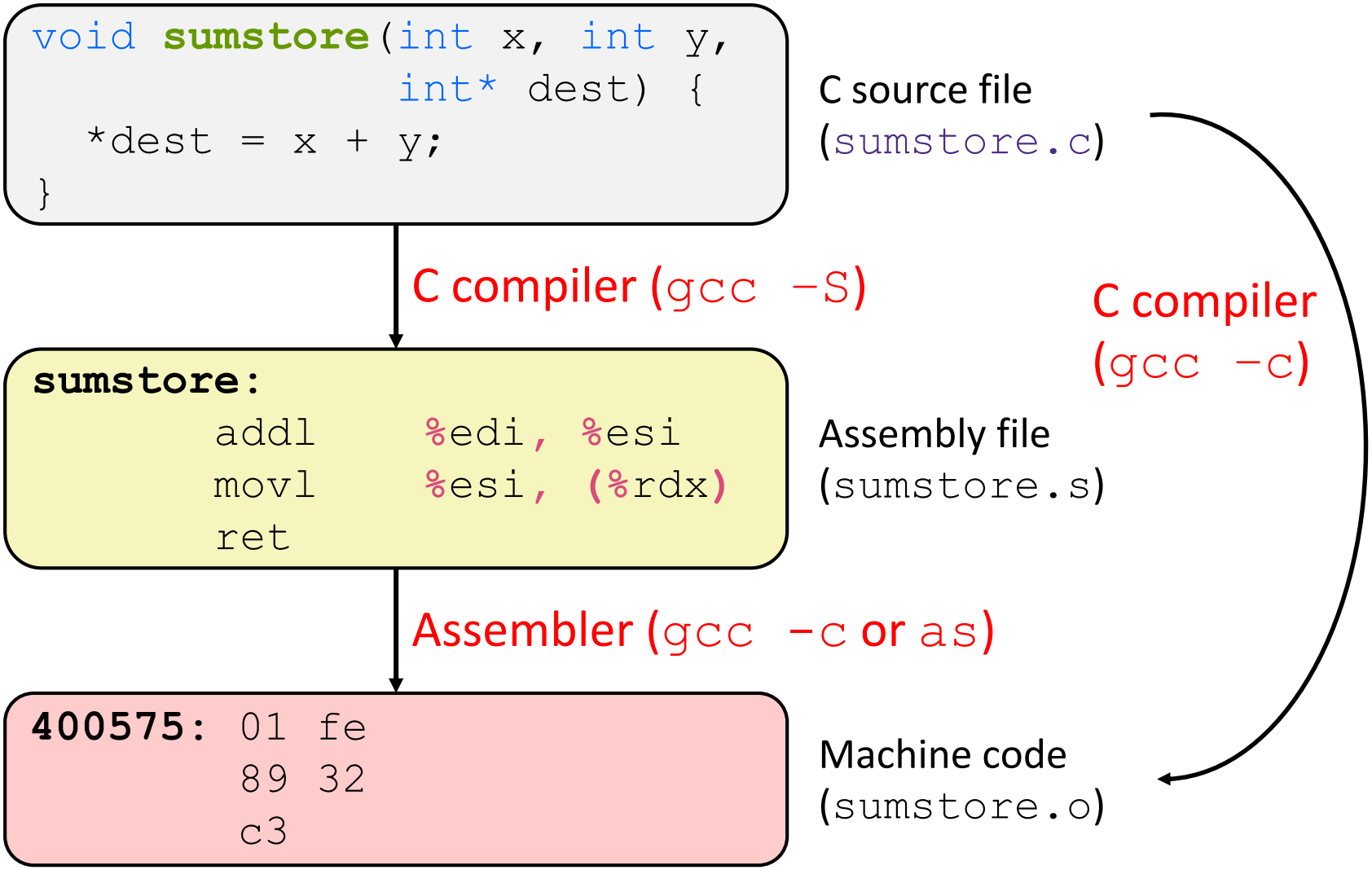
- What does this mean?
  - `argc` contains the number of strings on the command line (the executable name counts as one, plus one for each argument).
  - `argv` is an array containing *pointers* to the arguments as strings (more on pointers later)

- Example: `$ ./foo hello 87`
  - `argc = 3`
  - `argv[0]="./foo", argv[1]="hello", argv[2]="87"`

C Workflow


Editor (emacs, vi) or IDE (eclipse)
EDIT
foo.h
foo.c
bar.c
Source files (.c, .h)
"COMPILE" (compile + assemble)
foo.o
bar.o
Object files (.o)
Statically-linked libraries
libZ.a
LINK
LINK
bar
Shared libraries
libc.so
LINK
LOAD
bar
EXECUTE, DEBUG, …

C to Machine Code



When Things Go South…

- Errors and Exceptions
  - C does not have exception handling (no `try`/`catch`)
  - Errors are returned as integer error codes from functions
  - Because of this, error handling is ugly and inelegant

- Processes return an "exit code" when they terminate
  - Can be read and used by parent process (shell or other)
    - In main: return EXIT_SUCCESS; or return EXIT_FAILURE; (e.g., 0 or 1)

- Crashes
  - If you do something bad, you hope to get a "segmentation fault" (believe it or not, this is the "good" option)

Poll Everywhere

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- Are Java and C mostly similar (S) or significantly different (D) in the following categories?
  - List any differences you can recall (even if you put 'S')

Language Feature	S/D	Differences in C
Control structures		
Primitive datatypes		
Operators		
Casting		
Arrays		
Memory management		

Java vs. C (351 refresher)

- Are Java and C mostly similar (S) or significantly different (D) in the following categories?
  - List any differences you can recall (even if you put 'S')

Language Feature	S/D	Differences in C
Control structures	S	
Primitive datatypes	S/D	Similar but sizes can differ (char, esp.), unsigned, no boolean, uninitialized data, …
Operators	S	Java has >>>, C has ->
Casting	D	Java enforces type safety, C does not
Arrays	D	Not objects, don't know their own length, no bounds checking
Memory management	D	Manual (malloc/free), no garbage collection

Primitive Types in C

- Integer types
  - `char`, `int`
- Floating point
  - `float`, `double`
- Modifiers
  - `short` [int]
  - `long` [int, double]
  - `signed` [char, int]
  - `unsigned` [char, int]

C Data Type	32-bit	64-bit	printf
char	1	1	%c
short int	2	2	%hd
unsigned short int	2	2	%hu
int	4	4	%d / %i
unsigned int	4	4	%u
long int	4	8	%ld
long long int	8	8	%lld
float	4	4	%f
double	8	8	%lf
long double	12	16	%Lf
pointer	4	8	%p

Typical sizes – see `sizeofs.c`

C99 Extended Integer Types

- Solves the conundrum of "how big is an `long int`?"

```
#include <stdint.h>

void foo(void) {
  int8_t  a;  // exactly 8 bits, signed
  int16_t b;  // exactly 16 bits, signed
  int32_t c;  // exactly 32 bits, signed
  int64_t d;  // exactly 64 bits, signed
  uint8_t w;  // exactly 8 bits, unsigned
  ...
```

Use extended types in most cse333 code

```
void sumstore(int x, int y, int* dest) {
```

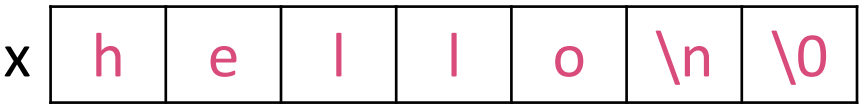
But `int` is usually fine for simple counters

```
void sumstore(int32_t x, int32_t y, int32_t* dest) {
```

Basic Data Structures

- C does not support objects!!!
- **Arrays** are contiguous chunks of memory
  - Arrays have no methods and do not know their own length
  - Can easily run off ends of arrays in C – security bugs!!!
- **Strings** are null-terminated char arrays
  - Strings have no methods, but `string.h` has helpful utilities

```
char* x = "hello\n";
```



- **Structs** are the most object-like feature, but are just collections of fields – no "methods" or functions
  - (but can contain pointers to functions!)

Function Definitions

- Generic format:

```
returnType fname(type param1, …, type paramN) {
    // statements
}
```

```
// sum of integers from 1 to max
int sumTo(int max) {
  int i, sum = 0;

  for (i = 1; i <= max; i++) {
    sum += i;
  }

  return sum;
}
```

Function Ordering

- You *shouldn't* call a function that hasn't been declared yet

sum_badorder.c

```c
#include <stdio.h>

int main(int argc, char** argv) {
  printf("sumTo(5) is: %d\n", sumTo(5));
  return 0;
}

// sum of integers from 1 to max
int sumTo(int max) {
  int i, sum = 0;

  for (i = 1; i <= max; i++) {
    sum += i;
  }
  return sum;
}
```

Solution 1: Reverse Ordering

- Simple solution; however, imposes ordering restriction on writing functions (who-calls-what?)

sum_betterorder.c

```c
#include <stdio.h>

// sum of integers from 1 to max
int sumTo(int max) {
  int i, sum = 0;

  for (i = 1; i <= max; i++) {
    sum += i;
  }
  return sum;
}

int main(int argc, char** argv) {
  printf("sumTo(5) is: %d\n", sumTo(5));
  return 0;
}
```

Solution 2: Function Declaration

- Teaches the compiler arguments and return types; function definitions can then be in a logical order

sum_declared.c

Code examples from slides are on the course web for you to experiment with!

```c
#include <stdio.h>

int sumTo(int);  // func prototype

int main(int argc, char** argv) {
  printf("sumTo(5) is: %d\n", sumTo(5));
  return 0;
}

// sum of integers from 1 to max
int sumTo(int max) {
  int i, sum = 0;
  for (i = 1; i <= max; i++) {
    sum += i;
  }
  return sum;
}
```

Declaration vs. Definition

- C/C++ make a careful distinction between these two

- Definition: the thing itself
  - *e.g.* code for function, variable definition that creates storage
  - Must be **exactly one** definition of each thing (no duplicates)

- Declaration: description of a thing defined elsewhere
  - *e.g.* function prototype, external variable declaration
    - Often in header files and incorporated via `#include`
    - Should also `#include` declaration in the file with the actual definition to check for consistency
  - Needs to appear in **all files** that use the thing
    - Should appear before first use

Multi-file C Programs

C source file 1 (sumstore.c)

```
void sumstore(int x, int y, int* dest) {
  *dest = x + y;
}
```

definition

C source file 2 (sumnum.c)

```
#include <stdio.h>

void sumstore(int x, int y, int* dest);

int main(int argc, char** argv) {
  int z, x = 351, y = 333;
  sumstore(x,y,&z);
  printf("%d + %d = %d\n",x,y,z);
  return 0;
}
```

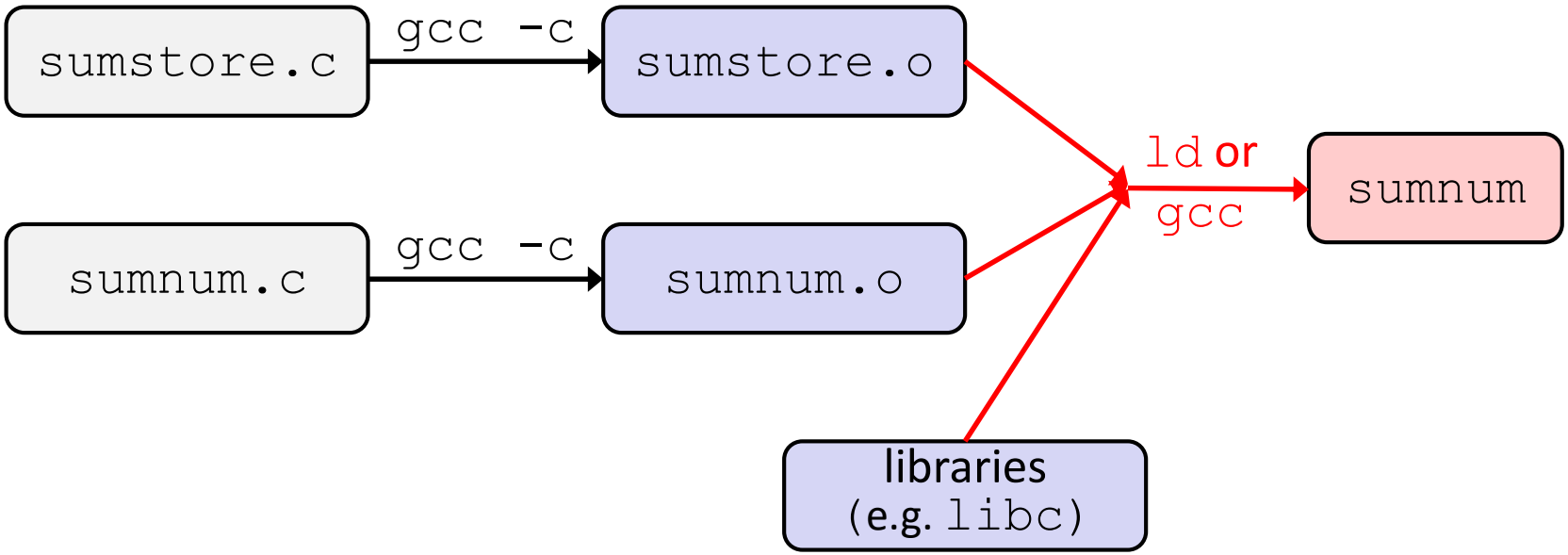
declaration

Compile together:

```
$ gcc -o sumnum sumnum.c sumstore.c
```

Compiling Multi-file Programs

- The **linker** combines multiple object files plus statically-linked libraries to produce an executable
  - Includes many standard libraries (*e.g.* `libc`, `crt1`)
    - A *library* is just a pre-assembled collection of `.o` files



Poll Everywhere

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- Which of the following statements is **FALSE**?
  - **A. With the standard `main()` syntax, It is always safe to use `argv[0]`.**
  - **B. We can't use `uint64_t` on a 32-bit machine because there isn't a C integer primitive of that length.**
  - **C. Using function declarations is beneficial to both single- and multi-file C programs.**
  - **D. When compiling multi-file programs, not all linking is done by the Linker.**
  - **E. We're lost…**

To-do List

- Explore the website *thoroughly*: http://cs.uw.edu/333
- Computer setup: CSE labs, attu, or CSE Linux VM
- Exercise 0 is due 10 am **sharp** before Monday's class
  - Find exercise spec on website, submit via Gradescope
  - Sample solution will be posted Monday after class
  - Give it your best shot
- Project repos created and hw0 out tomorrow
  - Ask questions on Ed!
  - More questions? Bring them (and your laptop) to section