Topic 4
Exceptions and File I/O

"A slipping gear could let your M203 grenade launcher fire when you least expect it. That would make you quite unpopular in what's left of your unit."

- *THE U.S. Army's PS magazine, August 1993,* quoted in *The Java Programming Language, 3rd edition*

When Good Programs Go Bad

- A variety of errors can occur when a program is running. For example:
  - (real) user input error. bad url
  - device errors. remote server unavailable
  - physical limitations. full disk
  - code errors. interact with code that does not fulfill its contact (pre and post conditions)
- when an error occurs
  - return to safe state, save work, exit gracefully
- error handling code may be far removed from code that caused the error

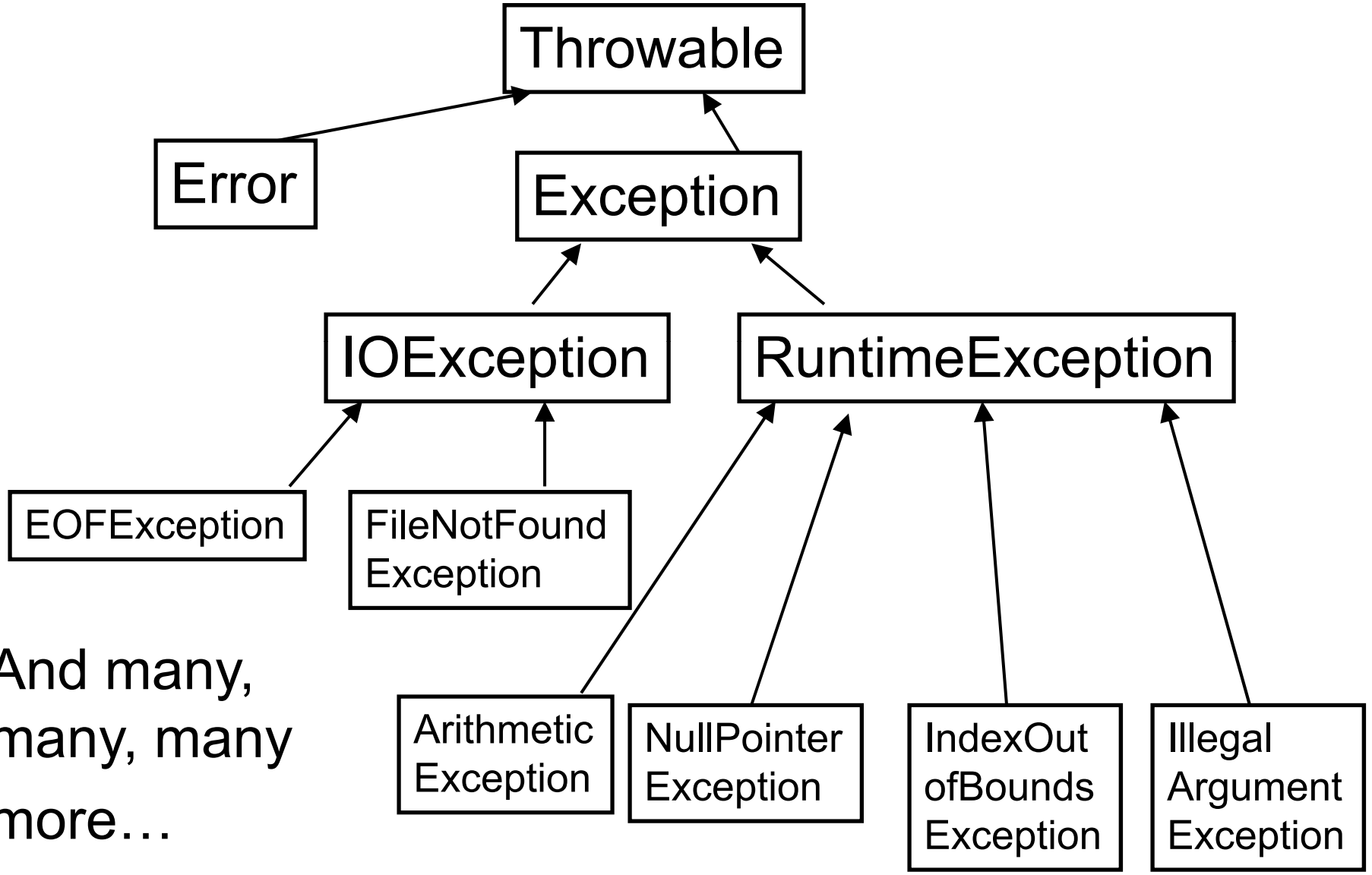
How to Handle Errors?

- It is possible to detect and handle errors of various types.
- Problem: this complicates the code and makes it harder to understand.
  - the error detection and error handling code have little or nothing to do with the *real* code is trying to do.
- A tradeoff between ensuring correct behavior under all possible circumstances and clarity of the code

Exceptions

- Many languages, including Java use a mechanism know as *Exceptions* to handle errors at runtime
  - In Java Exception is a class with many descendants.
  - **ArrayIndexOutOfBoundsException**
  - **NullPointerException**
  - **FileNotFoundException**
  - **ArithmeticException**
  - **IllegalArgumentException**

Partial Exceptions Hierarchy



And many, many, many more…

Creating Exceptions

- As a program runs, if a situation occurs that is handled by exceptions then an Exception is *thrown.*
  - An Exception object of the proper type is created
  - flow of control is transferred from the current block of code to code that can handle or deal with the exception
  - the normal flow of the program stops and error handling code takes over (if it exists.)

Attendance Question 1

Is it possible for the following method to result in an exception?

```
// pre: word != null
public static void printLength(String word){
    String output = "Word length is " + word.length();
    System.out.println( output );
}
```

A. Yes

B. No

Unchecked Exceptions

- Exceptions in Java fall into two different categories
  - *checked (other than Runtime) and unchecked (Runtime)*
- unchecked exceptions are ***completely preventable*** and should never occur.
  - They are caused by logic errors, created by us, the programmers.
- Descendents of the RuntimeException class
- Examples: ArrayIndexOutOfBoundsException, NullPointerException, ArithmeticException
- There does not *need* to be special error handling code
  - just regular error prevention code
- If error handling code was required programs would be unwieldy because so many Java statements have the possibility of generating or causing an unchecked Exception

Checked Exceptions

- "Checked exceptions represent conditions that, although exceptional, can reasonably be expected to occur, and if they do occur must be dealt with in some way.[other than the program terminating.]"
  - *Java Programming Language third edition*
- Unchecked exceptions are due to a programming logic error, our fault and preventable if coded correctly.
- Checked exceptions represent errors that are unpreventable by us!

Required Error Handling Code

- If you call a method that can generate a checked exception you must choose how to deal with that possible error
- For example one class for reading from files is the FileReader class

```
public FileReader(String fileName)
  throws FileNotFoundException
```

- This constructor has the possibility of throwing a `FileNotFoundException`
- `FileNotFoundException` is a checked exception

Checked Exceptions in Code

- If we have code that tries to build a FileReader we must deal with the possibility of the exception

```
import java.io.FileReader;

public class Tester
{
	public int countChars(String fileName)
	{	FileReader r = new FileReader(fileName);
		int total = 0;
		while( r.ready() )
		{	r.read();
			total++;
		}
		r.close();
		return total;
	}
}
```

- The code contains a syntax error. "unreported exception java.io.FileNotFoundException; must be caught or declared to be thrown."

Handling Checked Exceptions

- In the code on the previous slide there are in fact 4 statements that can generate checked exceptions.
  - The FileReader constructor
  - the ready method
  - the read method
  - the close method
- To deal with the exceptions we can either state this method throws an Exception of the proper type or handle the exception within the method itself

Methods that throw Exceptions

- It may be that we don't know how to deal with an error within the method that can generate it
- In this case we will pass the buck to the method that called us
- The keyword `throws` is used to indicate a method has the possibility of generating an exception of the stated type
- Now any method calling ours must also throw an exception or handle it

Using the `throws` Keyword

```
public int countChars(String fileName)
      throws FileNotFoundException, IOException
{     int total = 0;
      FileReader r = new FileReader(fileName);
      while( r.ready() )
      {     r.read();
            total++;
      }
      r.close();
      return total;
}
```

- Now any method calling ours must also throw an exception or handle it

Using `try-catch` Blocks

- If you want to handle the a checked exception locally then use use the keywords `try` and `catch`
- the code that could cause an exception is placed in a block of code preceded by the keyword `try`
- the code that will handle the exception if it occurs is placed in a block of code preceded by the keyword `catch`

Sample `try` and `catch` Blocks

```
public int countChars(String fileName)
{       int total = 0;
        try
        {       FileReader r = new FileReader(fileName);
                while( r.ready() )
                {       r.read();
                        total++;
                }
                r.close();
        }
        catch(FileNotFoundException e)
        {       System.out.println("File named "
                        + fileName + "not found. " + e);
                total = -1;
        }
        catch(IOException e)
        {       System.out.println("IOException occured " +
                        "while counting chars. " + e);
                total = -1;
        }
        return total;
}
```

Mechanics of `try` and `catch`

- Code that could cause the checked exception is placed in a try block
  - note how the statements are included in one try block.
  - Each statement could be in a separate try block with an associated catch block, but that is very unwieldy (see next slide)
- Each try block must have 1 or more associated catch blocks
  - code here to handle the error. In this case we just print out the error and set result to -1

Gacky `try catch` Block

```
public int countChars3(String fileName)
{       int total = 0;
        FileReader r = null;
        try
        {       r = new FileReader(fileName);      }
        catch(FileNotFoundException e)
        {       System.out.println("File named "
                        + fileName + "not found. " + e);
                total = -1;       }
        try
        {       while( r.ready() )
                {       try
                        {       r.read();         }
                        catch(IOException e)
                        {       System.out.println("IOException "
                                        + "occurred while counting "
                                        + "chars. " + e);
                                total = -1;
                        }
                        total++;
                }
        }
        catch(IOException e)
        {     System.out.println("IOException occurred while counting chars. " + e);
              total = -1;}
        try
        {     r.close();
        }
        catch(IOException e)
        {     System.out.println("IOException occurred while counting chars. " + e);
              total = -1;}
        return total;
}
```

More `try` `catch` Mechanics

- If you decide to handle the possible exception locally in a method with the `try` block you must have a corresponding `catch` block
- the `catch` blocks have a parameter list of 1
- the parameter must be `Exception` or a descendant of `Exception`
- Use multiple `catch` blocks with one `try` block in case of multiple types of `Exception`s

What Happens When Exceptions Occur

- If an exception is thrown then the normal flow of control of a program halts
- Instead of executing the regular statements the Java Runtime System starts to search for a matching catch block
- The first matching catch block based on data type is executed
- When the catch block code is completed the program does not "go back" to where the exception occurred.
  - It finds the next regular statement after the catch block

Counting Chars Again

```
public int countChars(String fileName)
{  int total = 0;
   try
   {    FileReader r = new FileReader(fileName);
        while( r.ready() )
        {       r.read();// what happens in an exception occurs?
                total++;
        }
        r.close();
   }
   catch(FileNotFoundException e)
   {    System.out.println("File named "
                        + fileName + "not found. " + e);
        total = -1;
   }
   catch(IOException e)
   {    System.out.println("IOException occured " +
                "while counting chars. " + e);
        total = -1;
   }
   return total;
}
```

Throwing Exceptions Yourself

- if you wish to throw an exception in your code you use the `throw` keyword
- Most common would be for an unmet precondition

```
public class Circle
{     private int iMyRadius;

      /** pre: radius > 0
       */
      public Circle(int radius)
      {     if (radius <= 0)
                  throw new IllegalArgumentException
                        ("radius must be > 0. "
                        + "Value of radius: " + radius);
            iMyRadius = radius;
      }
}
```

Attendance Question 2

What is output by the method `badUse` if it is called with the following code?

```
int[] nums = {3, 2, 6, 1};
badUse( nums );

public static void badUse(int[] vals){
     int total = 0;
     try{
          for(int i = 0; i < vals.length; i++){
               int index = vals[i];
               total += vals[index];
          }
     }
     catch(Exception e){
          total = -1;
     }
     System.out.println(total);
}
```

A. 1 B. 0 C. 3 D. -1 E. 5

Attendance Question 3

Is the use of a try-catch block on the previous question a proper use of try-catch blocks?

A. Yes

B. No

Error Handling, Error Handling Everywhere!

- Seems like a lot of choices for error prevention and error handling
  - normal program logic, e.g. if's for loop counters
  - assertions
  - try – catch block
- When is it appropriate to use each kind?

Error Prevention

- Us program logic, (ifs , fors) to prevent logic errors and unchecked exceptions
  - dereferencing a null pointer, going outside the bounds of an array, violating the preconditions of a method you are calling. e.g. the `charAt` method of the `String` class
  - use assertions as checks on your logic
    - you checked to ensure the variable `index` was within the array bounds with an if 10 lines up in the program and you are SURE you didn't alter it.
    - Use an `assert` right before you actually access the array

```
if( inbounds(index) )
{   // lots of related code
    // use an assertion before accessing
    arrayVar[index] = foo;
}
```

Error Prevention

- in 307 asserts can be used to check preconditions
  - Standard Java style is to use Exceptions
- Use try/catch blocks on checked exceptions
  - In general, don't use them to handle unchecked exceptions like NPE or AIOBE
- One place it is reasonable to use try / catch is in testing suites.
  - put each test in a try / catch. If an exception occurs that test fails, but other tests can still be run

File Input and Output

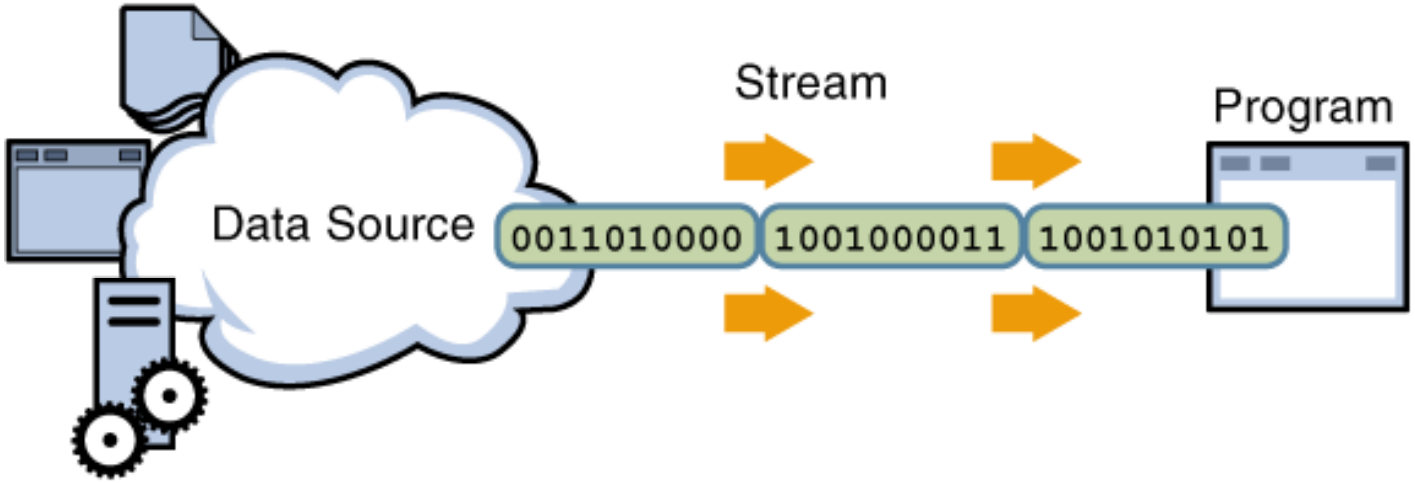
- Programs must often read from and write to files
  - large amounts of data
  - data not known at runtime
  - data that changes over time
- Each programming language has its own way of handling input and output
  - involves dealing with the operating system
  - if possible try to hide that fact as much as possible
- Java attempts to standardize input and output with the notion of a *stream,* an ordered sequence of data that has a source or destination.

Streams?

Dr. Egon Spengler:	Don't cross the streams.
Dr: Peter Venkman:	Why not?
Dr. Egon Spengler:	It would be bad.
Dr. Peter Venkman:	I'm fuzzy on the whole good/bad thing. what do you mean by "bad"?
Dr. Egon Spengler:	Try to imagine all life as you know it stopping instantaneously and every molecule in your body exploding at the speed of light.
Dr. Peter Venkman:	That's bad. Okay. Alright, important safety tip. Thanks Egon.

Streams

- A stream serves as a connection between your program and an external source or destination for bytes and bits
  - could be standard input or output, files, network connections, or other programs



Lots of Streams

- Java has over sixty (60!) different stream types in its java.io package
- part of the reason input and output are so difficult to understand in Java is the size and diversity of the IO library
- The type of stream you use depends on what you are trying to do
  - even then there are multiple options

Working with Files in Java

- Data is stored in digital form, 1s and 0s
- Work with these in packages of 8, the byte
- The IO library creates higher level abstractions so we think we are working with characters, Strings, or whole objects
- Some abstract classes
  - InputStream, OutputStream, Reader, and Writer
  - InputStream and OutputStream represent the flow of data (a stream)
  - Reader and Writer are used to read the data from a stream or put the data in a stream
  - *convenience classes* exist to make things a little easier

The Scanner class

- A class to make reading from source of input easier. New in Java 5.0
- Constructors

  Scanner(InputStream)

  Scanner(File)
- Methods to read lines from input

  boolean hasNextLine()
  String nextLine()
- Methods to read ints

  int readInt(), boolean hasNext()

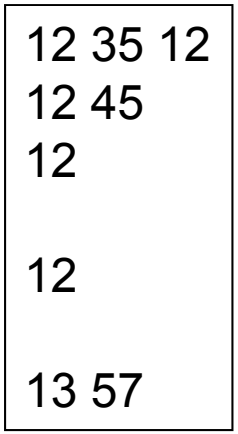
Scanner and Keyboard Input

- No exceptions thrown!
  - no try – catch block necessary!
- Set delimiters with regular expressions, default is whitespace

```
Scanner s = new Scanner(System.in);

System.out.print("Enter your name: ");
String name = s.nextLine();

System.out.print("Press Enter to continue: ");
s.nextLine();
```

Hooking a Scanner up to a File

```
import java.util.Scanner;
import java.io.File;
import java.io.IOException;

public class ReadAndPrintScores
{
    public static void main(String[] args)
    {   try
        {   Scanner s = new Scanner( new File("scores.dat") );
            while( s.hasNextInt() )
            {   System.out.println( s.nextInt() );
            }
             s.close();
        }
        catch(IOException e)
        {       System.out.println( e );
        }
    }
}
```



scores.dat

Writing to a File

```
//sample code to write 100 random ints to a file, 1 per line

import java.io.PrintStream;
import java.io.IOException;
import java.io.File;

import java.util.Random;

public class WriteToFile
{       public static void main(String[] args)
        {       try
                {       PrintStream writer = new PrintStream( new
                                File("randInts.txt"));
                        Random r = new Random();
                        final int LIMIT = 100;

                        for(int i = 0; i < LIMIT; i++)
                        {       writer.println( r.nextInt() );
                        }
                        writer.close();
                }
                catch(IOException e)
                {       System.out.println("An error occurred " +
                        + "while trying to write to the file");
                }
        }
}
```

Reading From a Web Page

```
public static void main(String[] args) {
    try {
       String siteUrl = "http://www.cs.utexas.edu/~scottm/cs307");
     URL mySite = new URL(siteURL);
       URLConnection yc = mySite.openConnection();
       Scanner in =
          new Scanner(new InputStreamReader(yc.getInputStream()));
       int count = 0;
       while (in.hasNext()) {
          System.out.println(in.next());
          count++;
       }
       System.out.println("Number of tokens: " + count);
       in.close();
    } catch (Exception e) {
       e.printStackTrace();
    }
}
```