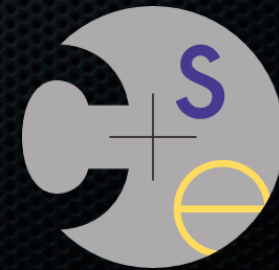


# CSE 333

## Lecture 1 - Intro, C refresher

**Hal Perkins**

Department of Computer Science & Engineering  
University of Washington





# Welcome!

Today's goals:

- **introductions**
- *course syllabus*
- *quick C refresher*



# Introductions

Us ([cse333-staff@cs](mailto:cse333-staff@cs))

- Hal Perkins (Instructor)
- Mark Davis (TA)
- Renshu Gu (TA)
- Soumya Vasisht

Most important: You!!



# Still trying to enroll?

We'll collect names at the end of the hour

Decisions later this week once we see how many people want to add, what resources we have, etc.



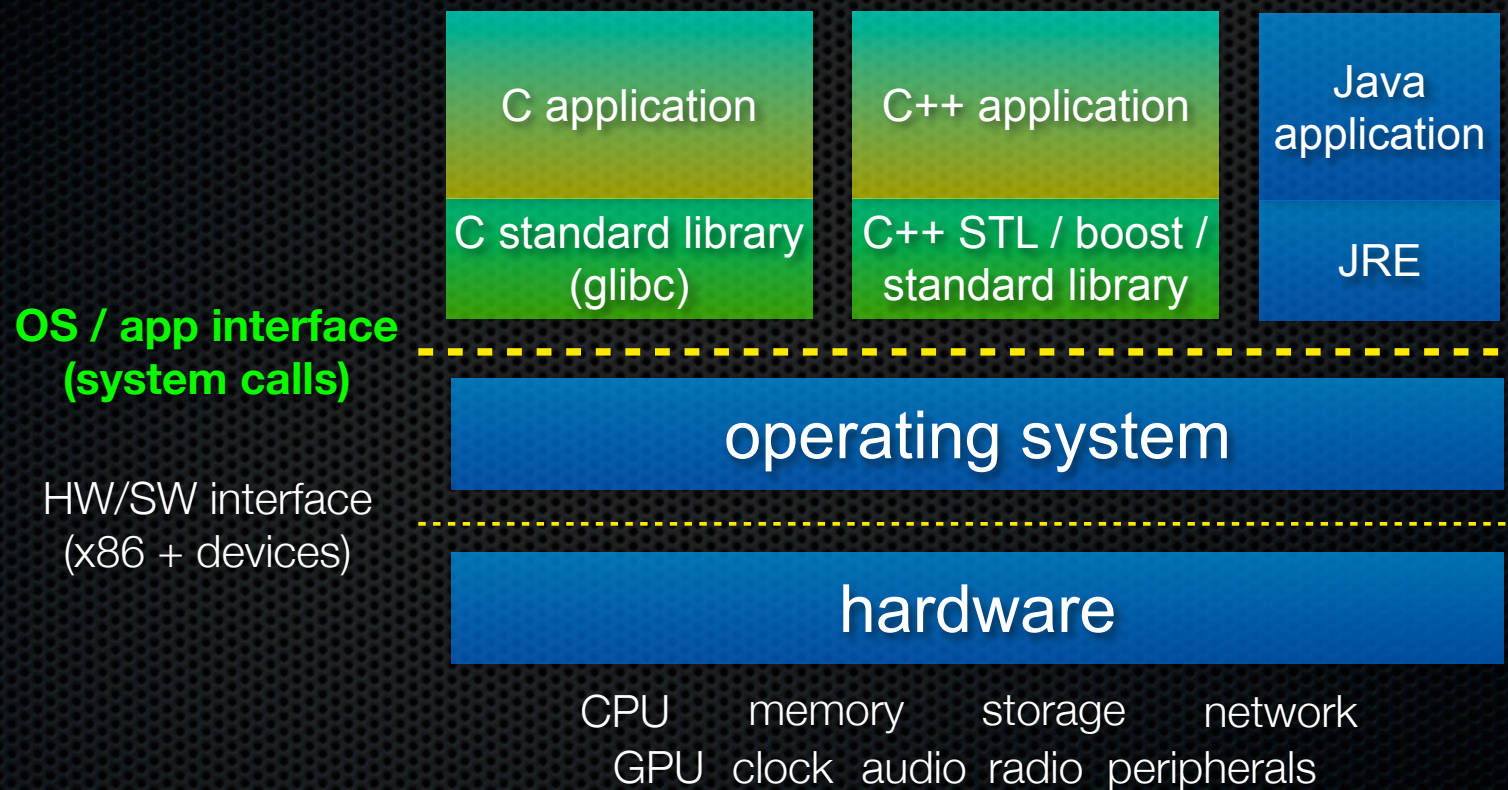
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# Course map: 100,000 foot view





# 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 understanding of the “layer below”
    - *quiz: is data safely on disk after a “write( )” system call returns?*



# 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



# What you will be doing

## Attending lectures and sections

- lecture: ~28 of them, MWF here
- sections: ~10 of them, Thu 8:30 (sorry), 9:30, 10:30, not here
- Take notes!!!! Don't expect everything to be on the web

## Doing programming projects

- 4 of them, successively building on each other, plus a warmup
- includes C, C++; file system, network

## Doing programming exercises

- one per lecture, due before the next lecture begins
- coarse-grained grading (0,1,2,3)

## Midterm and a final exam (your instructor is a traditionalist)

- Midterm date TBA shortly; will try to avoid lots of conflicts with other CSE classes



# Deadlines & Conduct

Need to get things done on time (very hard to catch up)

- Programming assignments: 4 late days, 2 max per project
- Exercises: no late days (max benefit that way)

Academic Integrity (details on the web; read them)

- I trust you implicitly; I will follow up if that trust is violated
- The rules boil down to: don't attempt to gain credit for something you didn't do; don't help others to do so
- That does **not** mean suffer in silence - you have colleagues, instructor, TAs - work with them; learn from each other!



# Course web/calendar

## Linked off of the course web page

- master schedule for the class (once it's done in a few days)
- links to:
  - ▶ lecture slides
  - ▶ code discussed in lectures
  - ▶ assignments, exercises (including due dates)
  - ▶ optional “self-exercise” solutions
  - ▶ various C/C++/Linux resources



# Welcome!

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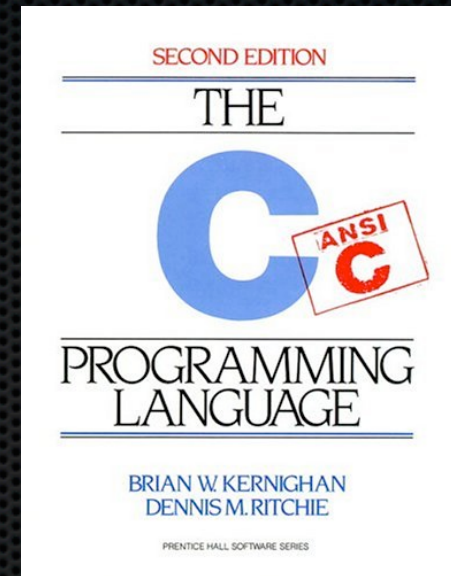
# C

Created in 1972 by Dennis Ritchie

- designed for creating system software
- portable across machine architectures
- most recently updated in 1999 (C99) and 2011 (C11)

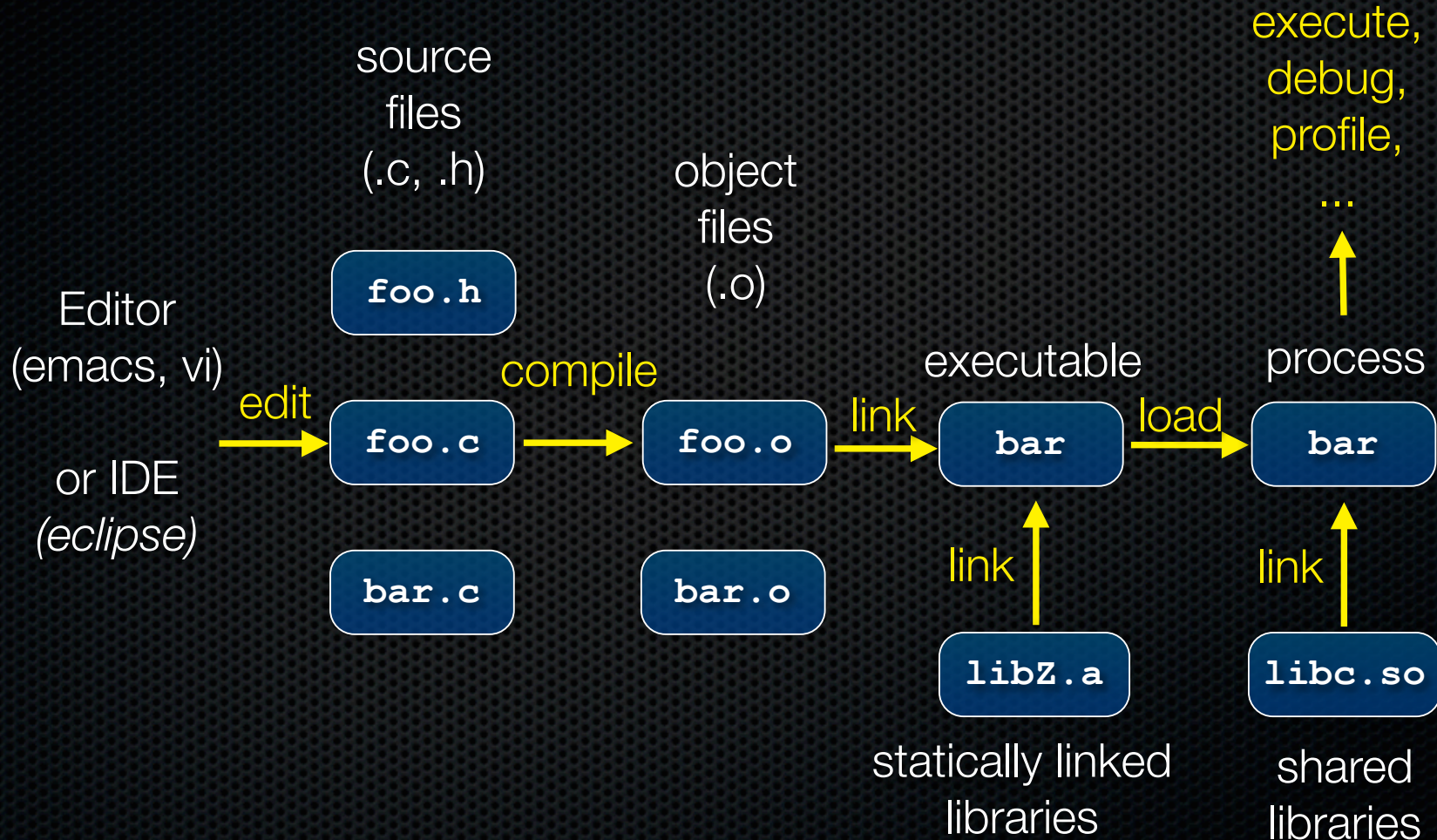
## Characteristics

- low-level, smaller standard library than Java
- procedural (not object-oriented)
- typed but unsafe; incorrect programs can fail spectacularly





# C workflow





# From C to machine code

C source file  
(dosum.c)

```
int dosum(int i, int j) {  
    return i+j;  
}
```

C compiler (gcc -S)

assembly source file  
(dosum.s)

```
dosum:  
    pushl    %ebp  
    movl    %esp, %ebp  
    movl    12(%ebp), %eax  
    addl    8(%ebp), %eax  
    popl    %ebp  
    ret
```

machine code  
(dosum.o)

```
80483b0: 55  
89 e5 8b 45  
0c 03 45 08  
5d c3
```

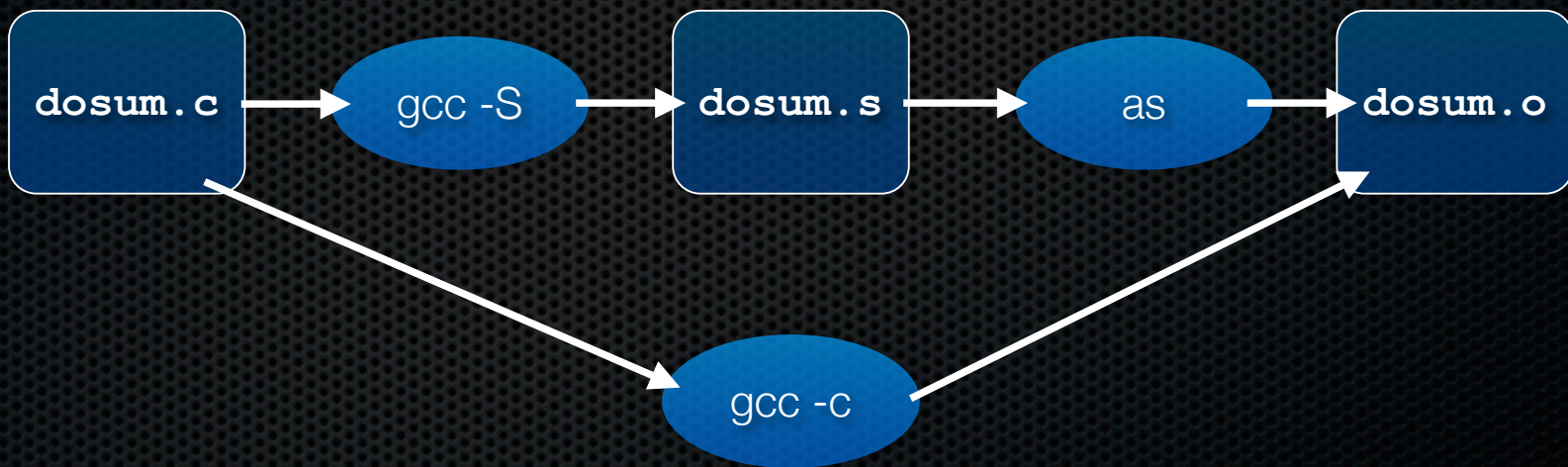
assembler (as)



# Skipping assembly language

Most C compilers generate .o files (machine code) directly

- i.e., without actually saving the readable .s assembly file





# Multi-file C programs

C source file  
(dosum.c)

```
int dosum(int i, int j) {  
    return i+j;  
}
```

this “prototype” of dosum() tells gcc about the types of dosum’s arguments and its return value

C source file  
(sumnum.c)

```
#include <stdio.h>  
  
int dosum(int i, int j),  
  
int main(int argc, char **argv) {  
    printf("%d\n", dosum(1, 2));  
    return 0;  
}
```

dosum() is implemented in dosum.c



# Multi-file C programs

C source file  
(dosum.c)

```
int dosum(int i, int j) {  
    return i+j;  
}
```

C source file  
(sumnum.c)

```
#include <stdio.h>  
  
int dosum(int i, int j);  
  
int main(int argc, char **argv) {  
    printf("%d\n", dosum(1,2));  
    return 0;  
}
```

why do we need  
this #include?

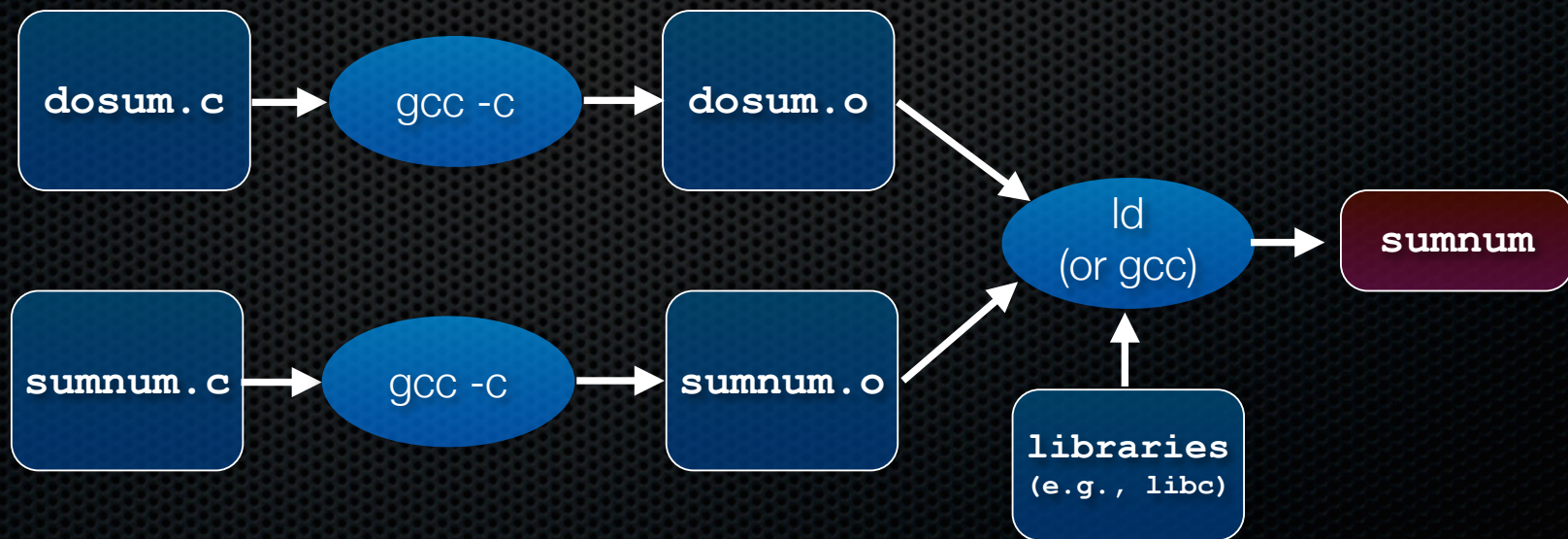
where is the  
implementation  
of printf?



# Compiling multi-file programs

Multiple object files are **linked** to produce an executable

- standard libraries (libc, crt1, ...) are usually also linked in
- a library is just a pre-assembled collection of .o files





# Object files

sumnum.o, dosum.o are **object files**

- each contains machine code produced by the compiler
- each might contain references to external symbols
  - ▶ variables and functions not defined in the associated .c file
  - ▶ e.g., sumnum.o contains code that relies on printf( ) and dosum( ), but these are defined in libc.a and dosum.o, respectively
- linking resolves these external symbols while smooshing together object files and libraries



# Let's dive into C itself

## Things that are the same as Java

- syntax for statements, control structures, function calls
- types: `int, double, char, long, float`
- type-casting syntax: `float x = (float) 5 / 3;`
- expressions, operators, precedence

`+ - * / % ++ -- = += -= *= /= %= < <= == != > >= && || !`

- scope (local scope is within a set of `{ }` braces)
- comments: `/* comment */` `// comment`



# Primitive types in C

see *sizeofs.c*

## integer types

- char, int

## floating point

- float, double

## modifiers

- short [int]
- long [int, double]
- signed [char, int]
- unsigned [char, int]

type	bytes (32 bit)	bytes (64 bit)	32 bit range	printf
<b>char</b>	1	1	[0, 255]	%c
short int	2	2	[-32768, 32767]	%hd
unsigned short int	2	2	[0, 65535]	%hu
<b>int</b>	4	4	[-2147483648, 2147483647]	%d
unsigned int	4	4	[0, 4294967295]	%u
long int	4	8	[-2147483648, 2147483647]	%ld
long long int	8	8	[-9223372036854775808, 9223372036854775807]	%lld
float	4	4	approx $[10^{-38}, 10^{38}]$	%f
<b>double</b>	8	8	approx $[10^{-308}, 10^{308}]$	%lf
long double	12	16	approx $[10^{-4932}, 10^{4932}]$	%Lf
pointer	4	8	[0, 4294967295]	%p



# C99 extended integer types

Solves the conundrum of “how big is a long int?”

```
#include <stdint.h>

void foo(void) {
    int8_t  w;    // exactly 8 bits, signed
    int16_t x;    // exactly 16 bits, signed
    int32_t y;    // exactly 32 bits, signed
    int64_t z;    // exactly 64 bits, signed

    uint8_t a;    // exactly 8 bits, unsigned
    ...etc.
}
```



# Similar to Java...

- variables
  - ▶ C99: don't have to declare at start of a function or block
  - ▶ need not be initialized before use (*gcc -Wall will warn*)

varscope.c

```
#include <stdio.h>

int main(int argc, char **argv) {
    int x, y = 5;    // note x is uninitialized!
    long z = x+y;

    printf("z is '%ld'\n", z); // what's printed?
    {
        int y = 10;
        printf("y is '%d'\n", y);
    }
    int w = 20;    // ok in c99
    printf("y is '%d', w is '%d'\n", y, w);
    return 0;
}
```



# Similar to Java...

## const

- a qualifier that indicates the variable's value cannot change
- compiler will issue an **error** if you try to violate this
- why is this qualifier useful?

consty.c

```
#include <stdio.h>

int main(int argc, char **argv) {
    const double MAX_GPA = 4.0;

    printf("MAX_GPA: %g\n", MAX_GPA);
    MAX_GPA = 5.0; // illegal!
    return 0;
}
```



# Similar to Java...

## for loops

- C99: can declare variables in the loop header

## if/else, while, and do/while loops

- C99: **bool** type supported, with #include <stdbool.h>
- any type can be used; 0 means **false**, everything else **true**

loopy.c

```
int i;

for (i = 0; i < 100; i++) {
    if (i % 10 == 0) {
        printf("i: %d\n", i);
    }
}
```



# Similar to Java...

pointy.c

parameters / return value

- C always passes arguments by value
- “pointers”
  - ▶ lets you pass by reference
  - ▶ more on these soon
  - ▶ least intuitive part of C
  - ▶ very dangerous part of C

```
void add_pbv(int c) {
    c += 10;
    printf("pbv c: %d\n", c);
}

void add_pbr(int *c) {
    *c += 10;
    printf("pbr *c: %d\n", *c);
}

int main(int argc, char **argv) {
    int x = 1;

    printf("x: %d\n", x);

    add_pbv(x);
    printf("x: %d\n", x);

    add_pbr(&x);
    printf("x: %d\n", x);

    return 0;
}
```



# Very different than Java

## arrays

- just a bare, contiguous block of memory of the correct size
- an array of 10 ints requires  $10 \times 4 \text{ bytes} = 40 \text{ bytes}$  of memory

arrays have no methods, do not know their own length

- C doesn't stop you from overstepping the end of an array!!
- many, many security bugs come from this



# Very different than Java

## strings

- array of `char`
- terminated by the `NULL` character `'\0'`
- are not objects, have no methods; `string.h` has helpful utilities



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



# Very different than Java

## errors and exceptions

- C has no exceptions (no try / catch)
- errors are returned as integer error codes from functions
- makes error handling ugly and inelegant

## crashes

- if you do something bad, you'll end up spraying bytes around memory, hopefully causing a "segmentation fault" and crash

## objects

- there aren't any; **struct** is closest feature (set of fields)



# Very different than Java

## memory management

- **you** must worry about this; there is no garbage collector
- local variables are allocated off of the stack
  - ▶ freed when you return from the function
- global and static variables are allocated in a data segment
  - ▶ are freed when your program exits
- you can allocate memory in the heap segment using `malloc( )`
  - ▶ you must free malloc'ed memory with `free( )`
  - ▶ failing to free is a leak, double-freeing is an error (hopefully crash)



# Very different than Java

## Libraries you can count on

- C has very few compared to most other languages
- no built-in trees, hash tables, linked lists, sort , etc.
- you have to write many things on your own
  - ▶ particularly data structures
  - ▶ error prone, tedious, hard to build efficiently and portably
- this is one of the main reasons C is a much less productive language than Java, C++, python, or others



# For Wednesday

Exercise 0 is due:

- <http://www.cs.washington.edu/education/courses/cse333/14sp/exercises/ex00.html>
- (Easier: look on the calendar or homework page for the link)

Post a message on the discussion board

- Get it to keep track of new messages for you!

Fill out the office hours doodle - help us pick good times

Sign up if you're still trying to add

Homework 0 out in a couple of days

- Mostly logistics (get files, fiddle with files, turn in files)
- Will send email to course mailing list (everyone in the class is automatically subscribed)



See you on Wednesday!