Week 14 - Wednesday

COMP 2000

Last time

- What did we talk about last time?
- Review up to Exam 1
  - Java basics
  - Enhanced `for` loops
  - Enums
  - Packages
  - Interfaces
  - Inheritance
  - Exceptions

Questions?

Project 4

Final exam

- Final exam will be held virtually:
  - Monday, April 27, 2020
  - 10:15 a.m. to 12:15 p.m.
- There will be multiple choice, short answer, and programming questions
- I recommend that you use an editor like Notepad++ to write your answers, since Blackboard doesn't play nice with tabs
- I **don't** recommend that you use Eclipse, since the syntax highlighting features will make you doubt yourself and try to get things perfect when getting them done is more important

Review up to Exam 2

JOptionPane

`JOptionPane`

- **`JOptionPane`** class provides static methods for:
  - Displaying a message
  - Asking a question
- Although it is possible to create a **`JOptionPane`** object, you almost never do
- Just call the static methods
  - Which means typing a lot of **`JOptionPane.`**

showMessageDialog() example

- To display "**This is a message.**" you could call the following:

```
JOptionPane.showMessageDialog(null,
   "This is a message.");
```

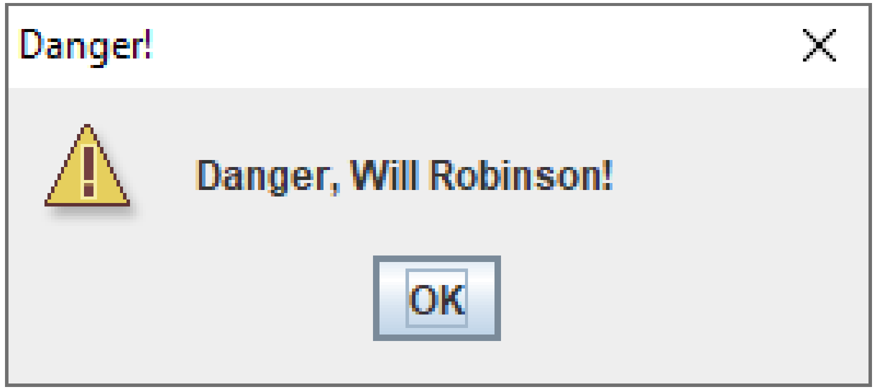
Adding a title

- Most **JOptionPane** methods have many overloads
- If you want to put a title on the window, you can pass it in as the third parameter
- But this overloaded method also requires an **int** parameter that says what kind of message you want
- To add the title "**Window Title**", you might call the following method:


```
JOptionPane.showMessageDialog(null,
   "This is a message.", "Window Title",
   JOptionPane.PLAIN_MESSAGE);
```

Different icons

- You can choose an icon associated with one of the following constants:
  - ERROR_MESSAGE
  - INFORMATION_MESSAGE
  - WARNING_MESSAGE
  - QUESTION_MESSAGE
  - PLAIN_MESSAGE

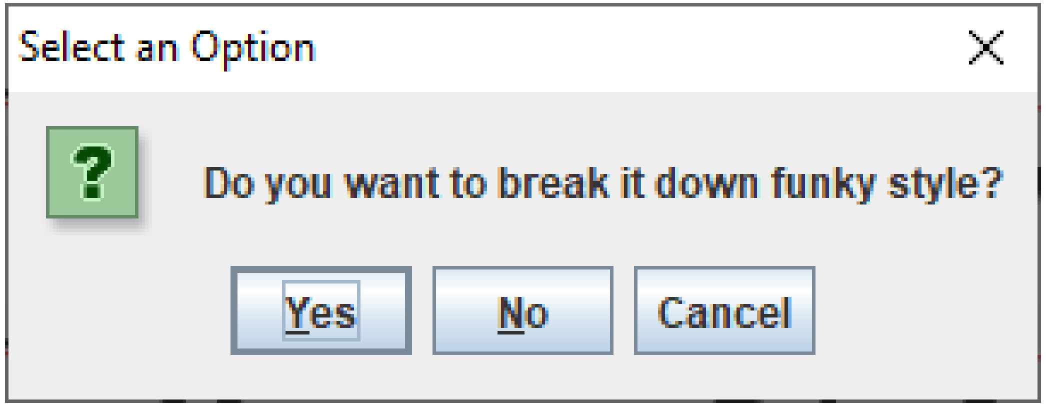



```
JOptionPane.showMessageDialog(null,
   "Danger, Will Robinson!", "Danger!",
   JOptionPane.WARNING_MESSAGE);
```

showConfirmDialog() example

```
int answer = JOptionPane.showConfirmDialog(null,
    "Do you want to break it down funky style?");
if(answer == JOptionPane.YES_OPTION)
    JOptionPane.showMessageDialog(null, "Dope!");
else
    JOptionPane.showMessageDialog(null, "Weak!");
```

- Hitting the X in the corner is the same as Cancel

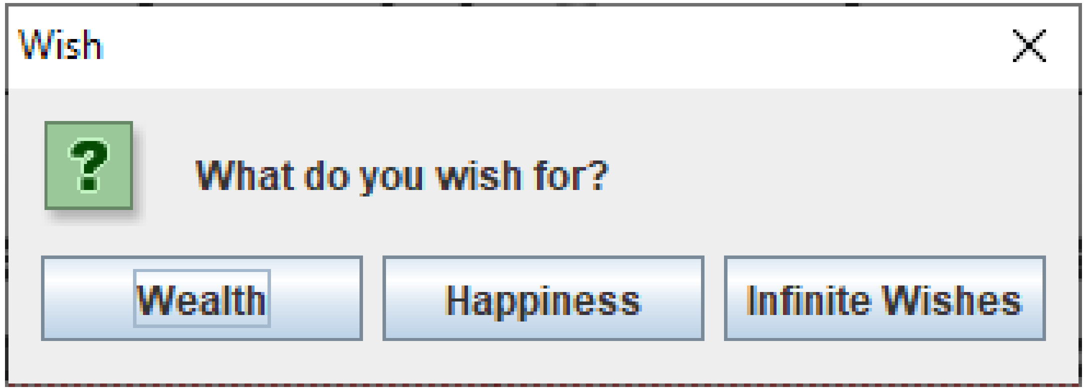


showOptionDialog() example

- Here's an example showing a dialog that allows a user to choose between Wealth, Happiness, and Infinite Wishes

```
String[] options = {"Wealth", "Happiness", "Infinite Wishes"};
int answer = JOptionPane.showOptionDialog(null,
   "What do you wish for?", "Wish", JOptionPane.DEFAULT_OPTION,
   JOptionPane.QUESTION_MESSAGE, null, options, null);
```

- Note that many parameters can be **`null`**: parent, icon, default option

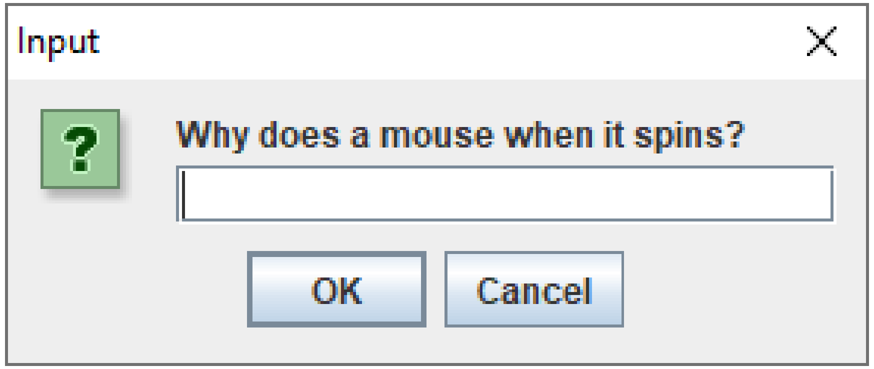


showInputDialog() example

- This input dialog asks a pressing question

```
String answer =
  JOptionPane.showInputDialog(null,
  "Why does a mouse when it spins?");
```

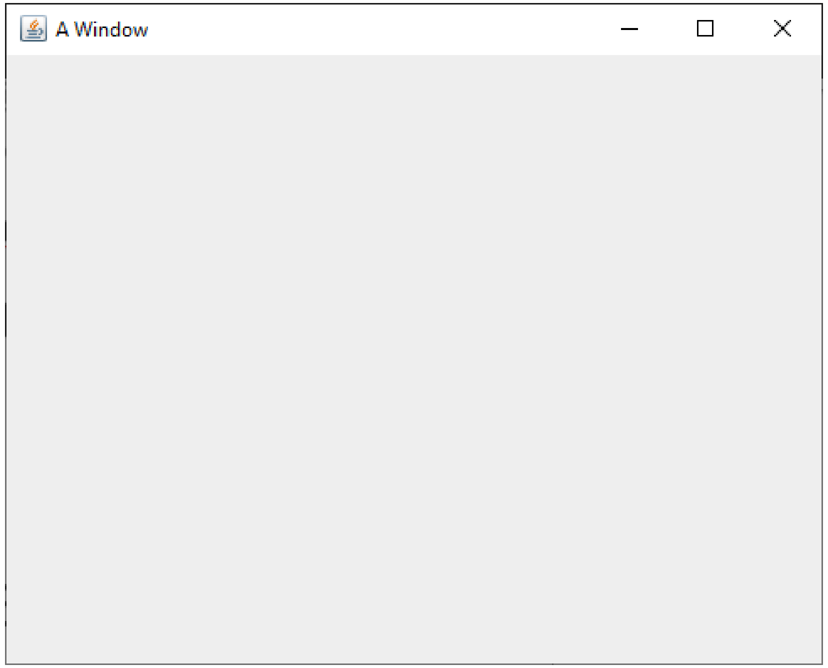
- As with other methods, there are overloaded versions that allow for titles, icons, and other options



JFrame

Creating a JFrame

- To create a **JFrame**, we will usually call its constructor that takes a **String**, giving it a title
- Then, we have to make it visible so that we can see it




```
JFrame frame = new JFrame("A Window");
frame.setVisible(true);
```

`setDefaultCloseOperation()`

- Next, you'll notice that closing the window doesn't end the program
  - The little red square on the Eclipse Console is still clickable, meaning that the program is running
- By default, closing the window by clicking its X only hides the window
- By calling the **`setDefaultCloseOperation()`**, we can make it so that the default operations is dispose (getting rid of the window)

```
JFrame frame = new JFrame("A Window");
frame.setSize(500, 400);
frame.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);
frame.setVisible(true);
```

- Many books suggest passing in **`JFrame.EXIT_ON_CLOSE`**, but you **should not!**
- Doing so will kill the rest of your program like **`System.exit()`**

Recap

- To use a **`JFrame`** you must:
  - Create a **`JFrame`** object
  - Set its size (either directly or by putting widgets on it and then calling **`pack()`**)
  - Set its default close operation to dispose
  - Make it visible
- Now that we've got a window, we can put widgets on it!

Widgets

- **Widget** is a generic term for a wide range of GUI controls
  - Buttons
  - Labels (allowing us to put text or images on a GUI)
  - Text fields
  - Text areas (like text fields but larger)
  - Menus
  - Checkboxes
  - Radio buttons
  - Lists
  - Combo boxes
  - Sliders

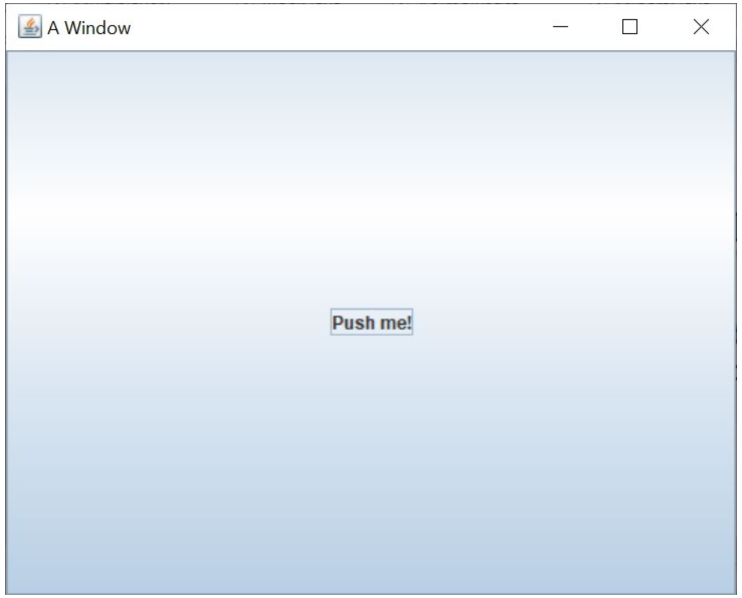
JButton

- A button you can click on is provided by the **JButton** class
- A **JButton** is usually created with text or an image
  - You'll need to make **JButton**s with images for Project 2
- Just creating the **JButton** doesn't do anything
- You have to add it to a **JFrame** (or other container) to see it
- Right now, we're just creating the buttons
- Next week, we'll learn how to add actions to them

```
JButton button = new JButton("Push me!");
```

Adding a JButton to a JFrame

- Once you've created a **JButton**, you can add it to a **JFrame** by calling the **add()** method on the **JFrame**
- All GUI containers have an **add()** method that allows us to add a widget to it




```
JFrame frame = new JFrame("A Window");
frame.setSize(500, 400);
frame.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);
JButton button = new JButton("Push me!");
frame.add(button);
frame.setVisible(true);
```

Displaying an icon on a JButton

- You can also make a **`JButton`** with an image instead of text
- To do so, you create an **`ImageIcon`** and pass that to the constructor of the **`JButton`**
- You'll need the path to an image


```
JButton bowieButton = new JButton(new ImageIcon("bowie.jpg"));
frame.add(bowieButton, BorderLayout.CENTER);
```

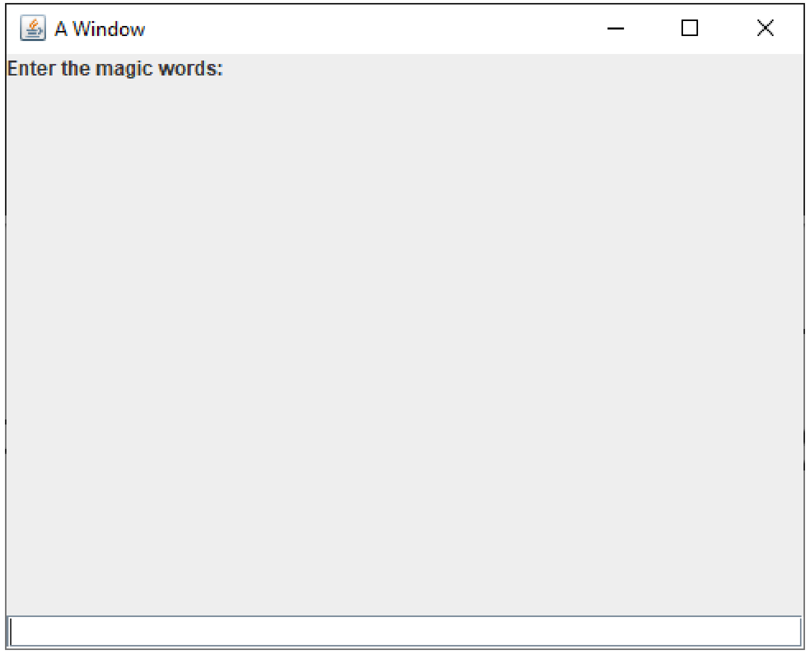
JLabel

- A **JLabel** is like a button you can't click
- Its constructors work just like the **JButton** ones
- It allows you to display text or an image


```
JLabel nameLabel = new JLabel("David Bowie");
JLabel bowieLabel = new JLabel(new ImageIcon("bowie.jpg"));
frame.add(nameLabel, BorderLayout.NORTH);
frame.add(bowieLabel, BorderLayout.CENTER);
```

JTextField

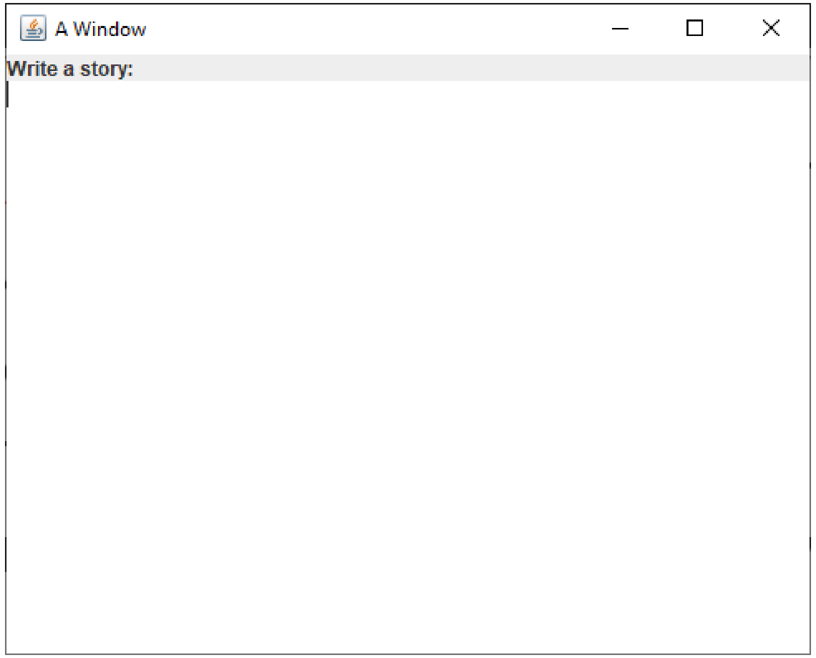
- A **JTextField** allows a user to enter a (short) amount of text
- Usually, you'll need a **JLabel** to tell the person what they should enter
- The example is ugly because the **JLabel** and the **JTextField** don't fill the 500 x 400 **JFrame**




```
JLabel messageLabel = new JLabel("Enter the magic words:");
JTextField magicField = new JTextField();
frame.add(messageLabel, BorderLayout.NORTH);
frame.add(magicField, BorderLayout.SOUTH);
```

JTextArea

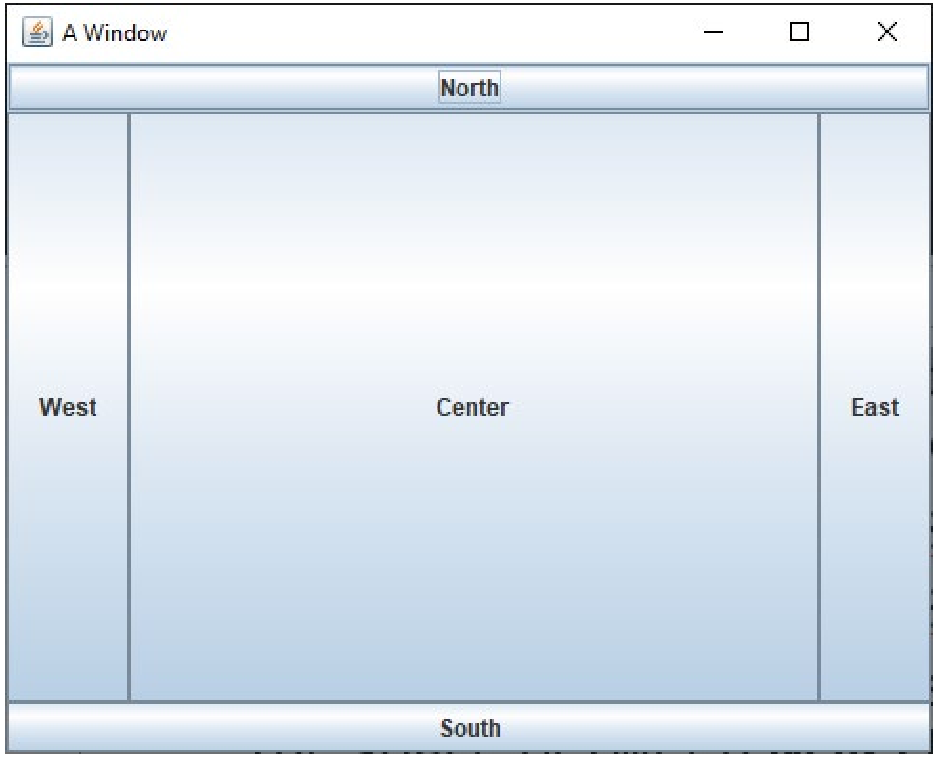
- A **`JTextField`** is for entering small pieces of information
  - Name
  - Address
  - Telephone number
- For larger texts, we can use a **`JTextArea`**




```
JLabel storyLabel = new JLabel("Write a story:");
JTextArea storyArea = new JTextArea();
frame.add(storyLabel, BorderLayout.NORTH);
frame.add(storyArea, BorderLayout.CENTER);
```

BorderLayout

- **`BorderLayout`** is the default layout for **`JFrame`**
- When you add widgets, you can specify the location as one of five regions:
  - **`BorderLayout.NORTH`** stretches the width of the container on the top
  - **`BorderLayout.SOUTH`** stretches the width of the container on the bottom
  - **`BorderLayout.EAST`** sits on the right of the container, stretching to fill all the space between **NORTH** and **SOUTH**
  - **`BorderLayout.WEST`** sits on the left of the container, stretching to fill all the space between **NORTH** and **SOUTH**
  - **`BorderLayout.CENTER`** sits in the middle of the container and stretches to fill all available space
- If you don't specify where you're adding a widget, it adds to **CENTER**
- If you add more than one widget to a region, the new one **replaces** the old
- Unused regions disappear



GridLayout

- **GridLayout** allows you to create a grid with a specific number of rows and columns
- All the cells in the grid are the same size
- As you add widgets, they fill each row


```
frame.setLayout(new GridLayout(4, 5));
for(int row = 0; row < 4; ++row)
  for(int column = 0; column < 5; ++column)
     frame.add(new JButton("" + (row * 5 + column + 1)));
```

Action Listeners

Making buttons do things

- We have added **`JButton`**s to **`JFrame`**s, but those buttons don't do anything
- When clicked, a **`JButton`** fires an event
- We need to add an action listener to do something when that event happens
- A CLI program runs through loops, calls methods, and makes decisions until it runs out of stuff to do
- GUIs usually have this **event-based** programming model
- They sit there, waiting for events to cause methods to get called

`ActionListener` interface

- What can listen for a **`JButton`** to click?
- Any object that implements **`ActionListener`**
- **`ActionListener`** is an interface like any other with a single abstract method in it:

```
void actionPerformed(ActionEvent e);
```

- We need to write a class with such a method
- We will rarely need to worry about the **`ActionEvent`** object
- But it does have a **`getSource()`** method that will give us the **`Object`** (often a **`JButton`**) that fired the event

Anonymous inner classes

- Now, we get to something tricky
- It's possible to create a class on the fly, right in the middle of other code
- Consider the following interface:

```
public interface NoiseMaker {
    String makeNoise();
}
```

- We can create, in the middle of other code, a class that implements **NoiseMaker**, like this:

```
NoiseMaker maker = new NoiseMaker() {
    public String makeNoise() {
        return "Yowza!";
    }
};
```

Adding an action listener

- The reason we brought up anonymous inner classes is that we can use this syntax to make an **`ActionListener`** object right when we need it, for a button

```
JButton button = new JButton("Push me!");
button.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        button.setText("Ouch!"); // arbitrary code
    }
}); // ugly: parenthesis for end of method call
```

- It's ugly, but it works

Java 8 style

- Before Java 8, we only had two choices:
  - Make a whole class that implements **`ActionListener`** and might have to do different actions based on which button fired the event
  - Make a separate anonymous inner class for every single button, each doing the action for that button
- Java 8 adds something called lambdas which actually make anonymous inner classes too, but the syntax is much nicer
- Java 8 style:

```
JButton button = new JButton("Push me!");
button.addActionListener(e -> button.setText("Ouch!"));
```

More on Java 8 style

- An interface with only a single method in it (like **`ActionListener`**) is called a **functional interface**
- Java 8 lets us instantiate functional interface by filling out the method:

```
(Type1 arg1, Type2 arg2, …) -> { /* method body */  }
```

- But if it's possible for the compiler to infer the argument types, they don't have to be written
- If you only have a single argument, you don't need parentheses
- And if you only have a single line in your method body, you don't need braces
- Multi-line example:

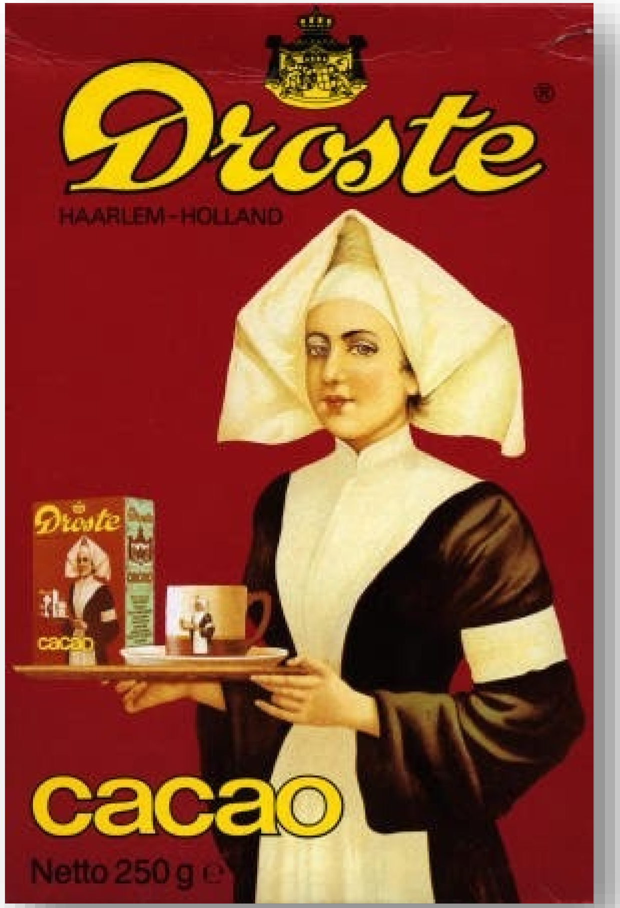
```
JButton button = new JButton("Push me!");
button.addActionListener(e -> {
    button.setText("Ouch!");
    button.setEnabled(false);
});
```

Recursion

To understand recursion, you must first understand recursion.

What is recursion?

- Defining something in terms of itself
- To be useful, the definition must be based on progressively simpler definitions of the thing being defined



Useful Recursion

Two parts:

- Base case(s)
  - Tells recursion when to stop
  - For factorial, $n = 1$ or $n = 0$ are examples of base cases
- Recursive case(s)
  - Allows recursion to progress
  - "Leap of faith"
  - For factorial, $n > 1$ is the recursive case

Approach for Problems

- Top down approach
- Don't try to solve the whole problem
- Deal with the next step in the problem
- Then make the "leap of faith"
- Assume that you can solve any smaller part of the problem

Code for Factorial

```
public static long factorial( int n )
{
  if( n <= 1 )
     return 1;
  else
     return n*factorial( n - 1 );
}
```

Base Case

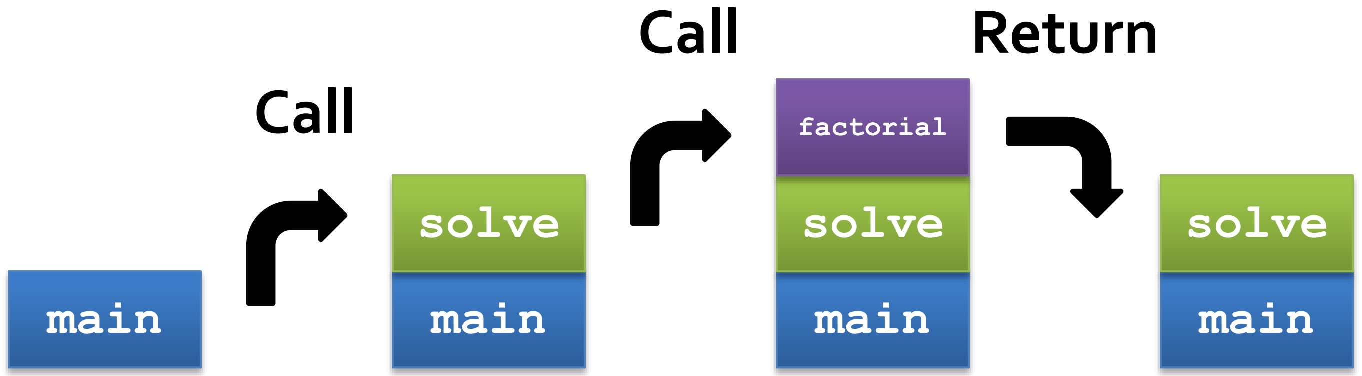
Recursive Case

Recursive style

- When we do recursion, we want to pass all the data in through our method arguments
- We want to get all of our results back through return statements
- Think of each recursive method call as a frozen moment in time
- Thus, we usually **don't** want to assign variables
- Instead, variables change *as they pass* to the next method call

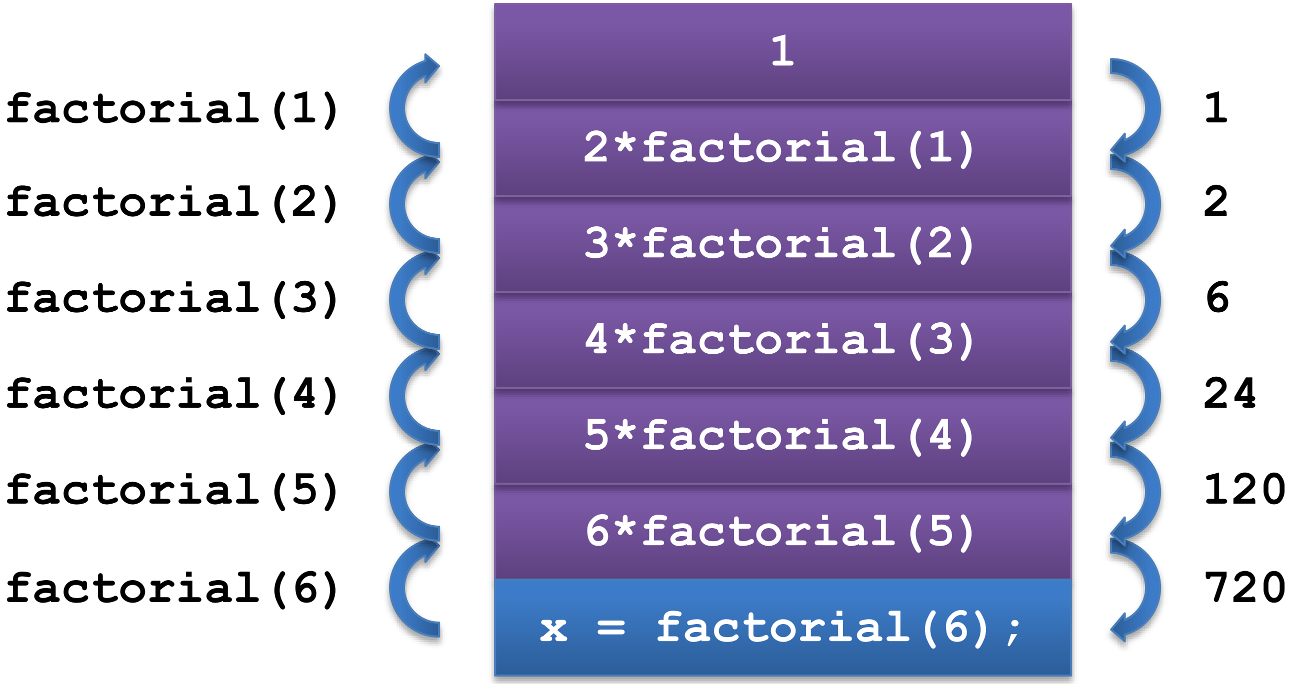
Call stack

- Local variables for each method are stored on the stack
- When a method is called, a copy of that method is **pushed** onto the stack
- When a method returns, that copy of the method **pops** off the stack



Example with Factorial

- Each copy of factorial has a value of ***n*** stored as a local variable
- For 6! :



Exponentiation

- Similarly, exponentiation is repeated multiplication
- Thus, $x^y = x \cdot x \cdot x \ldots \cdot x$
  (y times)
- Base case (***y*** = 0):
  - $x^0 = 1$
- Recursive case (***y*** > 0):
  - $x^y = x \cdot x^{y-1}$

- There is a more efficient way to do this, but you'll have to take COMP 2100 to talk about it

Code for exponentiation

```java
public static double power( double x, int y ){

  if( y == 0 )
     return 1.0;
  else
     return x * power( x, y - 1 );

}
```

Base Case

Recursive Case

Extra information

- Recursion sometimes requires similar information that can be passed along to each recursive call
- This information could be an index into a `String` or an array
- In graph or tree algorithms, it might be the parent node you visited previously
- There are recursive methods with 10 or more parameters
- There's nothing wrong with that, provided that you actually *need* them all

Summing an array

- What if we want to sum the values in an array called ***array***?
- We need some extra information: current index
- Base case (***index*** = ***length***):
  - Sum(from ***index*** onward):

    0 (Nothing left to sum)
- Recursive case (***index*** < ***length***):
  - Sum(from ***index*** onward):

    array[***index***] + Sum(from ***index*** + 1 onward)

Code for summing an array

```
public static double sum(double array[], int index) {

  if( index == array.length )
     return 0.0;
  else
     return array[index] + sum(array, index + 1);

}
```

Base Case

Recursive Case

Reversing a `String`

- What if we want to reverse the contents of a string called ***s***?
- We need some extra information: current index
- Base case (***index*** = ***length***):
  - Reverse(from ***index*** onward):

    "" (Nothing left to reverse)
- Recursive case (***index*** < ***length***):
  - Reverse(from ***index*** onward):

    s[***length*** – ***index*** - 1] + Reverse(from ***index*** + 1 onward)

Code for reversing a String

```
public static String reverse(String s, int index) {

  if( index == s.length() )
     return "";
  else
     return s.charAt(s.length() - index - 1) +
            reverse(s, index + 1);

}
```

Base Case

Recursive Case

Using the stack to go in reverse

- All stacks (including the call stack) are first-in last-out (FILO) structures
- In situations where we want to deal with things in backwards order, we can use this natural reversing tendency
- For example, if we want to print out a **`String`** in reverse, we can recurse through each character and print them as the recursion returns
- Doesn't make sense yet?

Printing a `String` in reverse

- What if we want to print the contents of a string called ***s*** *in reverse*?
- We need some extra information: current index
- Base case (***index*** = ***length***):
  - ReversePrint(from ***index*** onward):

    Print nothing
- Recursive case (***index*** < ***length***):
  - ReversePrint(from ***index*** onward):

    ReversePrint(from ***index*** + 1 onward)

    Then print ***s*** [***index***]

Code for printing a String in reverse

```
public static void reversePrint(String s, int index)
{


  if( index < s.length() ) {
        reversePrint(s, index + 1);
        System.out.print(s.charAt(index));
  }


}
```

(Empty)
Base Case

Recursive
Case

Reversing a `String` (the remix)

- We can even use this approach to reverse a string in a different manner than we did before
- Base case (***index*** = ***length***):
  - Backwards(from ***index*** onward):

    "" (Nothing left to reverse)
- Recursive case (***index*** < ***length***):
  - Backwards(from ***index*** onward):

    Backwards(from ***index*** + 1 onward) + ***s***[***index***]

Remixed code for reversing a String

```
public static String backwards(String s, int index) {

  if( index == s.length() )
     return "";
  else
     return backwards(s, index + 1) + s.charAt(index);

}
```

Base Case

Recursive Case

Merge Sort

Merge Sort algorithm (recursive)

- Beautiful divide and conquer algorithm
- Base case: List has size 1
  - You're done!
- Recursive case: List has size greater than 1
  - Divide your list in half
  - Recursively merge sort each half
  - Merge the two halves back together in sorted order

Merge Sort code

```
public static void mergeSort(int [] array) {

  if(array.length > 1) {
     int[] a = new int[array.length/2];
     int[] b = new int[array.length - a.length];
     for(int i = 0; i < a.length; ++i) //copy first half
          a[i] = array[i];
     for(int i = 0; i < b.length; ++i) //copy second half
          b[i] = array[i + a.length];
     mergeSort(a); //sort first half
     mergeSort(b); //sort second half
     merge(a, b, array);
  }
}
```

(Empty)
Base Case

Recursive
Case

Merging (the hard part)

- The code to merge two sorted subarrays into a third array trips up a lot of people
- Use three indexes, one for each array
- Always copy the smaller value from the two subarrays
- The tricky part is that you might no longer have anything left to copy from a subarray
- At that point, you must copy from the other subarray
- In other words, always check the validity of an index before using it

Merge code

```
public static void merge(int[] a, int[] b, int[] array) {
	int aIndex = 0;
	int bIndex = 0;
	for(int i = 0; i < array.length; ++i) {
		if(aIndex >= a.length)
			array[i] = b[bIndex++];
		else if(bIndex >= b.length)
			array[i] = a[aIndex++];
		else if(a[aIndex] <= b[bIndex])
			array[i] = a[aIndex++];
		else
			array[i] = b[bIndex++];
	}
}
```

Merging

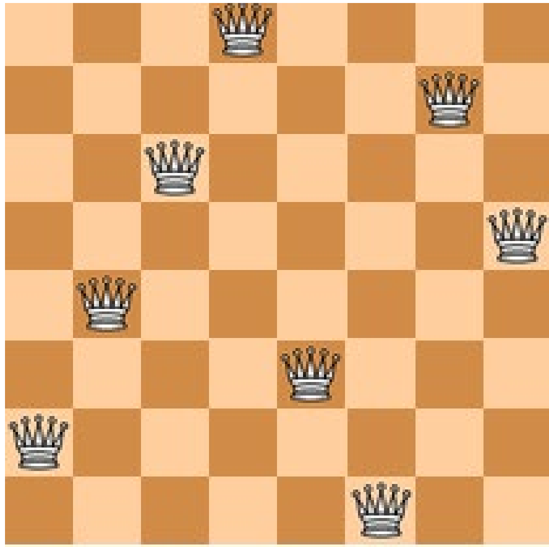
- I prefer the merging given on the previous slide
- A single `for` loop that fills the array makes sense to me
- I'm not a huge fan of using the postincrement operator (`aIndex++`), but this is what it's designed for:
  - Getting a value and then incrementing it, all in a single line of code
  - Otherwise, we'd need braces for the cases
- Note that you can combine the four seemingly repetitive cases into three cases (but not two)
- Another way to do the merge is with three `while` loops, given on the next slide

Merge code (alternative)

```
public static void merge(int[] a, int[] b, int[] array) {
	int aIndex = 0;
	int bIndex = 0;
	int i = 0;
	while(aIndex < a.length && bIndex < b.length) {
		if(a[aIndex] <= b[bIndex])
			array[i] = a[aIndex++];
		else
			array[i] = b[bIndex++];
		++i;
	}
	while(aIndex < a.length) {
		array[i] = a[aIndex++];
		++i;
	}
	while(bIndex < b.length) {
		array[i] = b[bIndex++];
		++i;
	}
}
```

N-Queens

- Given an ***N*** x ***N*** chess board, where ***N*** ≥ 4 it is possible to place ***N*** queens on the board so that none of them are able to attack each other in a given move
- Write a method that, given a value of ***N***, will return the total number of ways that the ***N*** queens can be placed



Problem solving approach

- We will use recursion to place queens on the board, one row at a time
- To save typing, we will use a loop to place the queen at each different column within the row and then recurse
  - Egad! A loop inside recursion!
  - It happens.
- If we have placed queens on all the rows, we return 1 (a successful placement)
- We sum up all the successful placements that our recursive children make

N-Queens algorithm (recursive)

- Base case: (***row*** = 8)
  - You have placed queens on rows 0-7
  - Return 1 (a successful placement)
- Recursive case: (***row*** < 8)
  - Keep a sum of the successful placements made by placing in future rows, initially 0
  - Try to place a queen on columns 0-7
    - For each successful column placement, recursively try to place queens on the next row and add those successful placements to your sum
  - Return sum

Files

Text files

- First, we're going to talk about **text files**
- All files are sequences of bytes stored in binary, but in text files, those bytes form human-readable text like words and numbers
- Unlike files storing data in binary, working with text files is similar to the command-line I/O we've been doing since before COMP 2000
- Examples of text files:
  - Source code for most programming languages (**`.c`**, **`.java`**, **`.py`** files, etc.)
  - Plain text files (often with a **`.txt`** extension)
  - Many configuration and log files

Reading

- Reading from a text file is straightforward
- We use **`Scanner`**, just like reading from the command line
- We just have to create a new **`File`** object that gives the file path we want to read from

```
Scanner in = new Scanner(new File("input.txt"));
```

- This code will read from some file called **`input.txt`**, as if someone were typing its contents into the command line

Scanner methods

- Recall that we can read correctly formatted text with a **`Scanner`** using the following methods
  - **`nextInt()`** Reads an **`int`** value
  - **`nextDouble()`** Reads a **`double`** value
  - **`next()`** Reads a white-space delimited **`String`**
  - **`nextLine()`** Reads a **`String`** up to the next newline (which can cause problems if there's a newline left over from previous reads)
- These methods are usually what you need to get the job done, but there are also **`nextBoolean()`**, **`nextByte()`**, **`nextFloat()`**, **`nextLong()`**, and **`nextShort()`** methods
- Note that all the integer reading methods have a second version that takes a base so that you can read values in bases 2-36

Writing

- Writing to files uses a different sequence of steps
- If you want to write to a text file, you've got to create a **`PrintWriter`** object, based on a **`FileOutputStream`** object (which takes the file name as a parameter)

```
PrintWriter out = new PrintWriter(new
  FileOutputStream("output.txt"));
```

- Once you've got a **`PrintWriter`**, you can use it just like **`System.out`**

Exceptions

- When making a **`Scanner`** from a **`File`** or making a **`PrintWriter`** from a **`FileOutputStream`** can potentially throw a **`FileNotFoundException`**
- Since it's a checked exception, you need a **`try-catch`** or a **`throws`**

Writing example

- This example opens a file called **`goodbye.txt`**, writes some text, and then closes the file
- Note that we are not showing the **`try`**-**`catch`** or **`throws`**

```
PrintWriter out = new PrintWriter(new
  FileOutputStream("goodbye.txt"));
out.println("So long!");
out.println("Farewell!");
out.println("Auf Wiedersehen!");
out.println("Goodbye!");
out.close();
```

Shut 'em down!

- You should always close files as soon as you're done reading from them or writing to them
- If you don't close files you're writing to before your program ends, output can be lost
- Keeping files open ties up system resources
- There's a maximum number of files one program can have open at a time
- Since we always want to close files, it's smart to put the closing in a `finally` block

Full example

- This example copies the text from **`input.txt`** to **`output.txt`**

```
Scanner in = null;
PrintWriter out = null;
try {
   in = new Scanner(new File("input.txt"));
   out = new PrintWriter(new FileOutputStream("output.txt"));
   while(in.hasNextLine())
      out.println(in.nextLine());
}
catch(FileNotFoundException e) {
   e.printStackTrace();
}
finally {
   if(in != null) in.close();
   if(out != null) out.close();
}
```

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 4 bytes
- In text, they can take up a lot more
- In text, you also need a space or other separator to divide the numbers

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

Most files are binary files

- Because they have a representation that is more compact (and more similar to how data is stored in your program), most files are binary (non-human-readable) files
- Many media files start with **metadata**
  - Format information
  - Size
- Then, they have the actual data (RGB values, audio samples, frames of video, etc.)
- Binary files include most common file formats: **`.jpg`**, **`.png`**, **`.mp3`**, **`.avi`**, **`.pdf`**, **`.docx`**, **`.pptx`**, and on and on

Reading binary files

- Reading from binary files uses a completely different set of objects than reading from text files
- We create a **`DataInputStream`** from a **`FileInputStream`**
- The **`FileInputStream`** takes the name of the file path

```
DataInputStream in = new DataInputStream(new
  FileInputStream("input.dat"));
```

- You can create a **`FileInputStream`** first on a separate line, but there's no need to do so

Example summing double values

- The following code assumes that a file contains starts with an **`int`** value giving the number of **`double`** values that come after it

```
DataInputStream in = null;
try {
   in = new DataInputStream(new FileInputStream("numbers.dat"));
   int length = in.readInt();
   double sum = 0.0;
   for(int i = 0; i < length; ++i)
       sum += in.readDouble();
   System.out.println("Sum: " + sum);
}
catch(IOException e) {
   System.out.println("File problems!");
}
finally {
   try{ in.close(); } catch(Exception e){}
}
```

Error handling

- The reading methods in **`DataInputStream`** can throw:
  - **`EOFException`** if the end of the file was reached but you still try to read something
  - **`IOException`** if the stream was closed (or something else goes wrong)
- Since **`EOFException`** and even **`FileNotFoundException`** are both children of **`IOException`**, it's possible (as we did on the previous slide) to have a single catch block that handles an **`IOException`**

Closing the file

- As with text files, we closed our files in a **`finally`** block
- You might have noticed that there was a baby **`try-catch`** block inside of there as well

```
finally {
   try{ in.close(); } catch(Exception e){}
}
```

- For whatever reason, closing a **`DataInputStream`** can throw an **`IOException`**
- By having a **`try-catch`** that will catch anything, we deal with the **`IOException`** as well as catching the **`NullPointerException`** that happens if we try to close a **`null`** **`DataInputStream`**
- Is that a good idea?
- Eh…it's fine: We're just trying to close the file and not crash our program

Writing binary files

- Writing to binary files is very similar to reading from binary files
- We create a **`DataOutputStream`** from a **`FileOutputStream`**
- The **`FileOutputStream`** takes the name of the file path

```
DataOutputStream out = new DataOutputStream(new
  FileOutputStream("output.dat"));
```

- The writing methods are similar too

Example writing double values

- The following code assumes that a file starts with an **`int`** value giving the number of **`double`** values that come after it

```
DataOutputStream out = null;
try {
   out = new DataOutputStream(new FileOutputStream("numbers.dat"));
   out.writeInt(100);
   for(int i = 0; i < 100; ++i)
      out.writeDouble(Math.random() * 1000);
}
catch(IOException e) {
   System.out.println("File problems!");
}
finally {
   try{ out.close(); } catch(Exception e){}
}
```

Putting the I/O together

- File input and output need to match each other well, especially for binary I/O
- If data values are out of order, you'll get garbage, and it'll be hard to know why
- Once you write the file output code, you can easily copy and paste it to write the input code
  - Change every **`out`** to **`in`**
  - Change every **`write`** to **`read`** (and move the method arguments to save return values)
- The structures are parallel

Serialization

- Serialization takes a reference to an object and dumps it into a file
- It writes representations to primitive types pretty much the same way that a `DataOutputStream` does
- And if there're objects inside of the object you're serializing, it serializes them too
- **And!** Serialization makes a note of all the objects that are getting serialized, so if it sees an object a second time, it just writes down a serial number for it instead of the whole thing

`Serializable` interface

- Serialization is one of the closest things to magic you'll see in programming
- You only need to implement the **`Serializable`** interface on your object
  - And the **`Serializable`** interface has no methods!
- It's just a way of marking an object as reasonable to try to dump into a file
- Most objects are reasonable to dump into a file!

Example Serializable class

- Here's a class we might want to be able to dump into a file

```
public class Troll implements Serializable {
  private String name;
  private int age;
  private Object hatedThing; // All trolls hate something
  public Troll(String name, int age, Object hatedThing) {
     this.name = name;
     this.age = age;
     this.hatedThing = hatedThing;
  }
  public Object getHatedThing() {
     return hatedThing;
  }
}
```

Writing using serialization

- To write an object marked **`Serializable`**, you need to create an **`ObjectOutputStream`**
- You create an **`ObjectOutputStream`** the same way that you create a **`DataOutputStream`**, by passing in a **`FileOutputStream`**
  - At this point, you might be wondering why all these objects take **`FileOutputStream`** objects and can't take just take a **`File`** object or even a file name
  - In actuality, you can pass in any **`OutputStream`** object (of which **`FileOutputStream`** is a child), like maybe one that sends the data across the network instead of storing it into a file
- An **`ObjectOutputStream`** object has many methods, but the only one that matters is **`writeObject()`**
- Pass your object to that method and it'll get written out in its totality, no fuss

Example of writing

- Here's some code that creates a couple of **`Troll`** objects and then writes them to a file called **`trolls.dat`**

```
Troll tom = new Troll("Tom", 351, "Bilbo Baggins");
Troll bert = new Troll("Bert", 417, tom);
ObjectOutputStream out = null;
try {
    out = new ObjectOutputStream(new FileOutputStream("trolls.dat"));
    out.writeObject(tom);
    out.writeObject(bert);
}
catch(IOException e) {
    System.out.println("Serialization failed.");
}
finally { try{ out.close(); } catch(Exception e){} }
```

Reading using serialization

- To read objects that have been serialized to a file, you need to create an **`ObjectInputStream`**
- You create an **`ObjectOutputStream`** the same way that you create a **`DataInputStream`**, by passing in a **`FileInputStream`**
- For each object serialized, you call the **`readObject()`** method to restore it from the file
- Note that **`readObject()`** has a return type of **`Object`**, so you'll need to cast your object if you want to store it in a reference of its own type

Example of reading

- Here's some code that reads in the **`Troll`** objects we serialized in the previous example

```
Troll tom = null;
Troll bert = null;
ObjectInputStream in = null;
try {
    in = new ObjectInputStream(new FileInputStream("trolls.dat"));
    tom = (Troll)in.readObject();
    bert = (Troll)in.readObject();
}
catch(IOException e) {
    System.out.println("Deserialization failed.");
}
finally { try{ in.close(); } catch(Exception e){} }
```

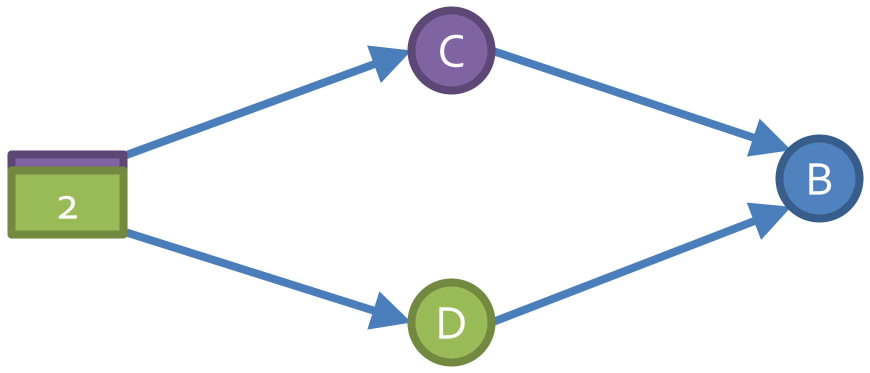
Networking

What is the Internet?

- The network of hardware and software systems that connects many of the world's computers
- Typically, people say the Internet and capitalize the "I" because there is only one
  - Until we meet aliens
  - Or decide to break off from the rest of the world
- The World Wide Web is the part of the Internet that is concerned with webpages
- The Internet also includes:
  - FTP
  - VOIP
  - Bittorrent
  - Multiplayer video games
  - Much, much more…

Packet switched

- The Internet is a packet switched system
- Individual pieces of data (called packets) are sent on the network
  - Each packet knows where it is going
  - A collection of packets going from point A to point B might not all travel the same route



IP addresses

- Computers on the Internet have addresses, not names
- **Google.com** is actually [`74.125.67.100`]
- **Google.com** is called a **domain**
- The Domain Name System or DNS turns the name into an address

IPv4

- Old-style IP addresses are in this form:
  - **`74.125.67.100`**
- 4 numbers between 0 and 255, separated by dots
- That's a total of 256^4 = 4,294,967,296 addresses
- But there are 7 billion people on earth…

IPv6

- IPv6 are the new IP addresses that are beginning to be used by modern hardware
  - 8 groups of 4 hexadecimal digits each
  - **`2001:0db8:85a3:0000:0000:8a2e:0370:7334`**
  - 1 hexadecimal digit has 16 possibilities
  - How many different addresses is this?
  - $16^{32} = 2^{128} \approx 3.4\times10^{38}$ is enough to have 500 trillion addresses for every cell of every person's body on Earth
  - Will it be enough?!

OSI 7 layer model

- 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	Unicode
5	**Session**	Salty	Sessions, sequencing, recovery	TLS
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

Physical layer

- There is where the rubber meets the road
- The actual protocols for exchanging bits as electronic signals happen at the physical layer
- At this level are things like RJ45 jacks and rules for interpreting voltages sent over copper
  - Or light pulses over fiber

Data link layer

- Ethernet is the most widely used example of the data layer
- Machines at this layer are identified by a 48-bit Media Access Control (MAC) address
- The Address Resolution Protocol (ARP) can be used for one machine to ask another for its MAC address
- Some routers allow a MAC address to be spoofed, but MAC addresses are intended to be unique and unchanging for a particular piece of hardware

Network layer

- The most common network layer protocol is Internet Protocol (IP)
- Each computer connected to the Internet should have a unique IP address
  - IPv4 is 32 bits written as four numbers from 0 – 255, separated by dots
  - IPv6 is 128 bits written as 8 groups of 4 hexadecimal digits
- We can use **`tracert`** on Windows to see the path of hosts leading to some IP address

Transport layer

- There are two popular possibilities for the transport layer
- Transmission Control Protocol (TCP) provides reliability
  - Sequence numbers for out of order packets
  - Retransmission for packets that never arrive
- User Datagram Protocol (UDP) is simpler
  - Packets can arrive out of order or never show up
  - Many online games use UDP because speed is more important

Session layer

- This layer doesn't necessarily exist in the TCP/IP model
- Transport Layer Security (TLS) uses the session layer
- TLS is the end-to-end encryption that HTTPS uses
- You know you're using TLS if there's a little lock showing on your browser
- Google is pushing for all websites to be HTTPS
- HTTPS is safer, but there's some overhead for the encryption, and websites have to have certificates for their public keys

Presentation layer

- The presentation layer is often optional
- It specifies how the data should appear
- This layer is responsible for character encoding (ASCII, UTF-8, etc.)
- MIME types are sometimes considered presentation layer issues

Application layer

- This is where the data is interpreted and used
- HTTP is an example of an application layer protocol
- A web browser takes the information delivered via HTTP and renders it
- Code you write deals significantly with the application layer

Mnemonics

- Seven layers is a lot to remember
- Mnemonics have been developed to help

Application	All	All	A	Away
Presentation	Pros	People	Powered-Down	Pretzels
Session	Search	Seem	System	Salty
Transport	Top	To	Transmits	Throw
Network	Notch	Need	No	Not
Data Link	Donut	Data	Data	Dare
Physical	Places	Processing	Packets	Programmers

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 the different connections straight

Common port numbers

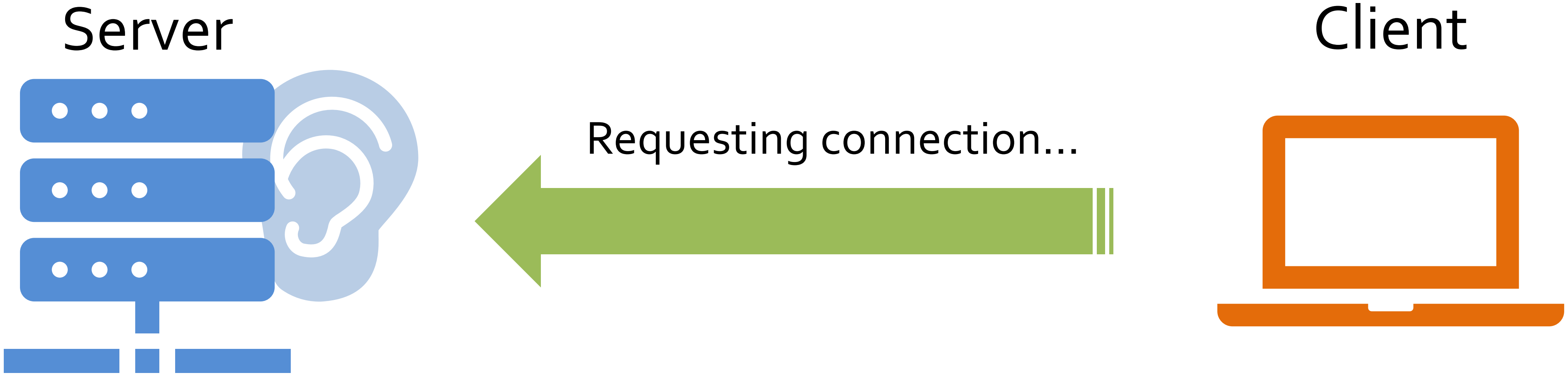
- Certain kinds of network communication are usually done on specific ports
  - **20** and **21**: File Transfer Protocol (FTP)
  - **22**: Secure Shell (SSH)
  - **23**: Telnet
  - **25**: Simple Mail Transfer Protocol (SMTP)
  - **53**: Domain Name System (DNS) service
  - **80**: Hypertext Transfer Protocol (HTTP)
  - **110**: Post Office Protocol (POP3)
  - **443**: HTTP Secure (HTTPS)

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

Listening server

- The server sits there, waiting for a client to connect
- Until that happens, the **`accept()`** method will not return
- When it does return, it will return with a socket that can be used for communicating with the client



Loopback IP address

- It's inconvenient to need two different computers to write network code
- For testing purposes, you can often use a single computer as both the server and the client
- To do so, you need to connect to yourself
- What's your IP address?
- Well, it might always be changing
- To make things simpler, there's a loopback IP address that always refers to the computer you're currently on: `127.0.0.1`
- The IPv6 loopback address is `::1` (where `::` is notation that means "fill in with appropriate numbers of zeroes")

Practice questions

- Write a program that prompts a user for a number with a **`JOptionPane`** method and uses another **`JOptionPane`** method to show whether or not the number is prime
- Create a **`JFrame`** containing an 8 × 8 grid of **`JButton`** objects
  - For those buttons that would be black in a chess board, use the **`setBackground()`** method to make them black
  - For the rest, use the **`setBackground()`** method to make them white
- Write a recursive method that sums up every other element in an array (in other words, only those with even indexes)
- Write a networked client program that
  - Connects to a specified port and IP address
  - Creates a **`Scanner`** to read from the socket
  - Tries to read whitespace-delimited words from the **`Scanner`** until it reads the **`String`** **`"###stop###"`**
  - Prints out the **`String`** it sees that comes first in lexicographic ordering (which is determined using **`compareTo()`**)

Quiz

Upcoming

Next time…

- Review everything after Exam 2
  - Dynamic data structures (including linked lists)
  - Generics
  - Java Collection Framework
    - `List`
      - `ArrayList`
      - `LinkedList`
    - `Map`
      - `HashMap`
      - `TreeMap`
    - `Set`
      - `HashSet`
      - `TreeSet`
  - Sorting tools
  - Design
  - Testing

Reminders

- **Finish Project 4**
  - **Due Friday**
- Review chapters 16 and 18 and notes
- Look over labs, quizzes, and projects to prepare
- Final Exam:
  - Monday, April 27, 2020
  - 10:15 a.m. to 12:15 p.m.