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Handling Exceptions

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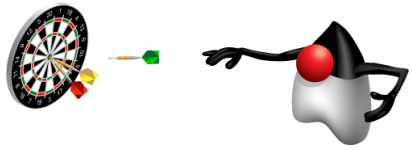
Objectives

After completing this lesson, you should be able to:

- Describe how Java handles unexpected events in a program
- List the three types of `Throwable` classes
- Determine what exceptions are thrown for any foundation class
- Describe what happens in the call stack when an exception is thrown and not caught
- Write code to handle an exception thrown by the method of a foundation class



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Topics

- Handling exceptions: an overview
- Propagation of exceptions
- Catching and throwing exceptions
- Multiple exceptions and errors

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What Are Exceptions?

Java handles unexpected situations using exceptions.

- Something unexpected happens in the program.
- Java doesn't know what to do, so it:
  - Creates an exception object containing useful information and
  - Throws the exception to the code that invoked the problematic method
- There are several different types of exceptions.

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Examples of Exceptions

- `java.lang.ArrayIndexOutOfBoundsException`
  - Attempt to access a nonexistent array index
- `java.lang.ClassCastException`
  - Attempt to cast on object to an illegal type
- `java.lang.NullPointerException`
  - Attempt to use an object reference that has not been instantiated
- You can create exceptions, too!
  - An exception is just a class.

```
public class MyException extends Exception { }
```


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Code Example

Coding mistake:

```
int[] intArray = new int[5];
intArray[5] = 27;
```

Output:

```
Exception in thread "main"
   java.lang.ArrayIndexOutOfBoundsException: 5
        at TestErrors.main(TestErrors.java:17)
```


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Another Example

Calling code in `main`:

```
19   TestArray myTestArray = new TestArray(5);
20   myTestArray.addElement(5, 23);
```

`TestArray` class:

```
13 public class TestArray {
14   int[] intArray;
15   public TestArray (int size) {
16     intArray = new int[size];
17   }
18   public void addElement(int index, int value) {
19     intArray[index] = value;                    }
20 }
```

Stack trace:

```
    Exception in thread "main"
    java.lang.ArrayIndexOutOfBoundsException: 5
        at TestArray.addElement(TestArray.java:19)
        at TestException.main(TestException.java:20)
    Java Result: 1
```


Types of `Throwable` classes

Exceptions are subclasses of `Throwable`. There are three main types of `Throwable`:

- `Error`
  - Typically an unrecoverable external error
  - Unchecked
- `RuntimeException`
  - Typically caused by a programming mistake
  - Unchecked
- `Exception`
  - Recoverable error
  - Checked *(Must be caught or thrown)*

Error Example: `OutOfMemoryError`

Programming error:

```
ArrayList theList = new ArrayList();
while (true) {
  String theString = "A test String";
  theList.add(theString);
  long size = theList.size();
  if (size % 1000000 == 0) {
     System.out.println("List has "+size/1000000
        +" million elements!");
  }
}
```

Output in console:

```
List now has 156 million elements!
List now has 157 million elements!
Exception in thread "main" java.lang.OutOfMemoryError: Java
    heap space
```


Quiz

Which of the following objects are checked exceptions?

a. All objects of type `Throwable`
b. All objects of type `Exception`
c. All objects of type `Exception` that are not of type `RuntimeException`
d. All objects of type `Error`
e. All objects of type `RuntimeException`

Topics

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- Propagation of exceptions
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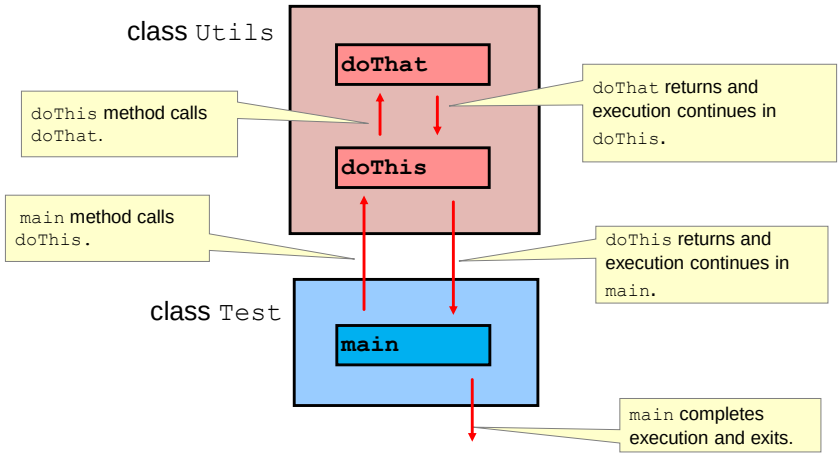
Normal Program Execution: The Call Stack



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How Exceptions Are Thrown

Normal program execution:

1. Caller method calls worker method.
2. Worker method does work.
3. Worker method completes work and then execution returns to caller method.

When an exception occurs, this sequence changes. An exception object is thrown and either:

- Passed to a `catch` block in the current method

or

- Thrown back to the caller method

Topics

- Handling errors: an overview
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Working with Exceptions in NetBeans

```
10  public class Utils {
11
12      public void doThis() {
13
14          System.out.println("Arrived in doThis()");
15          doThat();
16          System.out.println("Back in doThis()");
17
18      }
19
20      public void doThat() {
21          System.out.println("In doThat()");
22      }
23  }
24
```

No exceptions thrown; nothing needs be done to deal with them.

When you throw an exception, NetBeans gives you two options.

```
12      public void doThis() {
13
14          System.out.println("Arrived in doThis()");
15          doThat();
16          System.out.println("Back in doThis()");
17
18      }
19
20      public void doThat() {
21          System.out.println(
            throw new Exception();
23      }
24  }
25
```

unreported exception java.lang.Exception;
must be caught or declared to be thrown
--
(Alt-Enter shows hints)

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The `try/catch` Block

Option 1: Catch the exception.

```
try {
   // code that might throw an exception
   doRiskyCode();
}
catch (Exception e){
    String errMsg = e.getMessage();
   // handle the exception in some way
}
```

`try` block

`catch` block

Option 2: Throw the exception.

```
public void doThat() throws Exception{
   // code that might throw an exception
   doRiskyCode();
}
```


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Program Flow When an Exception Is Caught

`main` method:

```
01 Utils theUtils = new Utils();
02 theUtils.doThis();
03 System.out.println("Back to main method");
```

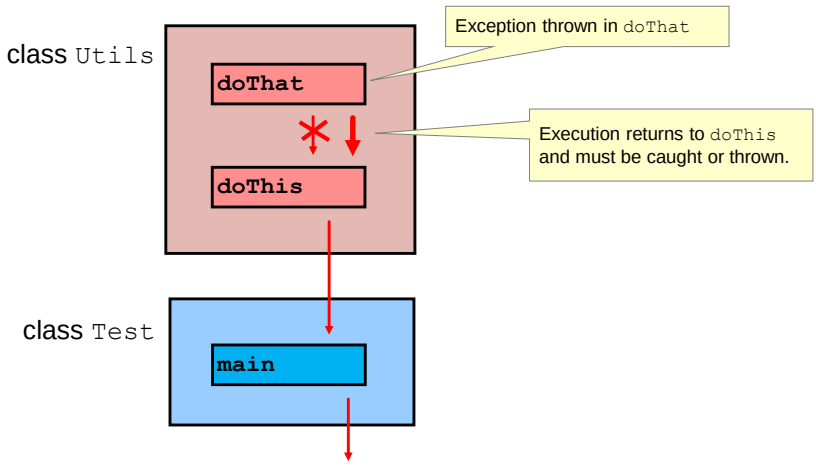
Output

```
run:
doThat: throwing Exception
doThis - Exception caught: Ouch!
Back to main method
BUILD SUCCESSFUL (total time: 0 seconds)
```

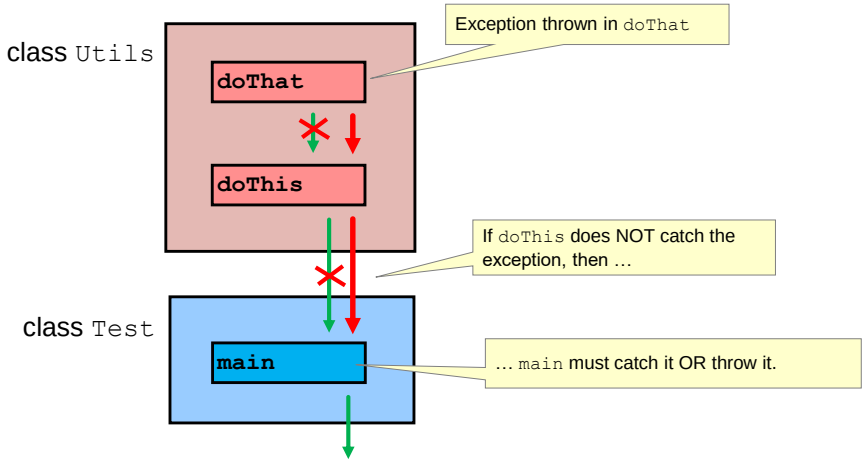
`Utils` class methods:

```
04 public void doThis() {
05   try{
06       doThat();
07   }catch(Exception e){
08     System.out.println("doThis - "
09      +" Exception caught: "+e.getMessage());
10   }
11 }
12 public void doThat() throws Exception{
13    System.out.println("doThat: Throwing exception");
14    throw new Exception("Ouch!");
15 }
```


When an Exception Is Thrown



Throwing `Throwable` Objects



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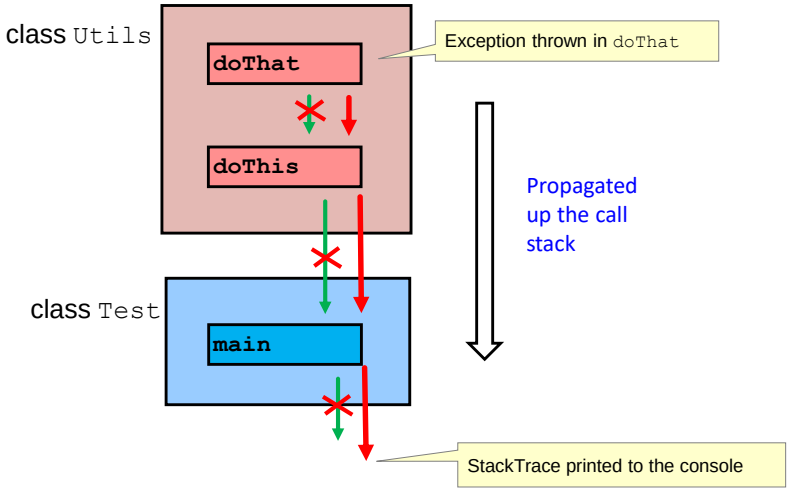
Uncaught Exception



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Exception Printed to Console

When the exception is thrown up the call stack without being caught, it will eventually reach the JVM. The JVM will print the exception's output to the console and exit.

```
Output - ClassExercises (run)
run:
Exception in thread "main" java.lang.RuntimeException: Uncompilable source
code - unreported exception java.lang.Exception; must be caught or declared
 to be thrown
        at examples.Utils.doThis(Utils.java:10)
        at examples.TestClass.main(TestClass.java:15)
Java Result: 1
BUILD SUCCESSFUL (total time: 1 second)
```


Summary of Exception Types

A `Throwable` is a special type of Java object.

- It is the only object type that:
  - Is used as the argument in a catch clause
  - Can be "thrown" to the calling method
- It has two direct subclasses:
  - `Error`
    - Automatically propagated up the call stack to the calling method
  - `Exception`
    - Must be explicitly handled and requires either:
      - A `try/catch` block to handle the error
      - A `throws` in the method signature to propagate up the call stack
    - Has a subclass `RuntimeException`
      - Automatically propagated up the call stack to the calling method

Exercise 14-1: Catching an Exception

In this exercise, you work with the `ShoppingCart` class and a `Calculator` class to implement exception handling.

- Change a method signature to indicate that it throws an exception.
- Catch the exception in the class that calls the method.

Quiz

Which one of the following statements is true?

a. A `RuntimeException` must be caught.
b. A `RuntimeException` must be thrown.
c. A `RuntimeException` must be caught or thrown.
d. A `RuntimeException` is thrown automatically.

Exceptions in the Java API Documentation

These are methods of the `File` Class.

Method Summary

Methods

Modifier and Type	Method and Description
boolean	`canExecute()` Tests whether the application can execute the file denoted by this abstract pathname.
boolean	`canRead()` Tests whether the application can read the file denoted by this abstract pathname.
boolean	`canWrite()` Tests whether the application can modify the file denoted by this abstract pathname.
int	`compareTo(File pathname)` Compares two abstract pathnames lexicographically.
boolean	`createNewFile()` Atomically creates a new, empty file named by this abstract pathname if and only if a file with this name does not yet exist.

Click to get the detail of `createNewFile`.

Note the exceptions that can be thrown.

createNewFile

```
public boolean createNewFile()
                    throws IOException
```

Atomically creates a new, empty file named by this abstract pathname if and only if a file with this name does not yet exist. The check for the existence of the file and the creation of the file if it does not exist are a single operation that is atomic with respect to all other filesystem activities that might affect the file.

Note: this method should *not* be used for file-locking, as the resulting protocol cannot be made to work reliably. The `FileLock` facility should be used instead.

Returns:

`true` if the named file does not exist and was successfully created; `false` if the named file already exists

Throws:

`IOException` - If an I/O error occurred

`SecurityException` - If a security manager exists and its `SecurityManager.checkWrite(java.lang.String)` method denies write access to the file

Since:

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Calling a Method That Throws an Exception

```
53      public void testCheckedException(){
54          File testFile = new File("//testFile.txt");
55
56          System.out.println("testFile exists: "+ testFile.exists());
57          testFile.delete();
58          System.out.println("testFile exists: "+ testFile.exists());
59      }
```

Constructor causes no compilation problems.

`createNewFile` can throw a checked exception, so the method must throw or catch.

```
53  public void testCheckedE
54
55          File testFile
            testFile.createNewFile();
57
58          System.out.println("testFile exists: "+ testFile.exists());
59          testFile.delete();
60          System.out.println("testFile exists: "+ testFile.exists());
61      }
```

unreported exception IOException; must be caught or declared to be thrown
---
(Alt-Enter shows hints)

Working with a Checked Exception

Catching `IOException`:

```
public static void main(String[] args) {
   TestClass testClass = new TestClass();

   try {
        testClass.testCheckedException();
    } catch (IOException e) {
        System.out.println(e);
    }
}

public void testCheckedException() throws IOException {
    File testFile = new File("//testFile.txt");
    testFile.createNewFile();
    System.out.println("testFile exists:"
       + testFile.exists());
}
```


Best Practices

- Catch the actual exception thrown, not the superclass type.
- Examine the exception to find out the exact problem so you can recover cleanly.
- You do not need to catch every exception.
  - A programming mistake should not be handled. It must be fixed.
  - Ask yourself, “Does this exception represent behavior I want the program to recover from?”

Bad Practices

```
public static void main(String[] args){
    try {
        createFile("c:/testFile.txt");
    } catch (Exception e) {
        System.out.println("Error creating file.");
    }
}
public static void createFile(String name)
        throws IOException{
    File f = new File(name);
    f.createNewFile();

    int[] intArray = new int[5];
    intArray[5] = 27;
}
```

Catching superclass?

No processing of exception class?

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Somewhat Better Practice

```
public static void main(String[] args){
    try {
        createFile("c:/testFile.txt");
    } catch (Exception e) {
        System.out.println(e);
     //<other actions>
    }
}
public static void createFile(String fname)
        throws IOException{
    File f = new File(name);
    System.out.println(name+" exists? "+f.exists());
    f.createNewFile();
    System.out.println(name+" exists? "+f.exists());
    int[] intArray = new int[5];
    intArray[5] = 27;
}
```

What is the object type?

`toString()` is called on this object.

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Topics

- Handling errors: an overview
- Propagation of exceptions
- Catching and throwing exceptions
- Multiple exceptions and errors

Multiple Exceptions

Directory must be writeable: `IOException`

```
public static void createFile()    throws IOException {
  File testF = new File("c:/notWriteableDir");

  File tempF = testF.createTempFile("te", null, testF);

  System.out.println
    ("Temp filename: "+tempF.getPath());
  int myInt[] = new int[5];
  myInt[5] = 25;
}
```

Arg must be greater than 3 characters: `IllegalArgumentException`

Array index must be valid: `ArrayIndexOutOfBoundsException`

Catching `IOException`

```
public static void main(String[] args) {
    try {
        createFile();
    } catch (IOException ioe) {
        System.out.println(ioe);
    }
}

public static void createFile() throws IOException {
    File testF = new File("c:/notWriteableDir");
    File tempF = testF.createTempFile("te", null, testF);
    System.out.println("Temp filename: "+tempF.getPath());
    int myInt[] = new int[5];
    myInt[5] = 25;
}
```


Catching `IllegalArgumentException`

```
public static void main(String[] args) {
    try {
        createFile();
    } catch (IOException ioe) {
        System.out.println(ioe);
    } catch (IllegalArgumentException iae){
        System.out.println(iae);
    }
}

public static void createFile() throws IOException {
    File testF = new File("c:/writeableDir");
    File tempF = testF.createTempFile("te", null, testF);
    System.out.println("Temp filename: "+tempF.getPath());
    int myInt[] = new int[5];
    myInt[5] = 25;
}
```

Catching Remaining Exceptions

```
public static void main(String[] args) {
   try {
       createFile();
   } catch (IOException ioe) {
       System.out.println(ioe);
   } catch (IllegalArgumentException iae){
       System.out.println(iae);
   } catch (Exception e){
       System.out.println(e);
   }
}
public static void createFile() throws IOException {
   File testF = new File("c:/writeableDir");
   File tempF = testF.createTempFile("te", null, testF);
   System.out.println("Temp filename: "+tempF.getPath());
   int myInt[] = new int[5];
   myInt[5] = 25;
}
```


Summary

In this lesson, you should have learned how to:

- Describe the different kinds of errors that can occur and how they are handled in Java
- Describe what exceptions are used for in Java
- Determine what exceptions are thrown for any foundation class
- Write code to handle an exception thrown by the method of a foundation class

Interactive Quizzes

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Practice 14-1 Overview: Adding Exception Handling

This practice covers the following topics:

- Investigating how the Soccer application can break under certain circumstances
- Modifying your code to handle the exceptions gracefully

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