Intro, C refresher

CSE 333 Spring 2020

Welcome – please set up your Zoom session. We'll start the actual class meeting at 11:30 am pdt

Instructor: Hal Perkins

Teaching Assistants:

Ramya Challa
Greg Guo
Travis McGaha
Cosmo Wang
Haoran Yu
Mengqui Chen
Zachary Keyes
Arjun Singh
Yifan Xu
Velocity Yu
John Depaszthory
CJ Lin
Guramrit Singh
Robin Yang

Lecture Outline

- **Course Introduction**
- Course Policies
  - https://courses.cs.washington.edu/courses/cse333/19wi/syllabus/
- C Intro

But first…

- It's all virtual, all the time this quarter
- Core infrastructure is same as usual (Gradescope, Gitlab, web, discussion board) except that lab machines are remote login only all quarter
- But lectures, sections, office hours – Zoom
- Most important: stay healthy, keep your (physical) distance from others, help others both in and out of class

Virtual Lectures

- First, an apology: classes really are going to be mostly lectures. Can't re-design a 10-week course for online in 2 or 3 weeks. So please bear with us.
- Conventions (from page on our web site)
  - Lecture will be recorded and archived – available to class only
  - If you have a question, type "hand" or "question" in Zoom chat window
    - If needed, indicate if we should pause recording while you're talking
  - Please keep your microphone muted during class unless you're using it for a question or during breakout room discussions
  - Lecture slides will be posted in advance along with "virtual handouts" for some lectures
- Fingers crossed that network will hold up under the load

Virtual Sections

- Sections: more Zoom
  - Not normally recorded so we can have open discussions and group work without people being too self-conscious
  - We're going to try to produce videos for things that would normally be done as demos or presentations in sections; details tba
    - Those will be available online
  - Slides and any sample code, worksheets, etc. posted as usual

Virtual Everything Else

- Office hours: also Zoom; probably using a waiting room to work with one person at a time (but will change if needed)
  - Not recorded or archived
  - Once gitlab repos are set up, if your question concerns your code (exercises, projects), please push latest code to the repo before meeting with TA to save some time
- And we'll use group or individual meetings, chats, etc. depending on what people want to try and what works
- You will be bombarded with email as we add these things to Canvas/Zoom. Feel free to ignore. ☺

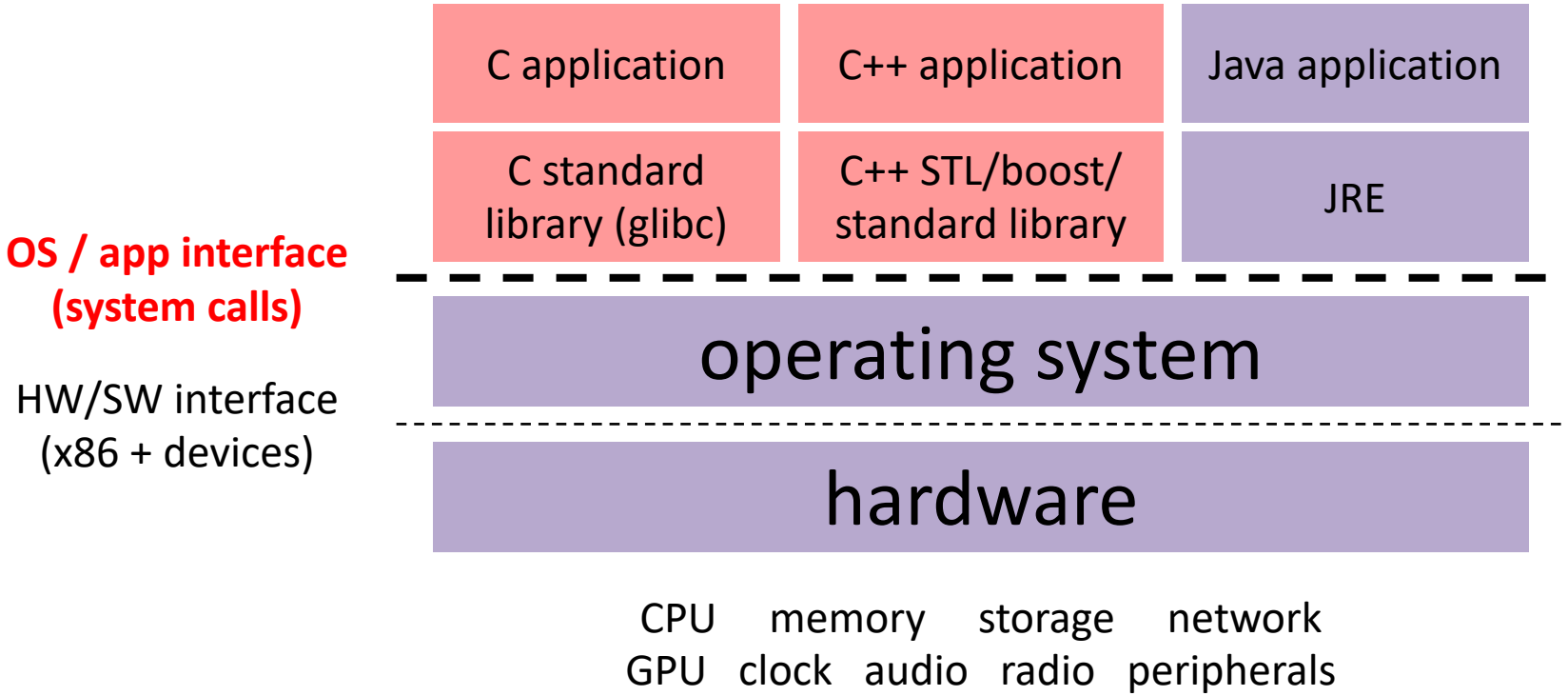
Introductions: Course Staff

- Hal Perkins (instructor)
  - Long-time CSE faculty member and CSE 333 veteran
- TAs:
  - Ramya Challa, Mengqui Chen, Arpad Depaszthory, Zachary Keyes, CJ Lin, Travis McGaha, Arjun Singh, Guramrit Singh, Cosmo Wang, Yifan Xu, Haoran Yu, Greg Guo, Robin Yang
  - 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

- ~150 students this quarter
  - There are no overload forms or waiting lists for CSE courses
- 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/cse333/20sp/syllabus/
  - Summary 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
  - Must log in using your **@uw.edu** Google identity (not cse)
  - Ask and answer questions – staff will monitor and contribute
- Staff mailing list: cse333-staff@cs for things not appropriate for discussion group (***don't*** email to instructor or individual TAs if possible)
- Course mailing list: for announcements from staff
  - Registered students automatically subscribed with your @uw email
- Office Hours: spread throughout the week
  - Schedule posted shortly and will start this week
  - Can also e-mail to staff list to make individual appointments

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 (~20)
  - Roughly one per lecture, due the morning before the next lecture
  - Coarse-grained grading (0, 1, 2, or 3)
- Programming Projects (0+4)
  - Warm-up, then 4 "homeworks" that build on each other
- Exams: nothing traditional; maybe 3-4 mini-exams
  - Stay tuned, still working on that

Grading (tentative)

- **Exercises:** 30% total
  - Submitted via GradeScope (account info mailed this morning)
  - Graded on correctness and style by TAs
- **Projects:** 50% total
  - Submitted via GitLab; must tag commit that you want graded
  - Binaries provided if you didn't get previous part working
- **Mini-Exams:** ~20%, if we have them

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

Deadlines and Student Conduct

- Late policies (standard quarters)
  - Exercises: no late submissions accepted, due 10 am
  - Projects: 4 late days for entire quarter, max 2 per project
  - Need to get things done on time – difficult to catch up!

- Academic Integrity (**read** the full policy on the web)
  - I 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

Deadlines (this quarter)

- We're hoping to stay close to a normal schedule to make progress, but…
  - Very unusual quarter (understatement)
  - We'll be quite flexible depending on circumstances

- We're going to start exercises right away
  - Need to discover how to get compute cycles now; no point in putting it off
  - But, first couple are "freebies" – won't count in final grade, but do them anyway so we can all figure out how to make this work, and so you start getting practice with C programming

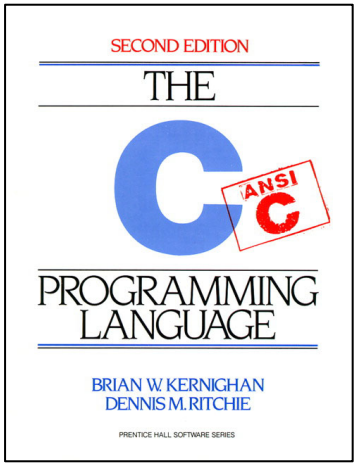
Deep Breath….

- 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/cse333/18sp/syllabus/
- **C Intro**
  - **Workflow, Variables, Functions**

C



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

- 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`

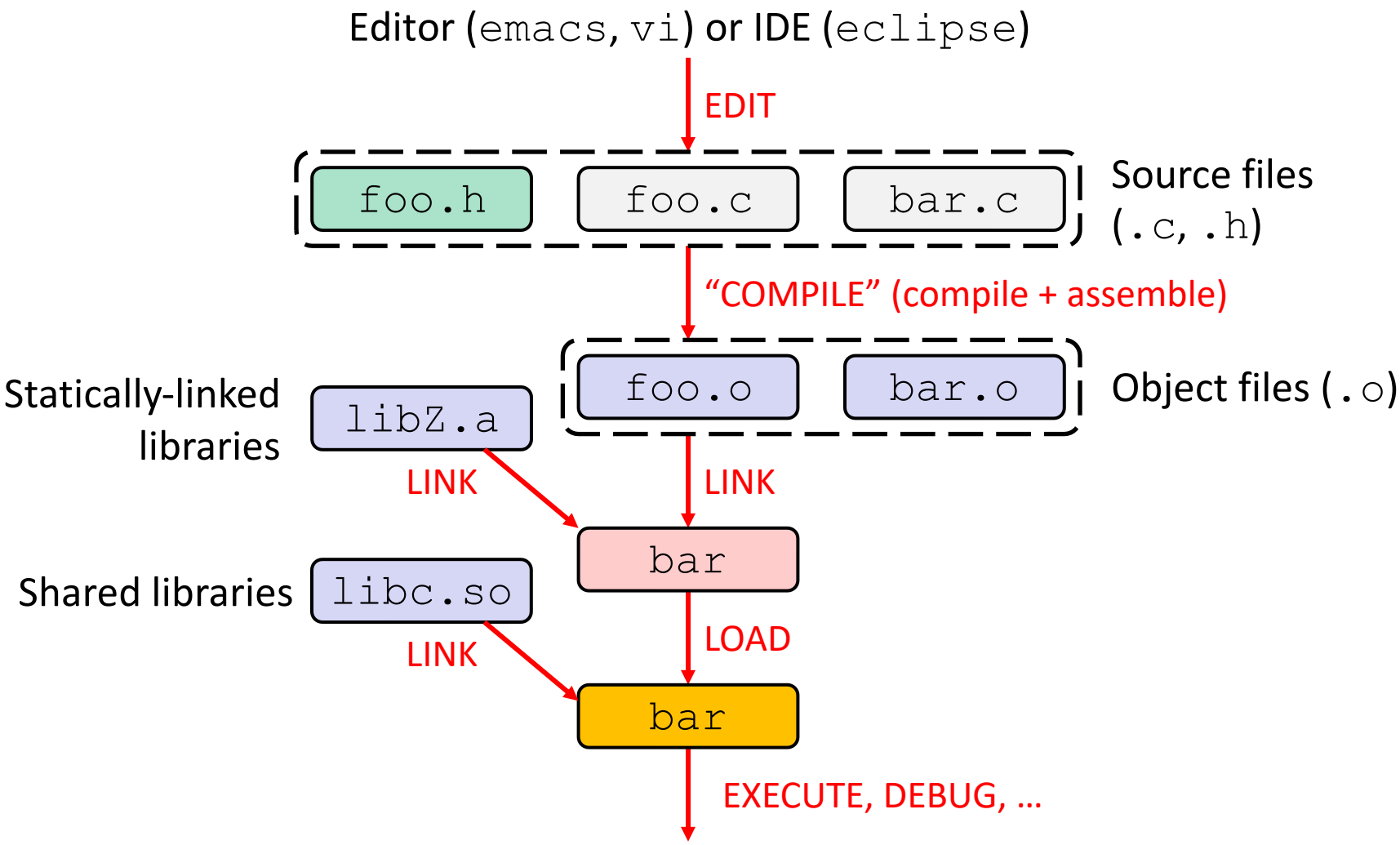
- To get command-line arguments in `main`, use:

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

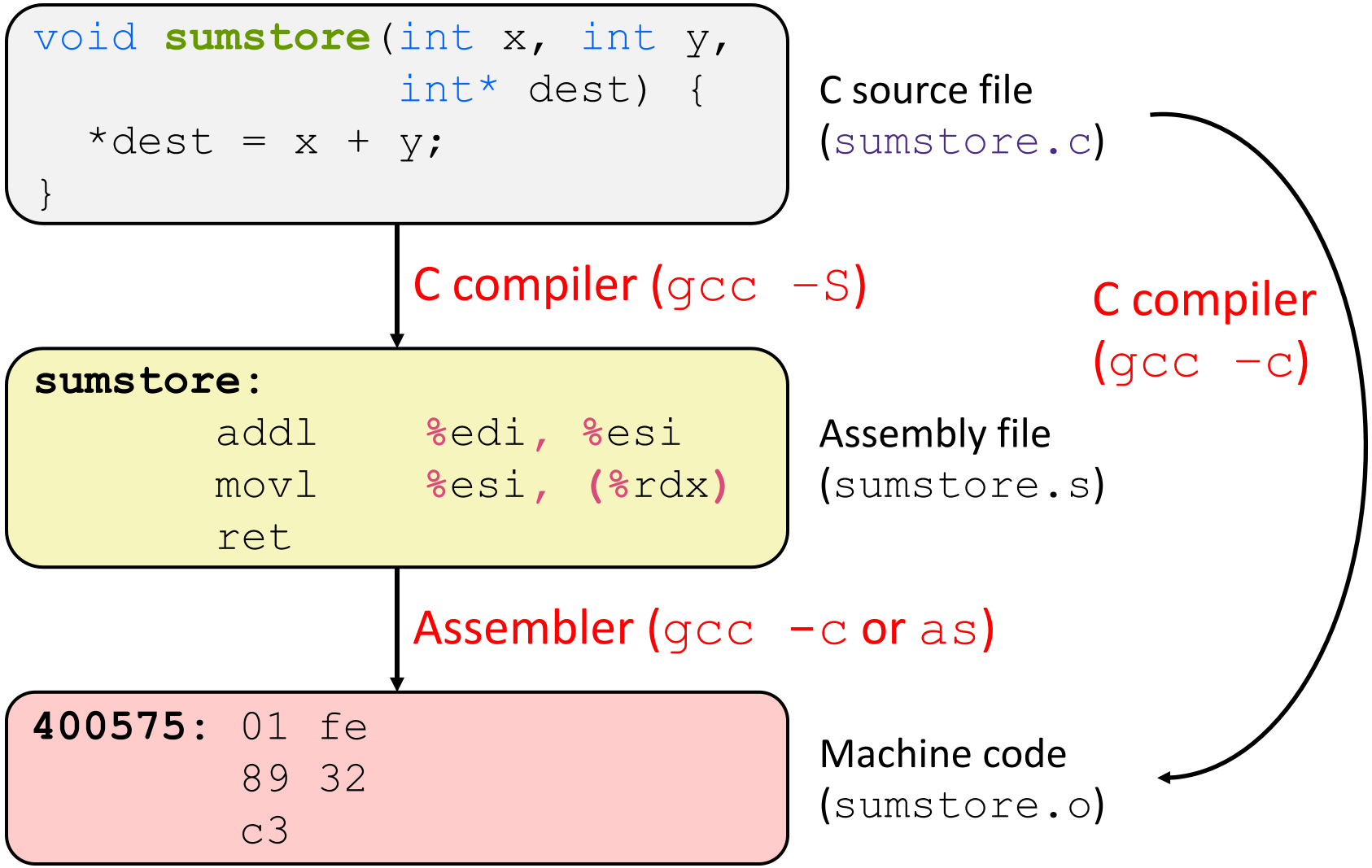
- What does this mean?
  - `argc` contains the number of strings on the command line (the executable name counts as one, plus one for each argument).
  - `argv` is an array containing *pointers* to the arguments as strings (more on pointers later)

- 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

- 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?
  - 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 cse333 code

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

```
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

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

```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;
}
```

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
  - *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 that 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;
}
```

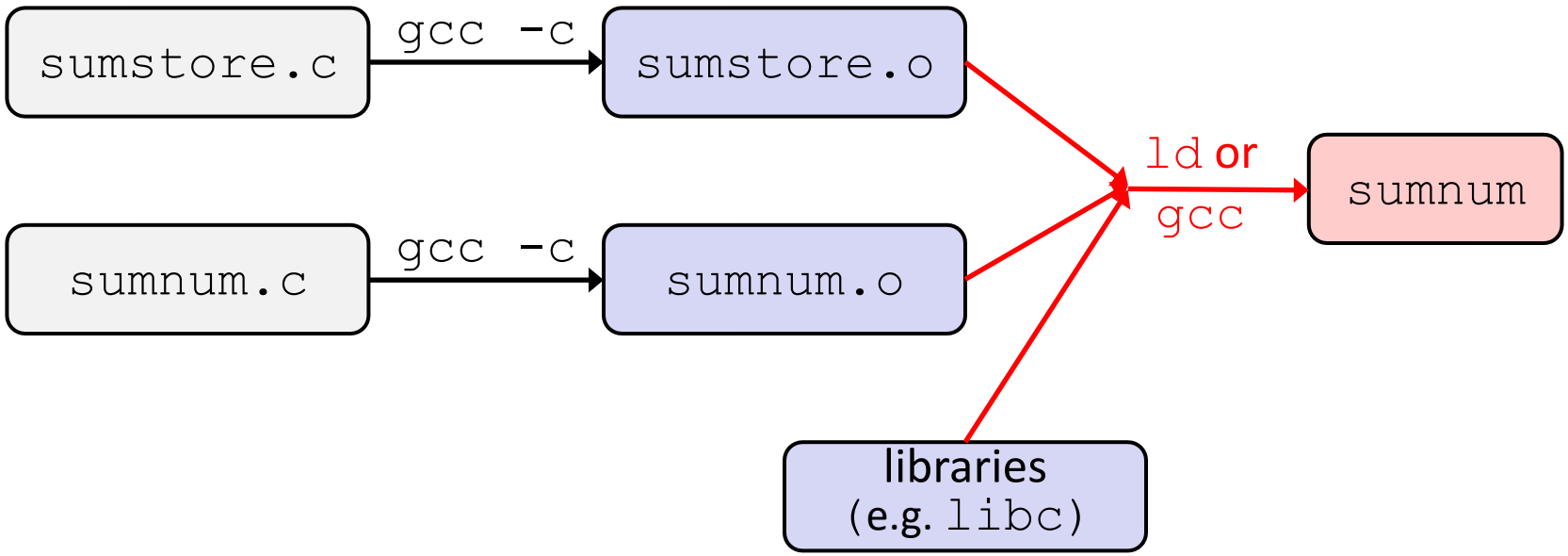
declaration

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 remote lab, attu, or CSE Linux VM
- Exercise 0 is due 10 am Wednesday before class*
  - Find exercise spec on website, submit via Gradescope
  - Sample solution will be posted Friday after class
  - Give it your best shot to get it done more-or-less on time*

    *but we'll figure out how to work around late exercises for this week…
- Gradescope accounts created just before class
  - Userid is your uw.edu email address
  - Exercise submission: find CSE 333 20sp, click on the exercise, drag-n-drop file(s)! That's it!! Ignore any messages about autograding not using this quarter