

A large, two-story, light-colored building with a red-tiled roof and a central tower, surrounded by green grass and trees under a clear blue sky.

MAHARISHI UNIVERSITY of MANAGEMENT

Engaging the Managing Intelligence of Nature

Computer Science Department

**CS390 Fundamental Programming
Practices (FPP)
Professor Anne McCollum**

Lecture 12:

Exception-Handling in

Java

Wholeness of the Lesson

Prior to the emergence of OO languages, error-handling was typically done using an unsystematic use of error codes. This approach led to confusion, programming errors, and costly maintenance. Java's exception-handling model (which is similar to those in other OO languages) systematizes the task of handling error conditions and integrates it with the OO paradigm supported by the language. This advance in programming practice illustrates the theme that “deeper knowledge has more profound organizing power.”

Outline of Topics

- What Is Exception-Handling All About?
- The Old (Non-OO) Way Of Doing It
- An Object-Oriented Error-Handling Strategy
- Classification of Error-Condition Classes
 - Objects of type Error
 - Other Unchecked Exceptions
 - Checked Exceptions
- Using/Creating Exception Classes
- Best Practices: When to Handle, When to Throw, When to Log
- Some Syntax Rules For Try/Catch
- The finally Keyword

What Is Exception-Handling All About?

- Problems can arise during execution of an application.
- Examples:
 - Try to open a file but can't
 - Try to access a database, but it's unavailable
 - Try to save data, but disk is full
 - Try to call a method on an uninitialized object
 - Try to access an array index beyond the defined array length
 - Try to divide a number by zero

- Regardless of the problem, error conditions in an application should be handled in one of two ways:

Either:

- Return to a safe state and enable the user to execute other commands
(for example, the user accidentally inputs incorrect data, such as an incomplete phone number – the application should ask the user to try again)
- Allow the user to save all work and terminate the application gracefully
(for example, a database may not be accessible, so the user should be allowed to "try again later")

But what is the right way to accomplish this objective?

The Old (Non-OO) Way Of Doing It

- In languages like C, it was common to handle error conditions by returning an "error code", such as -1 , to indicate that some operation has failed or a problem occurred. Many different types of problems need to be anticipated, means that there could be many different error codes. The calling function would have to interpret the codes and determine a course of action for each case.
- Two fundamental problems with this:

Problem 1: *Violation of Open-Closed Principle.*

Adding error codes at a later time means modifying existing code, which could be complex.

Suppose when a piece of code is first written, the developer can think of just two possible problems that might arise. So his function is defined so that if one problem arises, the code returns -1 , and if the other problem arises, it returns -2 . Then he writes error-handling code in the calling function to handle each error condition.


```
callingFunction(String s) {
    int code = saveData(s);
    if(code == -1) {
        handleOpenFileError();
    }
    else if(code == -2) {
        handleWriteToFileError();
    }
    else {
        doTheNormalThing(s);
    }
}
int saveData(String s) {
    int result = openFile("Special File");
    if(result == -1) return -1;
    else {
        result = writeToFile(s);
        if(result == -1) return -2;
        else return 0;
    }
}
```



Suppose later a new developer takes over the code and discovers that the file ought to be closed after using it, but it is possible that the "close" operation will fail. So he has to go into the code and add new conditions inside code blocks

```

callingFunction(String s) {
    int code = saveData(s);
    if(code == -1) {
        handleOpenFileError();
    }
    else if(code == -2) {
        handleWriteToFileError();
    }
    else if(code == -3) {
        handleCloseFileError();
    }
    else {
        doTheNormalThing(s);
    }
}

int saveData(String s) {
    int result = openFile("Special File");
    if(result == -1) return -1;
    else {
        result = writeToFile(s);
        if(result == -1) return -2;
        else {
            result = closeFile();
            if(result == -1) return -3;
            else return 0;
        }
    }
}

```

To update the code with the new error type, it is necessary to go into already complicated code and make modifications. This type of code modification is error-prone and is in opposition to the Open-Closed Principle

Problem 2: Confusion of data.

Is the error code also a valid return value?

If a method such as `saveData` in our example is really intended to return an integer, an integer such as `-1` might possibly represent a valid result of a computation rather than an error code. (And this problem doesn't go away just by picking a number different from `-1` to represent an error code.)

As a contrived example, suppose you have a function that performs the following operation: it accepts 3 integers `a`, `b`, `c` as input and then performs two successive integer divisions and returns the result:

```
contrivedDivide(int a, int b, int c) {  
    int temp = a / b;  
    return temp / c;  
}
```

The developer may decide that an error code of -1 should be returned if either b or c is 0 (since division by 0 is illegal).

```
contrivedDivide(int a, int b, int c) {  
    if(b == 0 || c == 0) return -1;  
    int temp = a / b;  
    return temp / c;  
}
```

But if this is done, how can the calling function distinguish between an error condition and the result of a legitimate execution of the function, as in

```
contrivedDivide(1, -1, 1); // returns -1, but no error
```

An Object-Oriented Error-Handling Strategy

Java's solution to the problem is very similar to the solution offered in most OO languages:

- An error of any kind is represented as a special kind of object
- When an error condition arises, an instance of the object is created by the Java runtime and "thrown" (similar to the way an "event" is triggered by a button click or other user action on a GUI)
- Code written by the developer then "catches" the error-related object, analyzes the information in this object as necessary, and performs some action to handle it.

Overview of the Process

Some object of type `CallingClass` wishes to call `myMethod` on an instance of `MyClass`, but `myMethod` is capable of throwing an `IOException`

In order to make the call, `CallingClass` must wrap the call in a try block, and, if an `IOException` is thrown, `CallingClass` must provide exception-handling code in a catch block to handle the error condition. Typically, it is handled by logging a message and displaying a message to the user.

```
public class MyClass {
    public void myMethod() throws IOException {
        //method body not shown here
    }
}

public class CallingClass {
    private static final Logger LOG
        = Logger.getLogger(
            CallingClass.class.getPackage().toString());
    MyClass m = new MyClass();

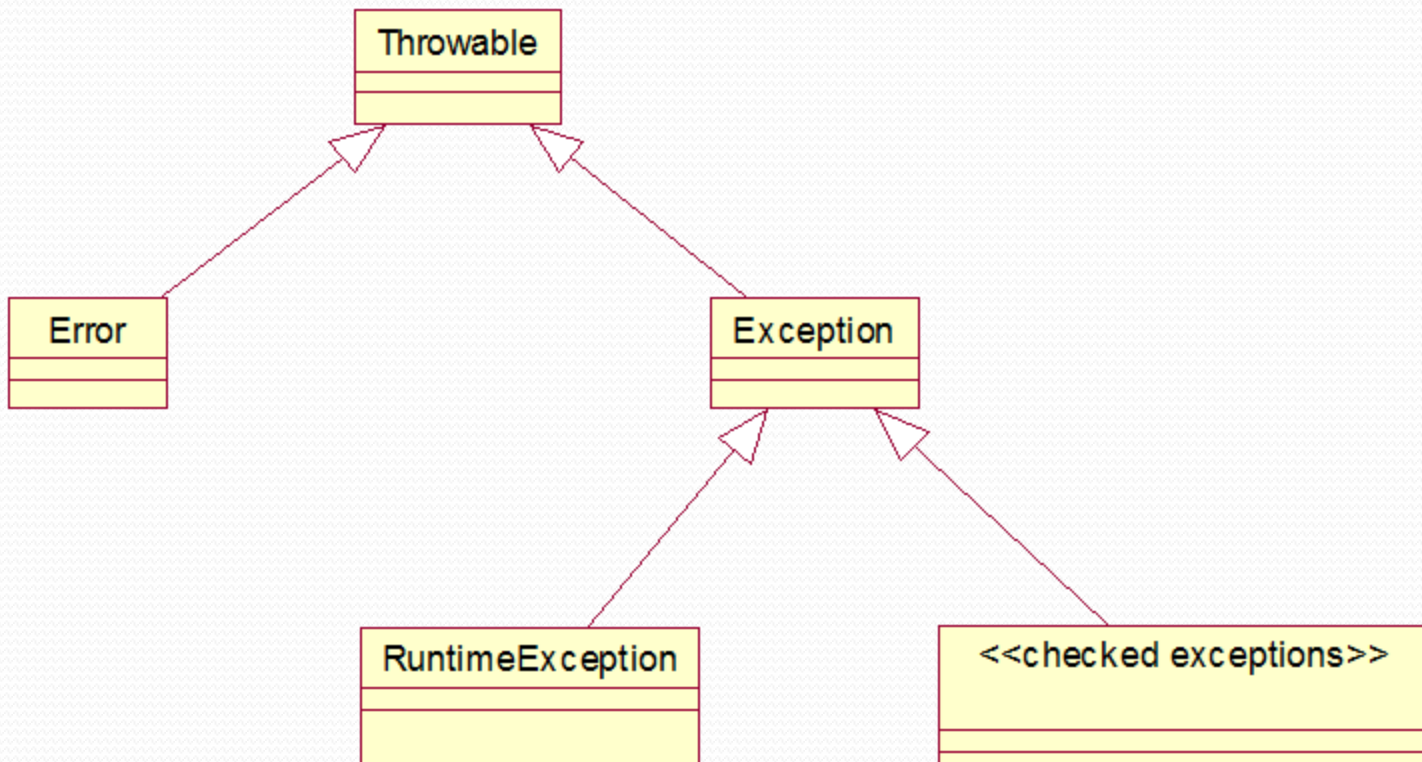
    public void callingMethod() {
        try {
            m.myMethod();
        } catch(IOException e) {
            LOG.warning("IO");
            displayMessage("Cannot read file.");
        }
        private void displayMessage(String s) {
            //code not shown
        }
    }
}
```

The situation described here is very common, though there are alternative ways to handle thrown exceptions – these will be described in more detail later in the lesson. See `demo lesson12.exceptionhandlingdemo`.

Main Point

Java's exception-handling model supports best practices in handling exceptions that arise during program execution. Likewise, establishing awareness in the home of all the laws of nature results in a life spontaneously lived in accord with natural law.

The Hierarchy of Java Classes That Represent Error Conditions

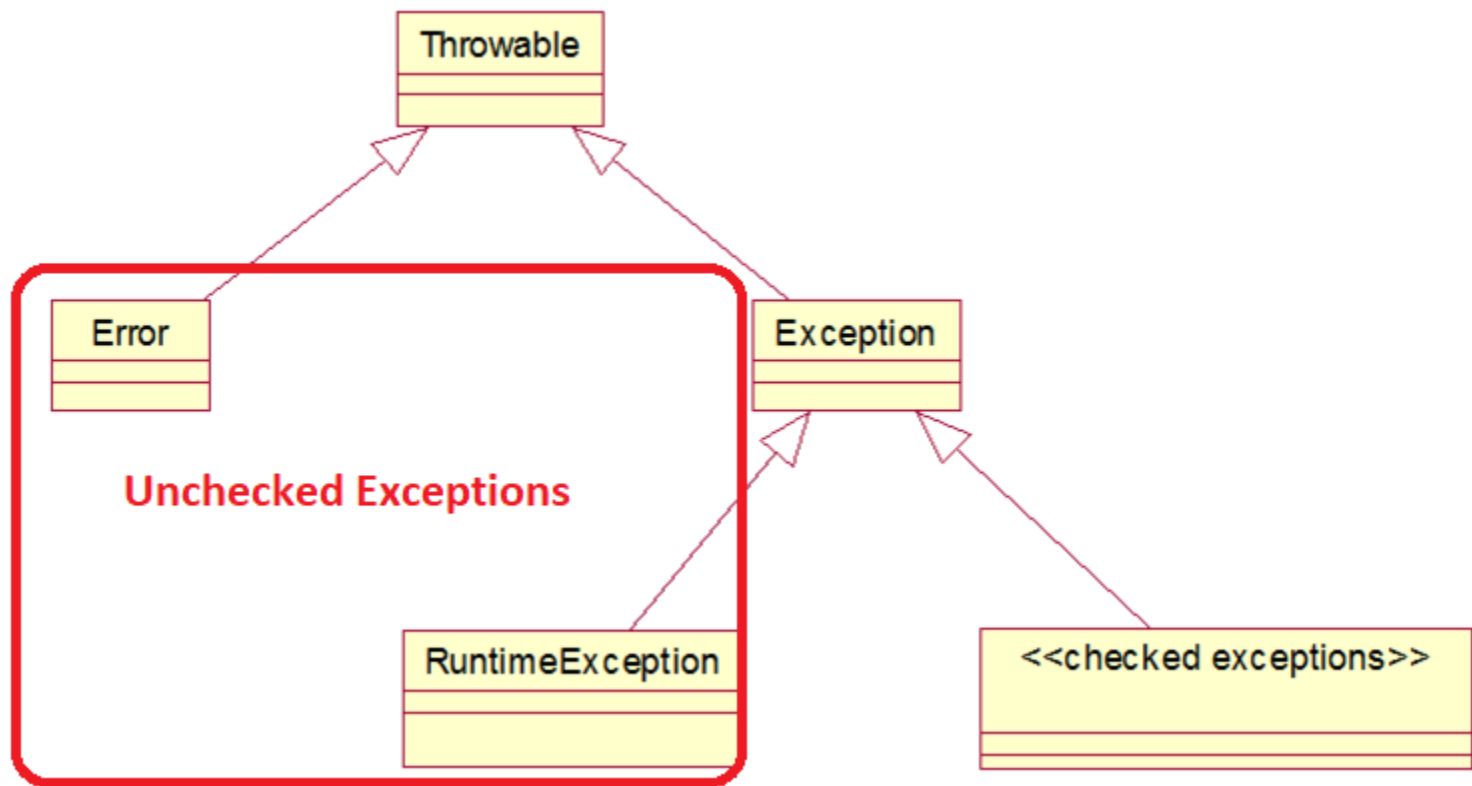


Classification of Error-Condition Classes

In Java, error-condition classes belong to one of three categories. (This is summarized in the next slide):

- *Error* – Objects in this category belong to the inheritance hierarchy headed by the `Error` class
- *Other Unchecked Exceptions* – Besides `Error` objects, unchecked exceptions include all objects that belong to the inheritance hierarchy headed by the class `RuntimeException`.
- *Checked Exceptions* – Exceptions in this category are subclasses of `Exception` but not subclasses of `RuntimeException`.

Overview: A Classification of Error-Condition Classes



Objects of type Error

- **Error objects** occur rarely. And if they do occur, the application must be terminated. Error objects describe:
 - internal errors,
 - JVM execution errors, or
 - resource exhaustion.
- When an Error like above occurs, the JVM *throws* an `Error` object. Typically, the JVM will handle the `Error` object by displaying a message to the console with the `Error` type and the sequence of method calls that led to the error condition (called a *stack trace*).
- **Developer's point of view:**
 - Beyond the developer's control, so nothing to do during program execution
 - Examples: system or hard disk crash.
 - *Note:* A `StackOverflowError` is an `Error` that can usually be handled by rewriting the code, but this is not done during program execution.

Example: (From Lesson 7 – Recursion). If you create an **illegal recursion**, you will typically cause a **StackOverflowError** to occur because the sequence of self-calls overflows the call stack.

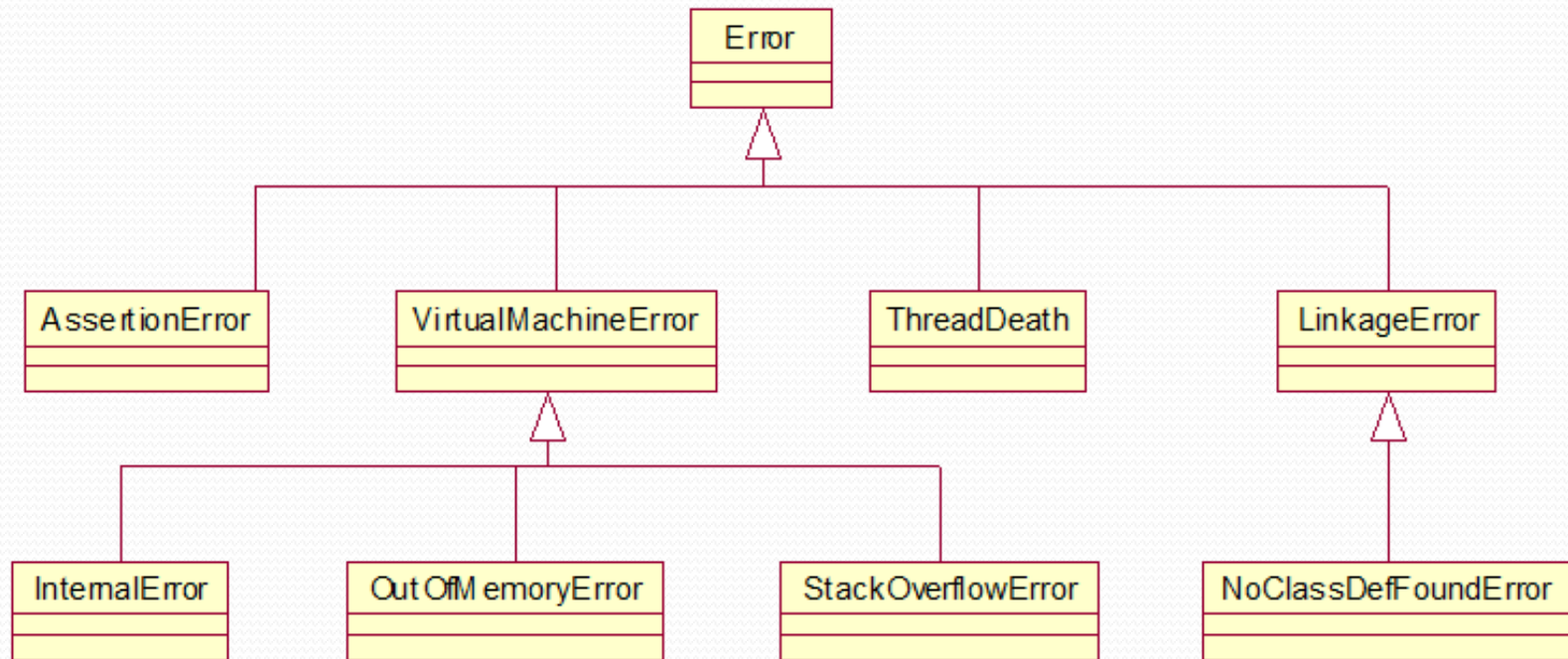
```
class MyClass {
    public static void main(String[] args) {
        new MyClass();
    }
    MyClass() {
        recurse("Hello");
    }
    String recurse(String s) {
        if (s == null) // ← no base case. This never happens
            return null;
        int r = RandomNumbers.getRandomInt();
        int n = s.length();
        if (r % 2 == 0)
            return recurse(s.substring(0, n / 2));
        else {
            return recurse(s.substring(n / 2, n));
        }
    }
}
```

Running this code leads to the following output: (next slide)

```
Exception in thread "main" java.lang.StackOverflowError
    at java.util.Random.nextInt(Unknown Source)
    at
pencil_4.probl.RandomNumbers.getRandomInt(RandomNumbers.java:20)
    at pencil_4.probl.MyClass.recurse(MyClass.java:15)
    at pencil_4.probl.MyClass.recurse(MyClass.java:20)
    at pencil_4.probl.MyClass.recurse(MyClass.java:20)
    at pencil_4.probl.MyClass.recurse(MyClass.java:18)
    at pencil_4.probl.MyClass.recurse(MyClass.java:20)
    at pencil_4.probl.MyClass.recurse(MyClass.java:20)
    at pencil_4.probl.MyClass.recurse(MyClass.java:20)
    at pencil_4.probl.MyClass.recurse(MyClass.java:18)
    at pencil_4.probl.MyClass.recurse(MyClass.java:20)
```

```
//output abbreviated
```

The Error Hierarchy



Causing the JVM to Throw an Error

- Invent your own piece of code that causes a `StackOverflowError` to be thrown. Could use JShell. See if you can do it by writing just a couple of lines of code.
- Then create another piece of code that causes an `OutOfMemoryError` to be thrown. Again, try to make your code as brief as possible.

Exercise 12.1 - Solution

StackOverflowError (infinite recursion)

```
jshell> int myMethod() {  
    ...> return myMethod() + 1;  
    ...> }  
| created method myMethod()
```



```
jshell> myMethod();  
| java.lang.StackOverflowError thrown  
|   at myMethod (#1:2)  
|   at myMethod (#1:2)  
|   at myMethod (#1:2)  
|   at myMethod (#1:2)  
|   at myMethod (#1:2)
```

OutOfMemoryError

```
jshell> String dbl(String s) {  
    ...> return s + s;  
    ...> }  
| created method dbl(String)
```



```
jshell> String t = "hello";  
t ==> "hello"  
  
jshell> for(int i = 0; i < 50; ++i) {  
    ...> t = dbl(t);  
    ...> }  
| java.lang.OutOfMemoryError thrown: Overflow: String length out of range  
|   at StringConcatHelper.checkOverflow (StringConcatHelper.java:46)  
|   at StringConcatHelper.mixLen (StringConcatHelper.java:118)  
|   at dbl (#1:2)  
|   at (#3:2)
```

Note: Using the following method shows the iteration where the error occurs:

```
for (int i = 0; i < 50; i++) {  
    System.out.println(Integer.toString(i));  
    t = dbl(t);  
}
```

Other Unchecked Exceptions

- Unchecked Exceptions include both Error objects and objects under the hierarchy RuntimeException. Similar to Error objects, when one of the RuntimeExceptions occurs, the JVM throws an object of type RuntimeException or one of its subclasses up the call stack. (See previous slide for an example of a call stack.)
- Usually, getting a RuntimeException indicates that the programmer needs to fix a logic error in code.
- Examples of RuntimeExceptions:

```
NullPointerException    //an object needs to be initialized
ClassCastException      //improper cast needs fixing
ArrayIndexOutOfBoundsException //adjust bounds of a loop
NumberFormatException    //could arise from trying to turn a
                        //non-numeric String into an Integer
```


Examples

```
class Test1 {  
    private Employee emp;  
    public static void main(String[] args) {  
        Test1 test = new Test1();  
        //NullPointerException at runtime  
        String name = test.emp.getName();  
    }  
}  
  
class Test2 {  
    public static void main(String[] args) {  
        List employees = new ArrayList();  
        employees.add(new Employee("Joe"));  
        employees.add(new Employee("Tim"));  
  
        //ClassCastException at runtime  
        Employee first = (Manager) employees.get(0);  
    }  
}
```

Throwing Runtime Exceptions

Because exceptions of type `RuntimeException` are unchecked, they can also be used by developers to indicate a *problem that needs to be corrected* (useful during development, not for production code).

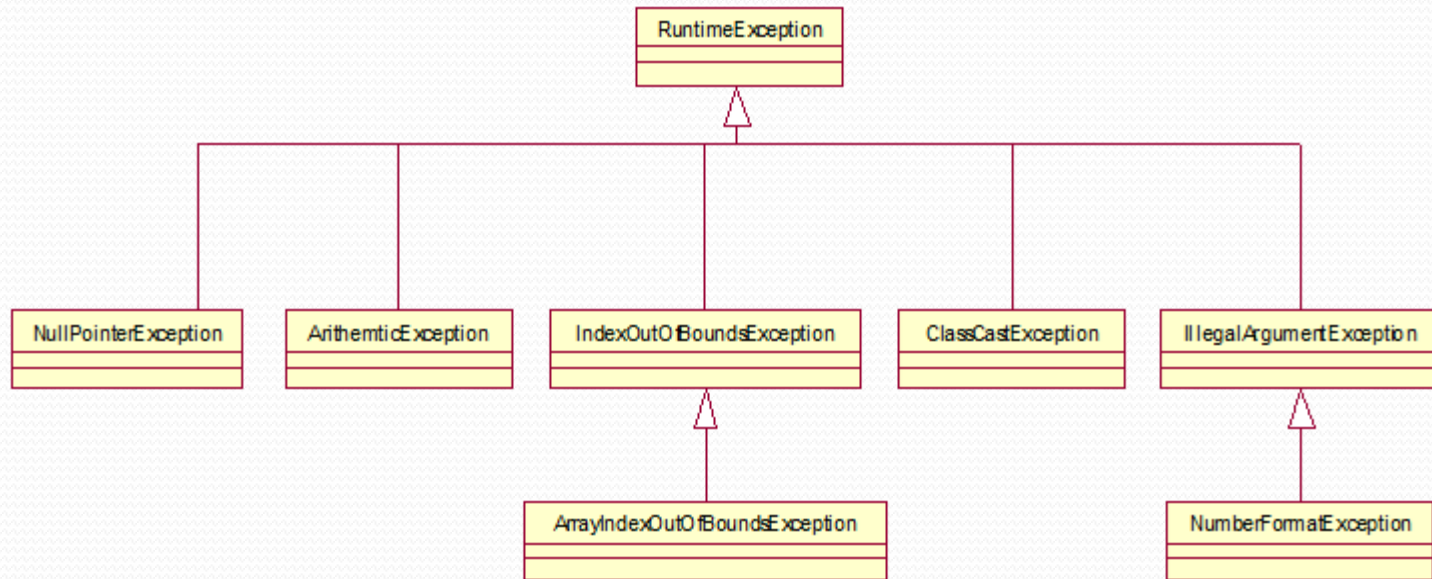
Two examples are `IllegalArgumentException` and `IllegalStateException`.

Example: (From the `Rational` class that was described in an earlier lab)

```
public Rational(int num, int denom) {  
    if (denom <= 0) {  
        throw new IllegalArgumentException(  
            "Cannot divide by 0. The Denominator must be positive");  
    }  
    this.num=num;  
    this.denom=denom;  
}
```

See `lesson12.improvedrational.Rational`

Hierarchy of RuntimeException

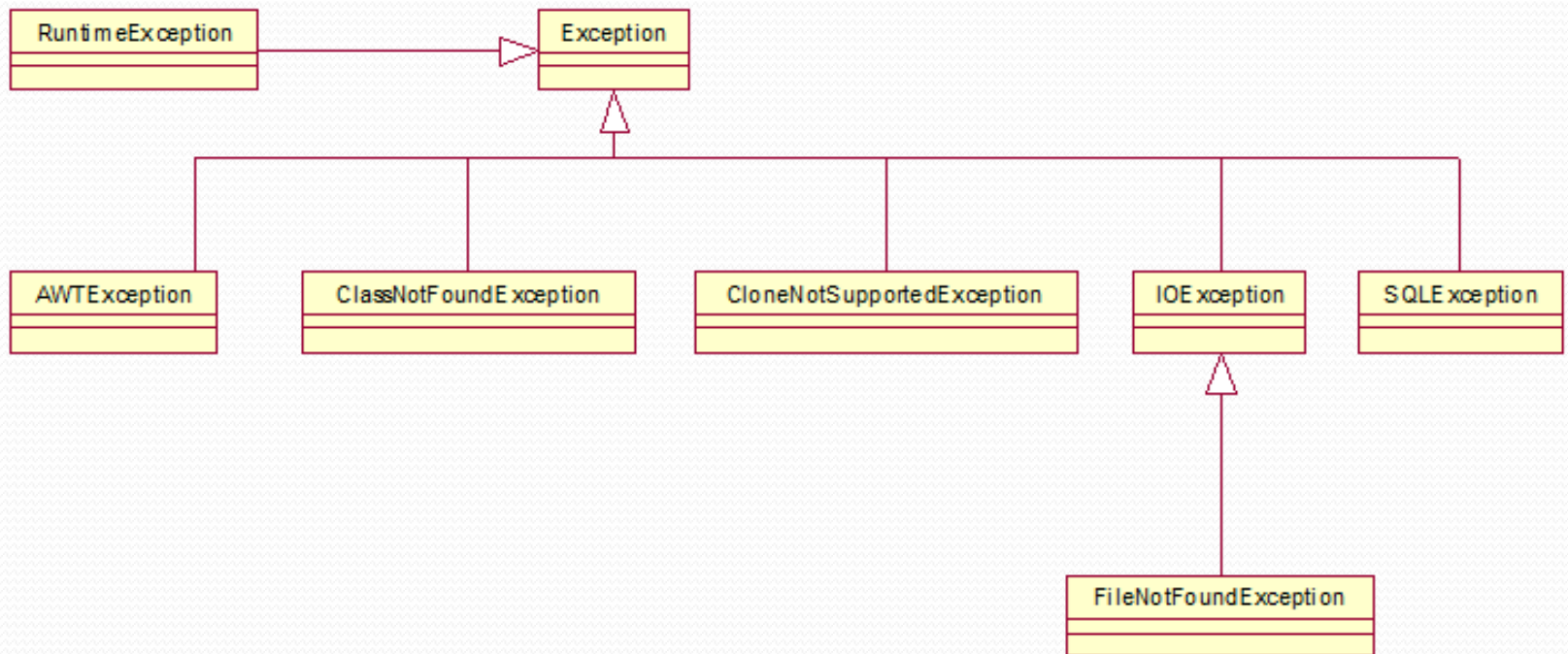


Checked Exceptions

- This kind of exception is considered by the JVM to be the kind of **error a developer must be prepared to handle**. Examples:
 - `CloneNotSupportedException`
 - `FileNotFoundException`
 - `SQLException`
 - `AWTException`
- Often, these exceptions arise when something goes wrong with the application's environment (can't find a file or class) or with an external system (an SQL query can't be executed).
- The JVM expects you the developer to *handle* any exception of this type that could possibly be thrown, and will **issue a compiler error** if you fail to do so. (This is the reason for the terminology "checked exception".)
- Note: The Java programming language does not *require* methods to catch or to specify unchecked exceptions (`RuntimeException`, `Error`, and their subclasses).

Hierarchy of Checked Exceptions

Not a checked
exception



Checked Exceptions

- Every method in the Java that has the possibility of throwing an `Exception` of type `Checked Exception` indicates this with a throws clause in its declaration.
- Two Examples in Java API:
 - The `clone` method in `Object`:
`protected clone() throws CloneNotSupportedException`
 - The constructor of the class `FileWriter` (in next lesson):
`public FileWriter(File file) throws FileNotFoundException`

- Four ways of handling a method that you called, which has a `throws` clause in its declaration:
 1. Do not attempt to handle directly; instead, declare that *your* method **throws** this kind of exception too
- Surround the calling code in a **try** block, and then do one of the following:
 2. write exception-handling code in a **catch** block (as in `lesson12.exceptionhandlingdemo`, mentioned earlier)
 3. partially handle the exception in a **catch** block, and then *re-throw* the exception to allow other methods in the call stack to handle it further
 4. **throw** a new kind of exception from within the **catch** block

Note: Be aware of the difference between **throw** and **throws**

Example for Case 1:

```
// Do not attempt to handle directly; instead,  
// declare that your method throws this kind of exception too.
```

```
// The CloneNotSupportedException is not handled directly. Instead  
// the clone method of Employee class declares that it also  
// throws CloneNotSupportedException
```

```
class Employee implements Cloneable {  
    . . . . .
```

```
    public Employee clone() throws CloneNotSupportedException {  
        Employee copy = (Employee)super.clone(); // throws an exception  
        copy.hireDate = (Date)hireDate.clone(); // throws an exception  
        return copy;  
    }  
    . . . . .
```

```
}
```

```
class OtherClass {  
    void callingMethod() {  
        Employee e = new Employee();  
        e.clone(); //compiler error - must enclose in try/catch  
                  //or declare that the method throws  
                  //CloneNotSupportedException  
    }  
}
```

Example for Case 2:

**// Enclose the calling code in a try block, and then
// write exception-handling code in a catch block**

```
class Employee implements Cloneable {  
    . . . . .  
  
    public Object clone(){  
        try {  
            Employee copy = (Employee)super.clone(); // throws exception  
            copy.hireDate = (Date)hireDate.clone(); // throws exception  
  
            return copy;  
        } catch(CloneNotSupportedException ex) {  
            // Exception handling code follows:  
            System.err.println("Unable to make a copy");  
        }  
    }  
  
    . . . . .  
}  
  
class OtherClass {  
    void callingMethod() {  
        Employee e = new Employee();  
        e.clone(); //this is ok - Exception already handled  
    }  
}
```

Example for Case 3:

```
// Enclose the calling code in a try block,  
//then, in a catch block,write some exception-handling code  
//and then re-throw the exception  
  
class Employee implements Cloneable {  
    . . . . .  
  
    public Object clone() throws CloneNotSupportedException{  
        try {  
            Employee copy = (Employee)super.clone(); // throws exception  
            copy.hireDate = (Date)hireDate.clone(); // throws exception  
            return copy;  
        } catch (CloneNotSupportedException ex) {  
            // partially handle the exception:  
            System.err.println("Unable to make a copy");  
            // rethrow the exception:  
            throw ex;  
        }  
    }  
    . . . . .  
}
```

You may want to repeatedly throw an exception to trace where the error started and what areas of code were affected.

Programmers often include information in the printout or log about what class and method where the exception occurred.

What Happens in Each Case

- Whenever an exception is thrown at runtime, the JVM looks to see if the active method has a `catch` clause whose `Exception` type matches the type of the thrown `Exception`. If not, it moves up the call stack to see if any calling methods provide a `catch` clause with a match.
- If `try/catch` blocks have been provided, and the catch block's parameter matches the thrown exception type, then:
 - the program skips the remainder of code in the `try` block
 - the program executes the code in the `catch` block

- The code inside a `catch` block may
 - a) gracefully handle the error condition – in which case the program will continue to run immediately after the `catch` block, or
 - b) cause the application to terminate (using `System.exit()`), or
 - c) re-throw the `Exception` that it just caught, or
 - d) throw a new `Exception` of a different type
- In cases b-d, when there is no finally block, the method immediately exits. In cases c-d, if there is a finally block, the finally block will be executed before the method can exit. (Discussed in the next slide and also at end.)

Example for Terminating the Application

```
class OtherClass {  
    void callingMethod() {  
        Employee e = new Employee();  
        //must handle or pass on the exception  
        try {  
            e.clone();  
        } catch(CloneNotSupportedException ex) {  
            System.exit(1);  
        }  
        //this code will not execute if catch  
        //clause is invoked  
        System.out.println(e.getName());  
    }  
}
```

The finally Keyword

- A `finally` clause can be introduced after all `catch` clauses.
- Any `finally` block is guaranteed to run after a `try/catch` block, even if a `return` or `break` occurs; even if another exception is thrown inside those blocks.
- Exception to the rule: If `System.exit()` occurs in one of the blocks, the `finally` clause is skipped.
- A `finally` clause is used to cleanup resources (like database connections, open files)

Main Point

Methods whose declaration includes a *throws* clause can be called by another method only if the calling method is declared with the same *throws* clause, or if a try/catch block is included to catch any of the declared exceptions that are thrown. This phenomenon is reminiscent of the Principle of Diving (also mentioned in lesson 10). Once the initial conditions have been met, a correct dive into the depths occurs automatically. The *throws* clause is the initial condition; the compiler then automatically structures the code requirements which handle any exceptions that may occur.

Summary of Exception Types

- **Errors.** An Error is thrown usually due to an internal JVM error or a problem beyond the control of the developer. **No adjustment to the code needs to be done** (except for StackOverflowError, usually from an illegal recursion).
- **Other unchecked exceptions** are objects of type RuntimeException, or one of its subclasses. These exceptions indicate a programming error that needs to be fixed. Examples: NullPointerException, ClassCastException, and ArrayIndexOutOfBoundsException. These objects should not be "caught" or used in conjunction with try/catch blocks, except when debugging is being done.
- **Checked exceptions** are exceptions that are subclasses of Exception that are not part of the RuntimeException hierarchy. **This is the one type of exception that must be handled in developer code.** If this code is missing, a compiler error will be issued. Calling a method that has a "throws <exception>" in its declaration, requires the caller to:
 - explicitly handle any exception that may arise from the call (using a try/catch block), or
 - pass the exception object up the call stack (using a throws declaration).

Using/Creating Exception Classes

- Sometimes when coding an application you find that one of Java's pre-defined exception classes provides a sensible implementation for your error conditions.

Example: You have a method `readData` that reads in a file and one day, for a file whose header promised

Content-length: 1024

you discover that the end of file is reached after only 733 characters.

So you equip `readData` with an exception. You read in the Java API docs that the `EOFException`

Signals that an EOF has been reached unexpectedly during input

You rewrite your `readData` method as follows:

```
String readData(Scanner in) throws EOFException {
    . . .
    while(true) {
        if(!in.hasNext()) { //EOF encountered—may be ok

            //something bad has happened
            if(actualLen < PROMISED_LEN){
                String msg = "expected " + promisedLen +
                    " but got only " + actualLen;
                throw new EOFException(msg);
            }
            else{
                . . .
            }
        }
    }
}
```

Creating Your Own Exception Class

Sometimes, the best solution is to create your own Exception class. You will be able to use your class just like any other exception. Define it as a subclass of Exception:

- Exception has three main constructors
 - a default constructor
 - a one-argument constructor (of String type) that accepts an error message
 - a one-argument constructor (of type Throwable) designed to store another exception type. Typically, you override these:

```
public class MyException extends Exception {  
    public MyException() {  
        super();  
    }  
    public MyException(String msg) {  
        super(msg);  
    }  
    public MyException(Throwable t) {  
        super(t);  
    }  
}
```

Best Practices:

When to Handle, When to Throw, When to Log

Which Class Should Handle An Exception?

- Exceptions are thrown at the exact point during execution where a problem arises
- Exceptions should be handled by a class that has enough knowledge to *intelligently* handle the exception.
- One or more classes in the application should be delegated the responsibility of knowing what to do in case an exception occurs. Often, this requires only the display of an appropriate message to the user when an exception occurs.

Example of Handling Exceptions

```
//In a Library class:
void displayNumberOfBooks() {
    try {
        //getNumberOfBooks "throws" an IllegalAccessException
        int numbooks = directory.getNumberOfBooks();
        userIO.setOutputString("Number of books is: "+ numbooks);
        userIO.setOutputValue();
    } catch (IllegalAccessException e){
        userIO.displayErrorMessage(e.getMessage());
    }
}
```

```
//In UserIO class:
void displayErrorMessage(String msg){
    JOptionPane.showMessageDialog(this,
                                msg,
                                "Error",
                                JOptionPane.ERROR_MESSAGE);
}
```

Best Practices: How to Set up Your Own Exception Classes

For production-level applications,

- pre-define a set of application-specific Exception classes as part of an overall error-handling policy.
- These classes represent a simple classification of the kinds of errors that might occur, and a mapping of these to a classification of the kinds of information you want to log and/or present to the user.

Example: In a small application, you may need only two kinds of exception: a `UserException` and a `SystemException`.

`UserException`: When the user makes a mistake

`SystemException`: When something goes wrong that is not the user's fault

Once this design decision has been made, then all exceptions that could arise in the application would be caught and either a `UserException` or `SystemException` would then be thrown.

```
public class UserException extends Exception {  
    public UserException() {  
        super();  
    }  
    public UserException(Throwable t) {  
        super(t);  
    }  
    public UserException(String msg) {  
        super(msg);  
    }  
}
```


Exercise 12.2 – Include Exception-Handling in Stack Implementation

In InClassExercise 9.1, we created an implementation `NodeStack` of the Stack ADT. The `peek` and `pop` operations return null when the stack is empty. Modify this implementation so that when `peek` or `pop` is called on an empty stack, a `StackException` is thrown.

To do this, first create your own `StackException` class. Then, update the clauses in the `peek` and `pop` code so they throw a `StackException` when `peek` or `pop` is called on an empty array.

Exercise 12.2 – Solution Part 1

// Create your own StackException class:

```
public class StackException extends Exception
{
    public StackException() {
        super();
    }
    public StackException(Throwable t) {
        super(t);
    }
    public StackException(String msg) {
        super(msg);
    }
}
```

Exercise 12.2 – Solution

```
// Change peek() & pop() to throw new StackException
public String peek() throws StackException {
    if(top != null) {
        return top.data;
    }
    else {
        throw new StackException("Stack is empty!");
    }
}

// the compiler will give an error until you to catch the thrown
exception
try {
    System.out.println(stack.peek());
    stack.printStack();
    System.out.println(stack.pop());
    stack.printStack();
} catch(StackException e) {
    System.out.println("StackException " + e.getMessage());
}
```

Useful Information

About Logging

- When an exception occurs, it is usually important to record it for later review (review by developers, business team, etc). Messages presented to the user or printed to the console are temporary and fleeting. It is easier to put more data into a *log file* and also easier to share for review.
- Pattern for logging:
 - Log a message (warning/error) when exception first occurs.
 - Throw an appropriate `Exception` up the call stack to the right controller.
 - Controller either handles or creates a user exception with a good message.

Using Java's Logger – Useful Information

- jdk 1.4 introduced the `Logger` class in package `java.util.logging`
- Create an instance like this at top line of `CallingClass`
`private static final Logger LOG = Logger.getLogger(CallingClass.class.getPackage().toString());`
- Permits setting of level (SEVERE, WARNING, INFO, FINE), handlers and formatters. Logging configuration is done in a properties file located in `<java_home>\jre\lib`.
- When an event occurs during runtime that needs to be logged, insert a line like this:

```
LOG.warning("Unauthorized user has attempted "  
           + "perform an action.");
```

Example

```
final String LOG_WARN_BAD_ID
    = "Unauthorized user has attempted perform an action."
final String BAD_ID_MSG
    = "You are not authorized to perform this function."

private static final Logger LOG =
    Logger.getLogger(Bookstore.class.getPackage().toString());

Bookstore(String id){
    this.id = id;
}
int getNumBooks() throws BadIdException {
    if(!isBadId(id)){
        return numBooks;
    }
    else {
        LOG.warning(LOG_WARN_BAD_ID);
        throw new BadIdException(BAD_ID_MSG);
    }
}
```

Main Point

To use Exceptions effectively, when an Exception is thrown, a message should be *logged* so that the support team can review later; the Exception should be *thrown* up the call stack until a class that knows how to handle the Exception is reached; and this final class should *catch* and *handle* the Exception in an appropriate way (often, this means presenting an error message to the user). In a similar way, creation itself is structured in layers; the activity at each layer has its own unique set of governing laws; laws that pertain to one level or layer may not be applicable at another level.

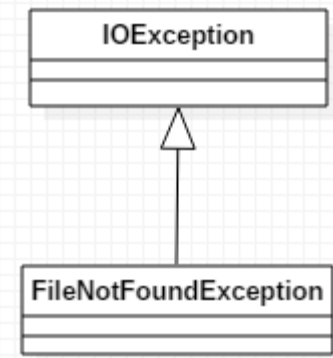
Some Syntax Rules for Try/Catch – Supported by the Compiler

1. Every use of try must have at least one corresponding catch clause or finally clause.
2. When an exception object is thrown, it will be caught by the nearest catch clause for which the catch clause parameter matches the class of the exception object, or *is a superclass of this class*

Example: The following produces a compiler error – 2nd catch clause is *unreachable*

```
try {  
    . . .  
}  
catch(IOException ex1) {  
    . . .  
}  
catch(FileNotFoundException ex2) {  
    . . .  
}
```

→
**unreachable
code**



The following however is legal

```
try {  
    . . .  
}  
catch (FileNotFoundException ex1) {  
    . . .  
}  
catch (IOException ex2) {  
    . . .  
}
```

This also explains why you never catch an "Exception" object directly – otherwise, you could end up catching all kinds of unchecked exceptions (by accident).

```
//bad programming style  
try {  
    . . .  
}  
catch (Exception e) {  
    . . .  
}
```

3. You can have try/catch blocks inside other try blocks and inside other catch blocks. And sometimes this is necessary.

```
try{
    try {
        . . .
    }
    catch (AnExceptionType ex1) {
        . . .
    }
}
catch (AnotherExceptionType ex2) {
    try {
        . . .
        {
            catch (ThirdExceptionType ex3) {
                . . .
            }
        }
    }
}
```

The finally Keyword

- A **finally** clause can occur after all catch clauses.
- A **finally** block is guaranteed to run after a try/catch block, even if a return or break occurs; even if another exception is thrown inside the try or catch.
- One exception to above: If `System.exit()` is encountered in one of the blocks, the app immediately terminates and the **finally** block is skipped.
- A **finally** clause is used to cleanup resources (like database connections, open files).

finally Exercise

Demo: lesson12.finallyexercise - understand the flow

```
class FinallyTest{
    public static void test() throws Exception {
        try {
            // return;                // 1
            // System.exit(0);         // 2
            // throw new Exception("first"); // 3a
        }
        catch (Exception x){
            System.out.println(x.getMessage());
            // throw new Exception("second"); // 3b (a&b included)
        }
        finally {
            System.out.println("finally!");
        }

        System.out.println("last statement "); // 3b not included
    }
    public static void main(String[] args){
        try{
            test();
        }
        catch(Exception x){
            System.out.println(x.getMessage());
        }
    }
}
```

Program Output

0: finally!
 last statement

1: finally!

2: no output

3a: first
 finally!
 last statement

3a & 3b: first
 finally!
 second

Examples of Proper Use of Java's Exception-Handling Model

Needs Improvement

```
//Triangle constructor
public Triangle(double side1, double side2, double side3) {
    double[] arr = sort(side1,side2,side3);
    double x = arr[0];
    double y = arr[1];
    double z = arr[2];
    if(x + y < z) {
        System.out.println("Illegal sizes for a triangle:
        "+side1+", "+side2+", "+side3);
        System.out.println("Using default sizes.");

        setValues(DEFAULT_SIDE,DEFAULT_SIDE,DEFAULT_SIDE);
        computeBaseAndHeight(DEFAULT_SIDE,
                                DEFAULT_SIDE,
                                DEFAULT_SIDE);
    }
    else {
        setValues(x,y,z);
        computeBaseAndHeight(x,y,z);
    }
}
```

Example of Java Exception-Handling

continued

```
//from Test class
public static void main(String[] args) {

    ClosedCurve[] objects = {new Triangle(4,5,6),
                             new Square(3),
                             new Circle(3)};

    //compute areas
    for(ClosedCurve cc : objects) {
        System.out.println(cc.computeArea());
    }

}
```

Improved Version

```
Logger log=Logger.getLogger("closedcurve.good");
//Triangle constructor
public Triangle(double side1, double side2, double side3) throws
    IllegalArgumentException {
    double[] arr = sort(side1,side2,side3);
    double x = arr[0];
    double y = arr[1];
    double z = arr[2];
    if(x + y < z) {
        // Instead of System.out.println, log msg & throw Exception
        log.warning("Illegal sizes of sides passed in");
        throw new IllegalArgumentException("Illegal sizes
            for a triangle: "+"+side1+", "+side2+", "+side3);
    }
    else {
        setValues(x,y,z);
        computeBaseAndHeight(x,y,z);
    }
}
```



```
//from Test class
public static void main(String[] args) {
    ClosedCurve[] objects = null;
    Triangle t = null;
    try {
        t = new Triangle(4,5,6);
        // catch & handle exception Triangle constructor throws:
    }
    catch(IllegalArgumentException e) {
        String msg = e.getMessage();
        JOptionPane.showMessageDialog(this, msg, "Error",
                                     JOptionPane.ERROR_MESSAGE);
        System.exit(0);
    }
    objects = {t, new Square(3), new Circle(3)};

    //compute areas
    for(ClosedCurve cc : objects) {
        System.out.println(cc.computeArea());
    }
}
```

Polymorphism in Exceptions

// You can also use Polymorphism to create and handle your Exceptions.
// Here is a base class for the exception classes for various shapes:

```
public class IllegalShapeException extends Exception {  
    public IllegalShapeException () {  
        super();  
    }  
    public IllegalShapeException (String className, String msg) {  
        super(className+" threw: "+msg);  
    }  
}
```

// Our triangle exception extends this shape exception...

```
public class IllegalTriangleException extends IllegalShapeException {  
  
    public IllegalTriangleException ()    { super(); }  
    public IllegalTriangleException (String msg) {  
        super("IllegalTriangleException", msg);  
    }  
}
```

Connecting the Parts of Knowledge With the Wholeness of Knowledge

Right action in the field of exception-handling

1. If a Java method has a `throws` clause in its declaration, the compiler requires the developer to create code that handles any potential exceptions from calling the method.
 2. To handle exceptions in the best possible way, logging should occur as soon as an exception is thrown, and the exception should be re-thrown up the call stack until a method belonging to a class with an appropriate set of responsibilities is reached – and within this method, the exception should be caught and handled.
-
3. **Transcendental Consciousness:** TC is the home of all the laws of nature, the home of "right action".
 4. **Wholeness moving within itself:** Action in the state of Unity
Consciousness is spontaneously right and uplifting to all of creation, as a whole.

