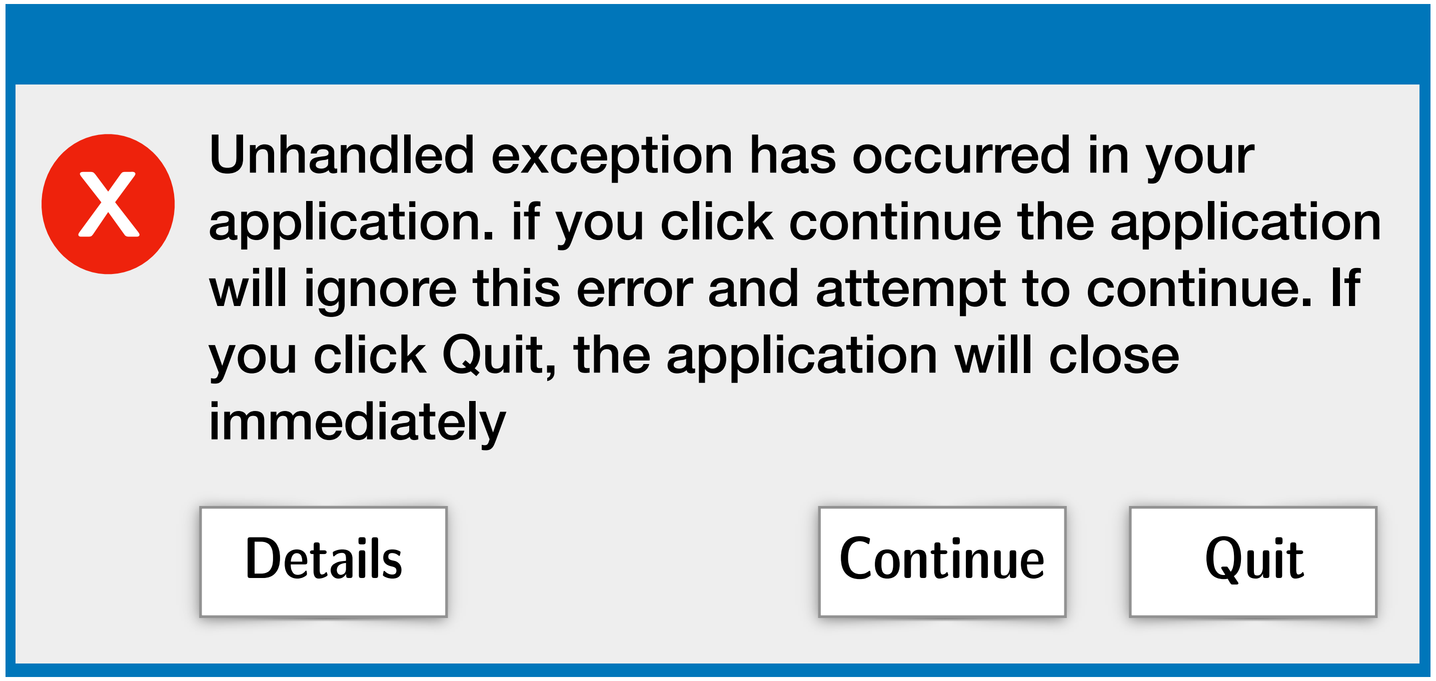


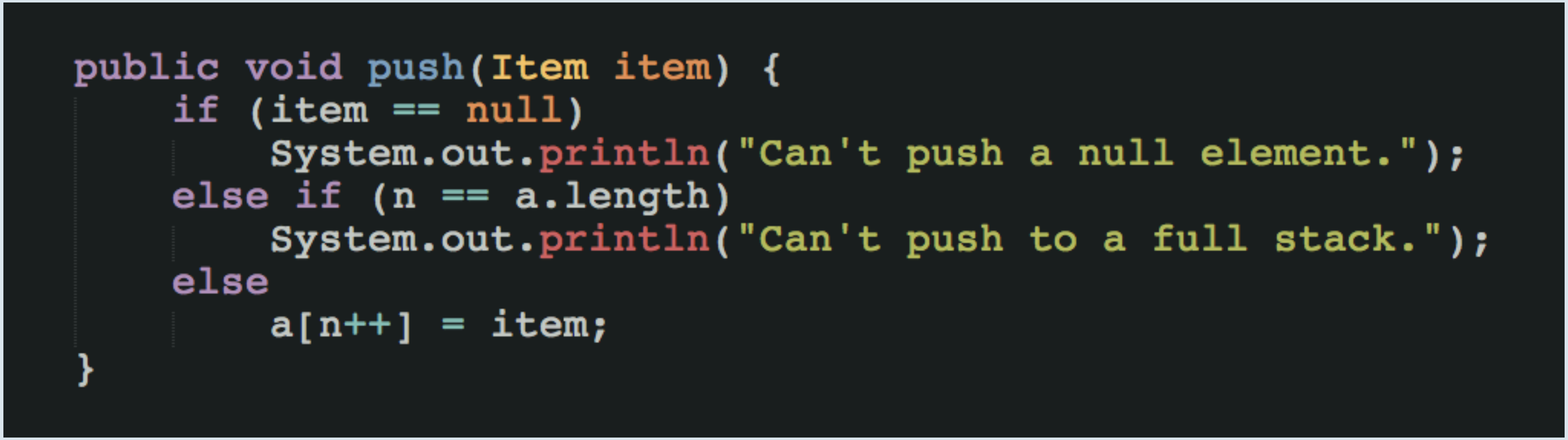
Unhandled exception has occurred in your application. if you click continue the application will ignore this error and attempt to continue. If you click Quit, the application will close immediately

Exception Handling

Ibrahim Albluwi

Warm Up Question!

From a *Software Engineering* point of view, what is wrong with the following implementation of the `push` method in an implementation of the `Stack` ADT?



```
public void push(Item item) {
    if (item == null)
        System.out.println("Can't push a null element.");
    else if (n == a.length)
        System.out.println("Can't push to a full stack.");
    else
        a[n++] = item;
}
```

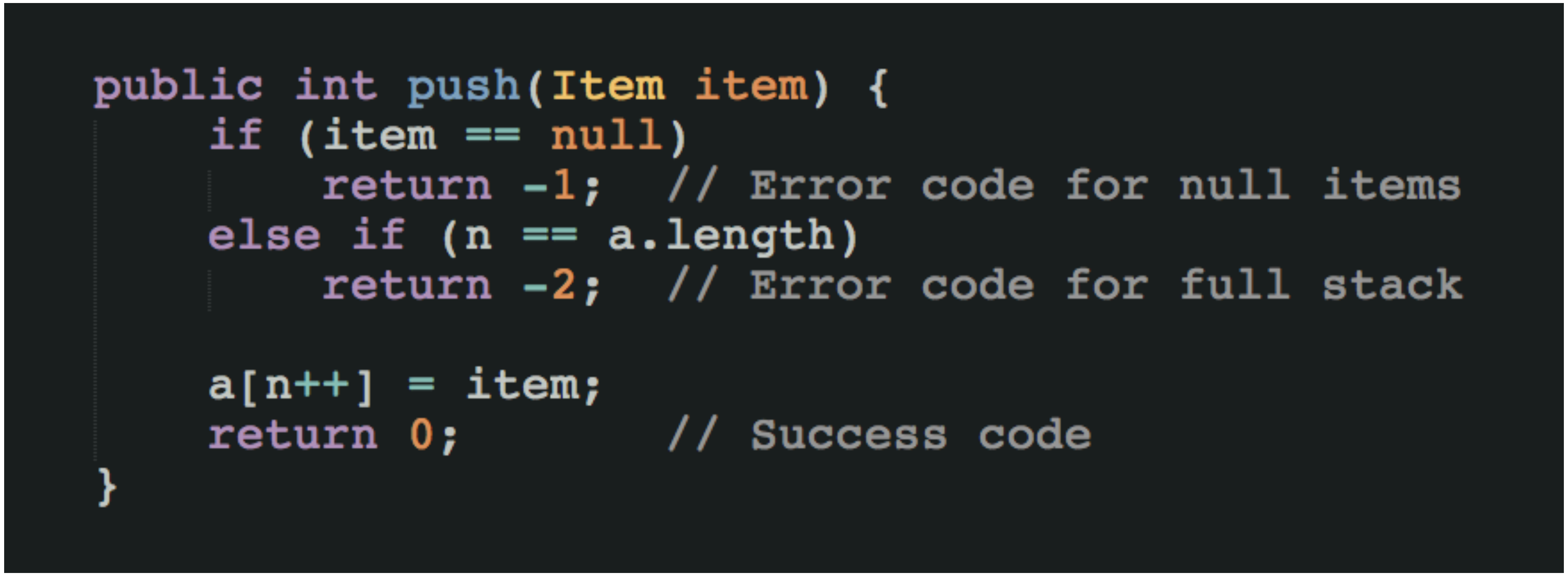
- What if the stack is used in a GUI application?
- How can the calling method know if a push is successful?

Candidate Solution: Error Codes

- Stack methods ***detect*** errors, but do not ***handle*** them.
- Stack methods return information about errors in the form of ***error codes***.

Advantages:

- Stack implementation is not tied to any certain error reporting mechanism.
- Clients of a Stack are well-informed about errors.



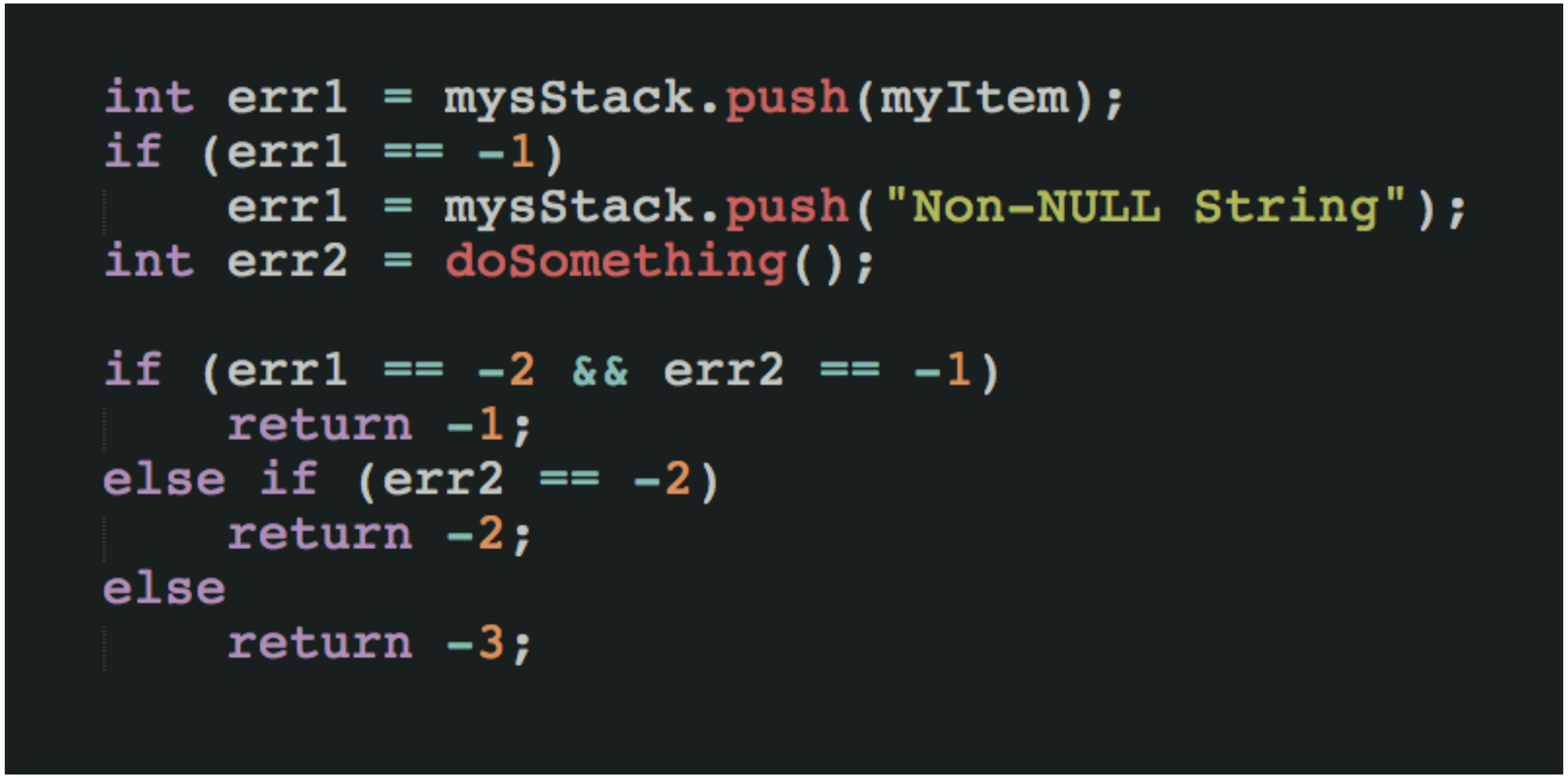
```
public int push(Item item) {
    if (item == null)
        return -1;  // Error code for null items
    else if (n == a.length)
        return -2;  // Error code for full stack

    a[n++] = item;
    return 0;       // Success code
}
```

Any problems?

Candidate Solution: Error Codes

Disadvantages:

- Code may be ***difficult to read, debug*** and ***maintain***:
  - -1, 0, 1, etc. are not inherently meaningful.
  - The same error code can have different meanings in different methods.
  - Error codes need to be manually propagated from one method to another.

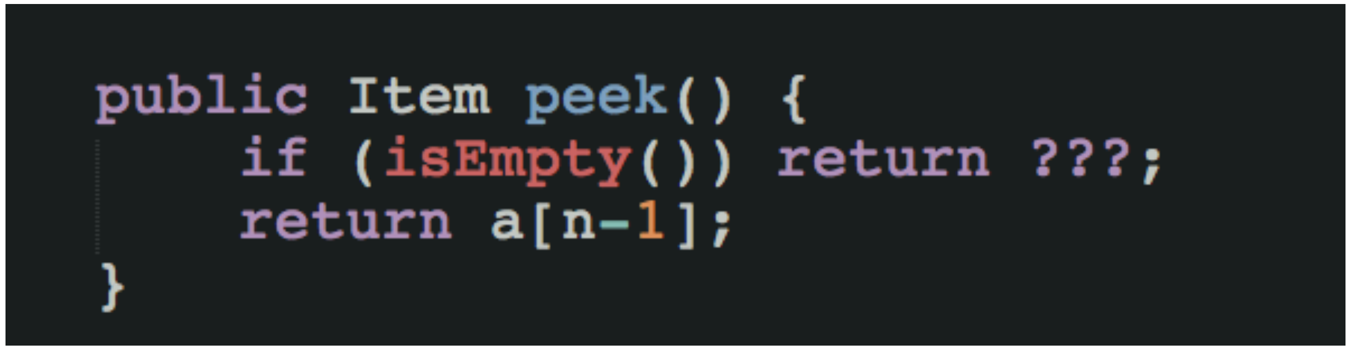


```
int err1 = mysStack.push(myItem);
if (err1 == -1)
    err1 = mysStack.push("Non-NULL String");
int err2 = doSomething();

if (err1 == -2 && err2 == -1)
    return -1;
else if (err2 == -2)
    return -2;
else
    return -3;
```

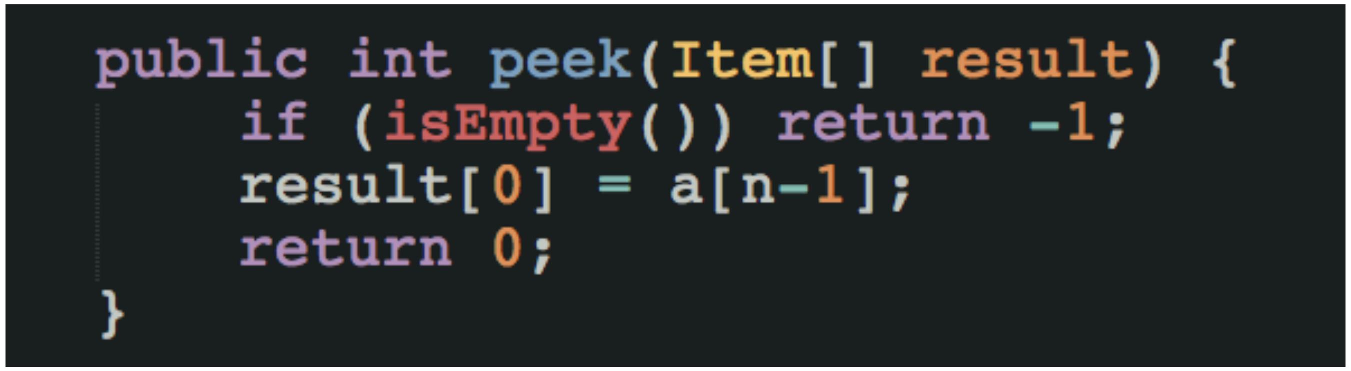
Candidate Solution: Error Codes

Disadvantages:

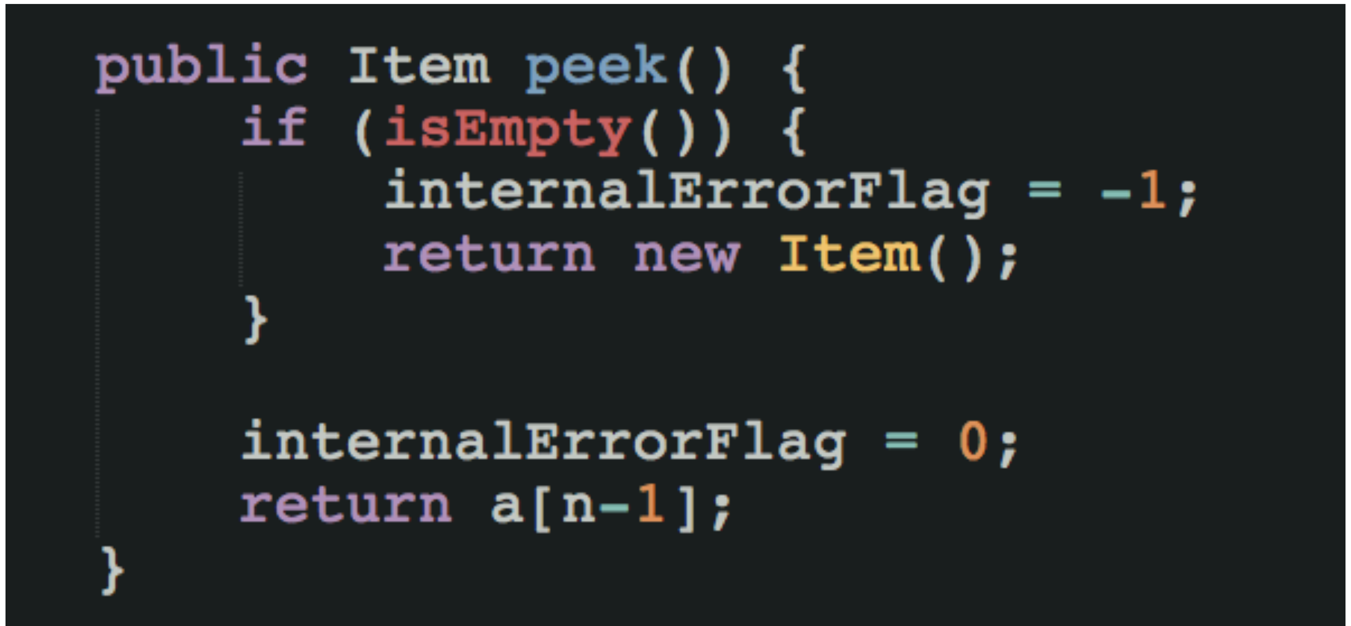
- Code may be ***difficult to read, debug*** and ***maintain***:
- API limitations need to be worked around!



```
public Item peek() {
    if (isEmpty()) return ???;
    return a[n-1];
}
```



```
public int peek(Item[] result) {
    if (isEmpty()) return -1;
    result[0] = a[n-1];
    return 0;
}
```



```
public Item peek() {
    if (isEmpty()) {
        internalErrorFlag = -1;
        return new Item();
    }

    internalErrorFlag = 0;
    return a[n-1];
}
```

Candidate Solution: Error Codes

Disadvantages:

- Code may be ***difficult to read, debug*** and ***maintain***:
- API limitations need to be worked around!
- Clients may not check for error codes.
  - Experience shows that error codes are often ignored!
  - Behavior is undetermined if errors are not accounted for.

Candidate Solution: Error Codes

Disadvantages:

- Code may be ***difficult to read, debug*** and ***maintain***:
- API limitations need to be worked around!
- Clients may not check for error codes.
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- What if unexpected errors occur that are not described by any error code?

Candidate Solution: Error Codes

Disadvantages:

- Code may be ***difficult to read, debug*** and ***maintain***:
- API limitations need to be worked around!
- Clients may not check for error codes.
  - Experience shows that error codes are often ignored!
  - Behavior is undetermined if errors are not accounted for.
- What if unexpected errors occur that are not described by any error code?
- No information about the trace of how the error occurred.

Solution: Exception Handling!

Exception Handling

Advantage 1: Allows separating error detection from error handling.

Advantage 2: Allows separating error handling code from regular code.

Advantage 3: Errors can't go unnoticed: *Specify or Handle* rule.

Advantage 4: Automatically propagate errors up the call stack.

Advantage 6: Keeps track of information on the error stack trace.

Advantage 7: Allows grouping and differentiating error types.

Throw something, catch something!

Catching Exceptions

```
… some code …
try {
    … some code …
    element = myStack.pop();
    … some code …
} catch(NoSuchElementException e) {
    // code that handles the exception
}
```

may throw a NoSuchElementException

Control is transferred to the catch block if a NoSuchElementException is thrown

Catching Exceptions

```
… some code …
try {
     … some code …
     element = myStack.pop();
     … some code …
} catch(NoSuchElementException e) {
     // code that handles the exception
} catch(FileNotFoundException e) {
     // code that handles the exception
} catch(IOException e) {
     // code that handles the exception
}
```

Add a catch block for every exception that you would like to handle.

Catching Exceptions

```
… some code …
try {
    … some code …
    element = myStack.pop();
    … some code …
} catch(NoSuchElementException e) {
    // code that handles the exception
} catch(FileNotFoundException e) {
    // code that handles the exception
} catch(IOException e) {
    // code that handles the exception
}
```

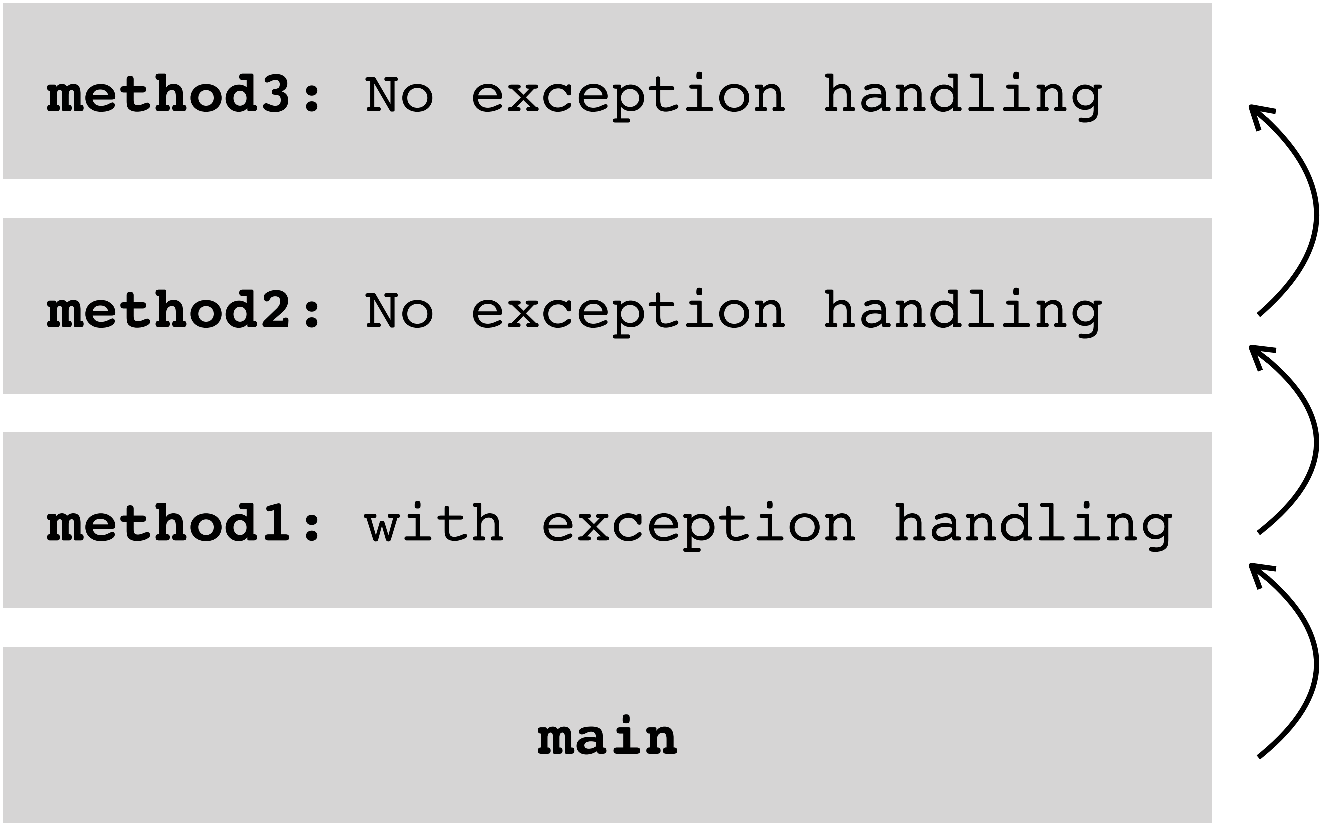
Object holding information about the exception: cause, message, stack trace, etc.

Catching Exceptions

```
… some code …
try {
    … some code …
    element = myStack.pop();
    … some code …
} catch(NoSuchElementException e) {
    // code that handles the exception
} catch(FileNotFoundException e) {
    // code that handles the exception
} catch(IOException e) {
    // code that handles the exception
} finally {
    // Example: close the file
}
```

Code to be executed regardless of whether an exception is thrown or not.

Stack Trace



method3: No exception handling

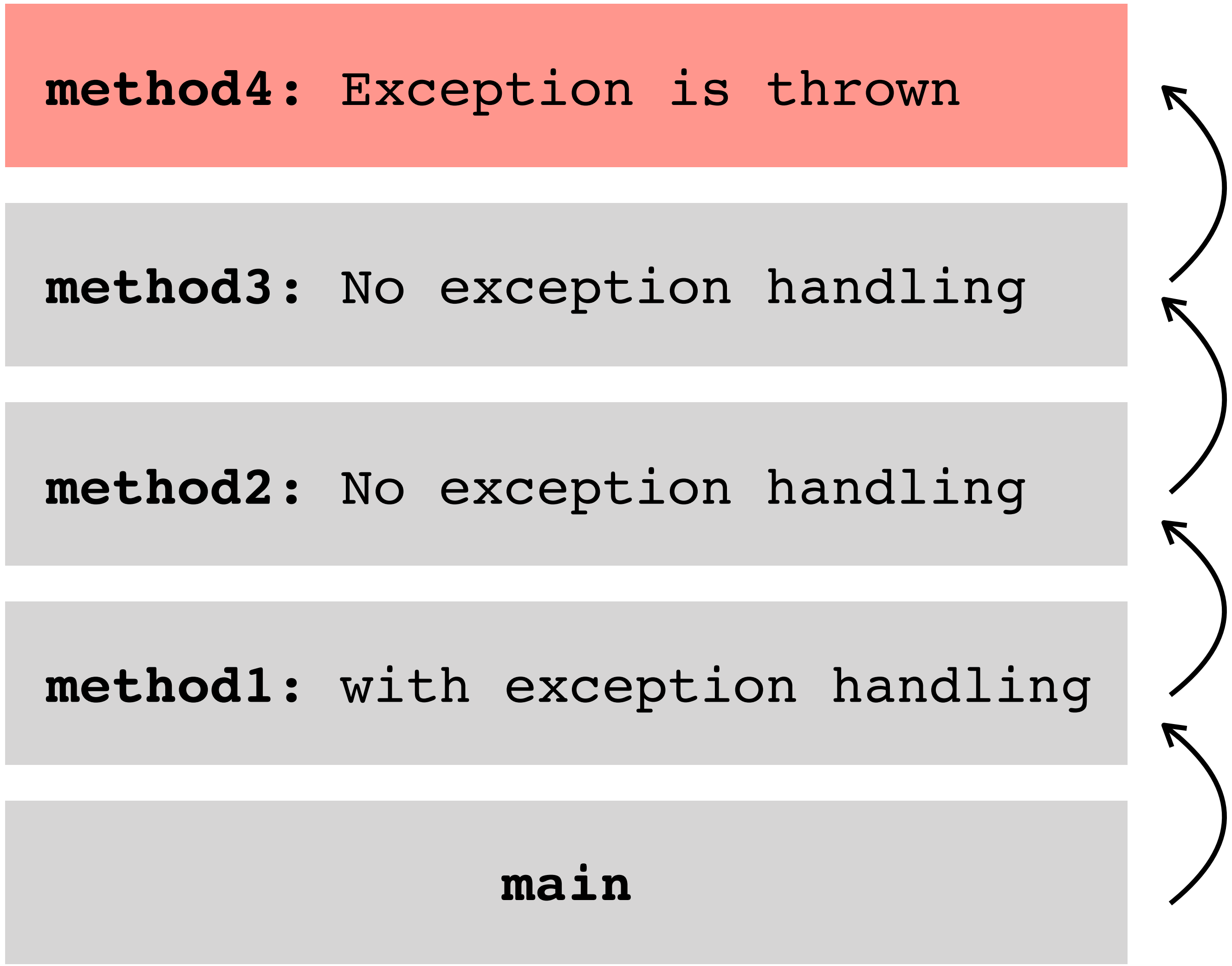
method2: No exception handling

method1: with exception handling

main

Stack Trace

Exception is propagated across the stack frames.



method4: Exception is thrown

method3: No exception handling

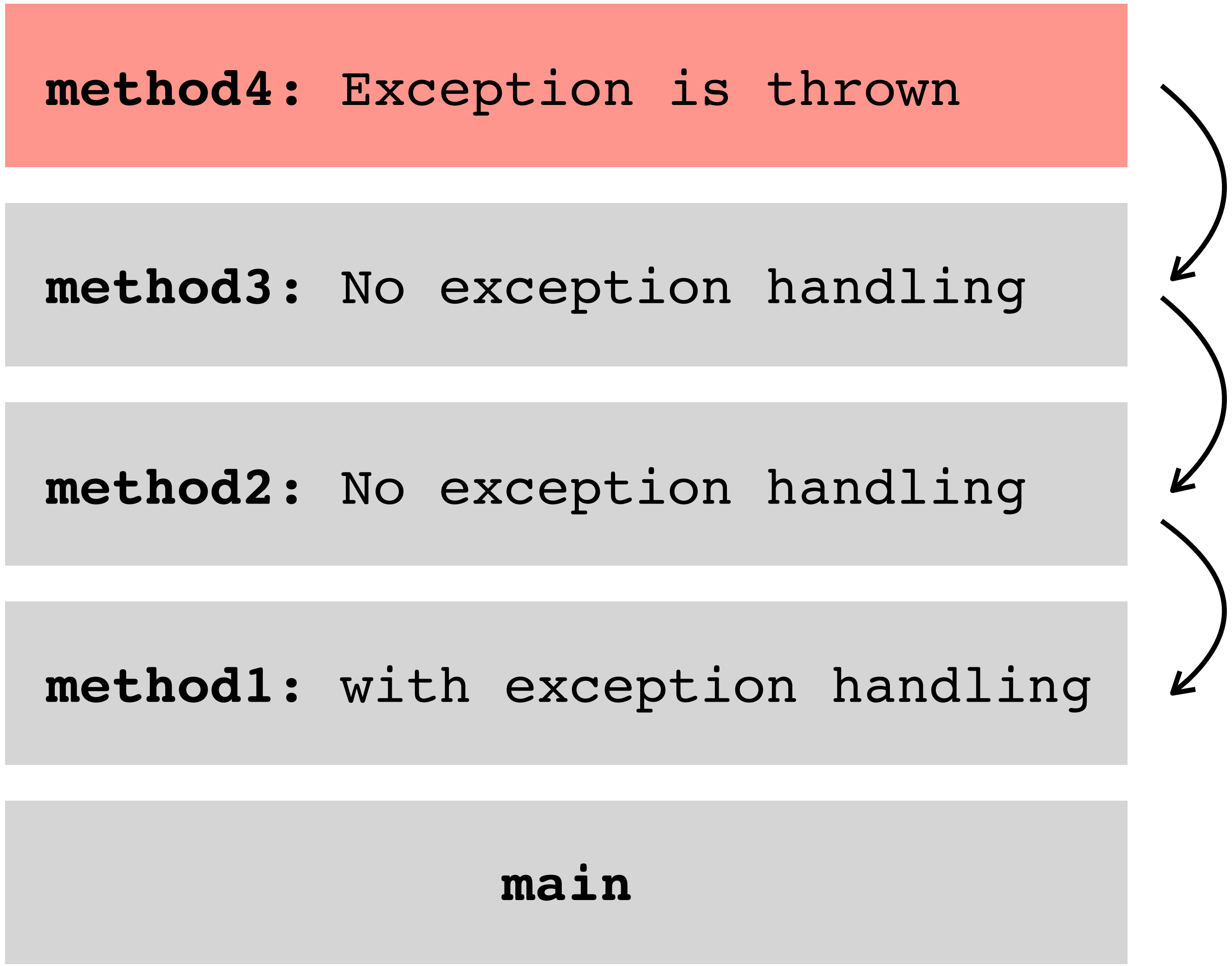
method2: No exception handling

method1: with exception handling

main

Stack Trace

Exception is propagated across the stack frames.



method4: Exception is thrown

method3: No exception handling

method2: No exception handling

method1: with exception handling

main

Information about the exception stack trace is stored in the exception object as it is being propagated across the stack frames.

Catching Exceptions

What to do with a caught exception?

- Address the issue! Make sure your code is in a good and stable state in spite of the error.
- Do not hide the issue! Make sure either the admin knows (by logging information) or the user knows (by showing an error message), etc.
- If it is not your responsibility to handle the exception, consider *decorating* the exception with some information and then re-throwing it again!

```
try { … } catch (SomeException e) {
   SomeOtherExceptionType newE = new SomeOtherExceptionType(e);
   // Add some information to newE
   throw newE;
}
```

Preserves information already stored in e.

Exception Handling

Advantage 1: Allows separating error detection from error handling.

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Separate Error Handling Code from Regular Code

Cleaner looking code

Instead of code that looks

like this ⟶

```
initialize errorCode = 0;
open the file;
if (theFileIsOpen) {
    determine the length of the file;
    if (gotTheFileLength) {
        allocate that much memory;
        if (gotEnoughMemory) {
            read the file into memory;
            if (readFailed) {
                errorCode = -1;
            }
        } else {
            errorCode = -2;
        }
    } else {
        errorCode = -3;
    }
    close the file;
    if (theFileDidntClose && errorCode == 0) {
        errorCode = -4;
    } else {
        errorCode = errorCode and -4;
    }
} else {
    errorCode = -5;
}
return errorCode;
```

Separate Error Handling Code from Regular Code

Write code that

looks like this ——>

```
try {
    open the file;
    determine its size;
    allocate that much memory;
    read the file into memory;
    close the file;
} catch (fileOpenFailed) {
   doSomething;
} catch (sizeDeterminationFailed) {
    doSomething;
} catch (memoryAllocationFailed) {
    doSomething;
} catch (readFailed) {
    doSomething;
} catch (fileCloseFailed) {
    doSomething;
}
```

Exception Handling

Advantage 1: Allows separating error detection from error handling.

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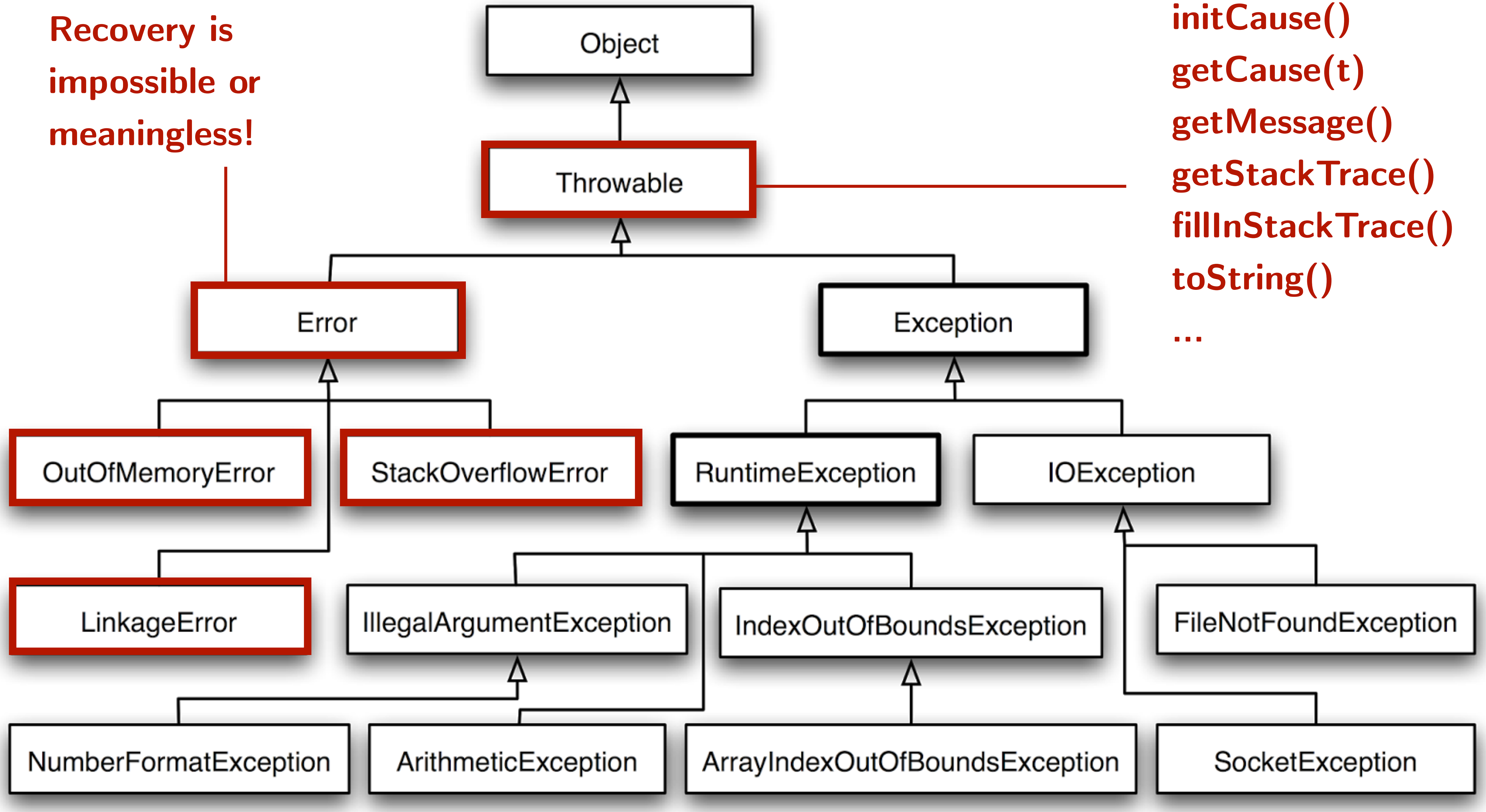
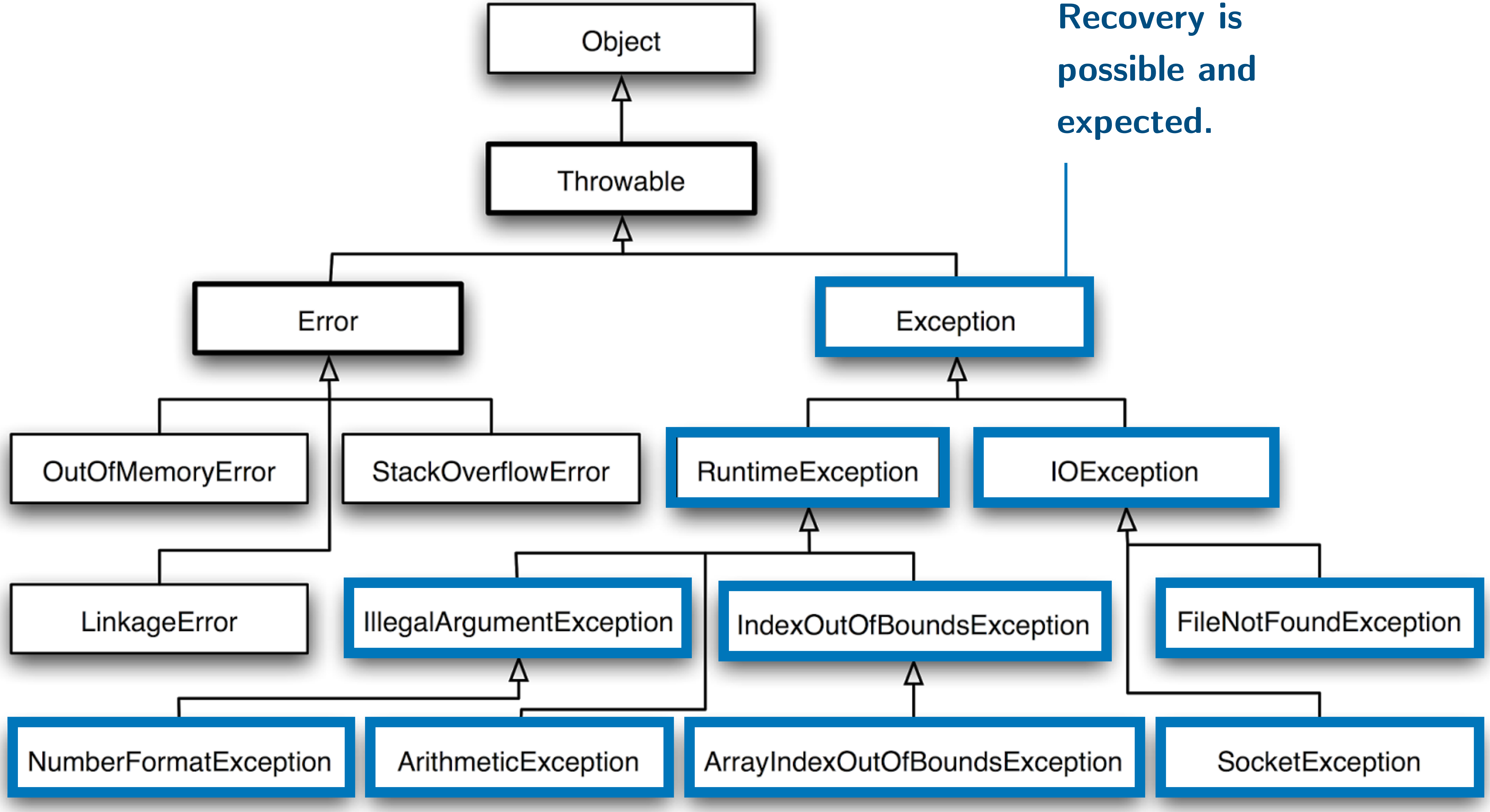
Java Exceptions Hierarchy

Recovery is impossible or meaningless!



initCause()
getCause(t)
getMessage()
getStackTrace()
fillInStackTrace()
toString()
...

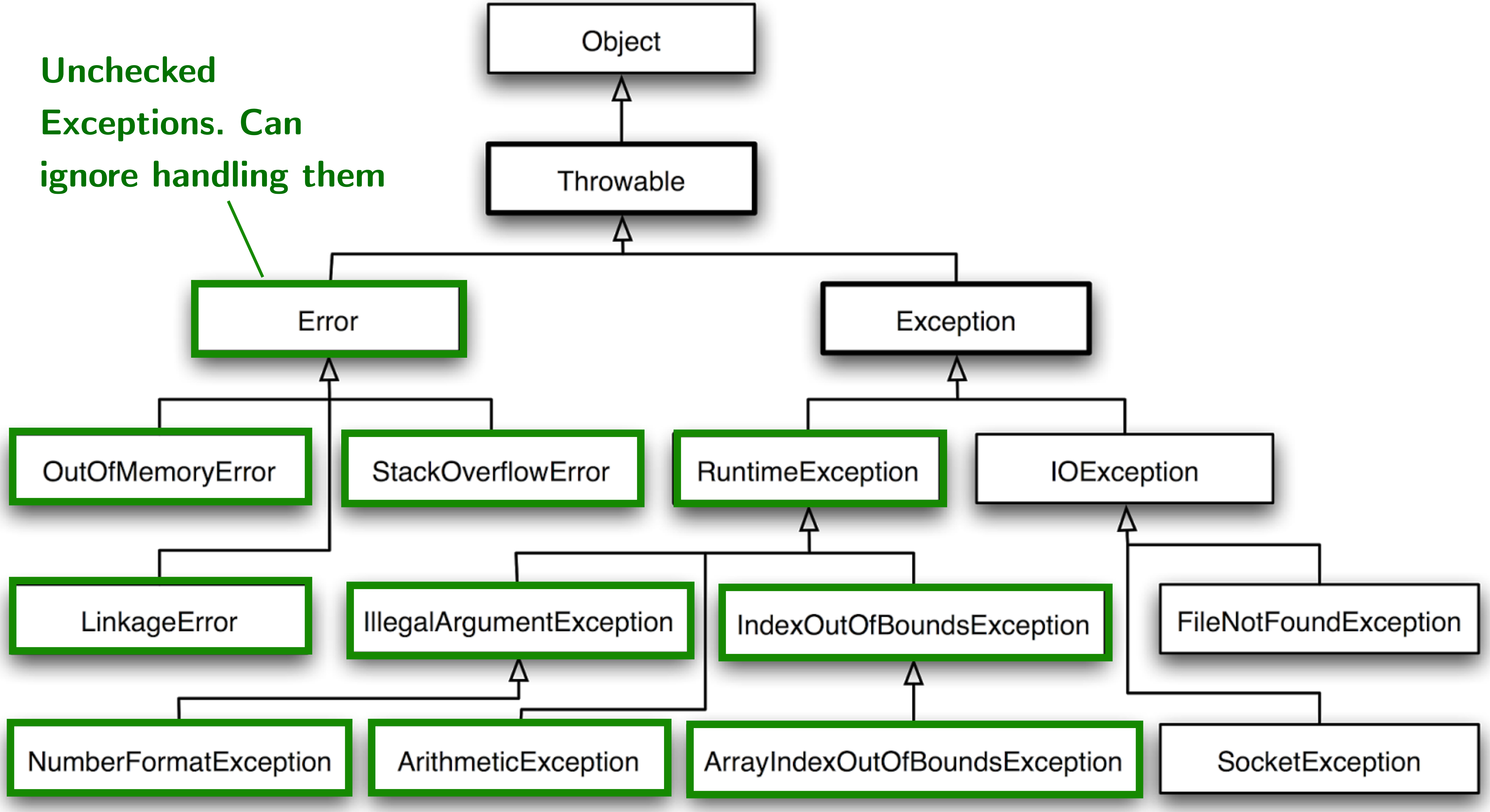
Java Exceptions Hierarchy



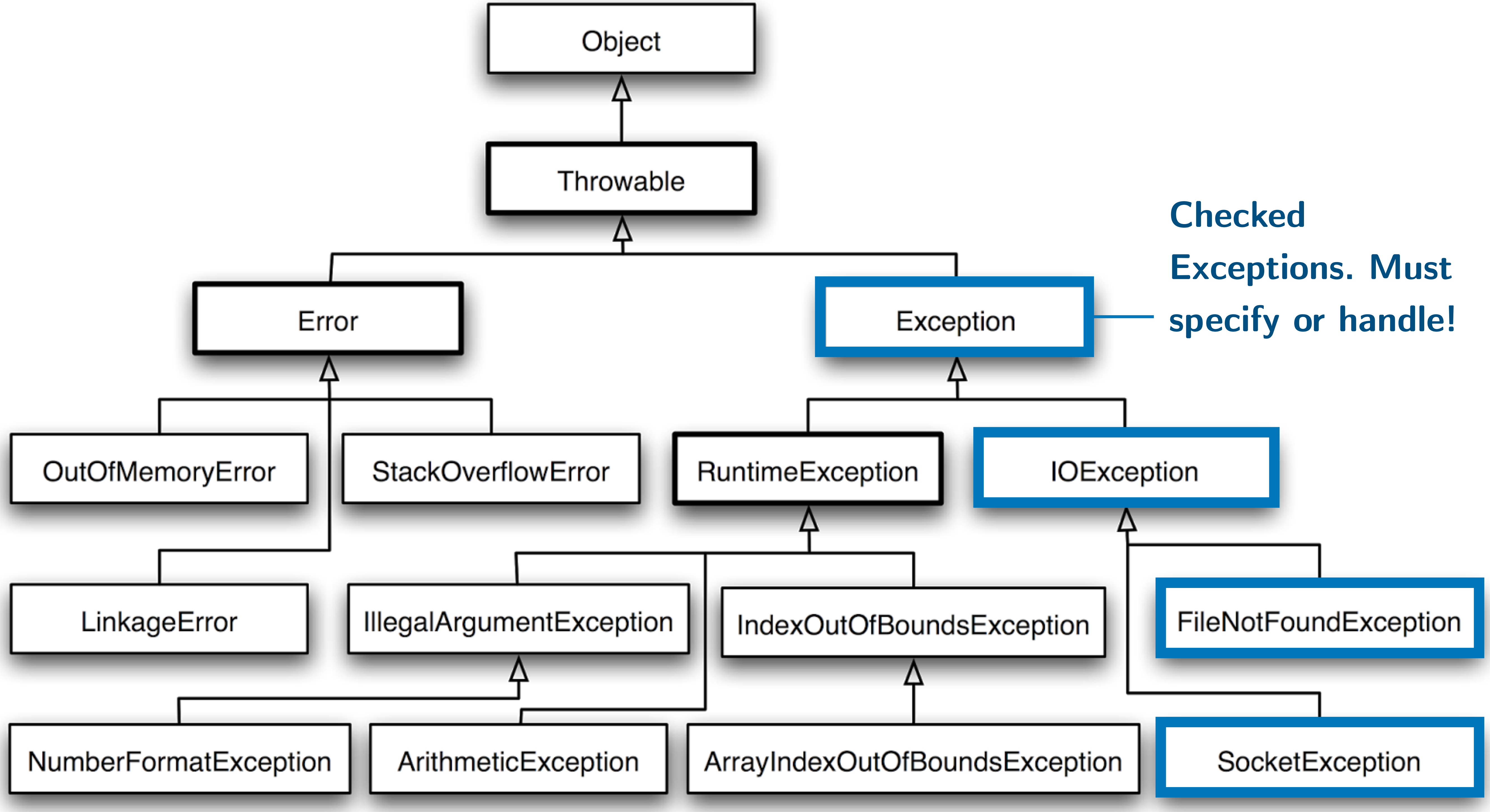
Recovery is possible and expected.

Java Exceptions Hierarchy

Unchecked Exceptions. Can ignore handling them



Java Exceptions Hierarchy



Checked Exceptions. Must specify or handle!

Unchecked Exceptions

Not checked by the compiler. Catching and handling these exceptions is optional. These exceptions are:

Subclasses of class Error: Like `StackOverflowError`, `OutOfMemoryError`, etc. It is not ordinarily expected for a program to be able to recover from these errors. Therefore, it doesn't make sense to enforce catching/handling them.

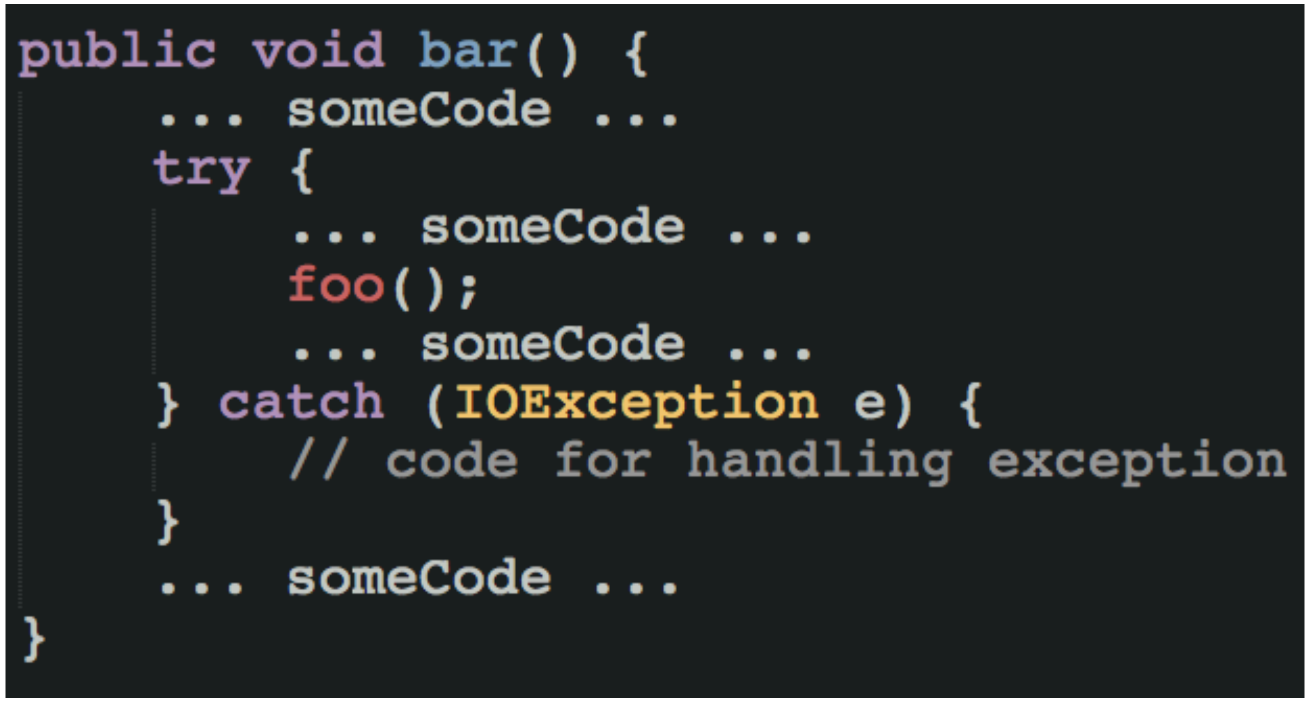
Subclasses of class RuntimeException: Like `ClassCastException`, `ArrayIndexOutOfBoundsException`, `ArithmeticException`, etc. These are typically caused by ***coding flaws***. Since, predicting coding flaws is difficult, enforcing catching/handling them is impractical.

Checked Exceptions

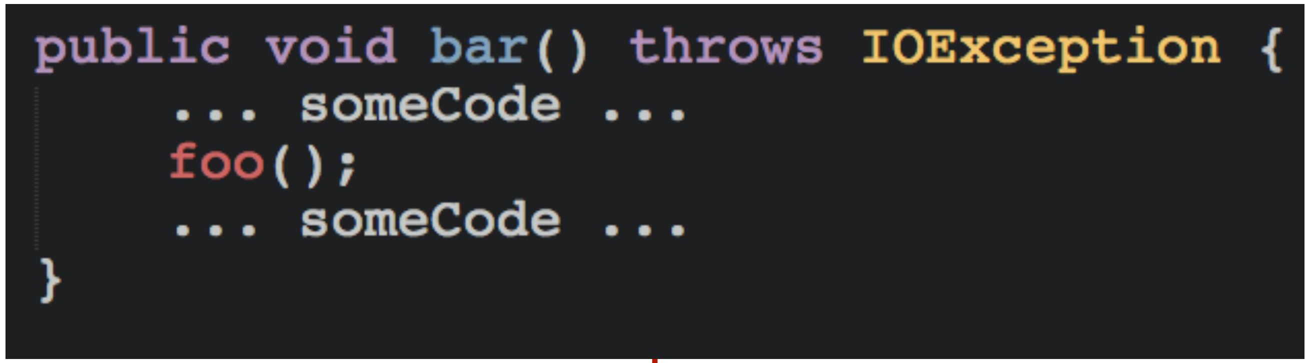
Checked by the compiler. Dealing with these exceptions is not optional. These exceptions include **everything inherited from class Exception**.

Assume method `foo()` throws an `IOException`, which is a checked exception. If method `bar()` calls method `foo()`, then it ***must*** do one of the following, or the compiler will complain:

Handle *or* **Specify**



```
public void bar() {
    ... someCode ...
    try {
        ... someCode ...
        foo();
        ... someCode ...
    } catch (IOException e) {
        // code for handling exception
    }
    ... someCode ...
}
```



```
public void bar() throws IOException {
    ... someCode ...
    foo();
    ... someCode ...
}
```

Methods calling bar() must either handle or specify!

Create Your Own Exceptions

- If the pre-defined Java Exceptions are not enough, create your own exceptions.
- Choose which Exception classes to subclass (Checked vs Unchecked).
- Organize your exception classes into an inheritance hierarchy to facilitate handling groups of exceptions together.

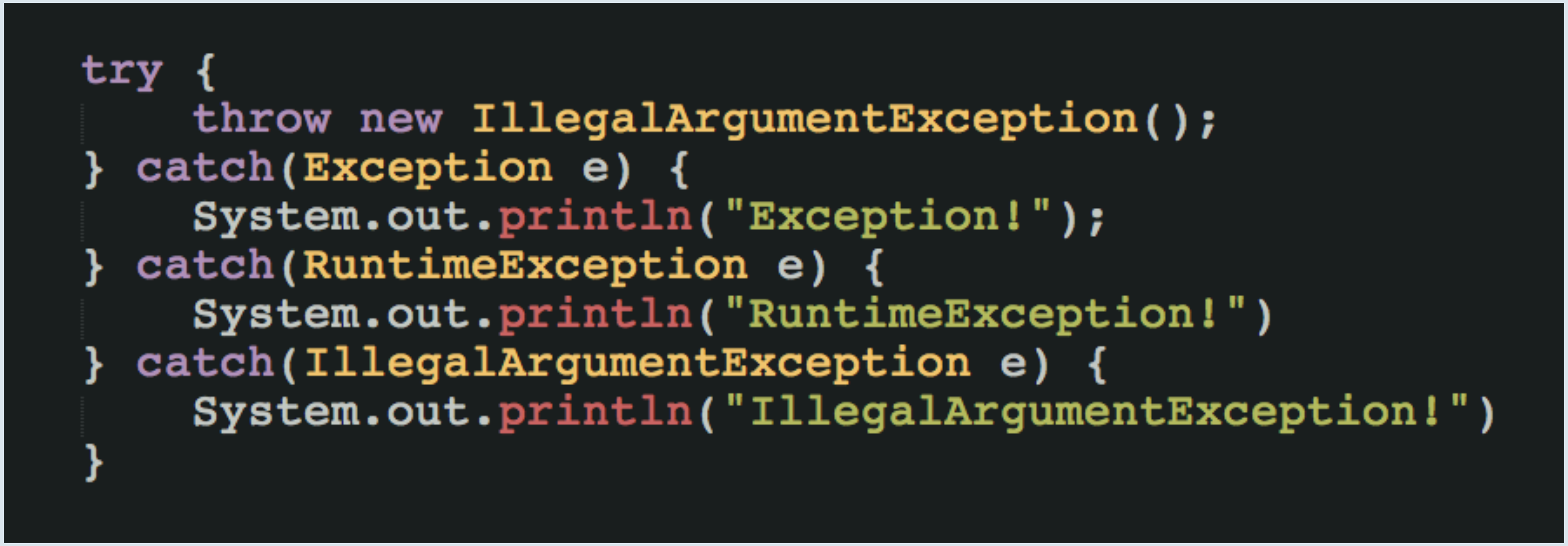
```
try { … }
catch (ConnectionException e) {
   // Handles ConnectionException, as well as subclasses
   // like LostConnectionException, InvalidAddressException,
   // AuthenticationErrorException, etc.
} catch (UserInputException e) {
   // Handles UserInputException, as well as subclasses
   // like NoInputProvidedException, InvalidCharsException,
   // DumbUserException, etc.
}
```

Note: These are hypothetical exceptions!

Quiz

http://etc.ch/iEiC

What is the output of the following piece of code?



```
try {
    throw new IllegalArgumentException();
} catch(Exception e) {
    System.out.println("Exception!");
} catch(RuntimeException e) {
    System.out.println("RuntimeException!")
} catch(IllegalArgumentException e) {
    System.out.println("IllegalArgumentException!")
}
```

A. `Exception!`

B. `RuntimeException!`

C. `IllegalArgumentException!`

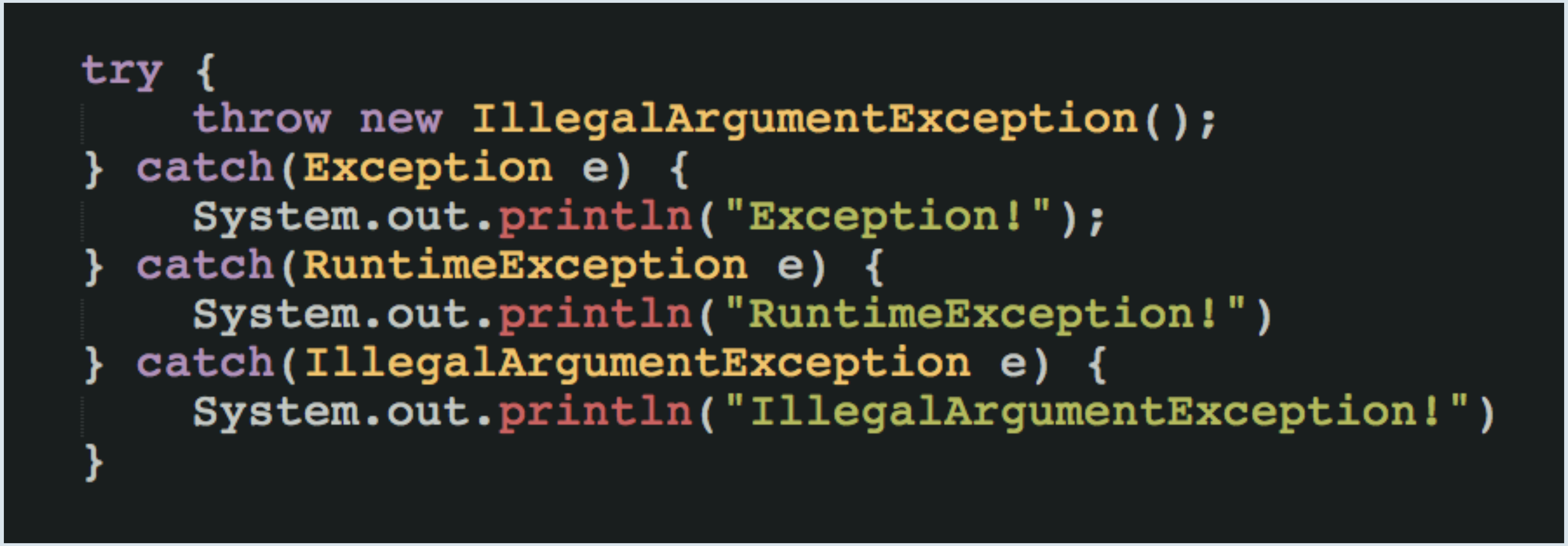
D. All of the above.

E. None of the above.

Quiz

http://etc.ch/iEiC

What is the output of the following piece of code?



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}
```

A. `Exception!`

B. `RuntimeException!`

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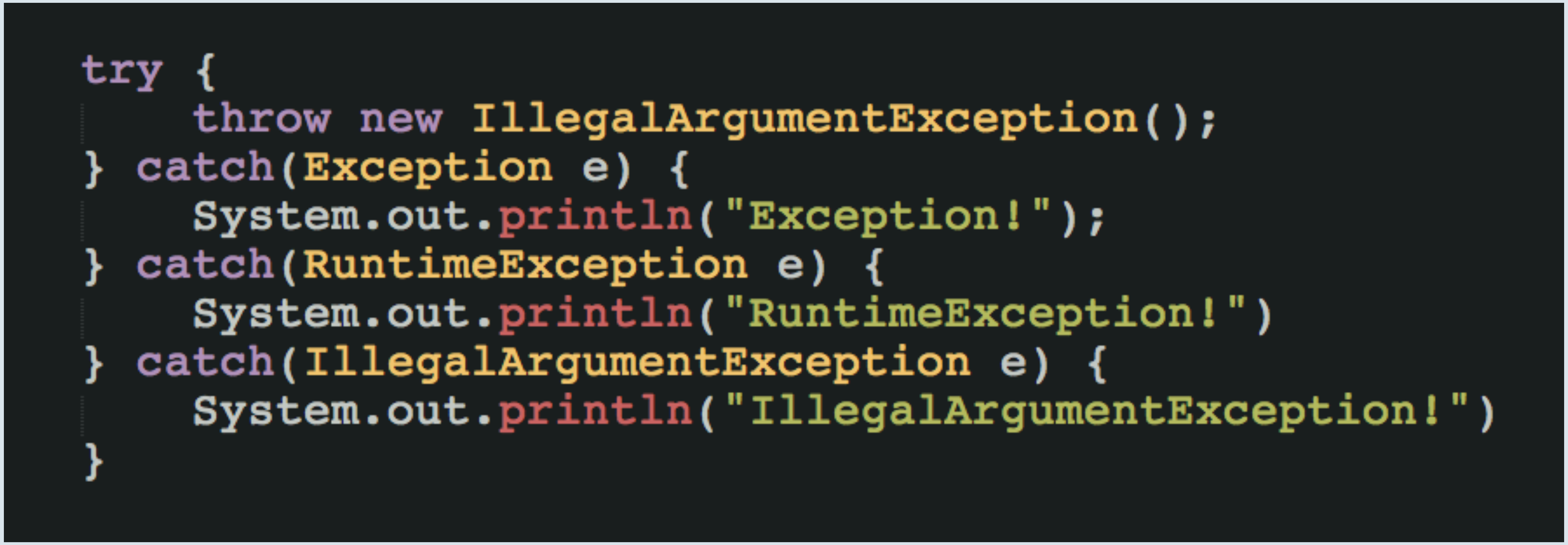
D. All of the above.

[✓ E.] None of the above.

Quiz

http://etc.ch/iEiC



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try {
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} catch(Exception e) {
    System.out.println("Exception!");
} catch(RuntimeException e) {
    System.out.println("RuntimeException!")
} catch(IllegalArgumentException e) {
    System.out.println("IllegalArgumentException!")
}
```
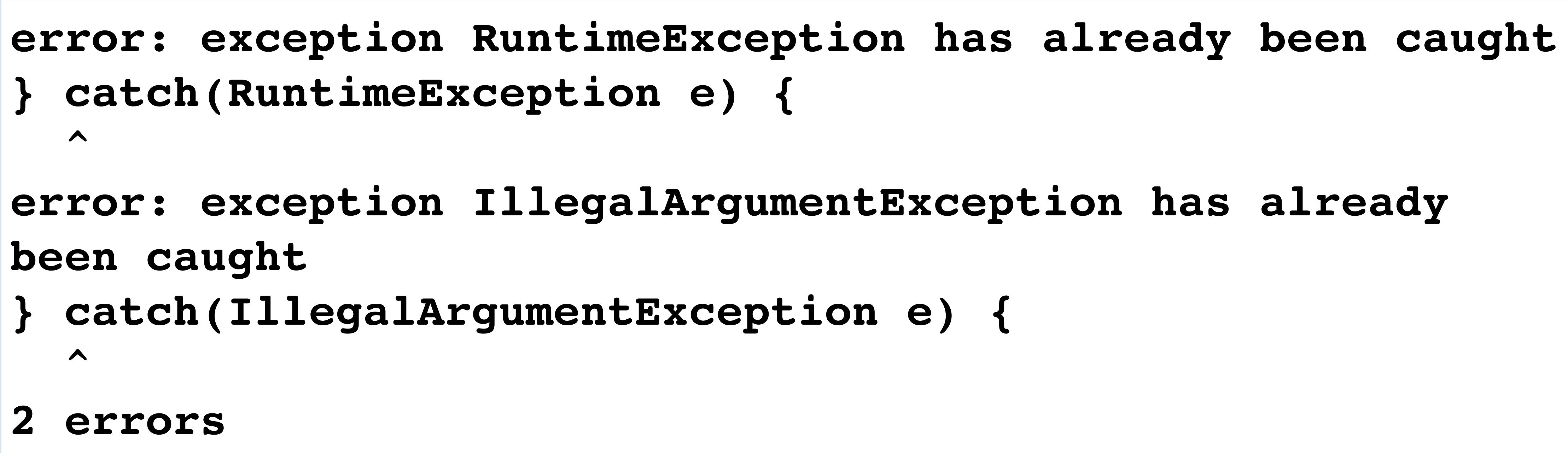
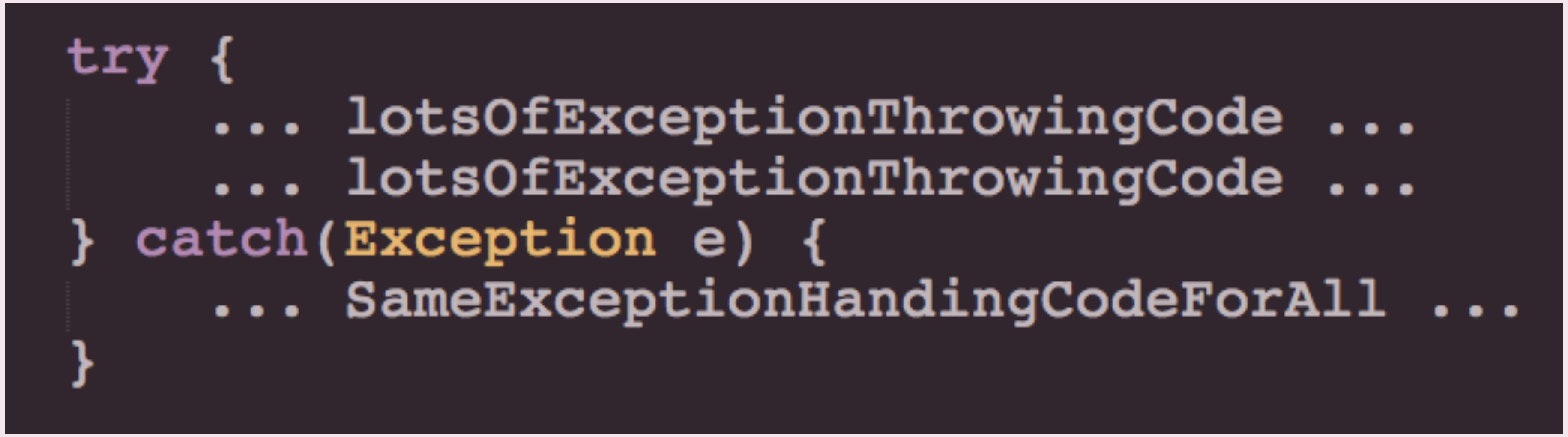



```
error: exception RuntimeException has already been caught
} catch(RuntimeException e) {
  ^
error: exception IllegalArgumentException has already
been caught
} catch(IllegalArgumentException e) {
  ^
2 errors
```

! *Exceptions must be caught from most specific to most general.*

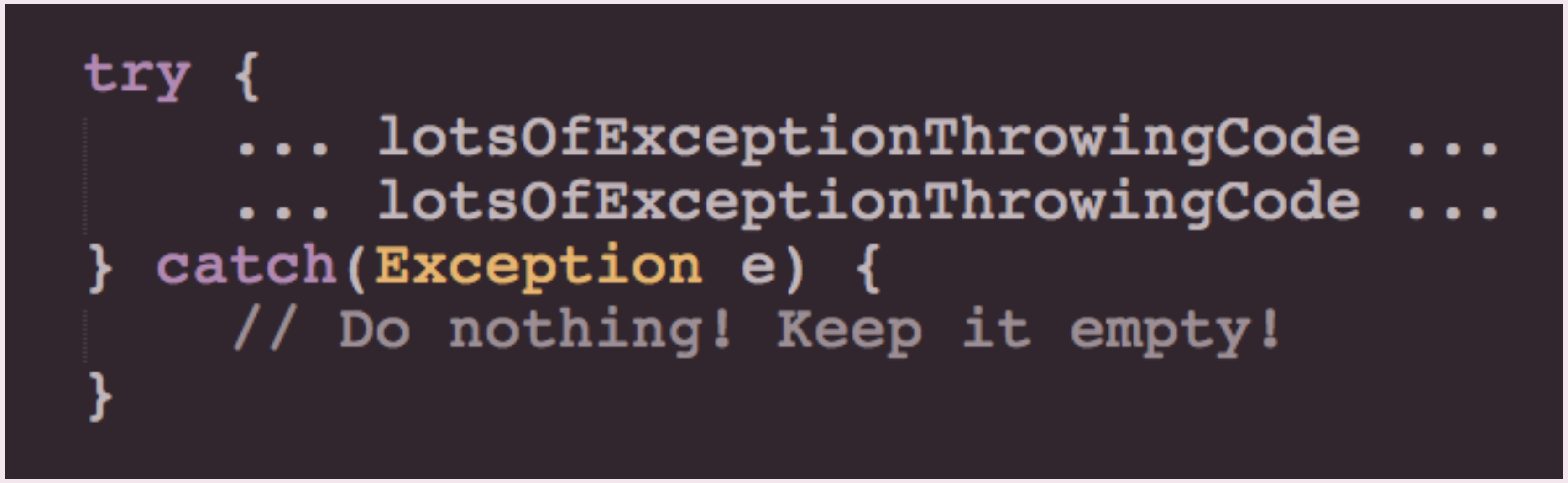
Bad Practice



```
try {
    ... lotsOfExceptionThrowingCode ...
    ... lotsOfExceptionThrowingCode ...
} catch(Exception e) {
    ... SameExceptionHandingCodeForAll ...
}
```

Bad Practice

[redacted]



```
try {
    ... lotsOfExceptionThrowingCode ...
    ... lotsOfExceptionThrowingCode ...
} catch(Exception e) {
    // Do nothing! Keep it empty!
}
```

Enumeration Types (Live Demo)

JavaDoc (Live Demo)

Anonymous Classes (Live Demo)

- Java Exceptions Hierarchy chart was retrieved Monday 22nd 2018 from: https://3.bp.blogspot.com/-j8y3jyEkRKg/WDCVASlGsoI/AAAAAAAADQ8/oTdt8ty-emUBcNuzVzXpZKpTU2nGWeVrACLcB/s1600/ExceptionClassHierarchy.png

- Pokemon images were retrieved Monday 22, 2018 from: http://cdn-static.denofgeek.com/sites/denofgeek/files/pokemon_4.jpg and from https://www.freepnglogos.com/uploads/gotta-catch-em-all-transparent-pokemon-logo-11.png and from https://t5.rbxcdn.com/e16e9d97109be187d2c9649a368fbc56