Intro, C refresher

CSE 333 Autumn 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:

Rehaan Bhimani	Ramya Challa	Eric Chan
Mengqi Chen	Ian Hsiao	Pat Kosakanchit
Arjun Singh	Guramrit Singh	Sylvia Wang
Yifan Xu	Robin Yang	Velocity Yu

Lecture Outline

- **Course Introduction**
- Course Policies
  - https://courses.cs.washington.edu/courses/cse333/20au/syllabus/
- C Intro

To get started…

- It’s all virtual, all the time this quarter

- Core infrastructure is same as it’s aways been (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, wear masks, keep your (physical) distance from others, help others
  - (And register and vote!)

Virtual Lectures

- Classes will be mostly lectures – more interaction in sections
  - Worked fairly well in Spring and Summer – but let us know where we could do better!
- 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

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; details tba
    - Those will be available online
  - Slides and any sample code, worksheets, etc. posted as always

Virtual Everything Else

- Office hours: also Zoom; combination of group gatherings, breakouts, waiting rooms, sign-up sheets to organize – all as needed
  - Not recorded or archived
  - Once gitlab repos are set up later today, if your question concerns your code (exercises, projects), please push latest code to the repo before meeting with TA to save some time
- You will be bombarded with email as we add these things to Canvas/Zoom. Feel free to file away for future reference. ☺

Stay in Touch – Speak up

- This is a strange world we're in and there's a lot of stress for many people

- 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

- We're all in this together but not all in the same way, so please show understanding and compassion for each other and help when you can – both in and outside of class

Introductions: Course Staff

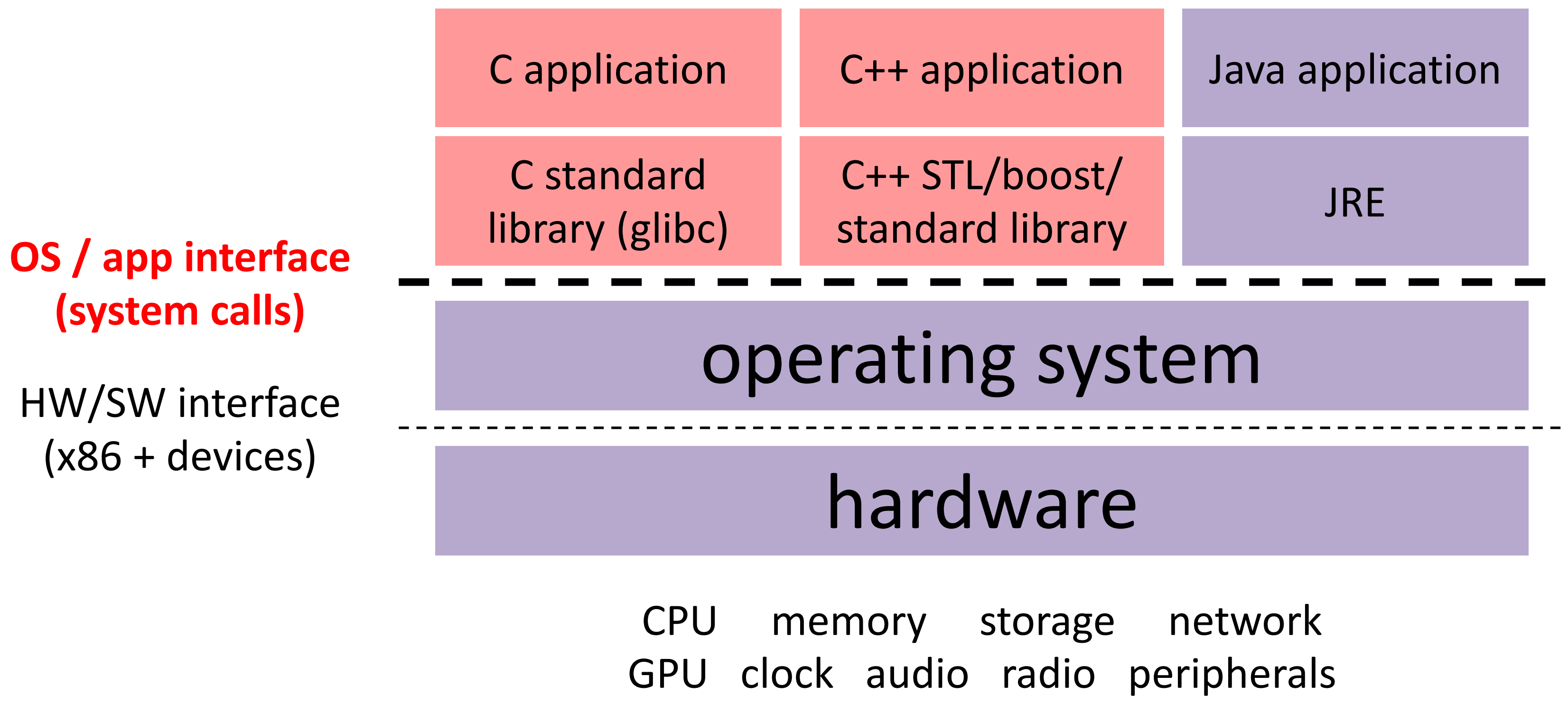
- Hal Perkins (instructor)
  - Long-time CSE faculty member and CSE 333 veteran
- TAs:
  - Rehaan Bhimani, Ramya Challa, Eric Chan, Mengqi Chen, Ian Hsiao, Pat Kosakanchit, Arjun Singh, Guramrit Singh, Sylvia Wang, Yifan Xu, Robin Yang, Velocity Yu
  - Available in section, office hours, and discussion group
  - An invaluable source of information and help
- Get to know us
  - We are here to help you succeed!

Introductions: Students

- ~165 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


C application
C++ application
Java application
C standard library (glibc)
C++ STL/boost/ standard library
JRE
OS / app interface (system calls)
operating system
HW/SW interface (x86 + devices)
hardware
CPU memory storage network
GPU clock audio radio peripherals

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/cse333/20au/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 Ed group
  - (***don't*** email to instructor or individual TAs if possible – helps us get quick answers for you and coordinate better if it goes to the staff)
- 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 right away
  - Can also e-mail to staff list to make individual appointments

Course Components

- Lectures (~30)
  - 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
- No traditional exams, but hoping to do ~4 “recap/review” assignments for things traditionally covered on exams

Grading (tentative)

- **Exercises:** ~35%
  - Submitted via GradeScope (account info mailed this morning)
  - Graded on correctness and style by TAs
- **Projects:** ~45% total
  - Submitted via GitLab; must tag commit that you want graded
  - Binaries provided if you didn't get previous part working
- **Recap/review assignments:** ~20%

- 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
  - Projects: 4 late days for entire quarter, max 2 per project
  - Need to get things done on time – difficult to catch up!
    - But given remote world, we'll work with you if things come 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

And off we go…

- Mid-week start, so we're going to fold together a lot of the usual MWThF week 1 into WThF
- 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**
  - Warmup/logistics for larger projects in sections tomorrow
    - HW0 (the warmup project) published this afternoon and gitlab repos created then. Feel free to ignore until section tomorrow and we'll walk through the whole thing.

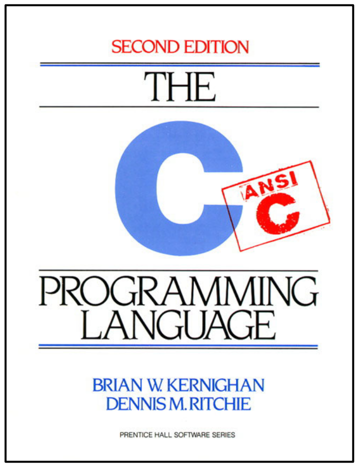
Deep Breath….

- 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`

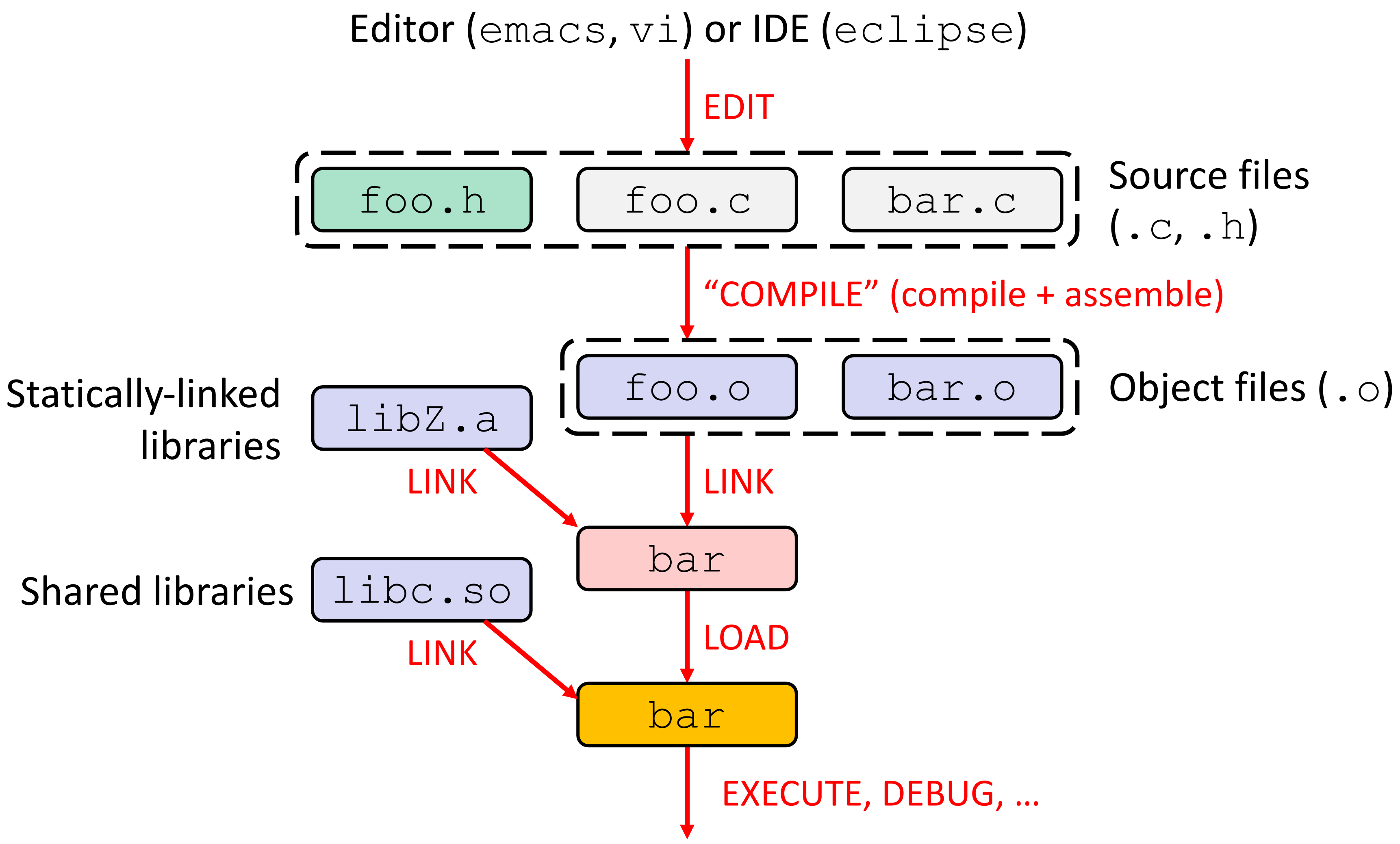
- To get command-line arguments in `main`, use:

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

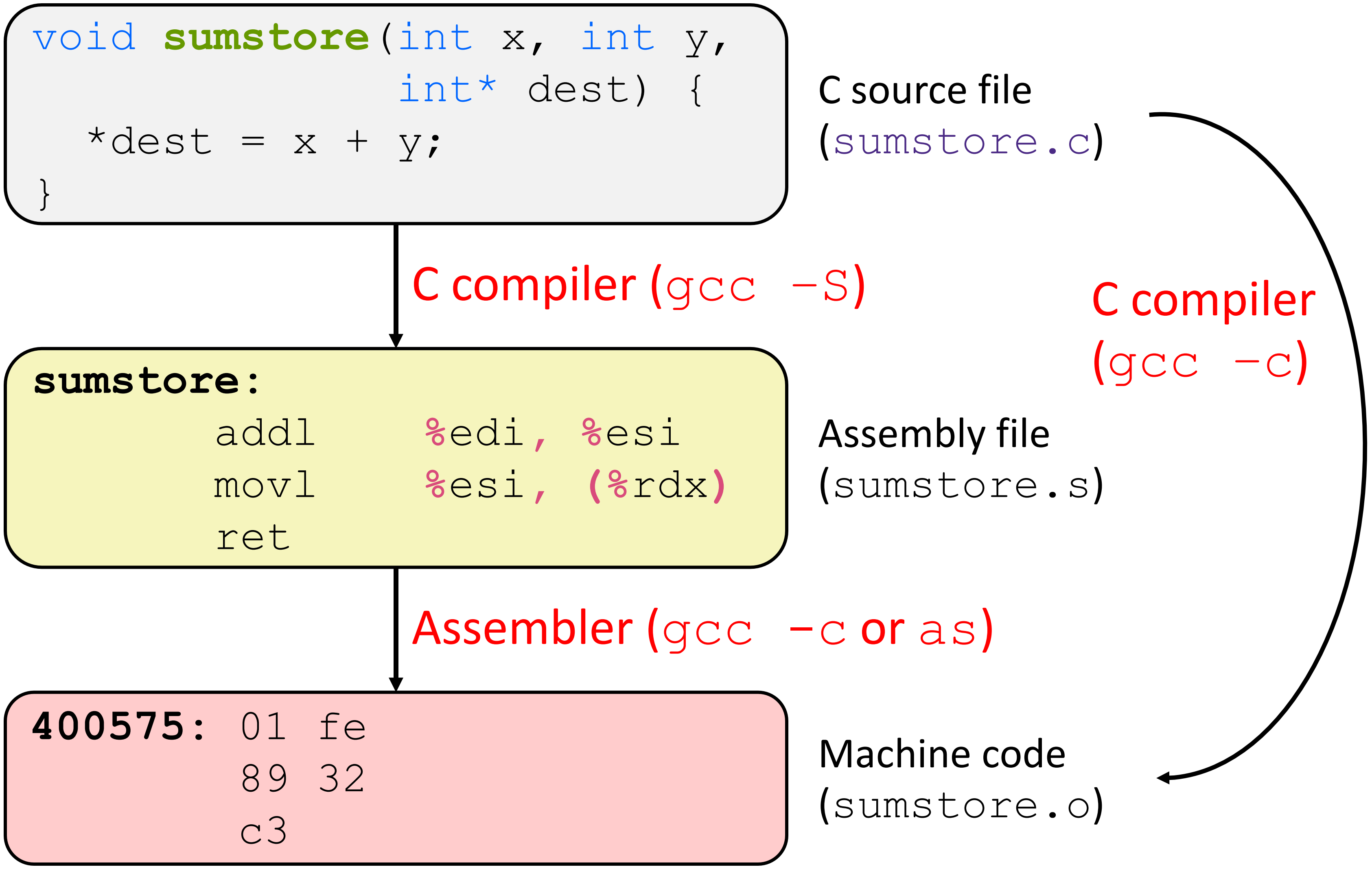
- What does this mean?
  - `argc` contains the number of strings on the command line (the executable name counts as one, plus one for each argument).
  - `argv` is an array containing *pointers* to the arguments as strings (more on pointers later)

- 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)
Statically-linked libraries
libZ.a
foo.o
bar.o
Object files (.o)
LINK
LINK
bar
Shared libraries
libc.so
LINK
LOAD
bar
EXECUTE, DEBUG, …

C to Machine Code



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

```
sumstore:
       addl    %edi, %esi
       movl    %esi, (%rdx)
       ret
```

```
400575: 01 fe
        89 32
        c3
```

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) {
```

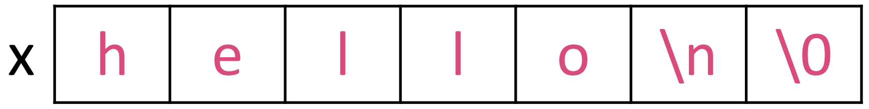
Basic Data Structures

- 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

```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)

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

definition

C source file 2
(sumnum.c)

```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;
}
```

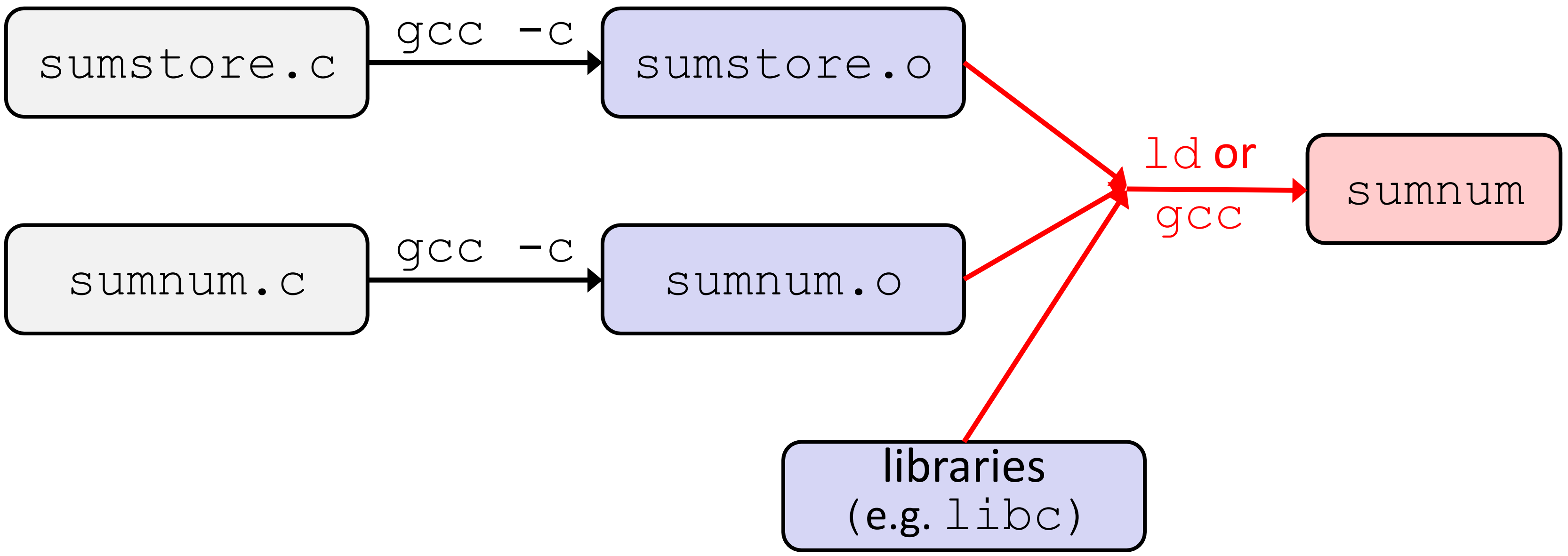
declaration

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 Friday 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 on time
- Gradescope accounts created just before class
  - Userid is your uw.edu email address
  - Exercise submission: find CSE 333 20au, click on the exercise, drag-n-drop file(s)! That's it!!
- Project repos created and hw0 out by tonight!!
  - All will become clear in sections tomorrow! ☺