Lecture 02
Introducing C

CS211 – Fundamentals of Computer Programming II

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Slides adapted from:
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Administrivia

- Lab01 is due on Friday
  - About half of you have finished it already
- Lab02 is released today
  - Due on Sunday
- Hw01 will be released tonight
  - Due next week Thursday

Today's Goals

- Introduce the basics of C programming
  - Compilation
  - Variables
  - Conditionals (if)
  - Iteration (while and for)
  - Input and Output (printf and scanf)

- Continue practicing working in the shell

Outline

- **Unix Shell Wrap-up**
- Hello World in C
- Compilation

- Computing Fibonacci Numbers
- Variables
- Iteration

- Other C Syntax
- Input and Output
- Separate Compilation

Commands for moving between directories

- Directory structure and moving through it
  - `ls`
    - Lists files in the current directory
  - `cd`
    - Change directory
  - `pwd`
    - Prints the path of the current directory

- Mis-typing something
  - "Command not found" means you tried to run something invalid
  - `fish: somecommandyoumistyped: command not found...`

Command flags

- `man`
  - Opens the manual pages for a program
  - Example: `man ls`

- Flags are configurations for a command that change what it does
  - `ls -l` lists files in the current directory in a vertical list with details
  - `ls -t` sorts the ls output by most recently modified
  - `ls -l -t` does both

- You can type multiple flags after a single dash
  - `ls -lt` is equivalent to `ls -l -t`

Working with files

- `cat path`
  - Prints out the contents of the file
- `mv path1 path2`
  - Moves a file from path1 to path2
- `cp path1 path2`
  - Copies a file from path1 to path2
- `rm path`
  - Deletes (removes) a file

Editing files

- There are many different terminal text editors
  - And there are holy wars about why one is *best*
  - **There is no best. Just use whatever you like**

- Example editors
  - Vim, Emacs, Nano

- In CS211, I'll be teaching you using the Micro text editor
  - Occasionally I'll open vim by accident. Someone yell at me when I do
  - https://micro-editor.github.io/

Editing with Micro

- micro filename
  - Opens micro, editing filename

- Works just like any text editor you've used
  - Mouse moves the cursor around, as do the arrow keys
  - Typing makes text appear
    - (This isn't true in some shell editors, looking at you vim)

  - Ctrl-s save the file
  - Ctrl-o open a file
  - Ctrl-q quit

Helpful guides

- Great lecture notes on using the shell
  - https://swcarpentry.github.io/shell-novice/
- Tool to explain various shell command syntax
  - https://explainshell.com/
- Tool to explain how to use various shell commands
  - Just type the command into the box at the top
  - https://tldr.ostera.io/

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Getting the examples from lecture

- First, make your own cs211 directory to store class stuff in
  - `cd ~/`
  - `mkdir cs211`

- The files for this class are in a zipped tarball (just like a zip file)
  - We can extract them right into your cs211/ directory

  - `cd ~/cs211/`
  - `tar -xvkf ~cs211/lec/02_intro_c.tgz`
  - `cd 02_intro_c`

  - What does that command do?: https://explainshell.com/explain?cmd=tar+-xvkf+%7Ecs211%2Flec%2F02_intro_c.tgz

Hello world C program

```c
#include <stdio.h>

int main(void) {
    printf("Hello, CS 211!\n");

    return 0;
}
```

Hello world C program

```
#include <stdio.h>

int main(void) {
    printf("Hello, CS 211!\n");

    return 0;
}
```

Hello world C program

```
#include <stdio.h>

int main(void) {
    printf("Hello, CS 211!\n");

    return 0;
}
```

A function named `main()`

No Arguments (`void`)

Returns an integer

Hello world C program

```
#include <stdio.h>

int main(void) {
    printf("Hello, CS 211!\n");

    return 0;
}
```

Call to the `printf()` function

One argument to the function, the string “Hello, CS211\n”

Hello world C program

```
#include <stdio.h>

int main(void) {
    printf("Hello, CS 211!\n");

    return 0;
}
```

The `printf()` function is a part of the standard input/output library, included here

Call to the `printf()` function

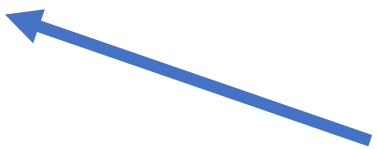
One argument to the function, the string “Hello, CS211\n”

Hello world C program

```c
#include <stdio.h>

int main(void) {
    printf("Hello, CS 211!\n");

    return 0;
}
```



Returns a value, 0
(which is of type `int`)

Hello world C program

```c
#include <stdio.h>

int main(void) {
    printf("Hello, CS 211!\n");

    return 0;
}
```

Two special things going on here:

1. main() is a special function name that is called when the program runs

Hello world C program

```c
#include <stdio.h>

int main(void) {
    printf("Hello, CS 211!\n");

    return 0;
}
```

Two special things going on here:

1. main() is a special function name that is called when the program runs

2. main() returns a number that specifies whether the program succeeded or failed and how
   - 0 means success
   - non-zero means failure
   - specific numbers mean different things to different programs

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How do you "run" C code?

- First, the C code needs to be translated
  - From human-readable source code
  - To machine code capable of being executed on a particular machine (definitely not human readable)
- This translation process is called "compiling"
  - The tool that does it is a "compiler"

What does machine code look like?

- Just a bunch of numbers
  - Your text editor would interpret those numbers as random characters

- The computer processor reads the numbers to figure out which instruction to run
  - This is a version of assembly code
  - See CS213 for *way* more details

Compiling a C program

- The compiler we'll use is referred to as `cc`
  - Short for C Compiler
  - It takes in C source code and outputs *executable* machine code

- `cc hello.c`
- `ls`
  `a.out hello.c`

- `./a.out`
  `Hello, CS 211!`

Compiling a C program

- a.out is the default name, but we probably want to use something more memorable
- The `-o` flag specifies the output filename for the compiler

- `cc -o hello hello.c`
- `ls`
  `hello hello.c`

- `./hello`
  `Hello, CS 211!`

Remember to compile!

- You need to re-compile code every time the source code changes

- You WILL forget to do this at some point
  - And you'll run the program but it'll do the old behavior rather than the new things you've written

Break + relevant xkcd

https://xkcd.com/303/

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Definition of Fibonacci Function

- $fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$

n	fib(n)
0	0
1	1
2	1
3	2
4	3
5	5
6	8
7	13
8	21

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib(int n){
   if (n < 2) {
      return n;
   } else {
      return fib(n - 2) + fib(n - 1);
   }
}
```

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib(int n){
  if (n < 2) {
    return n;
  } else {
    return fib(n - 2) + fib(n - 1);
  }
}
```

```
if (⟨test-expr⟩) { // evaluate ⟨test-expr⟩; then…
  ⟨then-stms⟩ // do these if ⟨test-expr⟩ was true
} else {
  ⟨else-stms⟩ // do these if ⟨test-expr⟩ was false
}
```

Statements can be nested in C

```
if (⟨first-test-expr⟩) {
  if (⟨second-test-expr⟩) {
    ⟨A-stms⟩
  } else {
    ⟨B-stms⟩
  }
} else {
  if (⟨third-test-expr⟩) {
    ⟨C-stms⟩
  } else {
    ⟨D-stms⟩
  }
}
```

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib(int n){
   if (n < 2) {
      return n;
   } else {
      return fib(n - 2) + fib(n - 1);
   }
}
```

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib(int n){
  if (n < 2) {
    return n;
  } else {
    return fib(n - 2) +
           fib(n - 1);
  }
}
```

C doesn't care about whitespace

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib(int n){if(n<2){return n;}else{return
fib(n-2)+fib(n-1);}}
```

C **really doesn't care** about whitespace

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib(int n){if(n<2){return n;}else{return
fib(n-2)+fib(n-1);}}
```

C **really doesn't care** about whitespace

But humans do!

So don't write your code this way!!!!!!!!!!

A note on style

- A lot of things are *possible* in C, but bad ideas
  - They can make things hard to read
  - They can be a source of bugs in code

- We try to provide you with what we think of as "good" C code

- We have a guide to how you should write your C code
  - https://nu-cs211.github.io/cs211-files/cstyle.html

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Values, objects, and variables

- **Values** are the actual information we want to work with
  - Numbers, Strings, Images, etc.
  - Example: 3 is an `int` value

- An **object** is a chunk of memory that can hold a value of a particular type.
  - Example: function `f` has a parameter `int x`
    - Each type `f` is called, a "fresh" object that can hold an int is "created"

- A **variable** is the name of an object

- Assigning to a variable changes the *value* stored in the object named by the variable

Example of definition and assignment

```
int z = 5;
z = 7;
z = z + 4;
```

- What happens?

Example of definition and assignment

```
int z = 5;
z = 7;
z = z + 4;
```

- What happens?
  1. The first statement is a definition.
     It creates an `int` object,
     names it `z`,
     and initializes it to the value `5`

Example of definition and assignment

```
int z = 5;
z = 7;
z = z + 4;
```

- What happens?
  2. The second statement is an assignment.
     It replaces the value `5`
     stored in the object named by `z`
     with the value `7`.

Example of definition and assignment

```
int z = 5;
z = 7;
z = z + 4;
```

- What happens?

z: 11

3. The third statement is also an assignment.
   It retrieves the current value of `z` (which is `7`),
   then adds `4` to it,
   and then stores the result back in the object named by `z`.

C: Typed imperative programming

- Imperative programming
  - Each line is a **statement** that changes the program's **state**
  - Usually, the values within a variable

- Type System
  - Variables have a type associated with them

  - The type determines qualities of the *object*
    - Example: how much memory it takes up

  - The type specifies what kind of *value* the variable holds
    - Example: integers, decimal numbers, strings, etc.

Types in C

- Hold an integer number (like 5 or 0 or -3)
  - char, short, int, long, size_t, int8_t, int16_t, int32_t, etc.
  - These can also specify signedness
    - unsigned: only 0 and greater
    - signed: negative, 0, or positive
- Hold a decimal number (like 6.238 or 0.00001 or -32566.5)
  - float, double
  - These are always negative, 0, or positive
- Difference between types: how big of a value they can hold
  - Short: 0 to 65536 OR signed short -32768 to 32767
  - Int: 0 to 4294967296 OR signed int -2147483648 to 2147483647
  - We'll have a whole future lecture on *why* the types are like this

More complicated example

```
int prev;
int curr = 5;
int next = 8;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```

More complicated example

```
int prev;
int curr = 5;
int next = 8;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```

prev: 

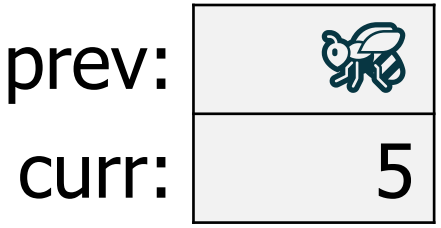
More complicated example

```
int prev;
int curr = 5;
int next = 8;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```



More complicated example

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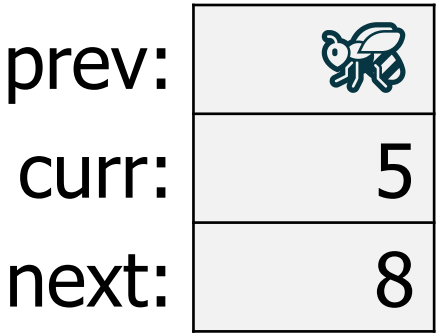
prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```



More complicated example

```
int prev;
int curr = 5;
int next = 8;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```

prev:	5
curr:	5
next:	8

More complicated example

```
int prev;
int curr = 5;
int next = 8;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```

prev:	5
curr:	8
next:	8

More complicated example

```
int prev;
int curr = 5;
int next = 8;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```

prev:	5
curr:	8
next:	13

More complicated example

```
int prev;
int curr = 5;
int next = 8;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```

prev:	8
curr:	8
next:	13

More complicated example

```
int prev;
int curr = 5;
int next = 8;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```

prev:	8
curr:	13
next:	13

More complicated example

```
int prev;
int curr = 5;
int next = 8;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```

prev:	8
curr:	13
next:	21

More complicated example

```
int prev;
int curr = 5;
int next = 8;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```

prev:	13
curr:	13
next:	21

More complicated example

```
int prev;
int curr = 5;
int next = 8;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```

prev:	13
curr:	21
next:	21

More complicated example

```
int prev;
int curr = 5;
int next = 8;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;

prev = curr;
curr = next;
next = prev + curr;
```

prev:	13
curr:	21
next:	34

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Statements and Conditions aren’t enough

- Those lines of code were actually implementing Fibonacci!
  - And they were doing it without requiring any recursion

- Problem: it’s really repetitive to have to write out the same lines of code again and again
- Solution: Iteration

Iteration with the While Statement

- Syntax

```
while (⟨test-expression⟩) {
  ⟨body-statements⟩
}
```

- Semantics
  1. Evaluate ⟨`test-expression`⟩ to a `bool`
  2. If the `bool` is *false* then skip to the statement after the `while` loop
  3. Execute ⟨`body-statements`⟩ (if the `bool` was true)
  4. Go back to step 1

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib_iterative(int n){
    long curr = 0;
    long next = 1;

    while (n > 0) {
        long prev = curr;

        curr = next;
        next = prev + curr;
        n = n - 1;
    }

    return curr;
}
```

For loops

- For loops allow you to combine iteration and incrementing
  - When you write a for statement like this:

```
for (⟨start-decl⟩; ⟨test-expr⟩; ⟨step-expr⟩) {
  ⟨body-stms⟩
}
```

  - It's as if you'd written this while statement:

```
{
  ⟨start-decl⟩;
  while (⟨test-expr⟩) {
    ⟨body-stms⟩
    ⟨step-expr⟩;
  }
}
```

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib_iterative(int n){
    long curr = 0;
    long next = 1;

    while (n > 0) {
        long prev = curr;

        curr = next;
        next = prev + curr;
        n = n - 1;
    }

    return curr;
}
```

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib_iterative(int n){
    long curr = 0;
    long next = 1;
    int i = 0;

    while (i < n) {
        long prev = curr;

        curr = next;
        next = prev + curr;
        i = i + 1;
    }

    return curr;
}
```

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib_iterative(int n){
    long curr = 0;
    long next = 1;
    int i = 0;

    for ( ; i < n; ) {
        long prev = curr;

        curr = next;
        next = prev + curr;
        i = i + 1;
    }

    return curr;
}
```

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib_iterative(int n){
    long curr = 0;
    long next = 1;
    // int i = 0;

    for (int i = 0; i < n; ) {
        long prev = curr;

        curr = next;
        next = prev + curr;
        i = i + 1;
    }

    return curr;
}
```

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib_iterative(int n){
    long curr = 0;
    long next = 1;

    for (int i = 0; i < n; i = i + 1) {
        long prev = curr;

        curr = next;
        next = prev + curr;
        //i = i + 1;
    }

    return curr;
}
```

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib_iterative(int n){
    long curr = 0;
    long next = 1;

    for (int i = 0; i < n; i = i + 1) {
        long prev = curr;

        curr = next;
        next = prev + curr;
    }

    return curr;
}
```

Break + Question

- What value will this code return when called as:
  - loop_function(3)
  - loop_function(5)
  - loop_function(6)

```
int loop_function(int test) {
  int retval = 0;
  while (test < 5) {
    retval = retval + 1;
    test = test + 1;
  }
  return retval;
}
```

Break + Question

- What value will this code return when called as:
  - loop_function(3) **returns 2**
  - loop_function(5) **returns 0**
  - loop_function(6) **returns 0**

```
int loop_function(int test) {
  int retval = 0;
  while (test < 5) {
    retval = retval + 1;
    test = test + 1;
  }
  return retval;
}
```

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Logical operators

- || &&
  - Logical OR, and Logical AND
  - a < 5 && b > 12

- !
  - Logical NOT
  - !(a < 5) -> (a >= 5)

- ==
  - Equality
  - 5 == 5 -> TRUE
  - 16 == -3 -> FALSE

  - Don’t mix it up with assignment (single equals sign)

Other operators you'll see around

- += *= -= /=
  - Perform the action of VAR = VAR operator ARG
  - a += 5 -> a = a + 5
  - a *= b -> a = a * b

- %
  - Modulus operator
  - Returns the remainder of division
  - 12 % 10 -> 2

- ~ | & ^
  - Bitwise NOT, OR, AND, and XOR (you'll learn these in CS213)
  - Importantly, ^ is not exponentiation!!!

Adding and Subtracting one

- `++  --`
  - Shorthand for plus 1 or minus 1
  - `++a  -> a += 1  ->  a = a + 1`

- The auto-increment/decrement operators can go before or after the variable
  - (--x) subtracts one and returns the new value of x from the expression
  - (x--) subtracts one but returns the *old* value of x from the expression

  - Usually, this doesn't matter, unless you write complicated statements that combine assignment and conditions
  - `if (--x > 0)` … (just don't do this)

Implementing Fibonacci in C

$$fib(n) = \begin{cases} n, & if\ n < 2; \\ fib(n-2) + fib(n-1), & otherwise \end{cases}$$

```
long fib_iterative(int n){
    long curr = 0;
    long next = 1;

    for (int i = 0; i < n; ++i) {  // i++ also works
        long prev = curr;

        curr = next;
        next = prev + curr;
    }

    return curr;
}
```

Ternary Operator

- ?:
  - Shorthand version of an if statement, determining result of expression
  - Example:
    - `return (a < 5) ? a : b;`
    - ```
      if (a < 5) {
        return a;
      } else {
        return b;
      }
      ```
  - You won't need to use this. Usually, it just makes code harder to read.
      ```

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- Unix Shell Wrap-up
- Hello World in C
- Compilation

- Computing Fibonacci Numbers
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- Iteration

- Other C Syntax
- **Input and Output**
- Separate Compilation

printf() function

- The usual way to print in C is the `printf()` function
  - Takes a *format string* followed by arguments to *interpolate* in place of the string's directives

```
printf("(%d, %d)\n", x, y);
```

`%d` directive means the argument is an `int`

Prints "`(`" + the value of x + "`, `" + the value of y + "`)\n`"

- `printf()` is in the stdio.h library, which needs to be `#include`-ed

Example: formatted output

```c
#include <stdio.h>
int main(void){
  int x = 5;
  double f = 5.1;
  printf("sizeof x: %zu bytes\n", sizeof(x));
  printf("sizeof f: %zu bytes\n", sizeof(f));
  printf("x: %d\nf: %.60e\n", x, f);
}
```

- A directive gives the argument's type and maybe some options
  - `%zu` type: `size_t` (the return result of `sizeof`)
  - `%d` type: `int`
  - `%.60e` type: `double`, include 60 digits of precision

How do you learn format specifiers?

- You look them up in a guide!
  - Even I don’t have them memorized…

- man 3 printf
  - Runs in the terminal
  - Shows details about printf

- google “printf directives”
  - cplusplus.com is a good resource
  - https://www.cplusplus.com/reference/cstdio/printf/

Reading user input

- To input numbers in C, use the `scanf()` function

- scanf reads keyboard input, converts it to the require type, and stores it in an existing variable:

```
int x = 0;
scanf("%d", &x);
```

  - Like `printf()`, `scanf()` uses a format string to determine what type to convert the input into
  - `&x` means to pass x's location, not its value (more on this next week)
  - Careful: `scanf()` directives aren't exactly the same as `printf()`

Example: reading input

```c
#include <stdio.h>

double sqr_dbl(double n){
  return n * n;
}

int main(void){
  double d = 0.0;
  scanf("%lf", &d);
  printf("%lf squared is %lf\n", d, sqr_dbl(d));
}
```

Example: reading multiple items

```c
#include <stdio.h>
int main(void){
   int x;
   int y;
   printf("Enter two integers: ");
   scanf("%d%d", &x, &y);
   printf("%d * %d = %d\n", x, y, x * y);
}
```

What if scanf() has an error?

- `scanf()` returns the number of successful conversions

```
#include <stdio.h>
int main(void){
   int x
   int y;
   printf("Enter two integers: ");
   if (scanf("%d%d", &x, &y) != 2) {
      printf("Input error\n");
      return 1;
   }
   printf("%d * %d == %d\n", x, y, x * y);
}
```

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Problems with compilation

- Two issues
  - Big programs take a very long time to compile
  - How can we reuse our functions in multiple programs?

- Let's focus on that second issue. It would be nice to:
  1. Write some functions in one file
  2. Call those functions from multiple programs (other files)

Solution: multiple C files

- You can write code in any number of different C files
  - And combine them together while compiling

- But we need some way to tell C code in one file about the existence of C code in another file
  - Solution: header files (.h)

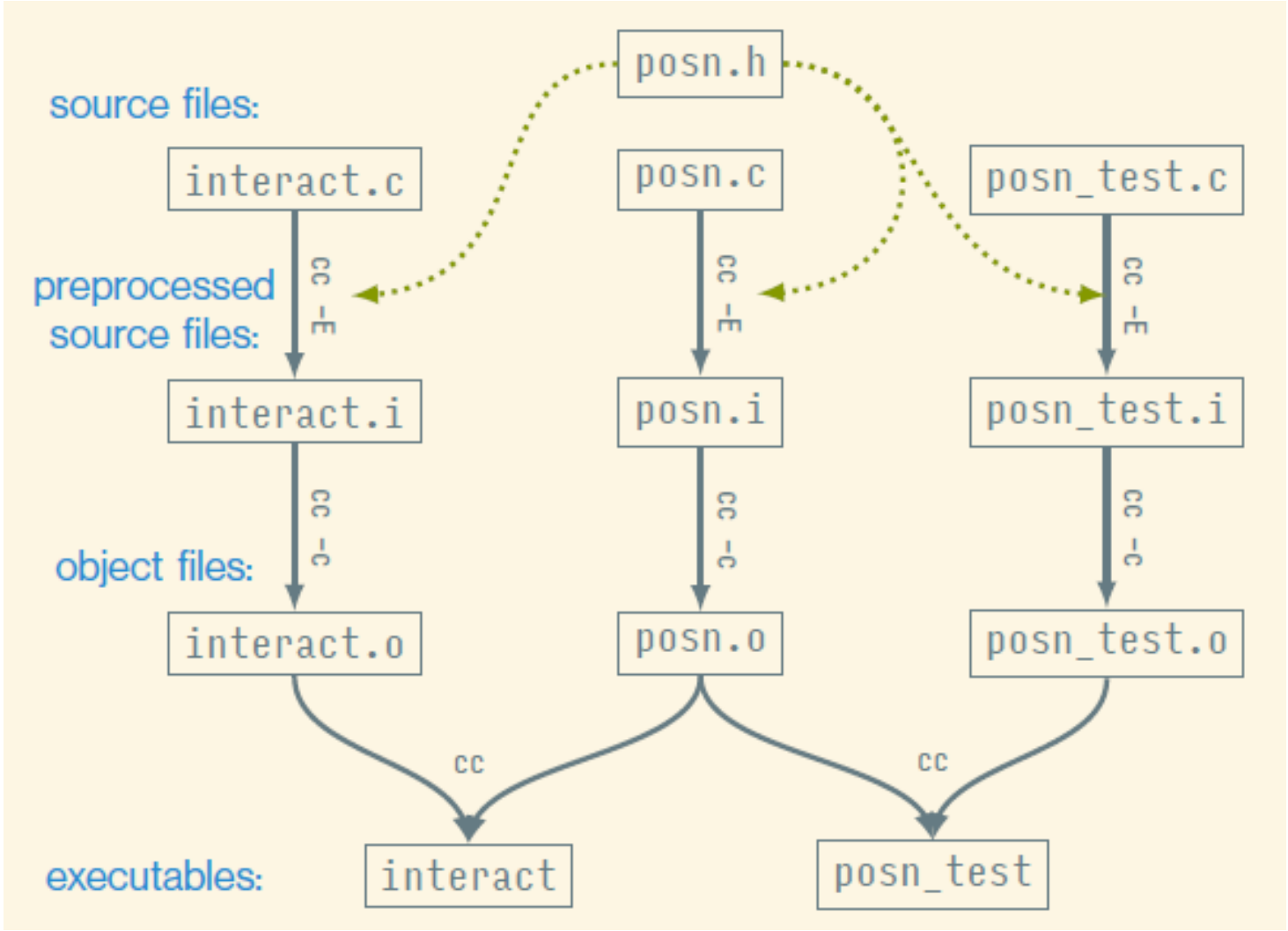
  - Header files list all the publicly available functions and variables from a C file
    - Usually there is a .c and .h file for various libraries
  - Header files are `#include`-ed at the top of your C file

Compiling multiple C files

- Usually we compile each C file separately
- Then combine multiple together into a single program

- Compilers have a middle step: object files (.o)
  - Still not human readable
  - Meant to be joined together into a single executable

Example of multiple compilation



Simplifying multiple compilation with Make

- Make is a tool for building programs out of multiple source files
  - Allows you to specify goals and requirements as "rules"
  - And then runs the compiler to fulfill those

- To build a file named ⟨goal⟩ using make, you run:

  `make ⟨goal⟩`

- `Make` looks around the current directory for a file named Makefile which specifies the various rules
  - We'll provide the Makefile for you in this class
  - But you'll have to use `make` to compile your programs

You now know the basics of C programming

- We’re missing a few simple things
  - You’ll practice those in Lab02 and Hw01
  - Structs!

- We’re missing some advanced features
  - We’ll cover those next week

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