Week 15 - Friday

CS222

Last time

- What did we talk about last time?
- Review up to Exam 2

Questions?

Project 6

Review after Exam 2

Binary search tree (BST)

- A binary search tree is binary tree with three properties:
  1. The left subtree of the root only contains nodes with keys less than the root's key
  2. The right subtree of the root only contains nodes with keys greater than the root's key
  3. Both the left and the right subtrees are also binary search trees

Example BST node in C

```
typedef struct _Tree
{
     int data;
     struct _Tree* left;
     struct _Tree* right;
} Tree;
```

File I/O

Files

- Think of a file as a stream of bytes
- It is possible to read from the stream
- It is possible to write to the stream
- It is even possible to do both
- Central to the idea of a stream is also a file stream pointer, which keeps track of where in the stream you are
- We have been redirecting **`stdin`** from and **`stdout`** to files, but we can access them directly as well

`fopen()`

- To open a file, call the **`fopen()`** function
- It returns a pointer to a **`FILE`** object
- Its first argument is the path to the file as a null-terminated string
- Its second argument is another string that says how it is being opened (for reading, writing, etc.)

```
FILE* file = fopen("data.txt", "r");
```

fopen() arguments

- The following are legal arguments for the second string

Argument	Meaning
`"r"`	Open for reading. The file must exist.
`"w"`	Open for writing. If the file exists, all its contents will be erased.
`"a"`	Open for appending. Write all data to the end of the file, preserving anything that is already there.
`"r+"`	Open a file for reading and writing, but it must exist.
`"w+"`	Open a file for reading and writing, but if it exists, its contents will be erased.
`"a+"`	Open a file for reading and writing, but all writing is done to the end of the file.

`fprintf()`

- Once you've got a file open, write to it using **`fprintf()`** the same way you write to the screen with **`printf()`**
- The first argument is the file pointer
- The second is the format string
- The third and subsequent arguments are the values

```
FILE* file = fopen("output.dat", "w");
fprintf(file, "Yo! I got %d on it!\n", 5);
```

fscanf()

- Once you've got a file open, write to it using **fscanf()** the same way you write to the screen with **scanf()**
- The first argument is the file pointer
- The second is the format string
- The third and subsequent arguments are pointers to the values you want to read into

```
FILE* file = fopen("input.dat", "r");
int value = 0;
fscanf(file, "%d", &value);
```

Closing files

- When you're doing using a file, close the file pointer using the **`fclose()`** function
- Files will automatically be closed when your program ends
- It's a good idea to close them as soon as you don't need them anymore
  - It takes up system resources
  - You can only have a limited number of files open at once

```
FILE* file = fopen("input.dat", "r");
int value = 0;
fscanf(file, "%d", &value);
fclose(file);
```

fputc() and **putc()**

- If you need to do character by character output, you can use **fputc()**
- The first argument is the file pointer
- The second is the character to output
- **putc()** is an equivalent function

```
FILE* file = fopen("output.dat", "w");
for( int i = 0; i < 100; i++ )
    fputc(file, '$');
```

`fgetc()` and `getc()`

- If you need to do character by character input, you can use **`fgetc()`**
- The argument is the file pointer
- It returns the character value or **`EOF`** if there's nothing left in the file
- **`getc()`** is an equivalent function

```
FILE* file = fopen("input.dat", "r");
int count = 0;

while( fgetc(file) != EOF )
	count++;

printf("There are %d characters in the file\n",
	count);
```

Standard streams

- C programs that run on the command line have the following file pointers open by default
  - **`stdin`**
  - **`stdout`**
  - **`stderr`**
- You can use them where you would use other file pointers

What is a binary file?

- Technically, **all** files are binary files
  - They all carry data stored in binary
- But some of those binary files are called **text files** because they are filled with human readable text
- When most people talk about binary files, they mean files with data that is only computer readable

Why use binary files?

- Wouldn't it be easier to use all human readable files?
- Binary files can be more efficient
  - In binary, all **`int`** values are the same size, usually 4 bytes
- You can also load a chunk of memory (like a WAV header) into memory with one function call

Integer	Bytes in text representation
`0`	1
`92`	2
`789`	3
`4551`	4
`10890999`	8
`204471262`	9
`-2000000000`	11

Changes to fopen()

- To specify that a file should be opened in binary mode, append a **b** to the mode string

```
FILE* file = fopen("output.dat", "wb");
```

```
FILE* file = fopen("input.dat", "rb");
```

- On some systems, the **b** has no effect
- On others, it changes how some characters are interpreted

fread()

- The **fread()** function allows you to read binary data from a file and drop it directly into memory
- It takes
  - A pointer to the memory you want to fill
  - The size of each element
  - The number of elements
  - The file pointer

```
double data[100];
FILE* file = fopen("input.dat", "rb");
fread(data, sizeof(double), 100, file);
fclose(file);
```

fwrite()

- The **fwrite()** function allows for binary writing
- It can drop an arbitrarily large chunk of data into memory at once
- It takes
  - A pointer to the memory you want to write
  - The size of each element
  - The number of elements
  - The file pointer

```
short values[50];
FILE* file = NULL;
//fill values with data
file = fopen("output.dat", "wb");
fwrite(values, sizeof(short), 50, file);
fclose(file);
```

fseek()

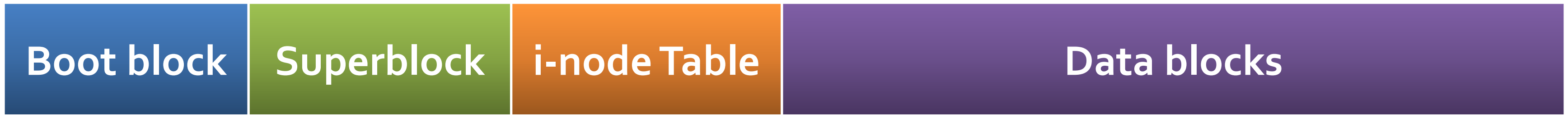
- The **fseek()** function takes
  - The file pointer
  - The offset to move the stream pointer (positive or negative)
  - The location the offset is relative to
- Legal locations are

SEEK_SET	From the beginning of the file
SEEK_CUR	From the current location
SEEK_END	From the end of the file (not always supported)

```
FILE* file = fopen("input.dat", "rb");
int offset;
fread(&offset,sizeof(int),1,file); //get offset
fseek(file, offset, SEEK_SET);
```

Partition layout

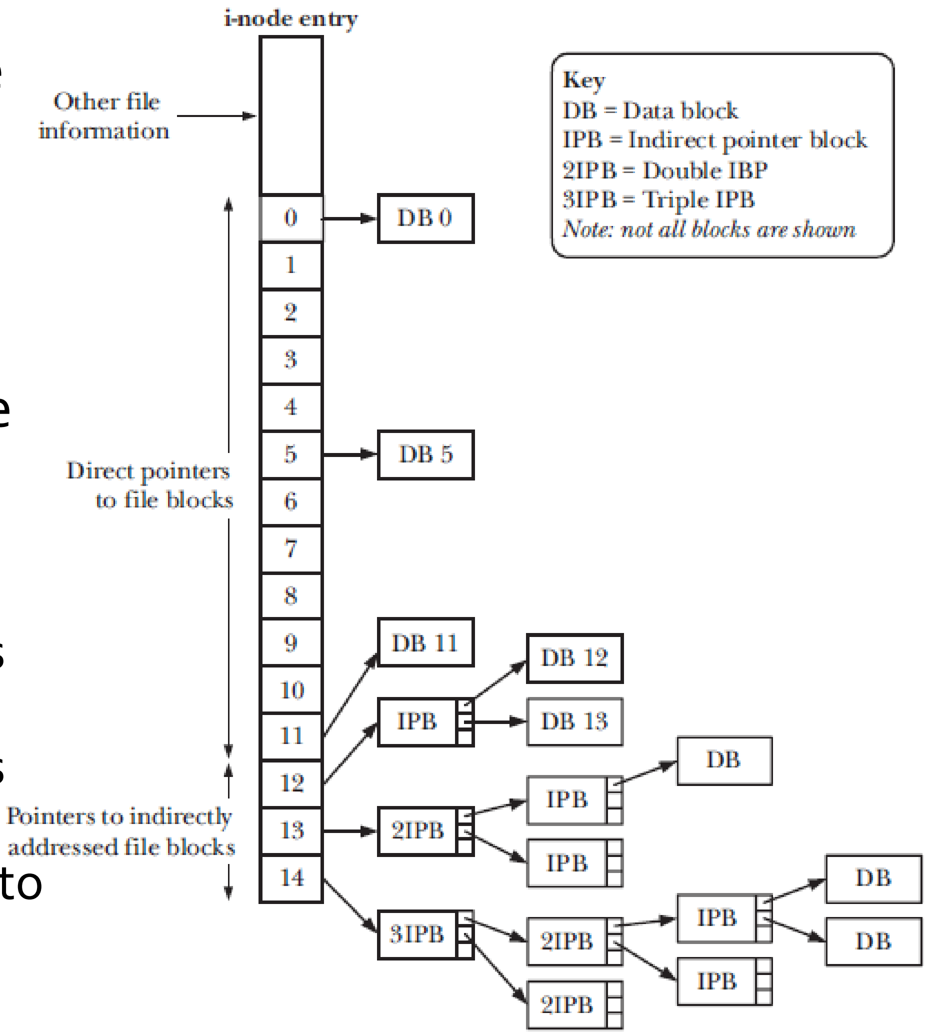
- Virtually all file systems have each partition laid out something like this



- The boot block is the first block and has information needed to boot the OS
- The superblock has information about the size of the i-node table and logical blocks
- The i-node table has entries for every file in the system
- Data blocks are the actual data in the files and take up almost all the space

i-nodes

- Every file has an i-node in the i-node table
- Each i-node has information about the file like type (directory or not), owner, group, permissions, and size
- More importantly, each i-node has pointers to the data blocks of the file on disk
- In ext2, i-nodes have 15 pointers
  - The first 12 point to blocks of data
  - The next points to a block of pointers to blocks of data
  - The next points to a block of pointers to pointers to blocks of data
  - The last points to a block of pointers to pointers to pointers to blocks of data



Networking

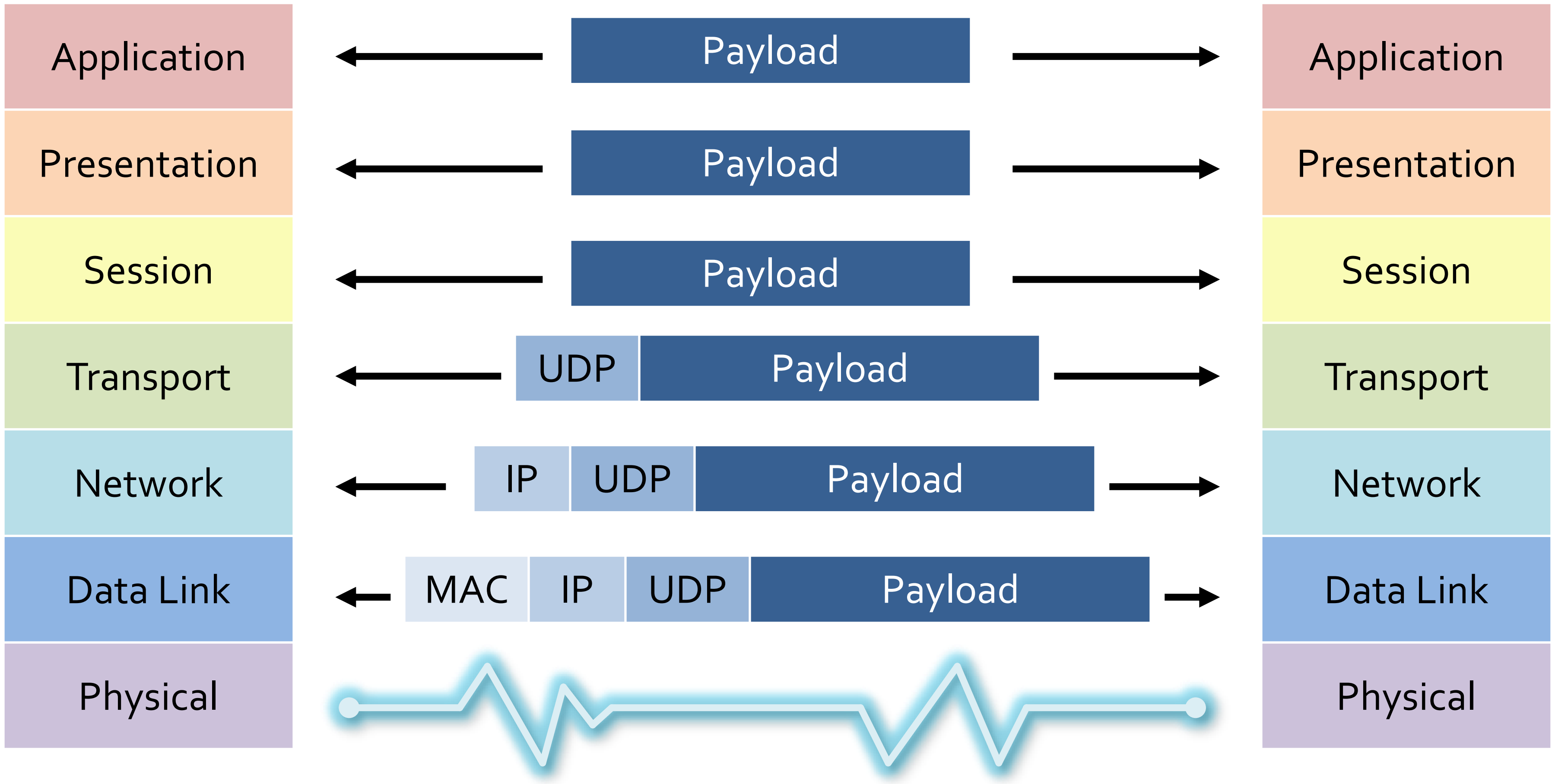
Layers

- Not every layer is always used
- Sometimes user errors are referred to as Layer 8 problems

Layer	Name	Mnemonic	Activity	Example
7	**Application**	Away	User-level data	HTTP
6	**Presentation**	Pretzels	Data appearance, some encryption	SSL
5	**Session**	Salty	Sessions, sequencing, recovery	IPC and part of TCP
4	**Transport**	Throw	Flow control, end-to-end error detection	TCP
3	**Network**	Not	Routing, blocking into packets	IP
2	**Data Link**	Dare	Data delivery, packets into frames, transmission error recovery	Ethernet
1	**Physical**	Programmers	Physical communication, bit transmission	Electrons in copper

Transparency

- The goal of the OSI model is to make lower layers transparent to upper ones



TCP/IP

- The OSI model is sort of a sham
  - It was invented after the Internet was already in use
  - You don't need all layers
  - Some people think this categorization is not useful
- Most network communication uses TCP/IP
- We can view TCP/IP as four layers:

Layer	Action	Responsibilities	Protocol
Application	Prepare messages	User interaction	HTTP, FTP, etc.
Transport	Convert messages to packets	Sequencing, reliability, error correction	TCP or UDP
Internet	Convert packets to datagrams	Flow control, routing	IP
Physical	Transmit datagrams as bits	Data communication	

TCP/IP

- A TCP/IP connection between two hosts (computers) is defined by four things
  - Source IP
  - Source port
  - Destination IP
  - Destination port
- One machine can be connected to many other machines, but the port numbers keep it straight

Sockets

Sockets

- **Sockets** are the most basic way to send data over a network in C
- A socket is **one end** of a two-way communication link between two programs
  - Just like you can plug a phone into a socket in your wall (if you are living in 1980)
  - Both programs have to have a socket
  - And those sockets have to be connected to each other
- Sockets can be used to communicate within a computer, but we'll focus on Internet sockets

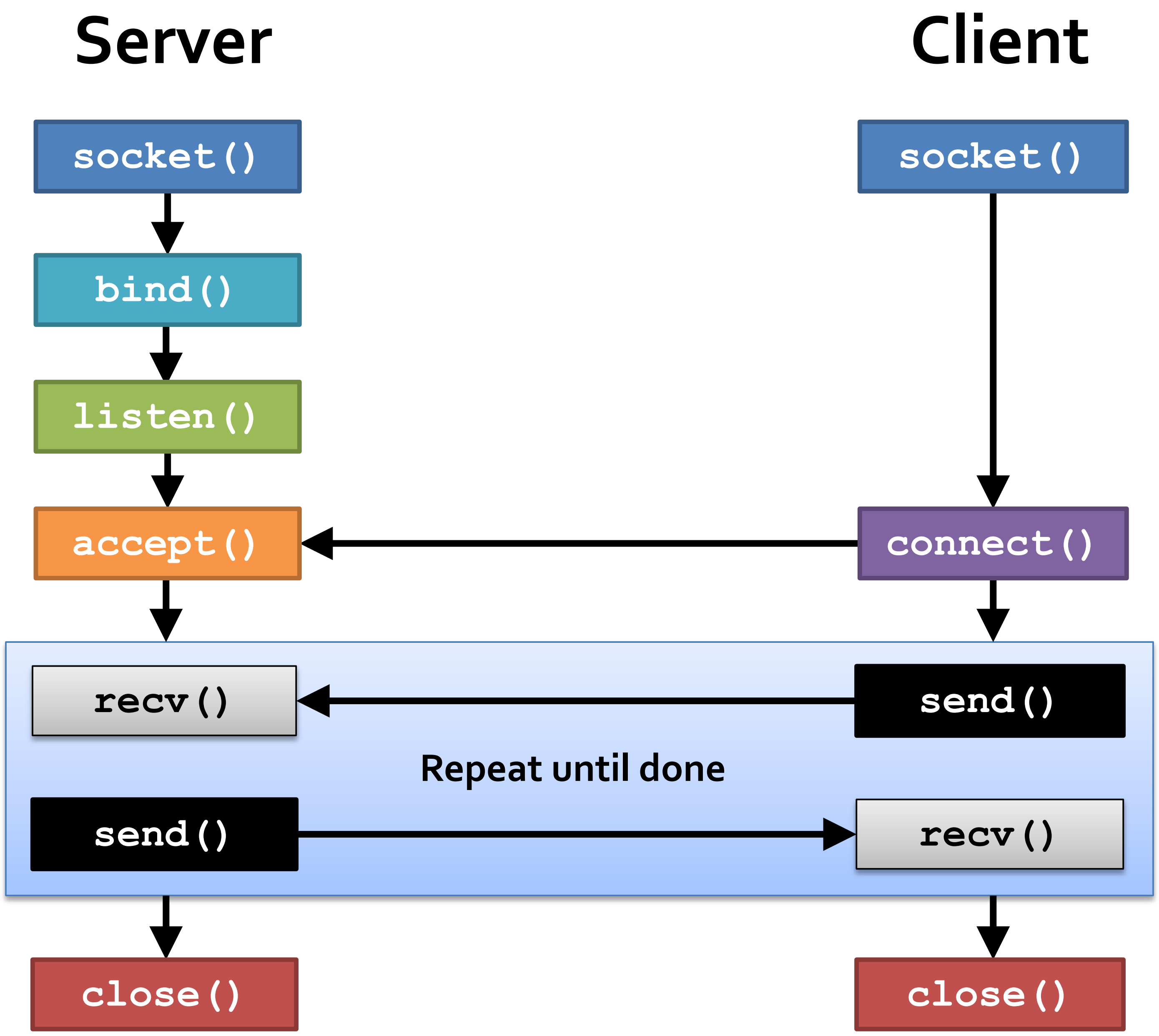
`socket()`

- If you want to create a socket, you can call the **`socket()`** function
- The function takes a communication domain
  - Will always be **`AF_INET`** for IPv4 Internet communication
- It takes a type
  - **`SOCK_STREAM`** usually means TCP
  - **`SOCK_DGRAM`** usually means UDP
- It takes a protocol
  - Which will always be **0** for us
- It returns a file descriptor (an **`int`**)

```
int sockFD = -1;
sockFD = socket(AF_INET, SOCK_STREAM, 0);
```

Clients vs. servers

- Using sockets is usually associated with a client-server model
- A **server** is a process that sits around waiting for a connection
  - When it gets one, it can do sends and receives
- A **client** is a process that connects to a waiting server
  - Then it can do sends and receives
- Clients and servers are processes, not computers
  - You can have many client and server processes on a single machine


Server
Client
socket()
socket()
bind()
listen()
accept()
connect()
recv()
send()
Repeat until done
send()
recv()
close()
close()

Sending

- Once you've created your socket, set up your port and address, and called **`connect()`**, you can send data
  - Assuming there were no errors
  - Sending is very similar to writing to a file
- The **`send()`** function takes
  - The socket file descriptor
  - A pointer to the data you want to send
  - The number of bytes you want to send
  - Flags, which can be **0** for us
- It returns the number of bytes sent

```
char* message = "Flip mode is the squad!";
send(socketFD, message, strlen(message)+1, 0);
```

Receiving

- Or, once you're connected, you can also receive data
  - Receiving is very similar to reading from a file
- The **`recv()`** function takes
  - The socket file descriptor
  - A pointer to the data you want to receive
  - The size of your buffer
  - Flags, which can be **0** for us
- It returns the number of bytes received, or **0** if the connection is closed, or **-1** if there was an error

```
char message[100];
recv(socketFD, message, 100, 0);
```

Servers

- Sending and receiving are the same on servers, but setting up the socket is more complex
- Steps:
  1. Create a socket in the same way as a client
  2. Bind the socket to a port
  3. Set up the socket to listen for incoming connections
  4. Accept a connection

Function pointers

- C can have pointers to functions
- You can call a function if you have a pointer to it
- You can store these function pointers in arrays and structs
- They can be passed as parameters and returned as values
- Java doesn't have function pointers
  - Instead, you pass around objects that have methods you want
  - C# has delegates, which are similar to function pointers

Declaring a function pointer

- The syntax is a bit ugly
- Pretend like it's a prototype for a function
  - Except take the name, put a ***** in front, and surround that with parentheses

```c
#include <math.h>
#include <stdio.h>

int main()
{
	double (*root) (double); //pointer named root
	root = &sqrt; //note there are no parentheses
	printf( "Root 3 is %lf", root(3) );
	printf( "Root 3 is %lf", (*root)(3) ); //also legal


	return 0;
}
```

C++

Overview

- C++ is based on C and easier to use
  - You can declare variables anywhere
    - Not the case in the C89 standard (where all variables had to be declared right after a block starts), but our **gcc** is following the C99 standard
  - It has function overloading
  - Most people think the I/O is cleaner
- The big addition is OOP through classes
- It's an approximate superset of C that includes most C structures

Hello, World in C++

- It's not too different from C
- We need different headers for C++ I/O

```
#include <iostream>

using namespace std;

int main()
{
	cout << "Hello, world!" << endl;
	return 0;
}
```

Output in C++

- Output uses the **cout** object (of type **ostream**)
- Instead of using formatting strings, **cout** uses the idea of a stream, where objects are placed into the stream separated by the extraction operator **<<**
- The **endl** object adds a newline to the stream
  - Of course, **"\n"** works too

```
int x = 50;

cout << "There are " << x << " ways to leave
your lover." << endl;
```

Input in C++

- Input uses the **`cin`** object (of type **`istream`**)
- **`cin`** also uses the idea of a stream, where items are read from the stream and separated by the insertion operator **>>**
- It reads items using whitespace as the separator, just like **`scanf()`**

```
int x = 0;
int y = 0;
int z = 0;
cout << "Enter the x, y, and z values: ";
cin >> x >> y >> z;
```

The `string` class

- Like Java, C++ has a class for holding strings, which makes life much easier
  - It's called **`string`** (with a lower case **`'s'`**)
- You must include **`<string>`** to use it
- Unlike **`String`** in Java, **`string`** is mutable
  - You can use array-style indexing to get and set individual characters

```
string a = "Can I kick it?";
string b = "Yes, you can!";
string c = a + "  " + b;
c[0] = 'D';
c[1] = 'i';
c[2] = 'd';
cout << c << end;
//prints Did I kick it?  Yes, you can!
```

The std namespace

- Java uses packages to keep different classes with the same name straight
- C++ uses namespaces
- The standard library includes I/O (**`<iostream>`**), the string class (**`<string>`**), STL containers (**`<vector>`**, **`<list>`**, **`<deque>`**, and others)
- If you use these in your program, put the following after your includes

```
using namespace std;
```

- The alternative is to specify the namespace by putting the it followed by two colons before the class name

```
std::string name = "Ghostface Killah";
```

Functions in C++

- Regular C++ functions are very similar to to functions in C
- A big difference is that prototypes are no longer optional if you want to call the function before it's defined
- Unlike C, function overloading allowed:

```
int max(int a, int b)
{
        return a > b ? a : b;
}

int max(int a, int b, int c)
{
        return max( a, max( b, c));
}
```

Pass by reference

- In C, all functions are pass by value
  - If you want to change an argument, you have to pass a pointer to the value
- In C++, you can specify that a parameter is pass by reference
  - Changes to it are seen on the outside
  - You do this by putting an ampersand (`&`) before the variable name in the header

```
void swap(int &a, int &b)
{
      int temp = a;
      a = b;
      b = temp;
}
```

Default parameter values

- C++ also allows you to specify default values for function parameters
- If you call a function and leave off those parameters, the default values will be used
- Default parameters are only allowed for the rightmost grouping of parameters

```
void build(int width = 2, int height = 4)
{
	cout << "We built this house with " <<
	width << " by " << height << "s.";
}
```

```
build();       //We built this house with 2 by 4s.
build(3);      //We built this house with 3 by 4s.
build(6, 8);   //We built this house with 6 by 8s.
```

The new keyword

- When you want to dynamically allocate memory in C++, you use **`new`** (instead of **`malloc()`**)
  - No cast needed
  - It "feels" a lot like Java

```
int* value = new int(); //make an int
int* array = new int[100]; //array of ints
Wombat* wombat = new Wombat(); //make a Wombat
Wombat* zoo = new Wombat[100];
//makes 100 Wombats with the default constructor
```

The **delete** keyword

- When you want to free dynamically allocated memory in C++, use **`delete`** (instead of **`free()`**)
  - If an array was allocated, you have to use **`delete[]`**

```
int* value = new int(); //make an int
delete value;

Wombat* wombat = new Wombat();
delete wombat;

Wombat* zoo = new Wombat[100];
delete[] zoo; //array delete needed
```

Object Oriented Programming

- C++ has several classically important elements of OOP:
  - Encapsulation
  - Dynamic dispatch
  - Polymorphism
  - Inheritance
  - Self-reference

Overloading operators

- In C++, you can **overload operators**, meaning that you can define what + means when used with classes you design
- Thus, the following ***could*** be legal:

```
Hippopotamus hippo;
Sandwich club;
Vampire dracula = club + hippo;
```

Templates

- Allow classes and functions to be written with a generic type or value parameter, then instantiated later
- Each necessary instantiation is generated at compile time
- Appears to function like generics in Java, but works very differently under the covers
- Most of the time you will **use** templates, not create them

Standard Template Library

- The Standard Template Library (STL) is a collection of templated classes designed to solve common programming problems
- The most common use of them is containers, similar to the Java Collections Framework (JCF) classes like **`LinkedList`** and **`HashMap`**
- A few important STL containers are:
  - **`list`**
  - **`map`**
    - **`multimap`**
  - **`set`**
    - **`multiset`**
  - **`stack`**
  - **`queue`**
    - **`deque`**
  - **`priority_queue`**
  - **`vector`**

Lab 15

Upcoming

Next time...

- There is no next time!

Reminders

- **Finish Project 6**
  - **Due tonight before midnight!**
- Study for Final Exam
  - 11:00am - 2:00pm, Tuesday, 5/08/2018 (Section A)
  - 11:00am - 2:00pm, Monday, 5/07/2018 (Section B)