Intro, C refresher

CSE 333 Spring 2025

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Lecture Outline

- **Course Introduction**
- Course Policies
  - https://courses.cs.washington.edu/courses/cse333/2sp/syllabus.html
- C Intro

Welcome Back…

- Welcome back! Hope you've had a great Spring break and are all set for a great quarter! But…

- 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 problems – 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

- Let's have a great quarter and stay on top of things!

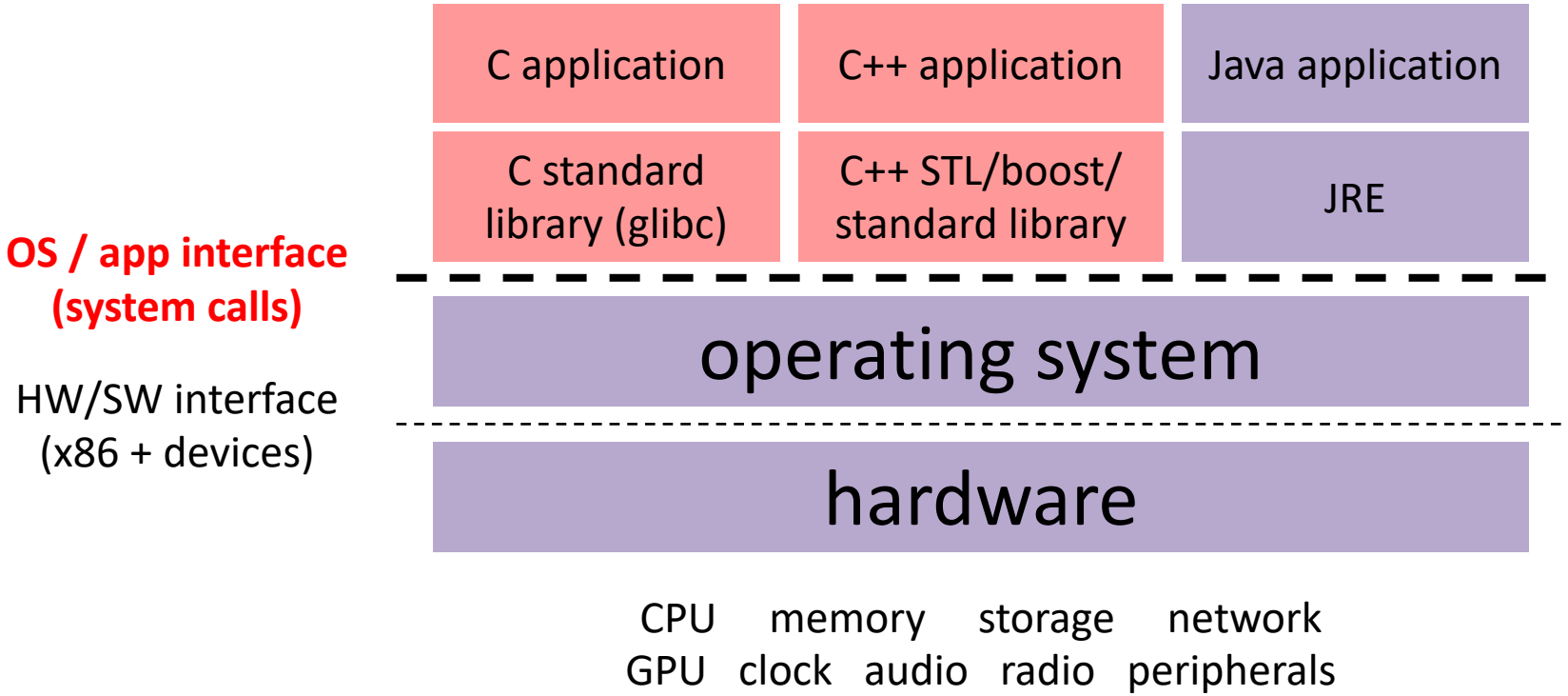
Introductions: Course Staff

- Hal Perkins (instructor)
  - Long-time CSE faculty member and CSE 333 veteran
- TAs:
  - Hannah Hempstead, Lainey Jeon, Hannah Jiang, Irene Lau, Nathan Li, Leanna Nguyen, Janani Raghavan, Deeksha Vatwani, Yiqing Wang, 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

- ~215 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

Lecture Outline

- Course Introduction
- **Course Policies**
  - https://courses.cs.washington.edu/courses/cse333/25sp/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 us 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 list)
- 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 = 3, 2, 1, or 0)
- 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
  - On course calendar now – please plan ahead
    - Midterm: Fri. May 9, in-class; Final: Wed. June 11, 2:30-4:20

Grading (tentative)

- **Exercises:** ~30%
  - Submitted via GradeScope (account info mailed later today)
  - Evaluated on correctness ("does it work") 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 & Late Policies

- Exercises: no late submissions accepted, due 10 am before class
  - Idea is to try out ideas introduced in lecture before the next 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

Conduct

- Academic Integrity (**read** the full policy on the web)
  - We want a collegial group helping each other succeed!
  - But: you must never misrepresent work done by someone else (or something else, including AI) as your own, without proper credit when appropriate, or assist others to do the same
    - Do not attempt to bypass learning by avoiding work, do not attempt to gain credit for something you didn't do, and don't help others to do so
  - Read the course policy carefully
  - We trust you to behave ethically
    - We have little sympathy for violations of that trust
    - Honest work is the most important feature of a university (or engineering or business or life). Anything less disrespects your colleagues, your instructor and TAs, and yourself
  - This does ***not*** mean suffer in silence – learn from the course staff and peers, talk, share ideas, use online resources to learn; *but* don't share or copy work that is supposed to be yours

Gadgets in Class

- 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
- 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 ☺
    - You *will* learn and retain more if you actively take notes during class

And off we go…

- This week: 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 Wednesday morning **10 am** before class
  - Warmup/logistics for larger projects in sections Thursday
    - HW0 (the warmup project) published and gitlab repos created before sections. OK to ignore details until then.

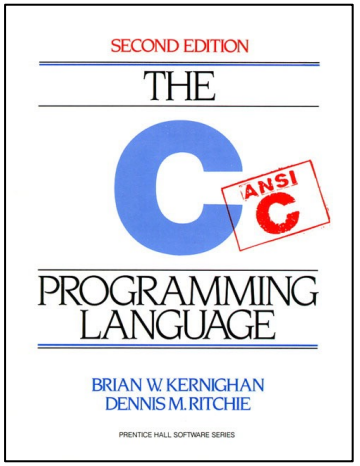
Deep Breath….

- 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/cse333/25sp/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) and 2023 (C23)
    - But core ideas have been stable for decades
- 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`

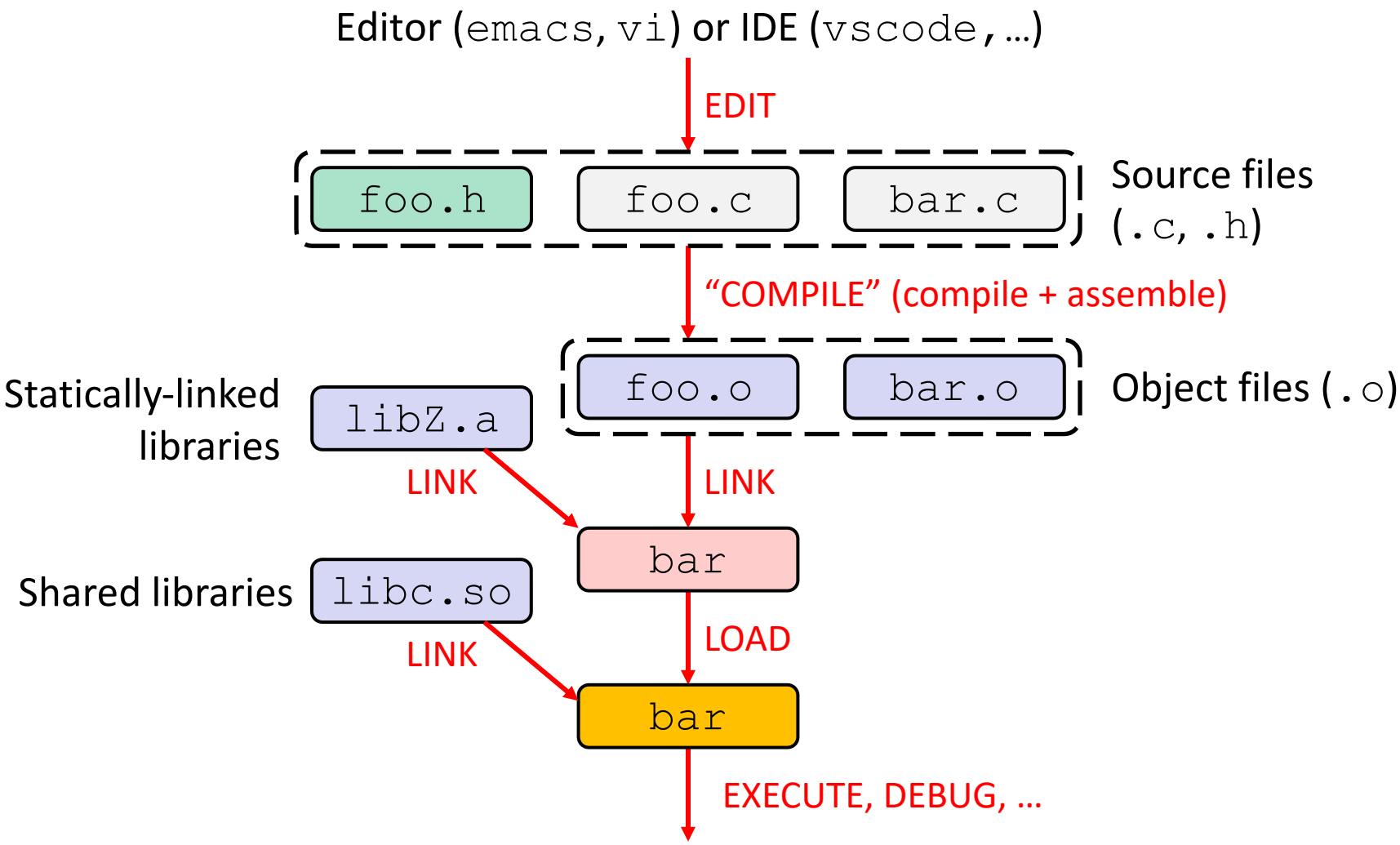
- To get command-line arguments in `main`, use:

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

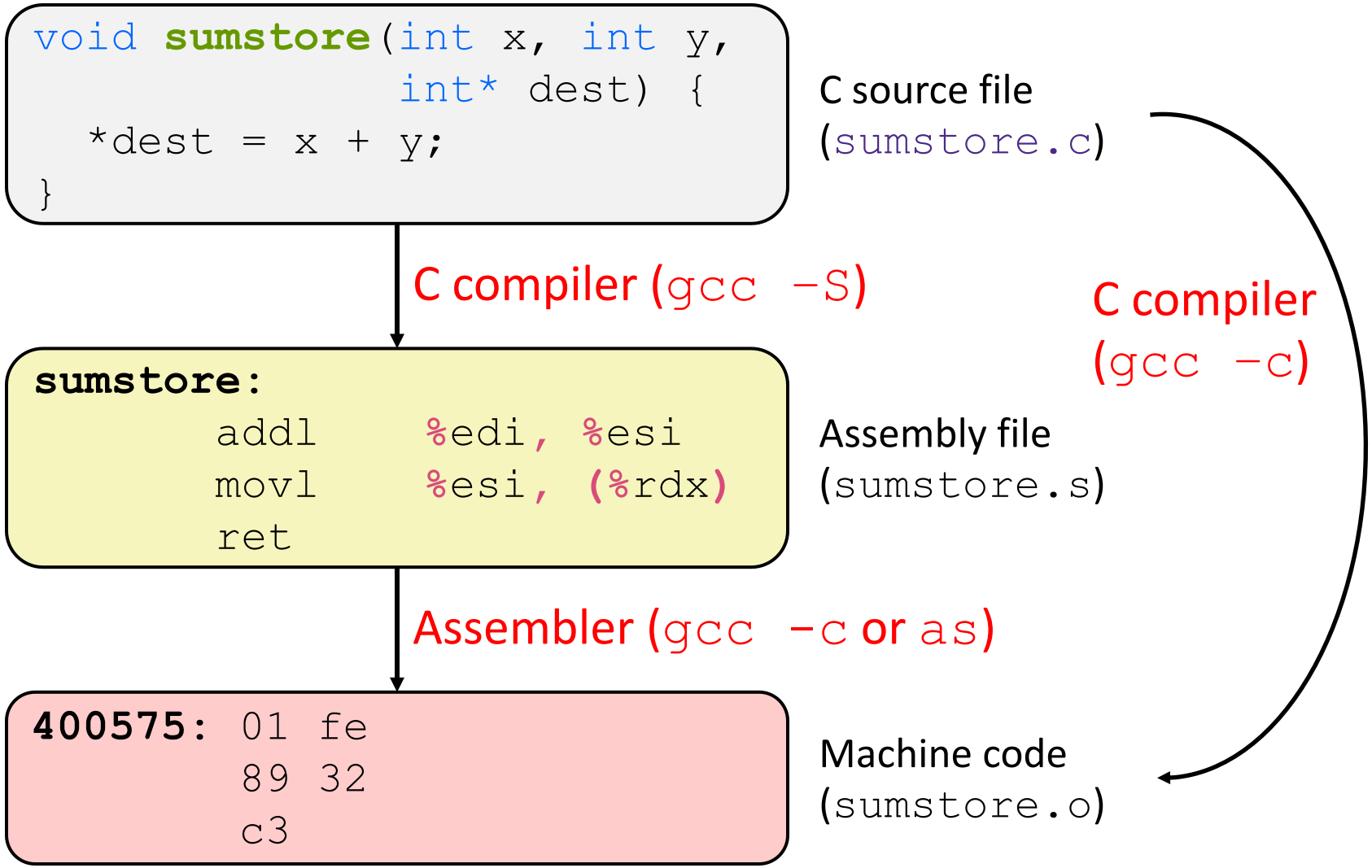
- What does this mean?
  - `argc` contains the number of strings on the command line (the executable name counts as one, plus one for each argument).
  - `argv` is an array containing *pointers* to the arguments as strings (more on pointers later)

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

C Workflow


Editor (emacs, vi) or IDE (vscode, …)
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)

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,      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 utility functions

```
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
  - We will use this for all functions – either local or libraries

sum_declared.c

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

```c
#include <stdio.h>

// = sum of integers from 1 to max
int sumTo(int max);  // func prototype

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

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;
}
```

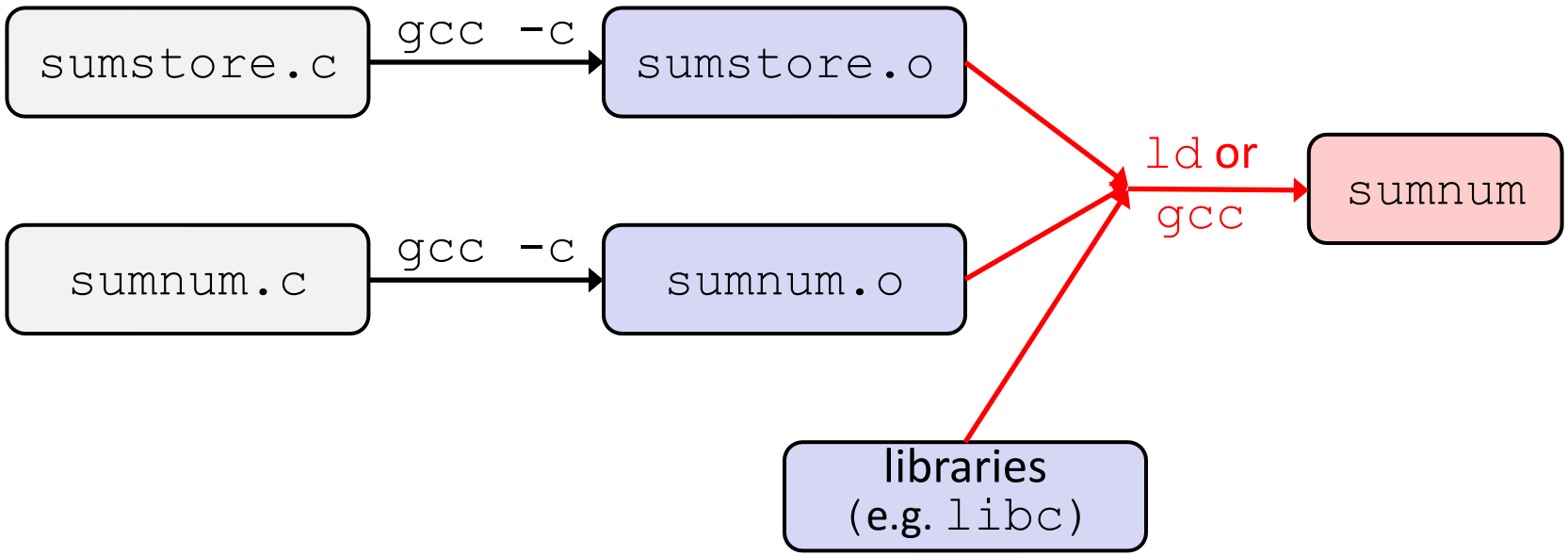
declaration

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 (details later)
  - 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** Wednesday before class
  - Find exercise spec on website, submit via Gradescope
  - Sample solution will be posted Wednesday after class
  - Give it your best shot and be sure to finish and submit on time
- Gradescope accounts created late this afternoon
  - Userid is your uw.edu email address
  - Exercise submission: find CSE 333 25wi in gradescope, click on the exercise, drag-n-drop file(s)! That's it!!
    - See resources page on course web for how to transfer files from attu / vscode / etc. to your local laptop to do drag-n-drop
- Project repos created and hw0 out mid-week
  - All will become clear in sections this week!