Intro, C refresher

CSE 333 Winter 2024

Instructor: Hal Perkins

Teaching Assistants:

Ann Baturytski, Noa Ferman, Hannah Jiang, Humza Lala, Leanna Nguyen, Varun Pradeep, Justin Tysdal, Deeksha Vatwani, Yiqing Wang, Wei Wu, Jennifer Xu

Lecture Outline

- **Course Introduction**
- Course Policies
  - https://courses.cs.washington.edu/courses/cse333/24wi/syllabus.html
- C Intro

Welcome Back…

- This has been a strange world for the last several years and it's still not the same as it was (and probably never will be…)
- Please speak up if things aren't (or are!) going well
  - We can often help if we know about things, so stay in touch with TAs, instructor, advising, friends and peers, others
  - Don't try to "tough it out" or pretend it will get better if you just ignore it – speak up when there's plenty of time to fix things!
- Please show understanding and compassion for each other and help when you can – both in and outside of class
- But also, we've been back in person for a couple of years now and things are mostly normal, so let's have a great quarter!

Introductions: Course Staff

- Hal Perkins (instructor)
  - Long-time CSE faculty member and CSE 333 veteran

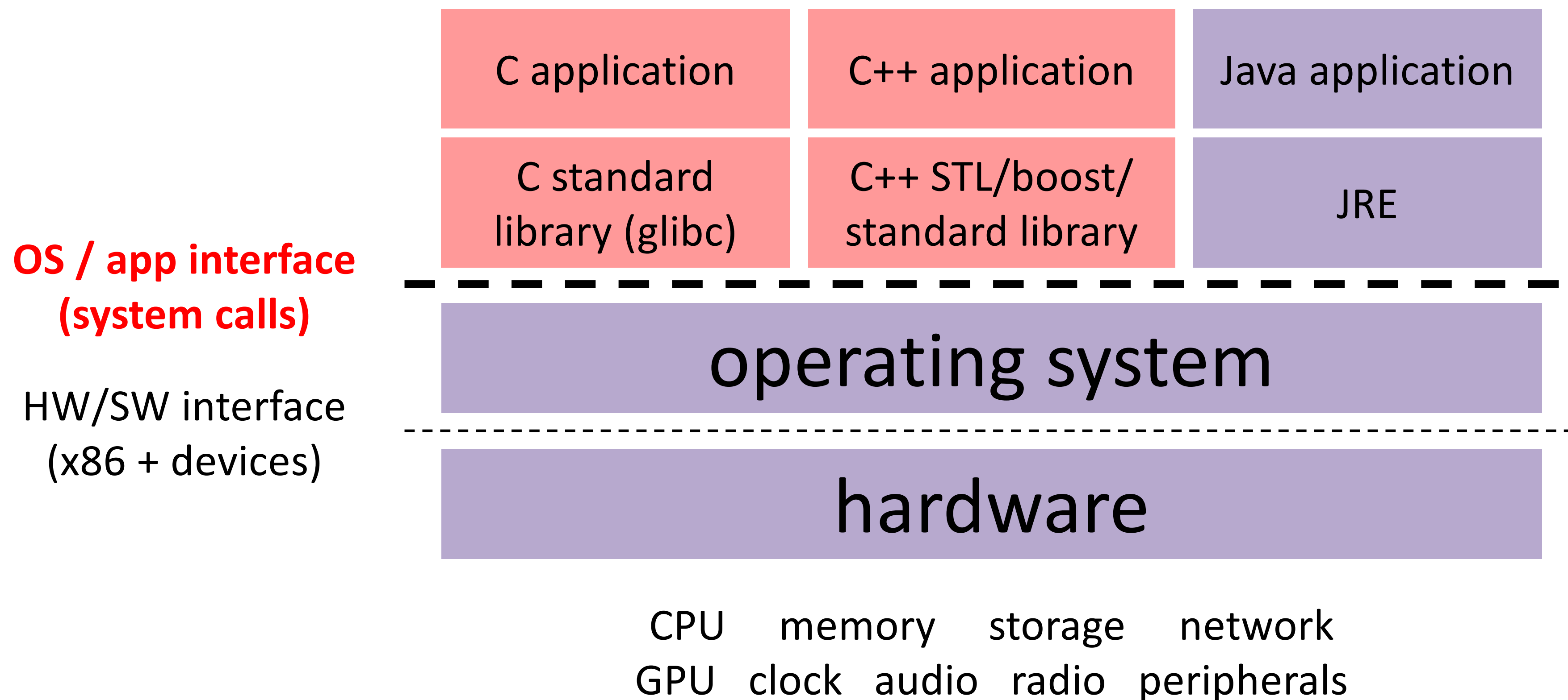
- TAs:
  - Ann Baturytski, Noa Ferman, Hannah Jiang, Humza Lala, Leanna Nguyen, Varun Pradeep, Justin Tysdal, Deeksha Vatwani, Yiqing Wang, Wei Wu, and Jennifer Xu
  - Available in section, office hours, and discussion group
  - An invaluable source of information and help

- Get to know us
  - We are here to help you succeed!

Introductions: Students

- ~195 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

Course Map: 100,000 foot view



Systems Programming

- The programming skills, engineering discipline, and knowledge you need to build a system
  - **Programming:** C / C++
  - **Discipline:** testing, debugging, performance analysis
  - **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?!?

- 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

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- Course Introduction
- **Course Policies**
  - https://courses.cs.washington.edu/courses/cse333/24wi/syllabus.html
  - Summary/highlights here, but you ***must*** read the full details online
- C Intro

Communication

- Website: http://cs.uw.edu/333
  - Schedule, policies, materials, assignments, etc.
- 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.
- Messages to staff: for things not suitable for ed chat messages 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)
- Announcements: will use broadcast Ed messages to send "things everyone must read and know"
- Office Hours: spread throughout the week
  - Schedule posted shortly and will start as soon as we can

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
- Programming Exercises (~18)
  - Roughly one per lecture, due the morning before the next lecture
  - Coarse-grained grading (check plus/check/check minus = 0, 1, 2, or 3)
- Programming Projects (0+4)
  - Warmup, then 4 “homeworks” that build on each other, individual work
- Midterm and final exam
  - Goal is to revisit and internalize concepts
  - Will be scheduled outside class so everyone can take at same time

Grading (tentative)

- **Exercises:** ~30%
  - Submitted via GradeScope (account info mailed after class)
  - Evaluated on correctness and code quality
- **Projects:** ~45% total
  - Submitted via GitLab; must tag commit that you want graded
  - "does it work" and code quality both matter, roughly similarly
  - Binaries provided if you didn't get previous part working or prefer to start with a known good solution to previous parts
- **Exams:** Midterm: ~10%, Final: ~15%

- More details on course website
  - You **must** read the syllabus there – you are responsible for it

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)
  - We trust you implicitly and will follow up if that trust is violated
  - In short: don’t attempt to gain credit for something you didn’t do and don’t help others do so either
  - 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 Friday morning **10 am** before class
  - Warmup/logistics for larger projects in sections Thursday
    - HW0 (the warmup project) published this afternoon 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 tomorrow! 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?

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- Course Introduction
- Course Policies
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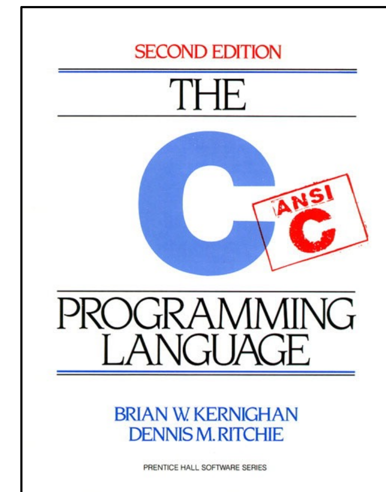
- **C Intro**
  - **Workflow, Variables, Functions**

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`

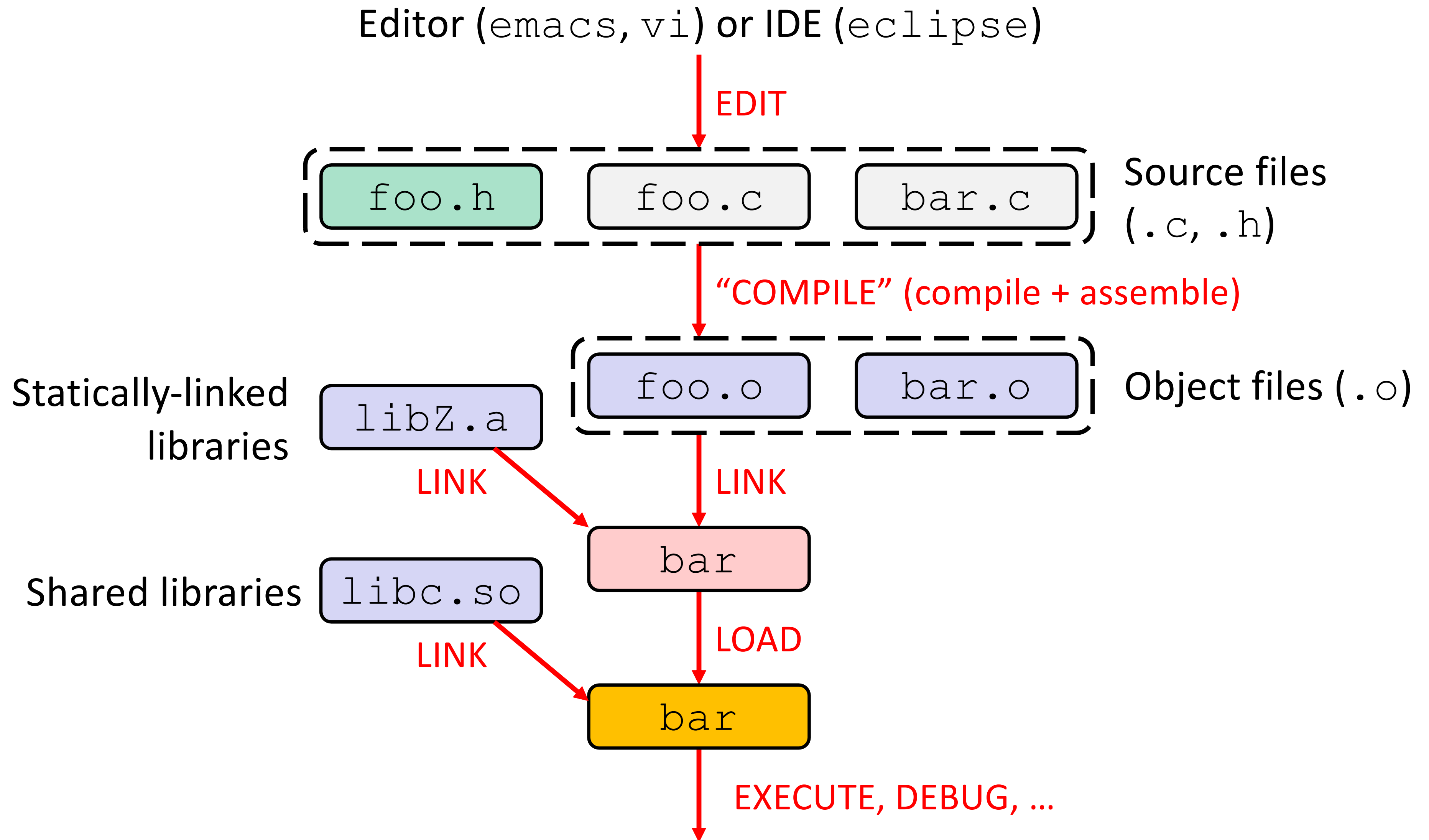
- To get command-line arguments in `main`, use:

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

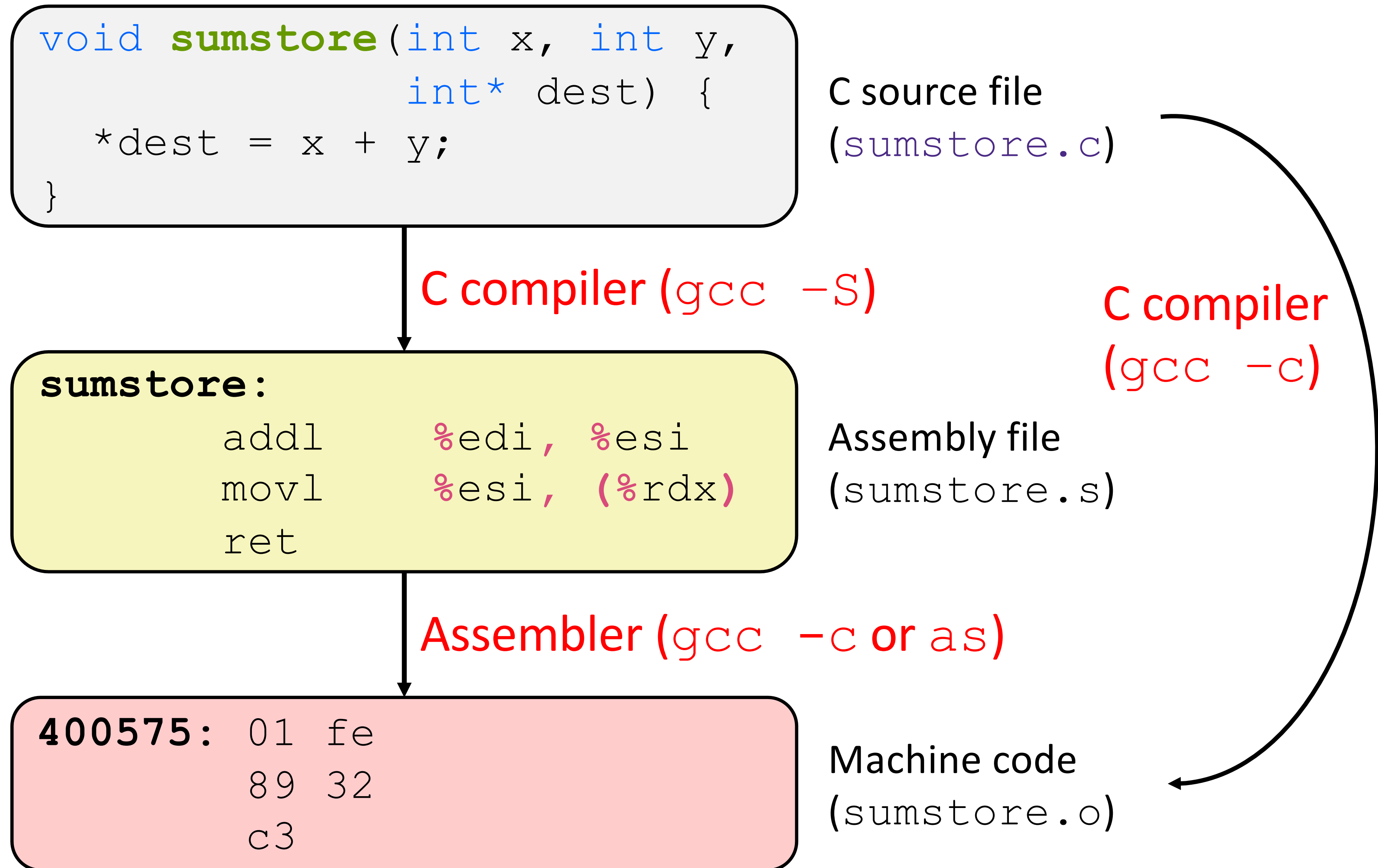
- What does this mean?
  - `argc` contains the number of strings on the command line (the executable name counts as one, plus one for each argument).
  - `argv` is an array containing *pointers* to the arguments as strings (more on pointers later)

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

C Workflow



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)

Java vs. C (351 refresher)

- Are Java and C mostly similar (S) or significantly different (D) in the following categories?

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) {
```

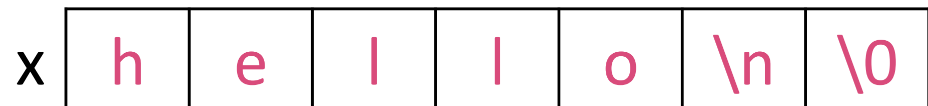
But int is usually fine for simple ints

```
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

```
#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

```
#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

Hint: code examples from slides are on the course web for you to experiment with

```
#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;
}
```

Function 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;
}
```

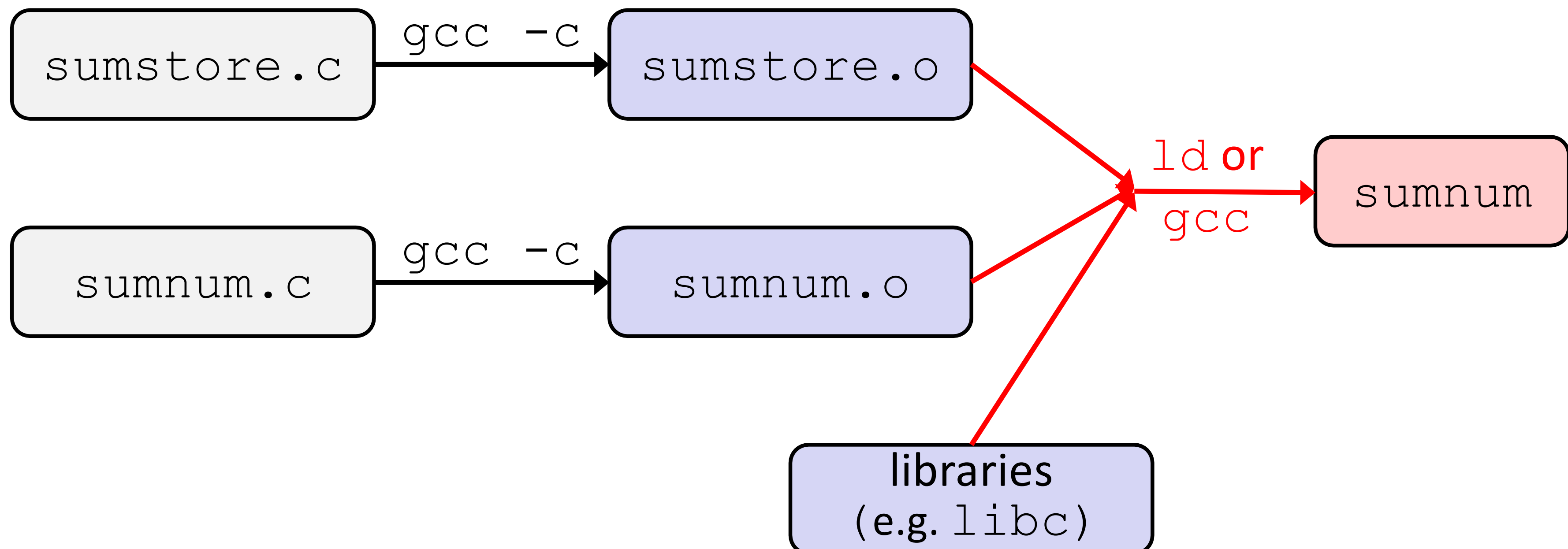
declaration

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



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** Friday before class
  - Find exercise spec on website, submit via Gradescope
  - Sample solution will be posted Friday after class
  - Give it your best shot and be sure to get it done on time
- Gradescope accounts created after class today
  - Userid is your uw.edu email address
  - Exercise submission: find CSE 333 24wi in gradescope, click on the exercise, drag-n-drop file(s)! That's it!!
- Project repos created and hw0 out later today
  - All will become clear in sections tomorrow! Bring your laptop!! ☺