Exception Handling

Introduction to Programming and Computational Problem Solving - 2

CSE 8B

Lecture 12

Announcements

- Assignment 6 is due Nov 9, 11:59 PM
- Quiz 6 is Nov 11
- Assignment 7 will be released Nov 9
  - Due Nov 16, 11:59 PM
- Educational research study
  - Nov 11, weekly survey
- Reading
  - Liang
    - Chapter 12

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

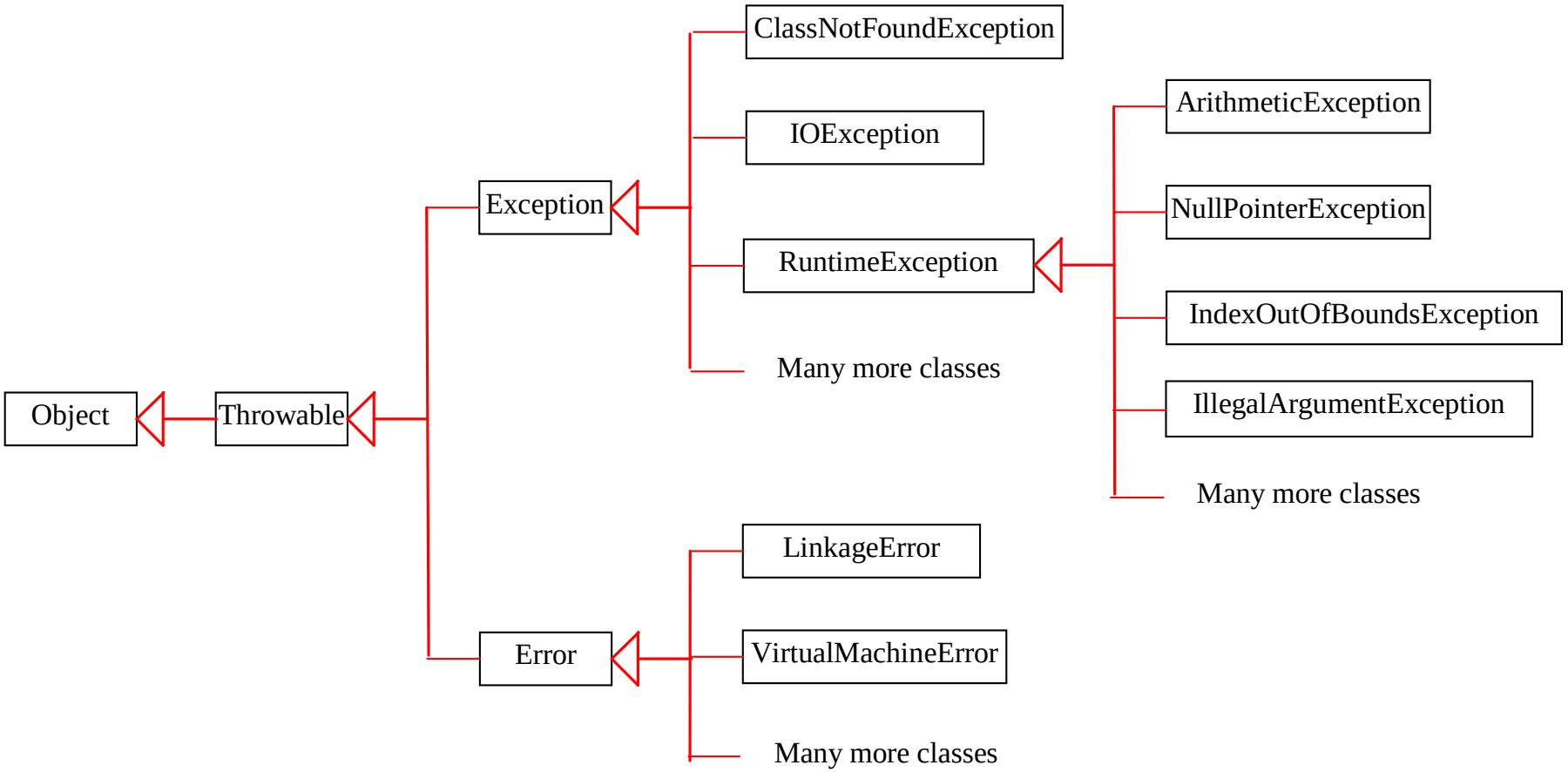
Exception handling

- 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

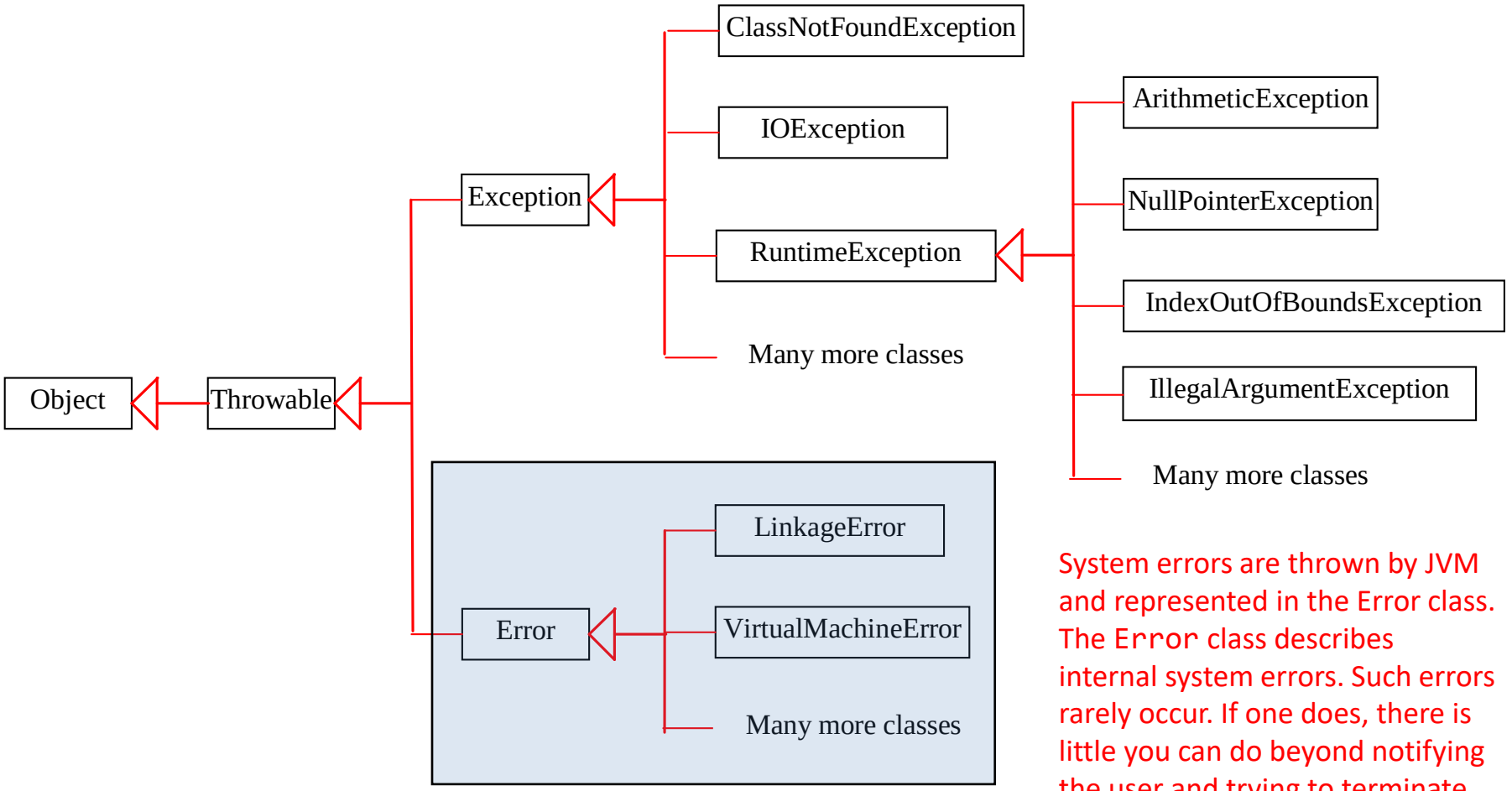
Exception types

- Exceptions are objects
  - Remember, objects are instances of classes
- The root class for exception is `java.lang.Throwable`
  - Three major types
    - System errors
    - Exceptions
    - Runtime Exceptions

Exception types



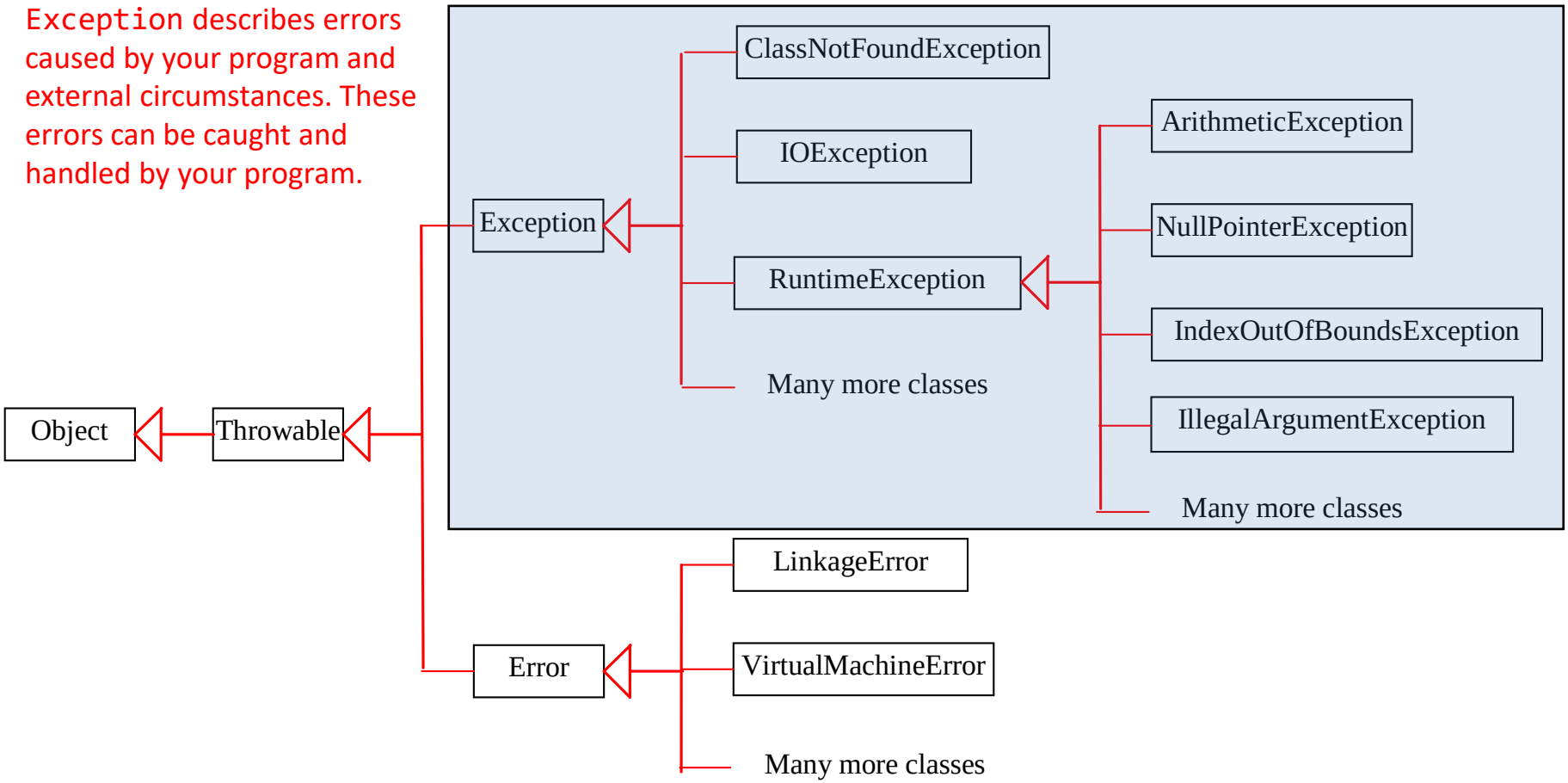
Error



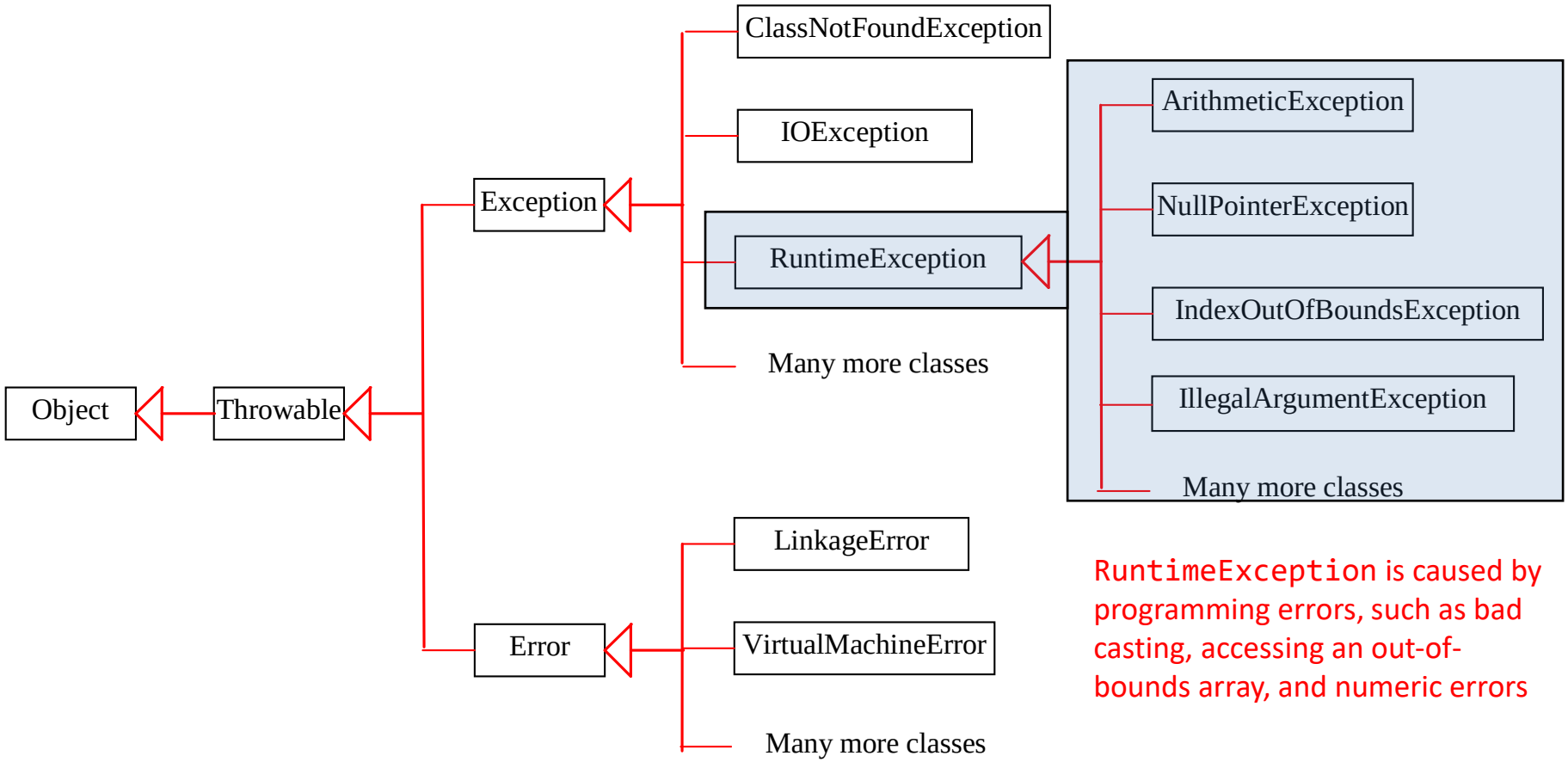
System errors are thrown by JVM and represented in the Error class. The `Error` class describes internal system errors. Such errors rarely occur. If one does, there is little you can do beyond notifying the user and trying to terminate the program gracefully.

Exception

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



RuntimeException



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

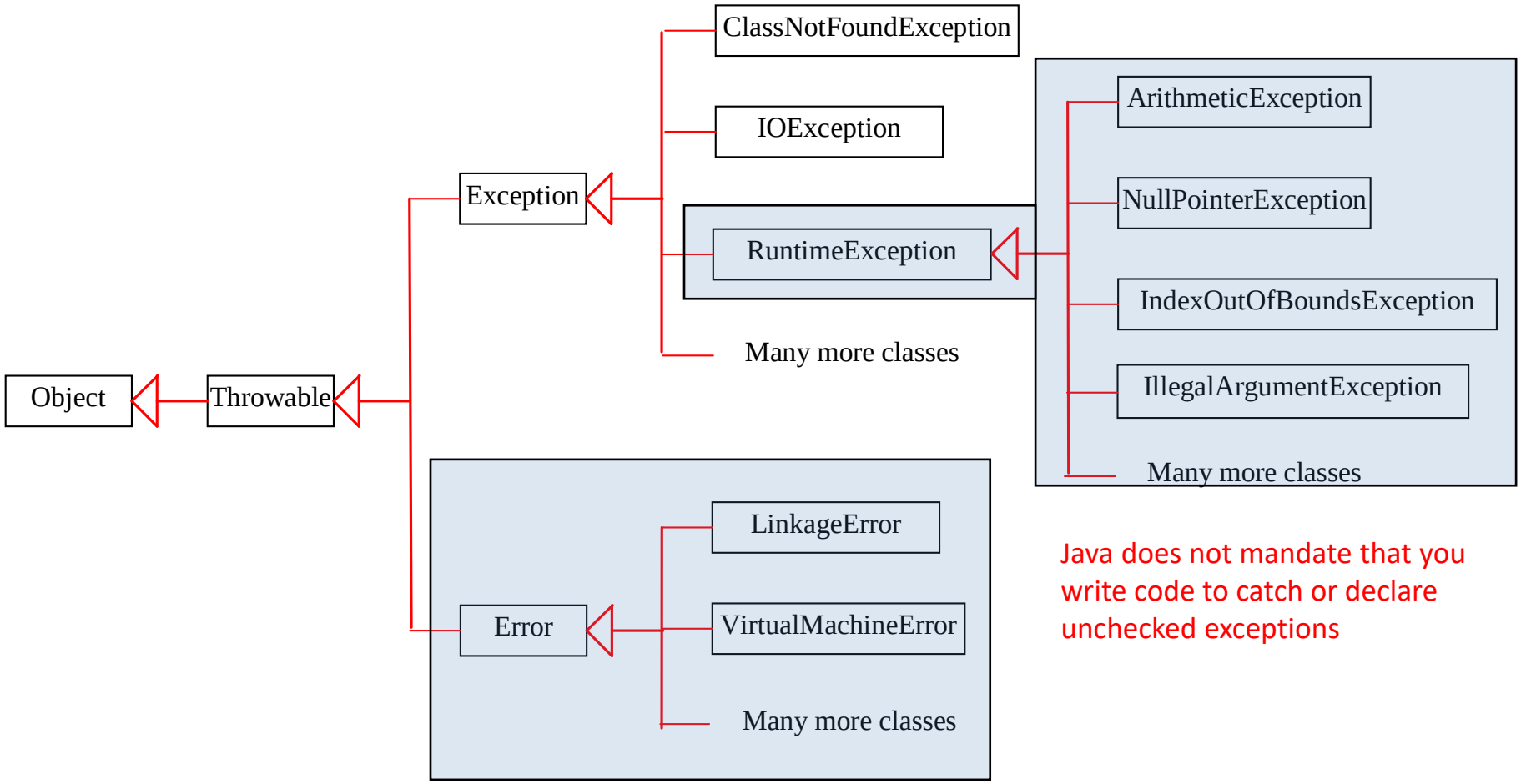
Exception types

- 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

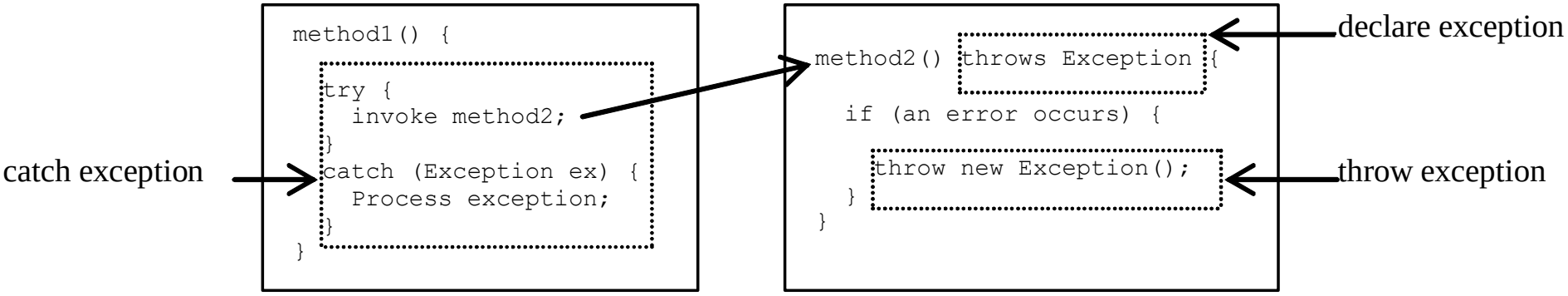
- `RuntimeException`, `Error`, and their subclasses are known as *unchecked exceptions*
  - Usually programming logic errors that are uncrecoverable
  - These should be corrected in the program
- All other exceptions are known as *checked exceptions*
  - **The compiler forces the programmer to check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

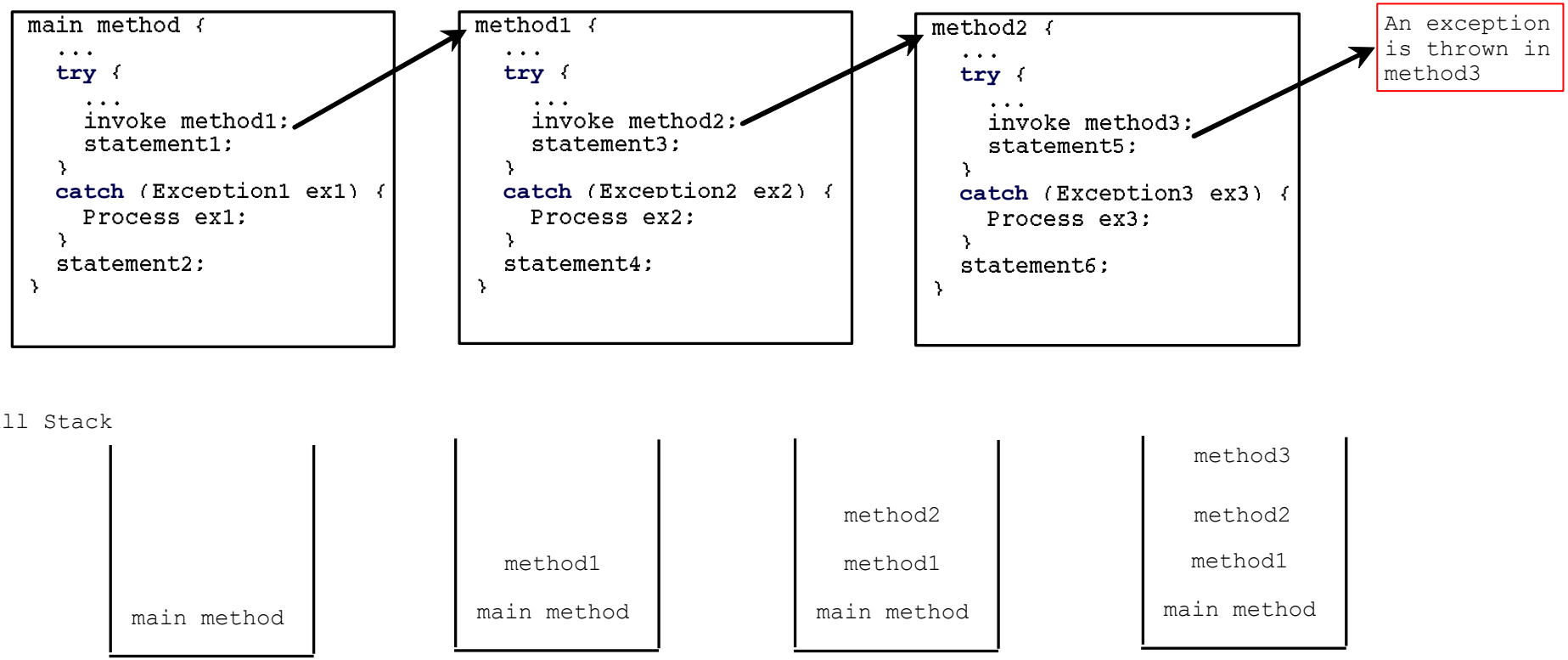
```
try {
  // Statements that may throw exceptions
}
catch (Exception1 exVar1) {
  // Handler for Exception1
}
catch (Exception2 | Exception3 | ... | ExceptionK exVar)
{
  // Same code for handling these exceptions
}
...
catch (ExceptionN exVarN) {
  // Handler for ExceptionN
}
```

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;
}
```

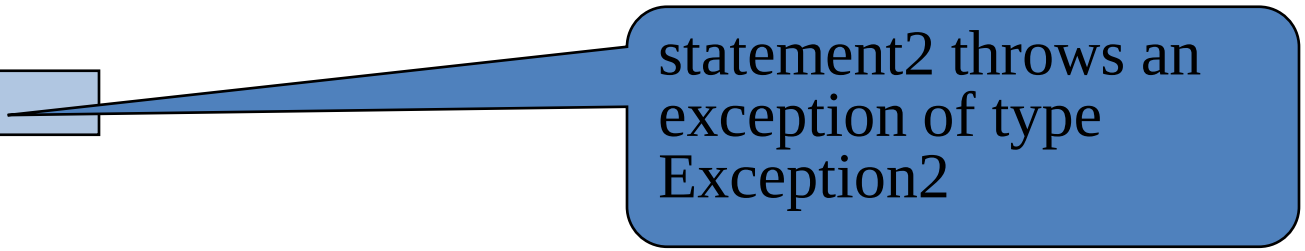
- You can also throw a new exception along with the original exception
  - This is called *chained exceptions*
    - https://docs.oracle.com/javase/tutorial/essential/exceptions/chained.html
    - Liang, section 12.6

Trace code

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

nextStatement;
```

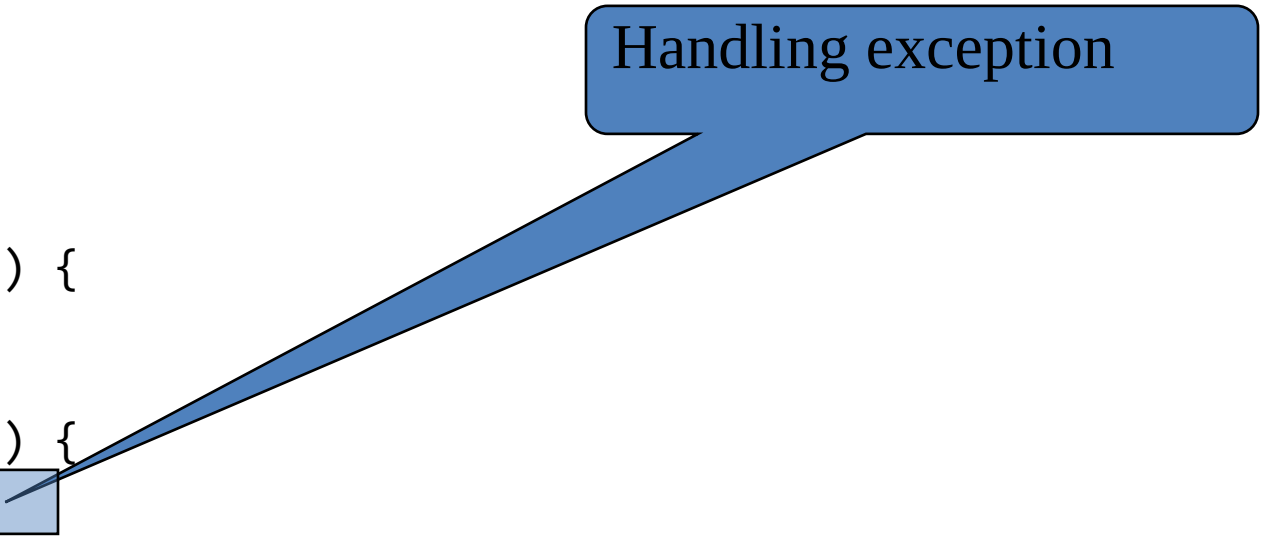
Trace code

```
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

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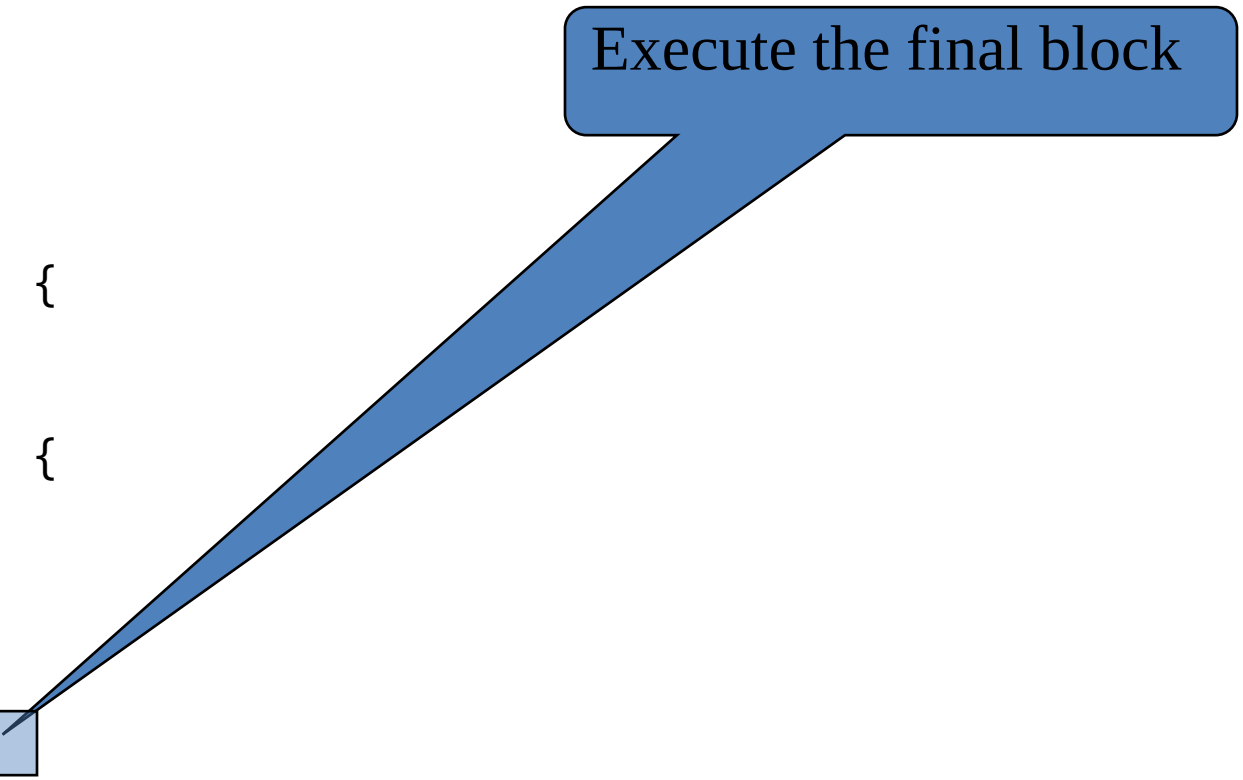
finally {
  finalStatements;
}

nextStatement;
```



Trace code

```
try {
  statement1;
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catch(Exception1 ex) {
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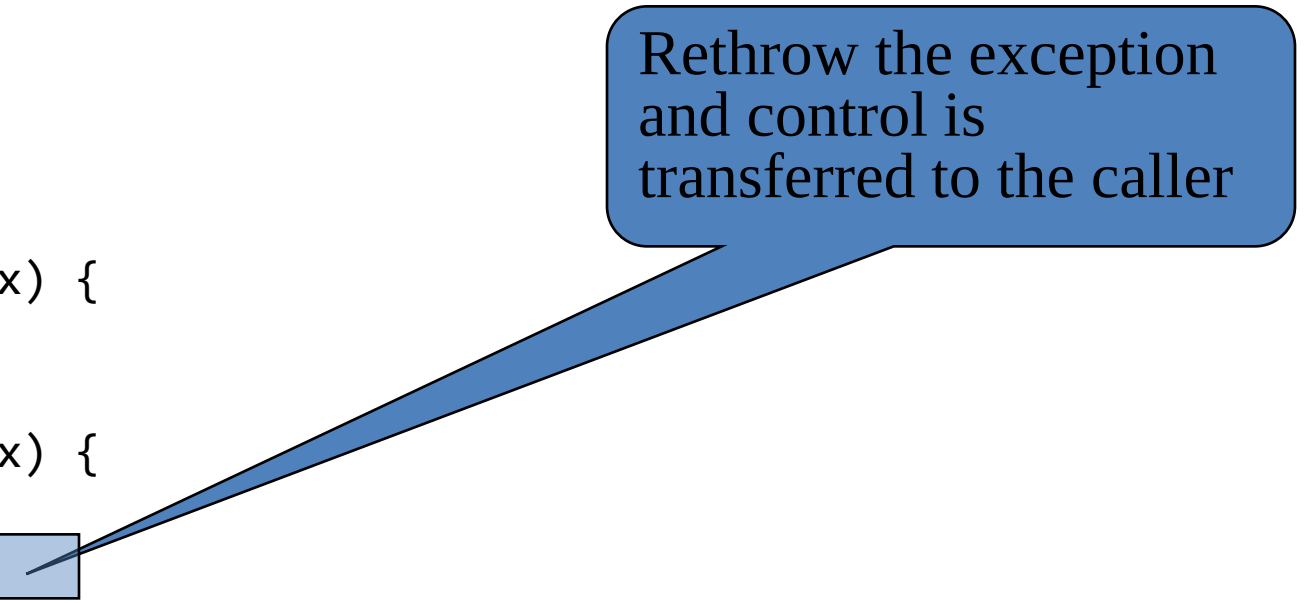

When to use a `try-catch` block

- 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

Next Lecture

- Assertions
- Text I/O
- Reading
  - Programming with Assertions

    https://docs.oracle.com/javase/8/docs/technotes/guides/language/assert.html
  - Liang
    - Chapter 12