Exceptions and Text File I/O

Introduction to Programming and Computational Problem Solving - 2

CSE 8B

Lecture 14

Announcements

- Assignment 6 is due May 24, 11:59 PM
  - Upgrade beginning May 27, 12:01 AM
- Assignment 7 will be released May 24
  - Due Jun 1, 11:59 PM
- Educational research study
  - May 26, weekly survey

Exceptions

- Exceptions are runtime errors caused by your program and external circumstances
  - These errors can be caught and handled by your program

Example: integer divide by zero

```
import java.util.Scanner;

public class Quotient {
  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);

    // Prompt the user to enter two integers
    System.out.print("Enter two integers: ");
    int number1 = input.nextInt();
    int number2 = input.nextInt();

    System.out.println(number1 + " / " + number2 + " is " +
      (number1 / number2));
  }
}
```

```
Exception in thread "main" java.lang.ArithmeticException: / by zero
```

Example: integer divide by zero

- Exception in thread "main" java.lang.ArithmeticException: / by zero
- First approach
  - Mitigate exception with if statement
  - Create a method, so we can reuse it

Example: integer divide by zero

```
import java.util.Scanner;

public class QuotientWithMethod {
  public static int quotient(int number1, int number2) {
    if (number2 == 0) {
      System.out.println("Divisor cannot be zero");
      System.exit(1);
    }

    return number1 / number2;
  }

  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);

    // Prompt the user to enter two integers
    System.out.print("Enter two integers: ");
    int number1 = input.nextInt();
    int number2 = input.nextInt();

    int result = quotient(number1, number2);
    System.out.println(number1 + " / " + number2 + " is "
      + result);
  }
}
```

Problem:
a method should
never terminate
a program

Example: integer divide by zero

- Exception in thread "main" java.lang.ArithmeticException: / by zero
- First approach
  - Mitigate exception with if statement
  - Create a method, so we can reuse it
    - Problem: a method should never terminate a program
- Second approach
  - Have the method notify the caller

Example: integer divide by zero

```
import java.util.Scanner;

public class QuotientWithException {
  public static int quotient(int number1, int number2) {
    if (number2 == 0)
      throw new ArithmeticException("Divisor cannot be zero");

    return number1 / number2;
  }

  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);

    // Prompt the user to enter two integers
    System.out.print("Enter two integers: ");
    int number1 = input.nextInt();
    int number2 = input.nextInt();

    try {
      int result = quotient(number1, number2);
      System.out.println(number1 + " / " + number2 + " is "
        + result);
    }
    catch (ArithmeticException ex) {
      System.out.println("Exception: an integer " +
        "cannot be divided by zero ");
    }

    System.out.println("Execution continues ...");
  }
}
```

Throw an ArithmeticException

Try something that may throw an exception

Catch an ArithmeticException

Handle the caught exception in the catch block

Exception handling

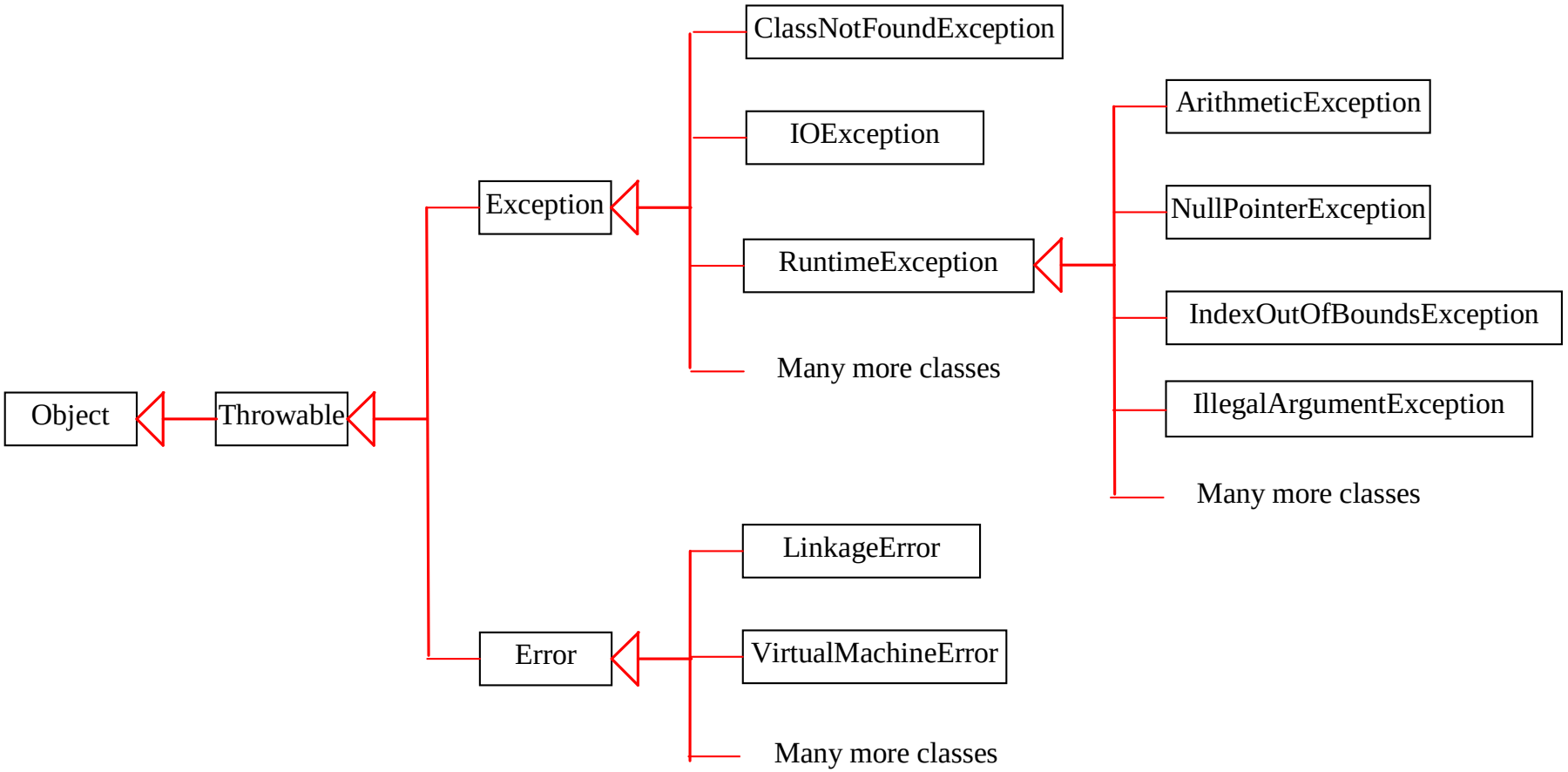
- Exception handling enables a method to throw an exception to its caller
- Without this capability, a method must handle the exception or terminate the program
- Separates
  - The detection of an error
  - The handling of an error

Exception types

- Exceptions are objects
  - Remember, objects are instances of classes
- The root class for exception is `java.lang.Throwable`

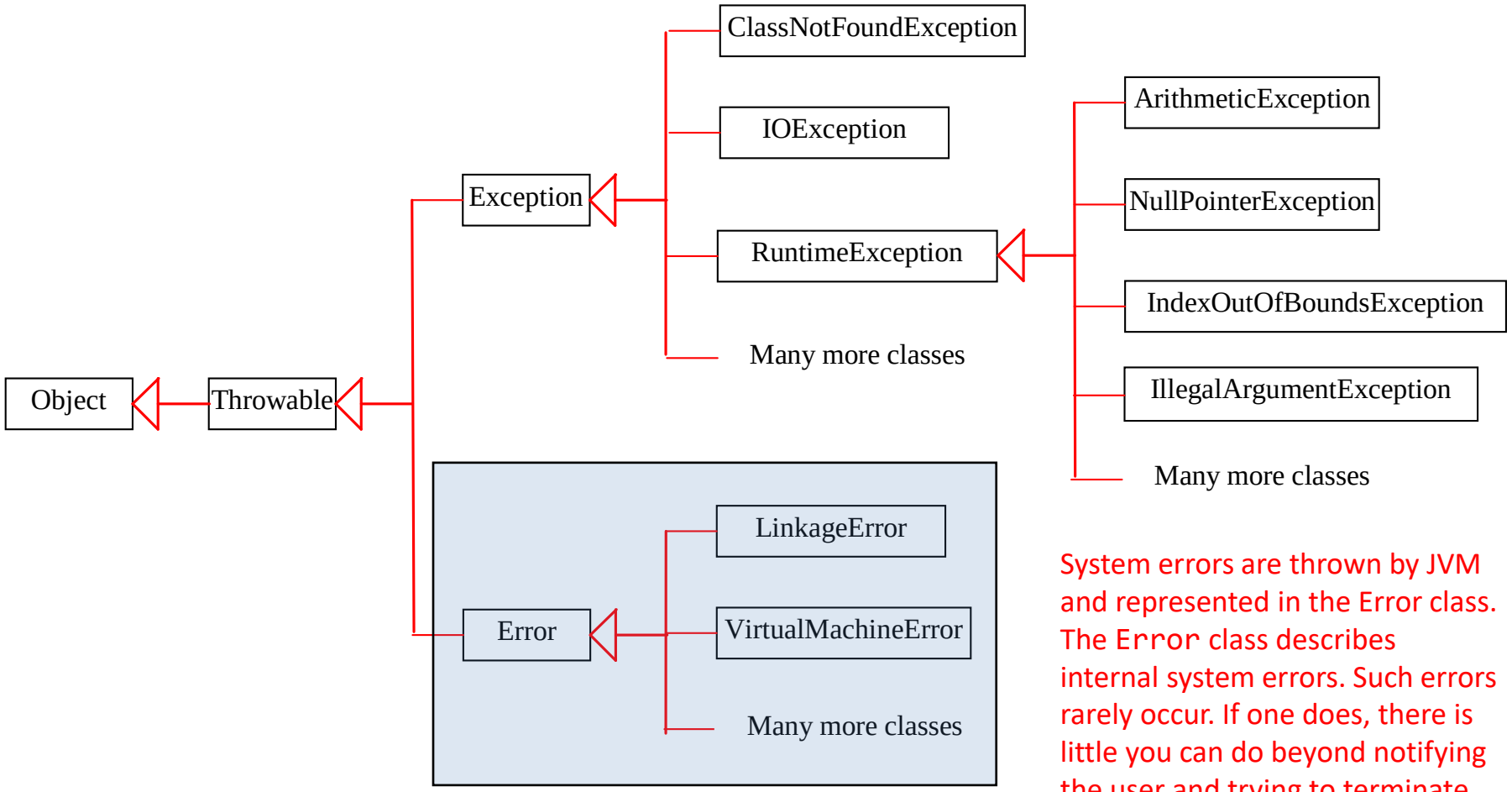
  https://docs.oracle.com/javase/8/docs/api/java/lang/Throwable.html
  https://docs.oracle.com/en/java/javase/11/docs/api/java.base/java/lang/Throwable.html
  - Three major types
    - System errors
    - Exceptions
    - Runtime Exceptions

Exception types



Error

https://docs.oracle.com/javase/8/docs/api/java/lang/Error.html
https://docs.oracle.com/en/java/javase/11/docs/api/java.base/java/lang/Error.html

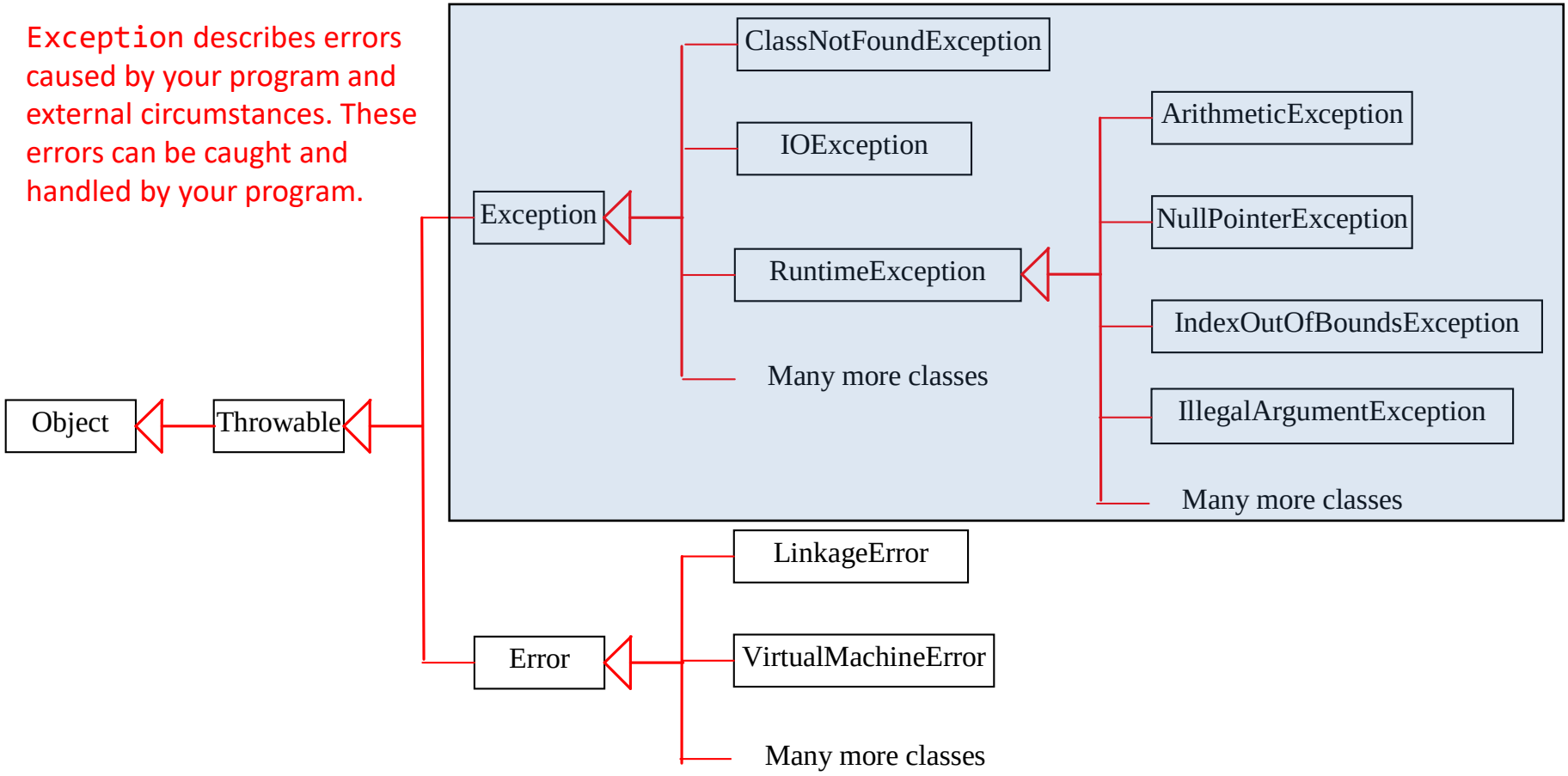


System errors are thrown by JVM and represented in the Error class. The `Error` class describes internal system errors. Such errors rarely occur. If one does, there is little you can do beyond notifying the user and trying to terminate the program gracefully.

Exception

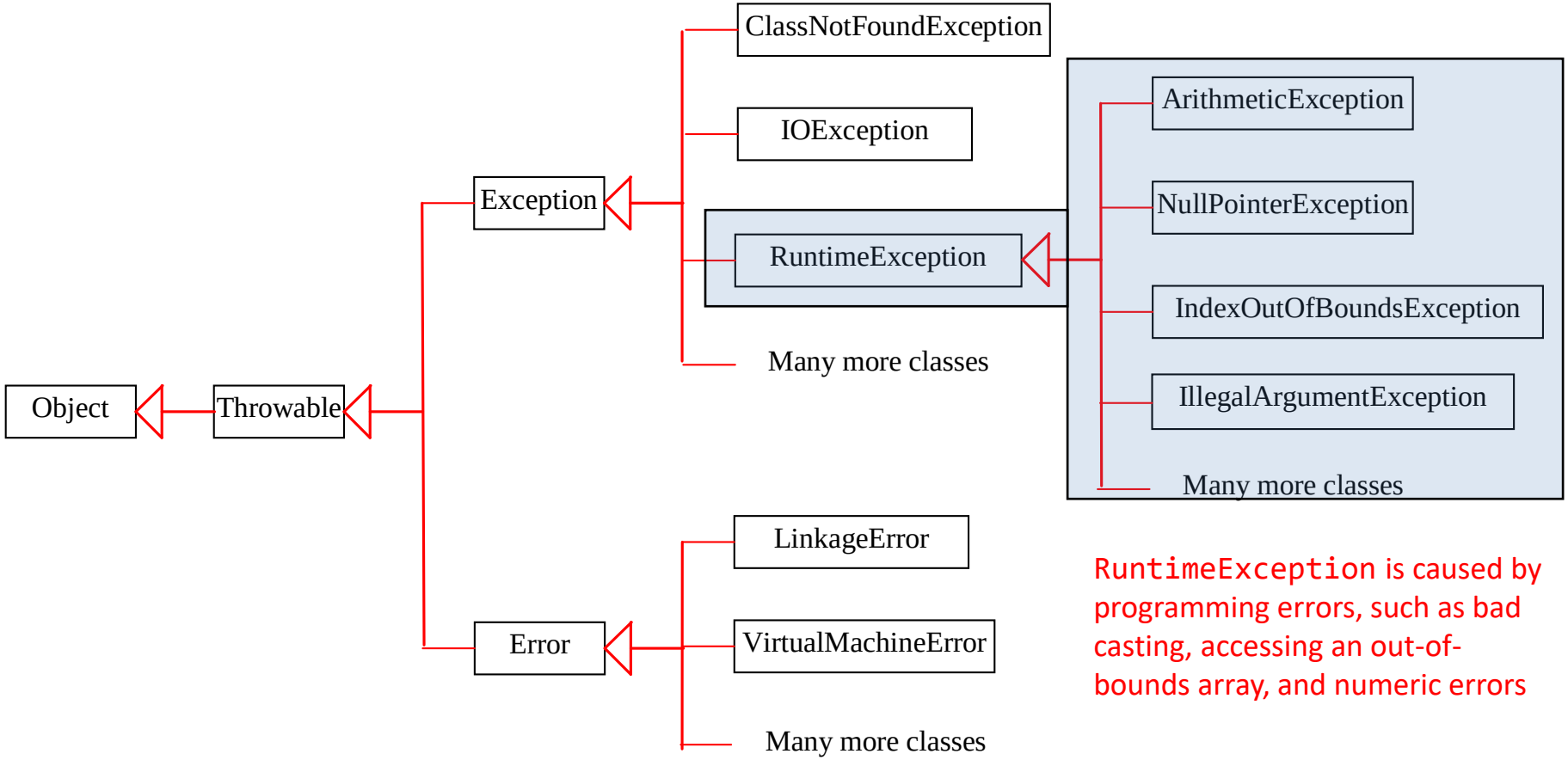
https://docs.oracle.com/javase/8/docs/api/java/lang/Exception.html
https://docs.oracle.com/en/java/javase/11/docs/api/java.base/java/lang/Exception.html

`Exception` describes errors caused by your program and external circumstances. These errors can be caught and handled by your program.



RuntimeException

https://docs.oracle.com/javase/8/docs/api/java/lang/RuntimeException.html
https://docs.oracle.com/en/java/javase/11/docs/api/java.base/java/lang/RuntimeException.html



`RuntimeException` is caused by programming errors, such as bad casting, accessing an out-of-bounds array, and numeric errors

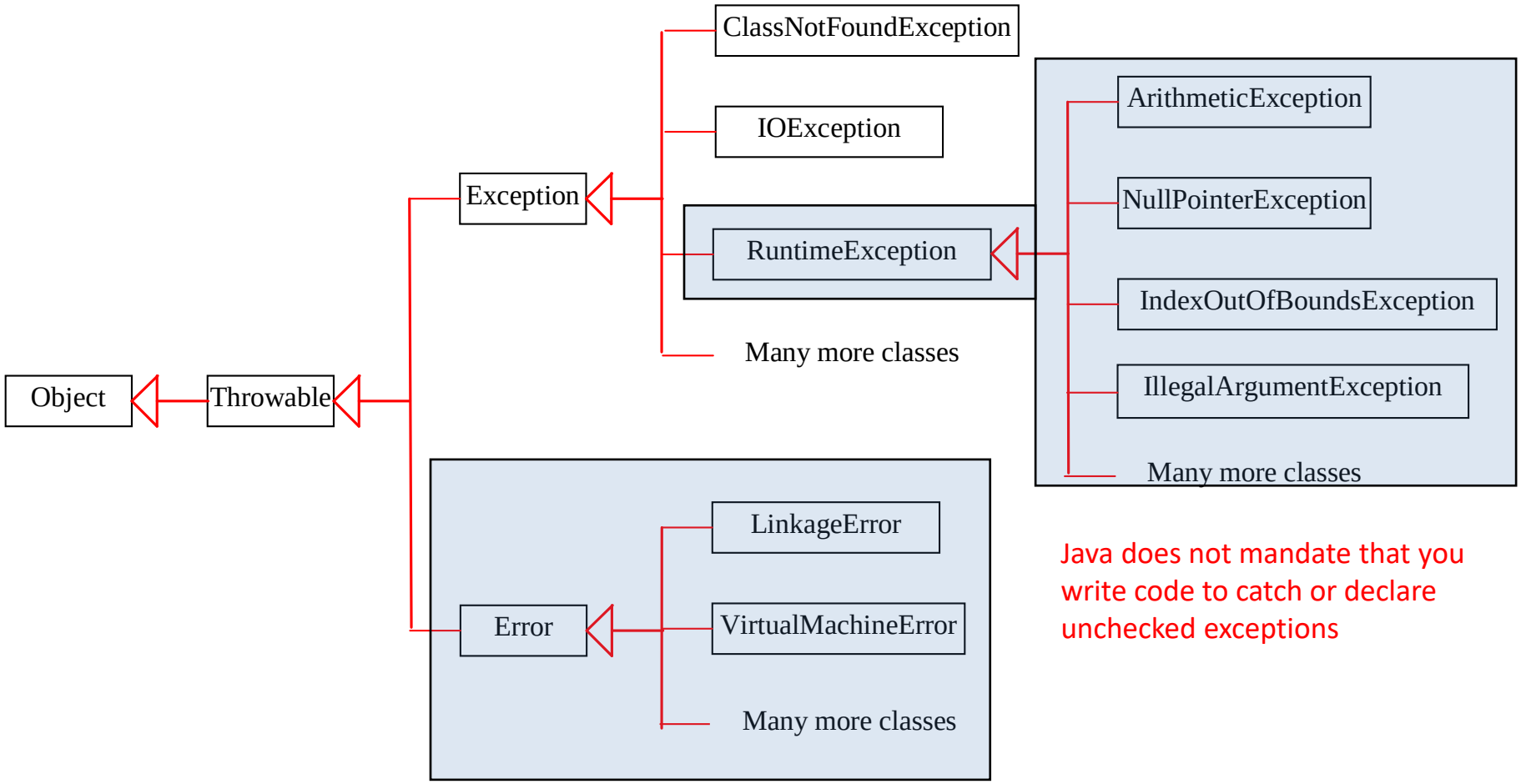
Exception types

- Exceptions are objects
  - Remember, objects are instances of classes
- The root class for exception is `java.lang.Throwable`
  - All Java exception classes inherit directly or indirectly from Throwable
  - Use overridden `getMessage()` member method
- You can create your own exception classes by extending `Exception` or a subclass of `Exception`

Unchecked exceptions vs. checked exceptions

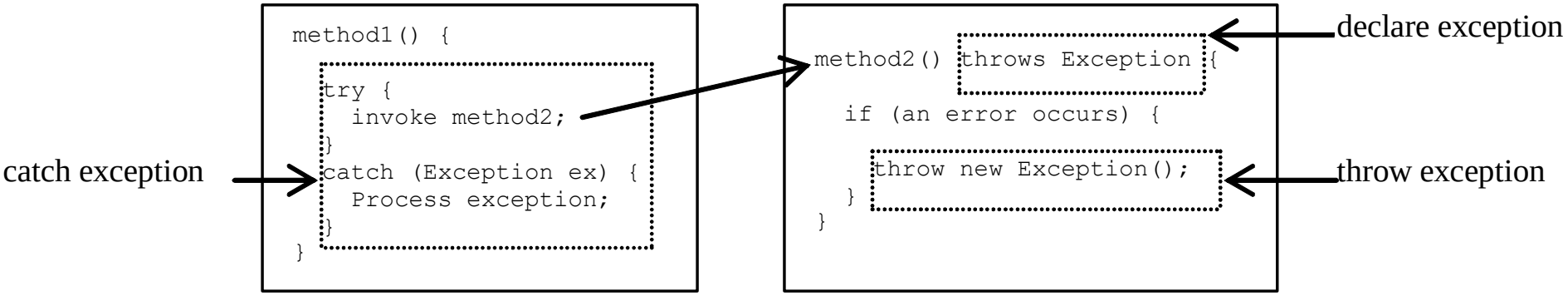
- `RuntimeException`, `Error`, and their subclasses are known as *unchecked exceptions*
  - Usually programming logic errors that are uncrecoverable
  - These should be corrected in the program
- All other exceptions are known as *checked exceptions*
  - **The compiler forces the programmer to check and deal with these exceptions**

Unchecked exceptions



Java does not mandate that you write code to catch or declare unchecked exceptions

Declaring, throwing, and catching exceptions



Declaring exceptions

- Every method must state the types of *checked exceptions* it might throw
  - This is called *declaring exceptions*
- Examples

```
public void myMethod()
    throws IOException

public void myMethod()
    throws IOException, OtherException
```

Throwing exceptions

- When the program detects an error, the program can create an instance of an appropriate exception type and throw it
  - This is called *throwing an exception*
- For example

```
// Set a new radius
public void setRadius(double newRadius)
    throws IllegalArgumentException {
  if (newRadius > 0)
    radius =  newRadius;
  else
    throw new IllegalArgumentException(
      "Radius cannot be negative");
}
```

Catching exceptions

- When an exception is thrown, it can be caught and handled in a `try-catch` block
  - If no exceptions are thrown in the `try` block, then the `catch` blocks are skipped
- If an exception is thrown in the `try` block, Java **skips the remaining statements in the `try` block** and starts the process of finding the code to handle the exception
  - This is called *catching an exception*

Catching exceptions

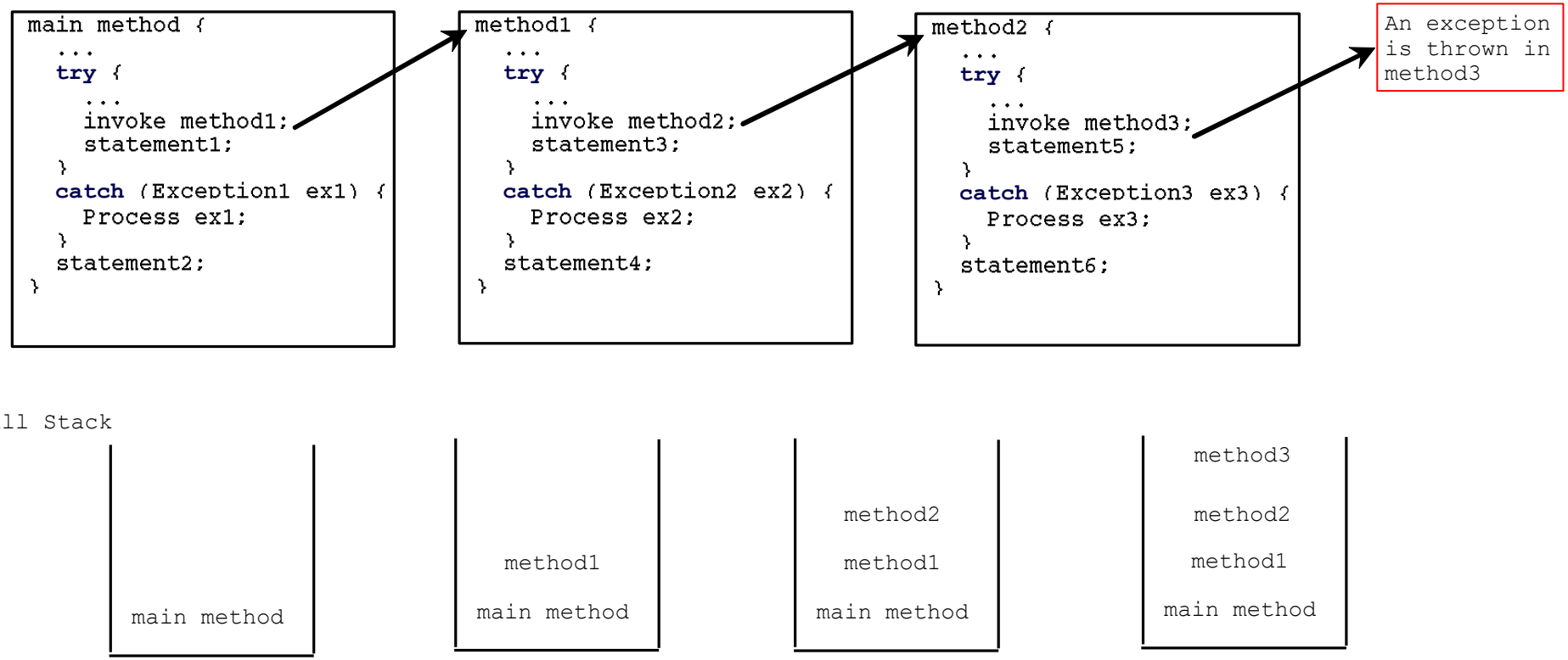
```
try {
  // Statements that may throw exceptions
}
catch (Exception1 exVar1) {
  // Handler for Exception1
}
catch (Exception2 | Exception3 | ... | ExceptionK exVar)
{
  // Same code for handling these exceptions
}
...
catch (ExceptionN exVarN) {
  // Handler for ExceptionN
}
```

The order exceptions are specified is important. A compile error occurs if a catch block for a superclass type appears before a catch block for a subclass type.

If no handler is found, then the program terminates and prints an error message on the console

Catching exceptions

- The code handling the exception is called the *exception handler*
  - It is found by *propagating the exception* backward through the call stacks, starting from the current method



Checked exceptions

- Remember, the compiler forces the programmer to check and deal with checked exceptions (i.e., any exception other than `Error` or `RuntimeException`)
- If a method declares a checked exception, you must invoke it in a `try-catch` block or declare to throw the exception in the calling method

```
void p1() {
  try {
    p2();
  }
  catch (IOException ex) {
    ...
  }
}
```

(a)

```
void p1() throws IOException {

  p2();

}
```

(b)

The `finally` clause

- The `finally` clause is always executed, regardless of whether an exception occurred

```
try {
  // statements
}
catch(TheException ex) {
  // handling statements
}
finally {
  // final statements
}
```

Rethrowing exceptions

- Java allows an exception handler to rethrow the exception if the handler cannot process the exception (or simply wants to let its caller be notified of the exception)

```
try {
  // statements
}
catch(TheException ex) {
  // handling statements before rethrowing
  throw ex;
}
```

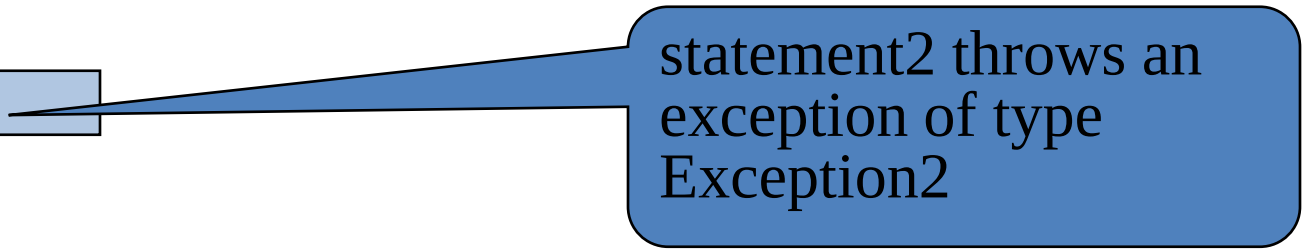
- You can also throw a new exception along with the original exception
  - This is called *chained exceptions*
    - https://docs.oracle.com/javase/tutorial/essential/exceptions/chained.html

Trace code

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
catch(Exception2 ex) {
  handling ex;
  throw ex;
}
finally {
  finalStatements;
}

nextStatement;
```

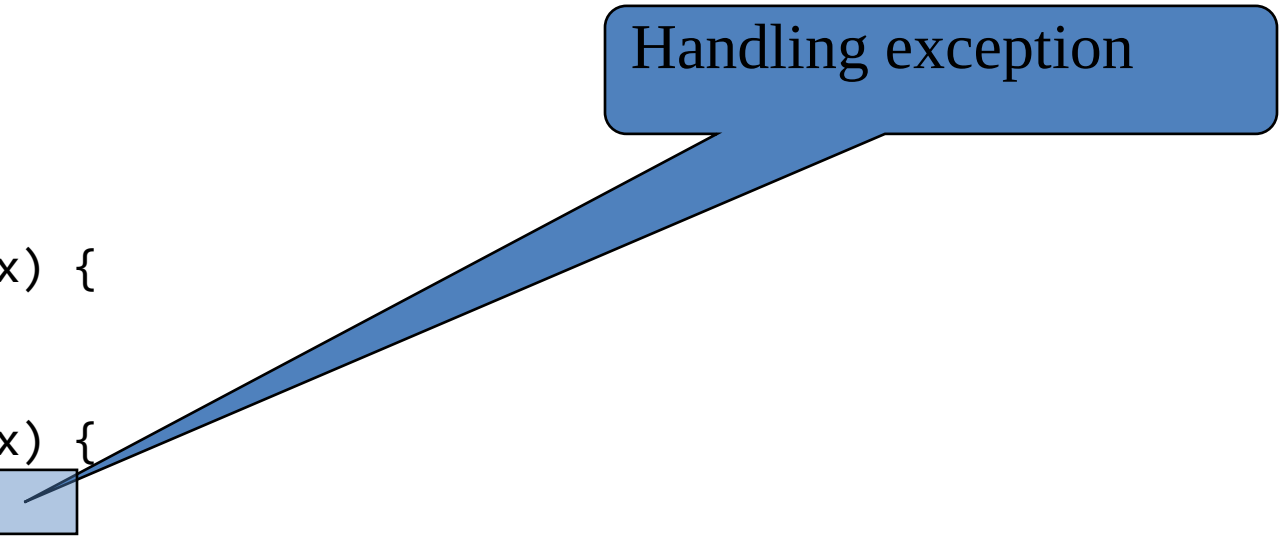
Trace code

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
catch(Exception2 ex) {
  handling ex;
  throw ex;
}
finally {
  finalStatements;
}

nextStatement;
```



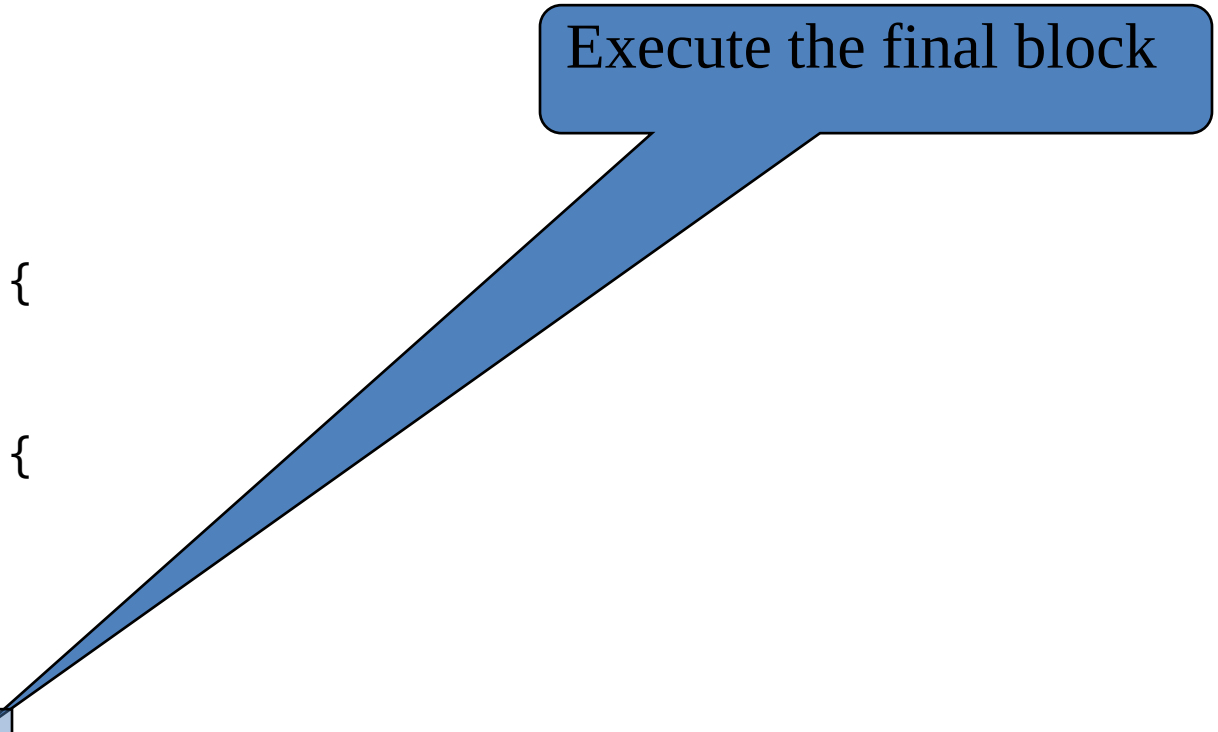
Trace code

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
catch(Exception2 ex) {
  handling ex;
  throw ex;
}
finally {
  finalStatements;
}

nextStatement;
```



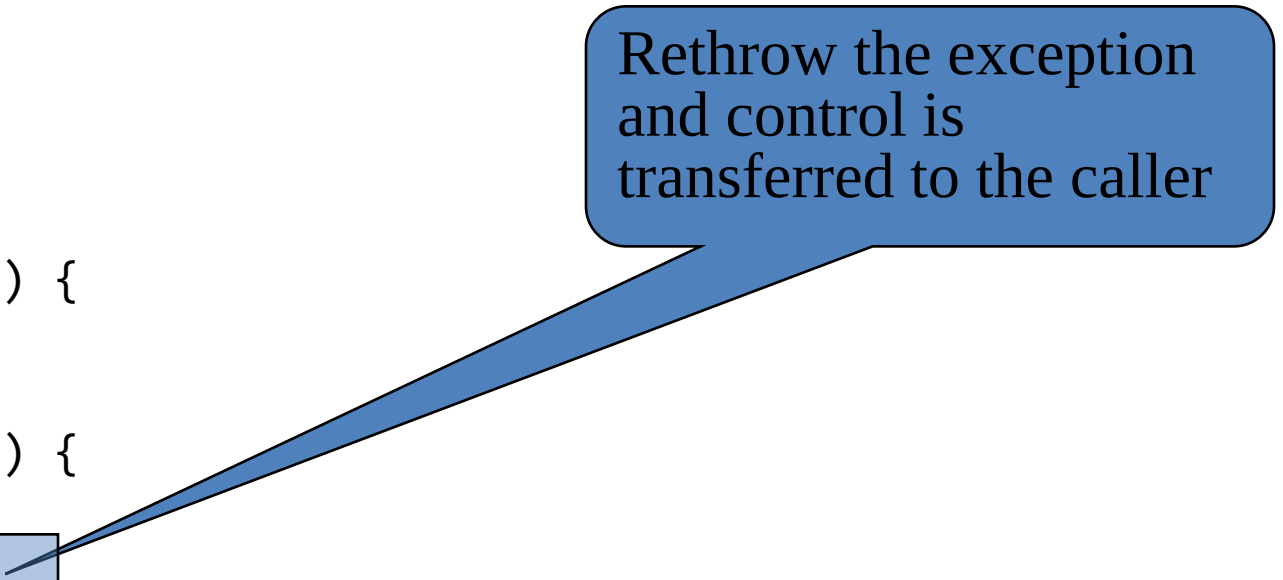
Trace code

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
catch(Exception2 ex) {
  handling ex;
  throw ex;
}
finally {
  finalStatements;
}

nextStatement;
```



Trace code

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
catch(Exception2 ex) {
  handling ex;
  throw ex;
}
finally {
  finalStatements;
}

nextStatement;
```



When to use a `try-catch` block

- Use a `try-catch` block to deal with **unexpected** error conditions
- Do not use it to deal with simple, **expected** situations
  - For example, use this

```
if (refVar != null)
  System.out.println(refVar.toString());
else
  System.out.println("refVar is null");
```

  instead of this

```
try {
  System.out.println(refVar.toString());
}
catch (NullPointerException ex) {
  System.out.println("refVar is null");
}
```

When to throw exceptions

- Remember, an exception occurs in a method
- If you want the exception to be processed by its caller, then you should create an exception object and throw it
- If you can handle the exception in the method where it occurs, then there is no need to throw it

Defining custom exception classes

- Use the exception classes in the Java API whenever possible
- If the predefined classes are insufficient, then you can define a custom exception class by extending the `java.lang.Exception` class

Exception handling

- Exception handling separates error-handling code from normal programming tasks
  - Makes programs easier to read and to modify
- The **`try`** block contains the code that is executed in **normal** circumstances
- The **`catch`** block contains the code that is executed in **exceptional** circumstances
- A method should **throw** an exception if the error needs to be handled by its caller
- Warning: exception handling usually requires more time and resources because it requires instantiating a new exception object, rolling back the call stack, and propagating the errors to the calling methods

Text I/O

- In order to perform I/O, you need to create objects using appropriate Java I/O classes
  - The objects contain the methods for reading/writing data from/to a file

    `File`
    - https://docs.oracle.com/javase/8/docs/api/java/io/File.html
    - https://docs.oracle.com/en/java/javase/11/docs/api/java.base/java/io/File.html

    `Scanner`
    - https://docs.oracle.com/javase/8/docs/api/java/util/Scanner.html
    - https://docs.oracle.com/en/java/javase/11/docs/api/java.base/java/util/Scanner.html

    `PrintWriter`
    - https://docs.oracle.com/javase/8/docs/api/java/io/PrintWriter.html
    - https://docs.oracle.com/en/java/javase/11/docs/api/java.base/java/io/PrintWriter.html

Absolute file names

- Absolute file name includes full path
  - Unix

    ```
    /home/bochoa/cse8b/assignment7/Assignment7.java
    ```

    - Java string

      ```
      String pathname =
          "/home/bochoa/cse8b/assignment7/Assignment7.java";
      ```

  - Windows

    ```
    C:\cse8b\assignment7\Assignment7.java
    ```

    - Java string

      ```
      String pathname =
          "C:\\cse8b\\assignment7\\Assignment7.java";
      ```

Relative file names

- Relative file name includes path relative to working directory
  - For example, if you are in directory `cse8b`
    - Unix

      `assignment7/Assignment7.java`

      - Java string

        ```
        String pathname = "assignment7/Assignment7.java"
        ```

    - Windows

      `assignment7\Assignment7.java`

      - Java string

        ```
        String pathname = "assignment7\\Assignment7.java"
        ```

The `File` class

- The `File` class is intended to provide an abstraction that deals with most of the machine-dependent complexities of files and path names in a machine-independent fashion
- The file name is a string
- The `File` class is a wrapper class for the file name and its directory path

java.io.File	
`+File(pathname: String)`	Creates a `File` object for the specified path name. The path name may be a directory or a file.
`+File(parent: String, child: String)`	Creates a `File` object for the child under the directory parent. The child may be a file name or a subdirectory.
`+File(parent: File, child: String)`	Creates a `File` object for the child under the directory parent. The parent is a `File` object. In the preceding constructor, the parent is a string.
`+exists(): boolean`	Returns true if the file or the directory represented by the `File` object exists.
`+canRead(): boolean`	Returns true if the file represented by the `File` object exists and can be read.
`+canWrite(): boolean`	Returns true if the file represented by the `File` object exists and can be written.
`+isDirectory(): boolean`	Returns true if the `File` object represents a directory.
`+isFile(): boolean`	Returns true if the `File` object represents a file.
`+isAbsolute(): boolean`	Returns true if the `File` object is created using an absolute path name.
`+isHidden(): boolean`	Returns true if the file represented in the `File` object is hidden. The exact definition of *hidden* is system-dependent. On Windows, you can mark a file hidden in the File Properties dialog box. On Unix systems, a file is hidden if its name begins with a period(.) character.
`+getAbsolutePath(): String`	Returns the complete absolute file or directory name represented by the `File` object.
`+getCanonicalPath(): String`	Returns the same as `getAbsolutePath()` except that it removes redundant names, such as "." and "..", from the path name, resolves symbolic links (on Unix), and converts drive letters to standard uppercase (on Windows).
`+getName(): String`	Returns the last name of the complete directory and file name represented by the `File` object. For example, new `File("c:\\book\\test.dat").getName()` returns `test.dat`.
`+getPath(): String`	Returns the complete directory and file name represented by the `File` object. For example, new `File("c:\\book\\test.dat").getPath()` returns `c:\book\test.dat`.
`+getParent(): String`	Returns the complete parent directory of the current directory or the file represented by the `File` object. For example, new `File("c:\\book\\test.dat").getParent()` returns `c:\book`.
`+lastModified(): long`	Returns the time that the file was last modified.
`+length(): long`	Returns the size of the file, or 0 if it does not exist or if it is a directory.
`+listFile(): File[]`	Returns the files under the directory for a directory `File` object.
`+delete(): boolean`	Deletes the file or directory represented by this `File` object.The method returns true if the deletion succeeds.
`+renameTo(dest: File): boolean`	Renames the file or directory represented by this `File` object to the specified name represented in dest. The method returns true if the operation succeeds.
`+mkdir(): boolean`	Creates a directory represented in this `File` object. Returns true if the the directory is created successfully.
`+mkdirs(): boolean`	Same as `mkdir()` except that it creates directory along with its parent directories if the parent directories do not exist.

The `File` class example

```
public class TestFileClass {
  public static void main(String[] args) {
    java.io.File file = new java.io.File("image/us.gif");
    System.out.println("Does it exist? " + file.exists());
    System.out.println("The file has " + file.length() + " bytes");
    System.out.println("Can it be read? " + file.canRead());
    System.out.println("Can it be written? " + file.canWrite());
    System.out.println("Is it a directory? " + file.isDirectory());
    System.out.println("Is it a file? " + file.isFile());
    System.out.println("Is it absolute? " + file.isAbsolute());
    System.out.println("Is it hidden? " + file.isHidden());
    System.out.println("Absolute path is " +
      file.getAbsolutePath());
    System.out.println("Last modified on " +
      new java.util.Date(file.lastModified()));
  }
}
```

File text I/O

- A `File` object encapsulates the properties of a file or a path, *but does not contain the methods for reading/writing data from/to a file*
- In order to perform I/O, you need to create objects using appropriate Java I/O classes
  - The objects contain the methods for reading/writing data from/to a file
- Use the `Scanner` class for reading text data from a file
- Use the `PrintWriter` class for writing text data to a file

Reading data from the console

- Create a `Scanner` object

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

  - Example

```
System.out.print("Enter a double value: ");
Scanner input = new Scanner(System.in);
double d = input.nextDouble();
```

Reading data using Scanner

- Reading data from the console

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

- Reading data from a file

```
Scanner input = new Scanner(new File(filename));
```

Reading data using Scanner

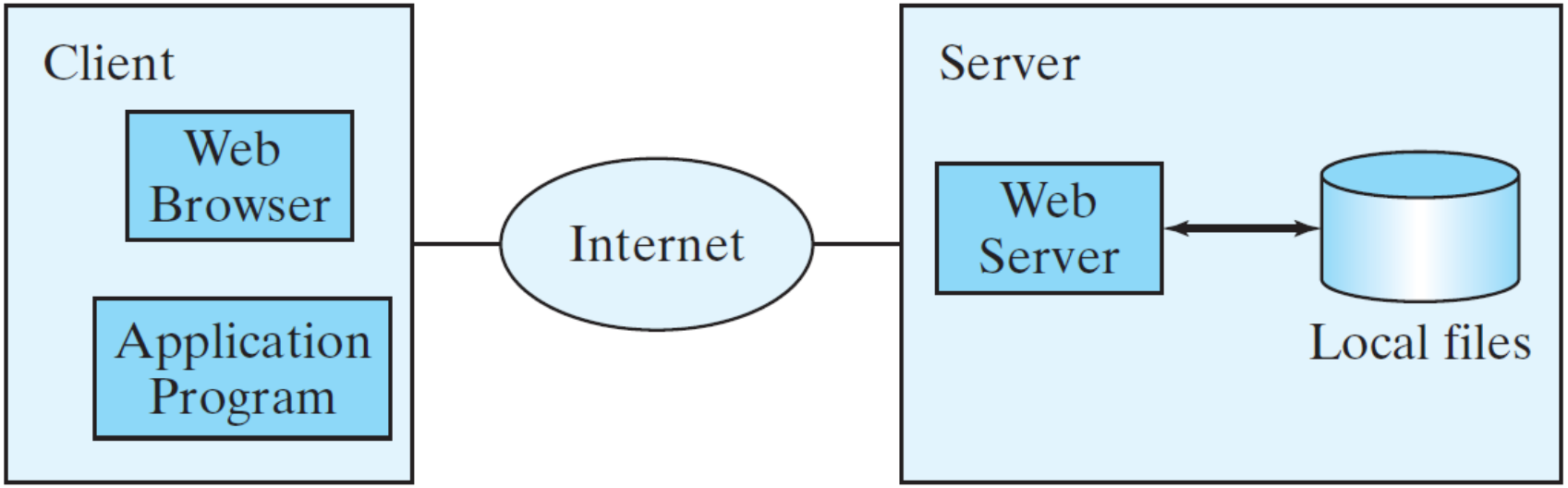
java.util.Scanner	
+Scanner(source: File)	Creates a Scanner object to read data from the specified file.
+Scanner(source: String)	Creates a Scanner object to read data from the specified string.
+close()	Closes this scanner.
+hasNext(): boolean	Returns true if this scanner has another token in its input.
+next(): String	Returns next token as a string.
+nextByte(): byte	Returns next token as a byte.
+nextShort(): short	Returns next token as a short.
+nextInt(): int	Returns next token as an int.
+nextLong(): long	Returns next token as a long.
+nextFloat(): float	Returns next token as a float.
+nextDouble(): double	Returns next token as a double.
+useDelimiter(pattern: String): Scanner	Sets this scanner's delimiting pattern.

Reading data from a file

```
public class ReadData {
  public static void main(String[] args) throws Exception {
    // Create a File instance
    java.io.File file = new java.io.File("scores.txt");

    // Create a Scanner for the file
    Scanner input = new Scanner(file);

    // Read data from a file
    while (input.hasNext()) {
      String firstName = input.next();
      String mi = input.next();
      String lastName = input.next();
      int score = input.nextInt();
      System.out.println(
        firstName + " " + mi + " " + lastName + " " + score);
    }

    // Close the file
    input.close();
  }
}
```

Reading data from the internet

- Just like you can read data from a file on the computer, you can read data from a file on the internet



Reading data from the internet

```
public class ReadFileFromURL {
  public static void main(String[] args) {
    System.out.print("Enter a URL: ");
    String URLString = new Scanner(System.in).next();

    try {
      java.net.URL url = new java.net.URL(URLString);
      int count = 0;
      Scanner input = new Scanner(url.openStream());
      while (input.hasNext()) {
        String line = input.nextLine();
        count += line.length();
      }

      System.out.println("The file size is " + count + " characters");
    }
    catch (java.net.MalformedURLException ex) {
      System.out.println("Invalid URL");
    }
    catch (java.io.IOException ex) {
      System.out.println("IO Errors");
    }
  }
}
```

Writing data using `PrintWriter`

java.io.PrintWriter	
+PrintWriter(filename: String)	Creates a PrintWriter for the specified file.
+print(s: String): void	Writes a string.
+print(c: char): void	Writes a character.
+print(cArray: char[]): void	Writes an array of character.
+print(i: int): void	Writes an int value.
+print(l: long): void	Writes a long value.
+print(f: float): void	Writes a float value.
+print(d: double): void	Writes a double value.
+print(b: boolean): void	Writes a boolean value.
Also contains the overloaded println methods.	A println method acts like a print method; additionally it prints a line separator. The line separator string is defined by the system. It is \r\n on Windows and \n on Unix.
Also contains the overloaded printf methods.	See lecture 4

Writing data to a file

```
public class WriteData {
  public static void main(String[] args) throws java.io.IOException {
    java.io.File file = new java.io.File("scores.txt");
    if (file.exists()) {
      System.out.println("File already exists");
      System.exit(0);
    }

    // Create a file
    java.io.PrintWriter output = new java.io.PrintWriter(file);

    // Write formatted output to the file
    output.print("John T Smith ");
    output.println(90);
    output.print("Eric K Jones ");
    output.println(85);

    // Close the file
    output.close();
  }
}
```

Use try-with-resources syntax

- When reading or writing programmers often forget to close the file
- The try-with-resources syntax automatically closes the files
  - Write file example

```
try (
      // Create a file
      java.io.PrintWriter output = new java.io.PrintWriter(file);
    ) {
      // Write formatted output to the file
      output.print("John T Smith ");
      output.println(90);
      output.print("Eric K Jones ");
      output.println(85);
    }
```

File I/O example

```
public class ReplaceText {
  public static void main(String[] args) throws Exception {
    // Check command line parameter usage
    if (args.length != 4) {
      System.out.println(
        "Usage: java ReplaceText sourceFile targetFile oldStr newStr");
      System.exit(1);
    }

    // Check if source file exists
    File sourceFile = new File(args[0]);
    if (!sourceFile.exists()) {
      System.out.println("Source file " + args[0] + " does not exist");
      System.exit(2);
    }

    // Check if target file exists
    File targetFile = new File(args[1]);
    if (targetFile.exists()) {
      System.out.println("Target file " + args[1] + " already exists");
      System.exit(3);
    }

    try (
      // Create input and output files
      Scanner input = new Scanner(sourceFile);
      PrintWriter output = new PrintWriter(targetFile);
    ) {
      while (input.hasNext()) {
        String s1 = input.nextLine();
        String s2 = s1.replaceAll(args[2], args[3]);
        output.println(s2);
      }
    }
  }
}
```

Next Lecture

- Abstract classes