Object Oriented Programming with Java

CHAP 1: JAVA PROGRAMMING BASICS

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Exceptions

- The term **exception** means an **exceptional condition** and is an occurrence that alters the normal program's instructions flow.

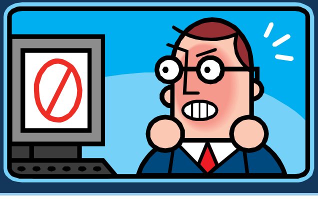
- What causes exceptions?
  - Hardware failures
  - resource exhaustion
  - bugs

Before Exceptions...

- In languages like C that don't have exceptions, programmers would make methods return a specific value if an error occurred, e.g.

```
int getStudentCountFromDatabase() {
  if (!database.connect())
    return -1;
  else
    return database.getStudentCount();
}
```

Why Is This Bad?

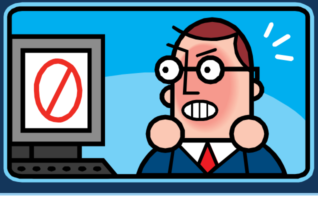


- It means the code which calls this method has to remember to check the return value
  - This code could be in a different library, or written by someone else
- What if `0` and `-1` are legitimate return values, e.g.

```
int getStudentMarksChangeFromDatabase() {
  if (!database.connect())
    return ????;
  else
    return database.getStudentMarksChange();
}
```

What should it return when an error occurs?

Why Is This Bad?

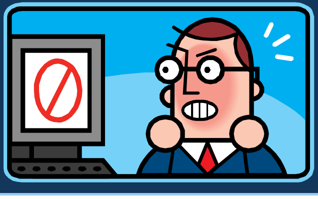


- It's hard to make sure that code recovers safely from an error, e.g.

```
boolean saveStudentsToFile() {
  file.open();

  if (db.connect())
    return false;
  file.write(db.getStudents());

  file.close();
  return true;
}
```

If an error occurs `file.close()` never gets called so it is left open

Why Is This Bad?



- It gets really complicated when the code that called the code that called the code needs to handle the error, e.g.

```
boolean amazingMethod() {
  if (!notSoGoodMethod())
    // Handle error!
}
boolean notSoGoodMethod() {
  if (!methodWrittenByMonkeys())
    return false;
  // Do other stuff
  return true;
}
boolean methodWrittenByMonkeys() {
  // ERROR!!!!
  return false;
}
```

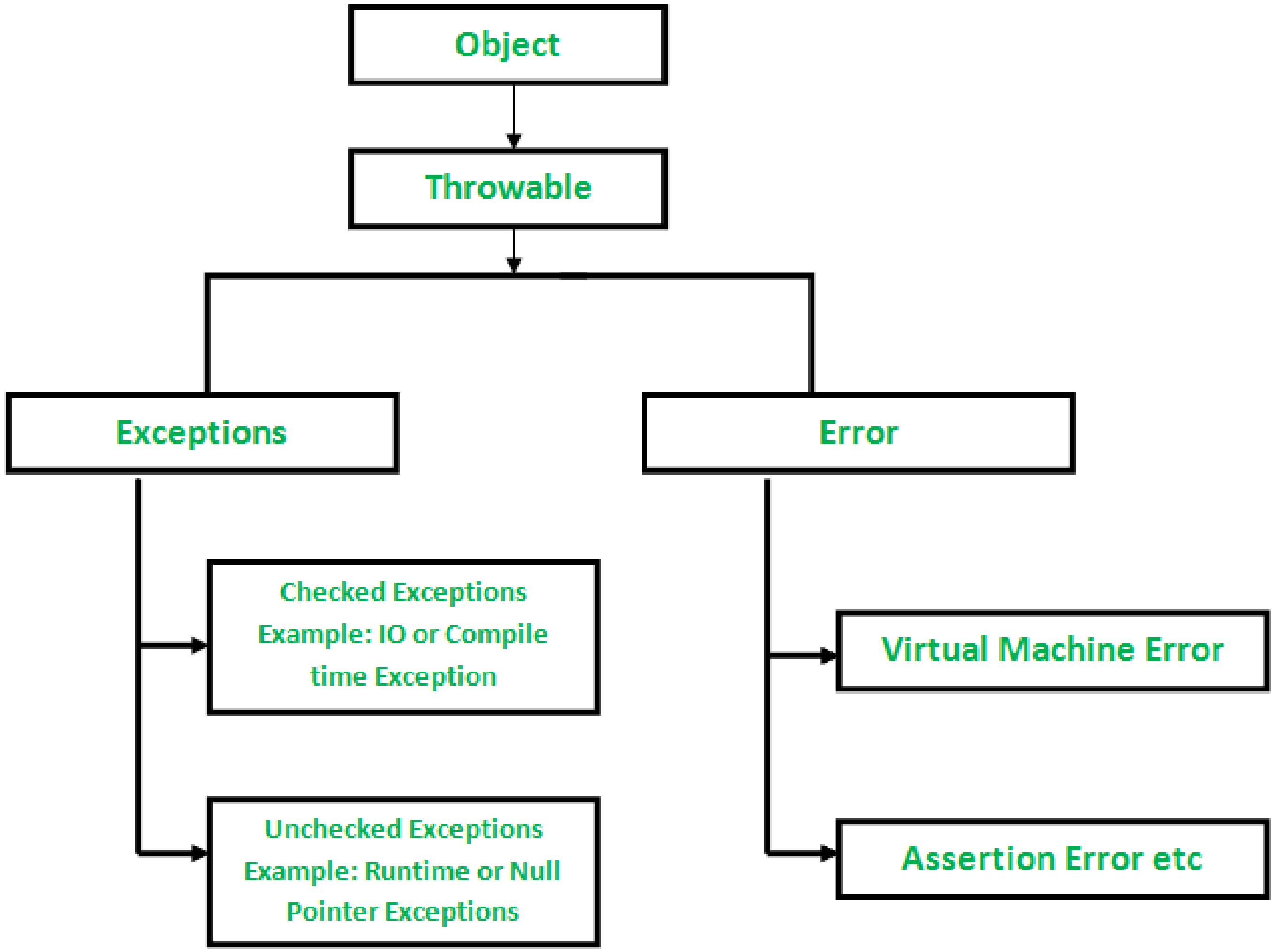
We have to keep checking the return values in each calling method

Exceptions In Java

- Are built into the Java language
- Are NOT return values
- Use `try` and `catch` blocks, e.g.

```
try {
  methodThatCouldFail();
}
catch (Exception ex) {
  System.out.println("Error occurred:" + ex.toString());
}
```

Exceptions Hierarchy


Object
Throwable
Exceptions
Error
Checked Exceptions Example: IO or Compile time Exception
Unchecked Exceptions Example: Runtime or Null Pointer Exceptions
Virtual Machine Error
Assertion Error etc

Exception Terminology

- When an exception event occurs in Java, an exception is said to be “**thrown**”
- The code responsible for doing something about the exception is called an “**exception handler**” and it “**catches**” the thrown exception
- For things that must happen whether or not there is an exception, there is the “**finally**” clause

Example

- Exceptions are objects of class `Exception`, e.g.

```
throw new Exception("Could not connect to DB")
```

- It has several useful methods
  - `getMessage()` - returns the error message
  - `printStackTrace()` - prints the stack trace to the console...

```
java.lang.NullPointerException
  at MyClass.bar(MyClass.java:9)
  at MyClass.foo(MyClass.java:6)
  at MyClass.main(MyClass.java:3)
```

Exception Objects

```
int getStudentsCountFromDatabase() throws Exception {
  if (!database.connect())
    throw new Exception("Could not connect to DB");
}

void printCount() {
  try {
    int count = getStudentsCountFromDatabase();

    System.out.println("Count:" + count);
  }
  catch (Exception ex) {
    System.out.println("Error occurred:" + ex.toString());
  } finally {
    connection.close();
  }
}
```

If no exception, then try block continues

If exception occurs, then we jump to the catch block

Finally always executes

Finally...

```
void saveDataToFile() {

  try {
    file.open();

    file.write(data);

    file.close();
  }
  catch (Exception ex)
    log("File Error");
    file.close();
  }
}
```

Code is duplicated!

- Sometimes we need to execute some code regardless of whether an exception is thrown
- For example a resource like a file or database connection may need to be released

Finally...

```
void saveDataToFile() {

  try {
    file.open();

    file.write(data);
  }
  catch (Exception ex) {
    log("File Error");
  }
  finally {
    file.close();
  }
}
```

- Code in the `finally` block is called
  - After the `try` if no exception occurred
  - After the `catch` if an exception did occur
- Why is this necessary? Couldn't the code just go at the end of the method...

Finally...

```
void saveDataToFile() {

  try {
    file.open();

    file.write(data);
  }
  catch (Exception ex) {
    log("File Error");
    return;
  }
  finally {
    file.close();
  }
}
```

Still called even though `catch` block returns

- Code in the `finally` block is even called if a catch block has a `return` statement

Example

```
public class ExampleExceptions {

  public static void main(String[] args) {
        myMethod();
  }
  static void myMethod() {
        try{
                // do stuff
                System.out.println("inside try.");
        } catch(Exception e) {
                // do exception handling
                System.out.println("inside catch.");
        } finally {
                // do cleanup
                System.out.println("inside finally.");
        }
  }
}
```

Example

- Run the program on the previous slide.
  - Why doesn’t “inside catch.” print out to the console?

- Add the following in the **try** and run it again:

```
int x = 8/0;
```

- Add the following in the **catch** one at a time and re-run the program:

```
System.err.println(e.toString());
System.err.println(e.getMessage());
e.printStackTrace();
```

“Try” It Out!

- What happens if you have no finally?
- What happens when you have a try by itself?
- What happens when you have a try and then some code and then the catch? A try and then a catch and then some code and then the finally?
- What happens if you have try and finally but no catch?

Throwing Exceptions

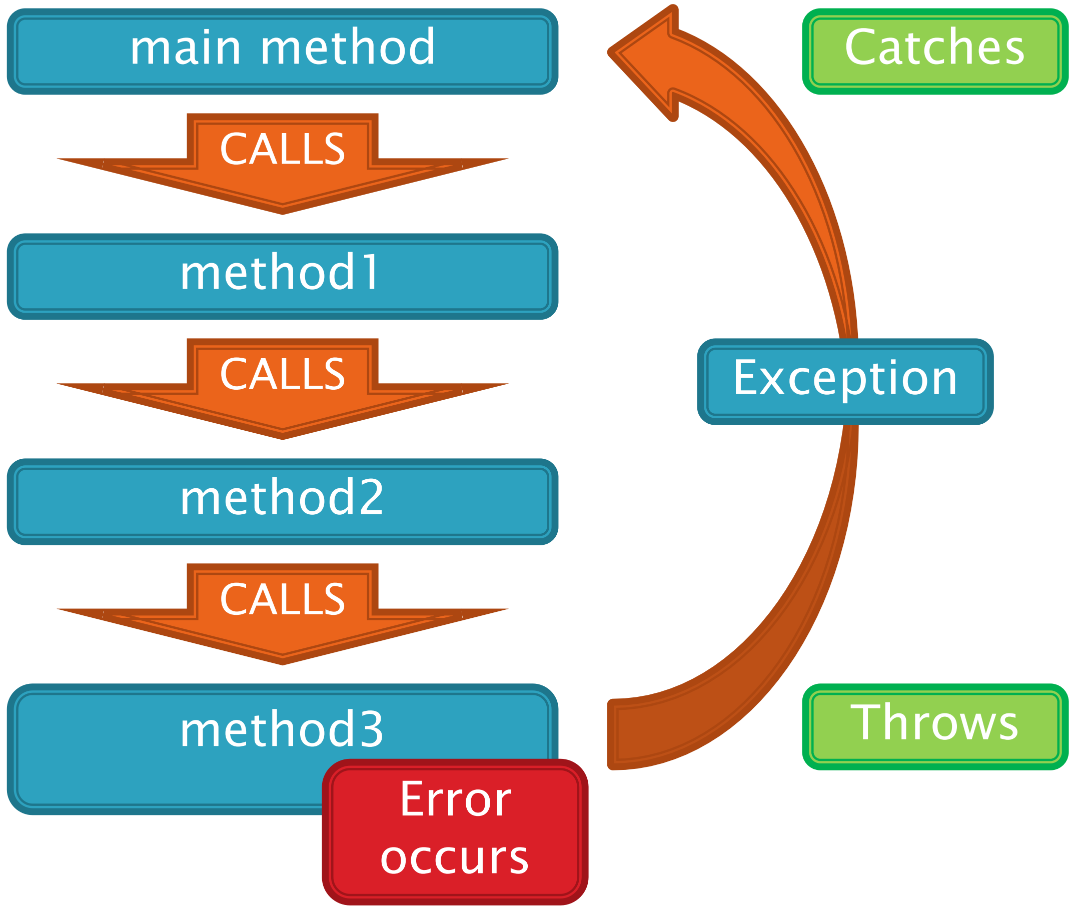
- If a method throws an exception and doesn't handle it (i.e. there is no `catch` block) then it must declare that it `throws` an exception, e.g

```
int getStudentsCountFromDatabase() throws Exception {
  if (!database.connect())
    throw new Exception("Could not connect to DB");
}
```

- Exceptions can be constructed with a `String` which is the error message

- This can be retrieved in the catch block using `getMessage()`

Try, throw, catch



Ducking Exceptions

```
try{
        // call method that throws an exception
        String myAnswer = doSomething(“test”);
} catch(Exception e) {
        // handle exception if it occurs
} finally {
        // cleanup
}

static String doSomething(String s) throws Exception {
        if(POTENTIAL PROBLEM) {
                throw new Exception();
        }

        // BODY OF METHOD

        return s;
}
```

Ducking the exception: If a method does not throw a checked Exception directly but calls a method that throws an exception then the calling method must handle the throw exception or declare the exception in its throws clause

Hands On

- Exceptions are Objects
  - java.lang.Exception
- Look up the Java API SE 18
  - What is the superclass of Exception?
  - What is the sibling of Exception?
  - Do you see the subclass called RuntimeException?

Checked vs. Unchecked Exceptions

- Checked exceptions are called compile-time exceptions because these exceptions are checked at compile-time by the compiler

  – Handle or Declare:
    - Exceptions Other Than Runtime Exceptions
    - Your Own Custom Exceptions

- Unchecked exceptions are called runtime exceptions

  –Can Handle If You Want:
    - Runtime Exceptions
    - Errors

Errors

- Exceptional situation that aren’t programmatic
- Not required to handle these
- Example--JVM running out of memory

```
try{
   // do stuff
   System.out.println("inside try.");

} catch(Error e) {
   // do exception handling
}
```

Runtime Exceptions

- These are a special kind of exception which aren't checked by the compiler
- They extend the `RuntimeException` class
- They can usually be handled by fixing programming logic, e.g.
  - `NullPointerException`
  - `ArrayIndexOutOfBoundsException`
  - `DivideByZeroException`
  - `ClassCastException`

Runtime Exceptions

- Thus it's usually bad practice to use these exceptions with `try` and `catch`, e.g.

```
void calculateAverageAge(int totalAge,
int numPeople) {

   try {
      int avgAge = totalAge / numPeople;
   }
   catch (DivideByZeroException ex) {
   }
}
```

Would be better to write the method so that it checks that `numPeople > 0` before doing the division

The Stack Trace

- This will be displayed if you don't handle a runtime exception or you call `printStackTrace()` on an exception object
- It will help you determine where the error occurred in your code
- It looks ugly but it can be very helpful!

The Stack Trace

Each item has a source file and line number

```
java.lang.ClassCastException: rw.ac.rca.shape.Triangle
cannot be cast to rw.ac.rca.shape.Square

    at rw.ac.rca.shape.MainApp.realShape(MainApp.java:50)

    at rw.ac.rca.shape.MainApp.main(MainApp.java:19)
```

If the exception occurred in a library, then look for the first reference to a class in your project

Hands On

```
public class RuntimeExceptionExample {
  public static void main(String[] args) {
      System.out.println("hello from main");
      myMethod();
  }
  static void myMethod() {
      System.out.println("hello from my method.");
      myNextMethod();
  }
  static void myNextMethod() {
      int x = 8/0;
  }
}
```

What happens when you run this?

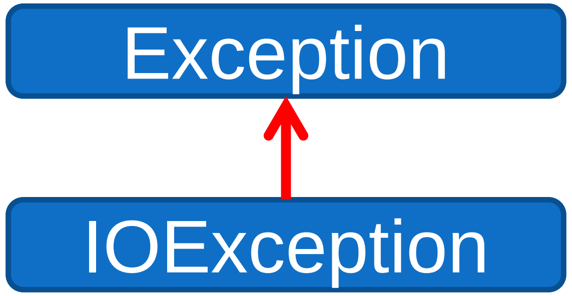
Exception Matching

```
void saveDataToRemoteFile() {
  try {
    file.open();

    file.write(data);
  }
  catch (IOException ex) {
    log("File Error");
  }
  catch (SocketException ex) {
    log("Connection Error");
  }
  finally {
    file.close();
  }
}
```

- Code in a `try` block might throw different exceptions
- These can be caught in separate `catch` blocks

Exception Hierarchy

```
void saveToRemoteFile() {
  try {
    file.open();

    file.write(data);
  }
  catch (IOException ex) {
    log("File Error");
  }
  catch (Exception ex) {
    log("Unknown Error");
  }
  finally {
    file.close();
  }
}
```



- The first `catch` block one with a matching exception type will be used
- `Exception` is the super class of all exceptions so will match any exception

Exception Hierarchy

```
void saveToRemoteFile() {
  try {
    file.open();

    file.write(data);
  }
  catch (Exception ex) {
    log("Unknown Error");
  }
  catch (IOException ex) {
    log("File Error");
  }
  finally {
    file.close();
  }
}
```

This will catch all exceptions so the second block will never be used

- So `catch` blocks should be put in the order of the exception class hierarchy

Create Your Own Exceptions

```
class myException extends Exception { }

class TextEx {
    void doStuff() throws myException {
        throw new myException();
    }
}
```

What is wrong with the above?

Will it compile?

Rethrowing Exceptions

```
void someMethod() {
        doStuff();
    }
void doStuff() throws Exception {
    try {
        throw new Exception();
    } catch(Exception e) {
        throw e;
    }
}
```

What happens when you run this?

JVM Exceptions

- JVM Exceptions
  - Thrown by the JVM

- Programmatic Exceptions
  - Thrown by the application or API programmers

Null Pointer Exception Example

```
public static void main(String[] args) {
    String s = null;

    if(s.equals("hi")) {
        // do something
    }
}
```

Number Format Exception Example

```
public static void main(String[] args) {
    int answer = divideLargeNumbers(5, 6);
    System.out.println(answer);
}
static int divideLargeNumbers(int i, int j){
    if(j <100 || i < 100) {
        throw new NumberFormatException();
    }
    return i/j;
}
```

Common Exceptions By Type

JVM	Programmatic
ArrayIndexOutOfBoundsException	IllegalArgumentException
ClassCastException	IllegalStateException
NullPointerException	NumberFormatException
ExceptionInInitializerError	AssertionError
StackOverflowError	
NoClassDefFoundError	

Advantages of Exception Handling in Java

- Provision to complete program execution
- Easy identification of program code and error-handling code
- Avoiding propagation of errors
- Meaningful error reporting
- Identifying error types

References

- Oracle's Java tutorials: https://docs.oracle.com/javase/tutorial/essential/exceptions/index.html

EoF