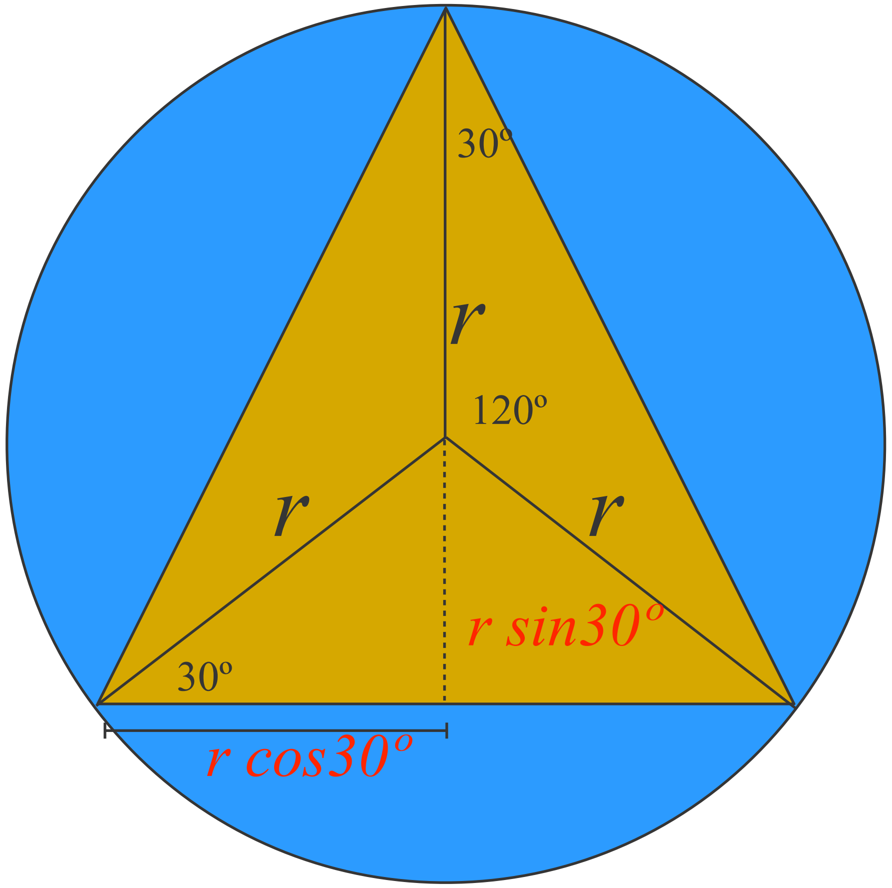
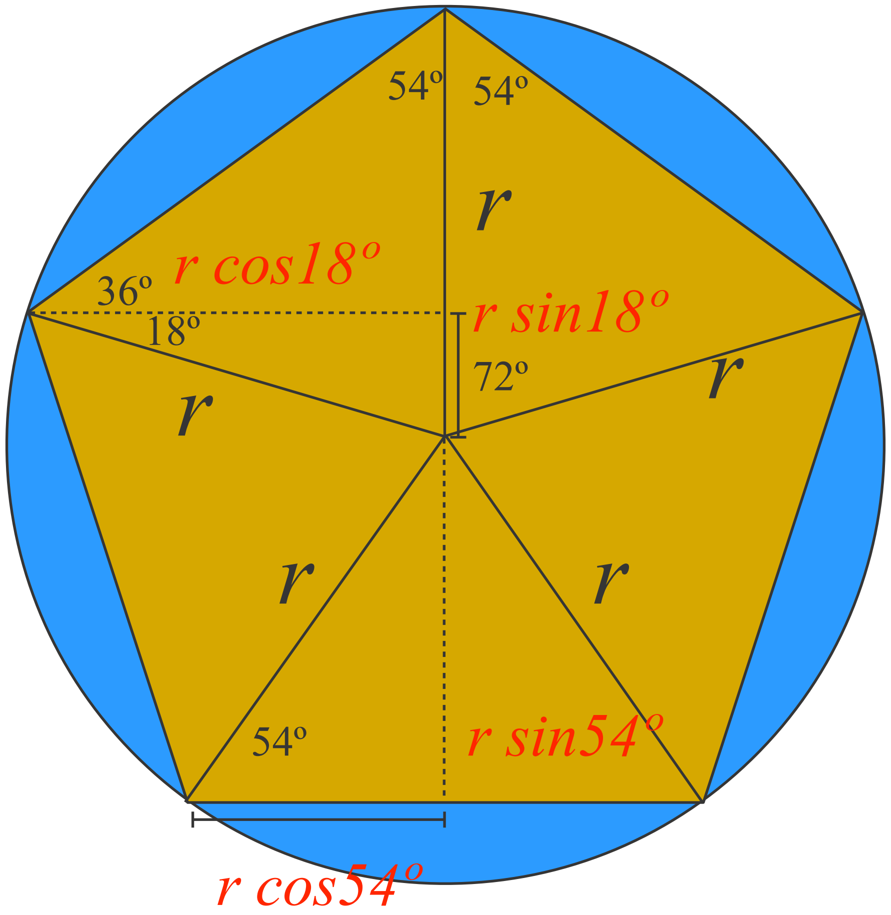
Help Session This Week

- This week's help session will be held **today** from 4:30 to 6:30 in SMTH 108
- Exam 2:
  - **November 1st, Thursday**
  - **6:30 – 7:30pm CL50 225** and **FRNY G140**
  - Same format as Exam 1
  - Coverage: all topics up to GUIs
  - Can bring in one sheet of paper

Project 5 Triangle Calculations



Project 5 Pentagon Calculations



Exception Handling

CS 18000
Sunil Prabhakar
Department of Computer Science
Purdue University

When things go wrong

- Good programs should be robust -- i.e., they should be able to handle exceptional situations.
- What happens if we are trying to input an integer value and the user enters ten, or 3.45?
- A good program should tell the user to re-enter a valid integer.
- So far, this situation would result in the termination of our program when we execute Integer.parseInt() on this invalid string.
- How do we prevent this?

Handling errors

- One idea is to use if -then style tests whenever we expect that an error may arise.
- This is the style in C -- return values can signal the existence of an error.
- But this is clumsy, and inelegant.
- In Java, the exception handling mechanism is used instead.
- Erroneous (or unexpected) cases are handled by a special type of control flow.

Exceptions

- An *exception* is used to indicate that something unusual (that prevents regular processing) has occurred.
- When an exception occurs, or is *thrown*, an Exception object is created, and the normal sequence of flow is terminated.
- An exception handling mechanism is invoked which is responsible for handling or *catching* the thrown exception.

Uncaught Exceptions

- When a (runtime) exception is thrown, and the program does not specify how to handle it, it causes the program to terminate:

```
import javax.swing.*;
  public class ReadInt{
    public static void main(String[] args){
      String inputStr;
    int i;
    inputStr = JOptionPane.showInputDialog(null, "Enter
    Deposit Amount");
    i = Integer.parseInt(inputStr);
  }
}
```

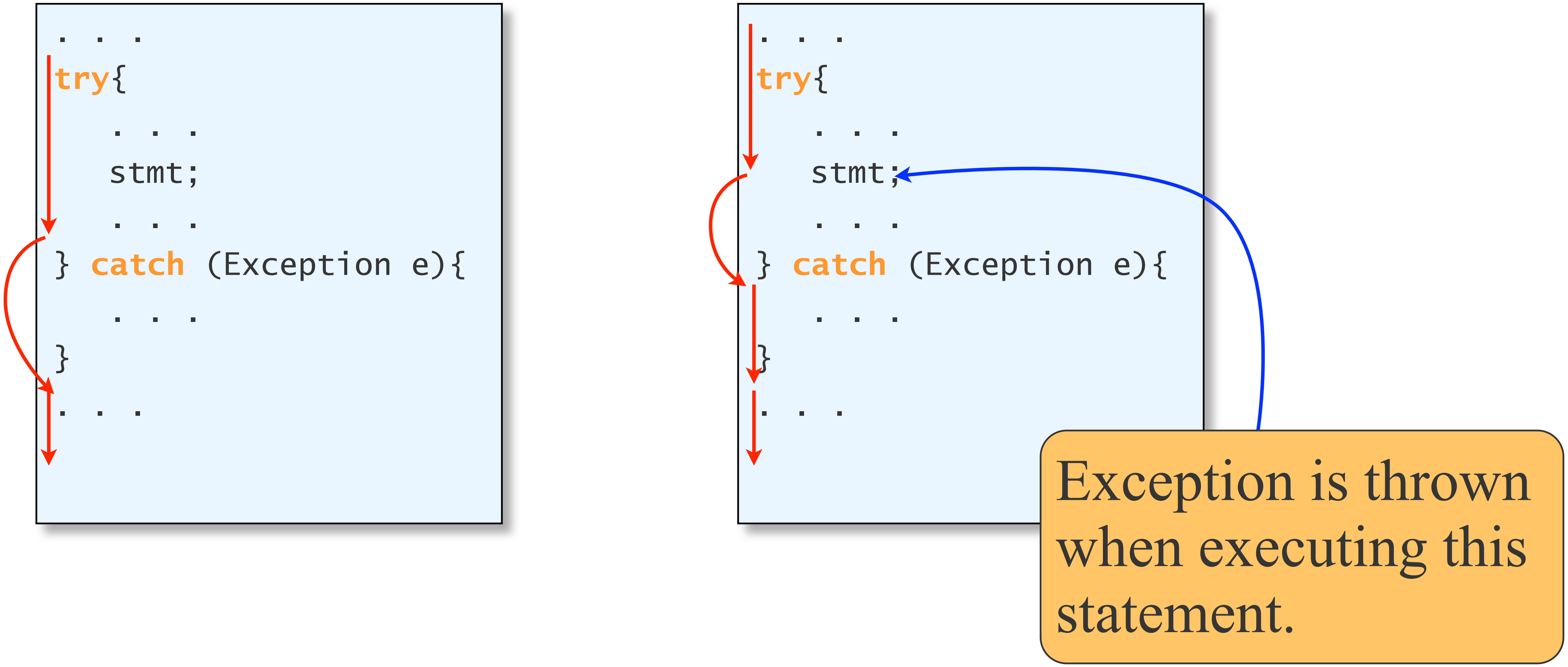
Catching an exception

```java
String inputStr;
int i;
inputStr = JOptionPane.showInputDialog(null,
           "Enter an integer");
try{

  i = Integer.parseInt(inputStr);

} catch (Exception e){
  System.out.println("Invalid integer");
}
```

Exception control-flow

No exception

Exception thrown



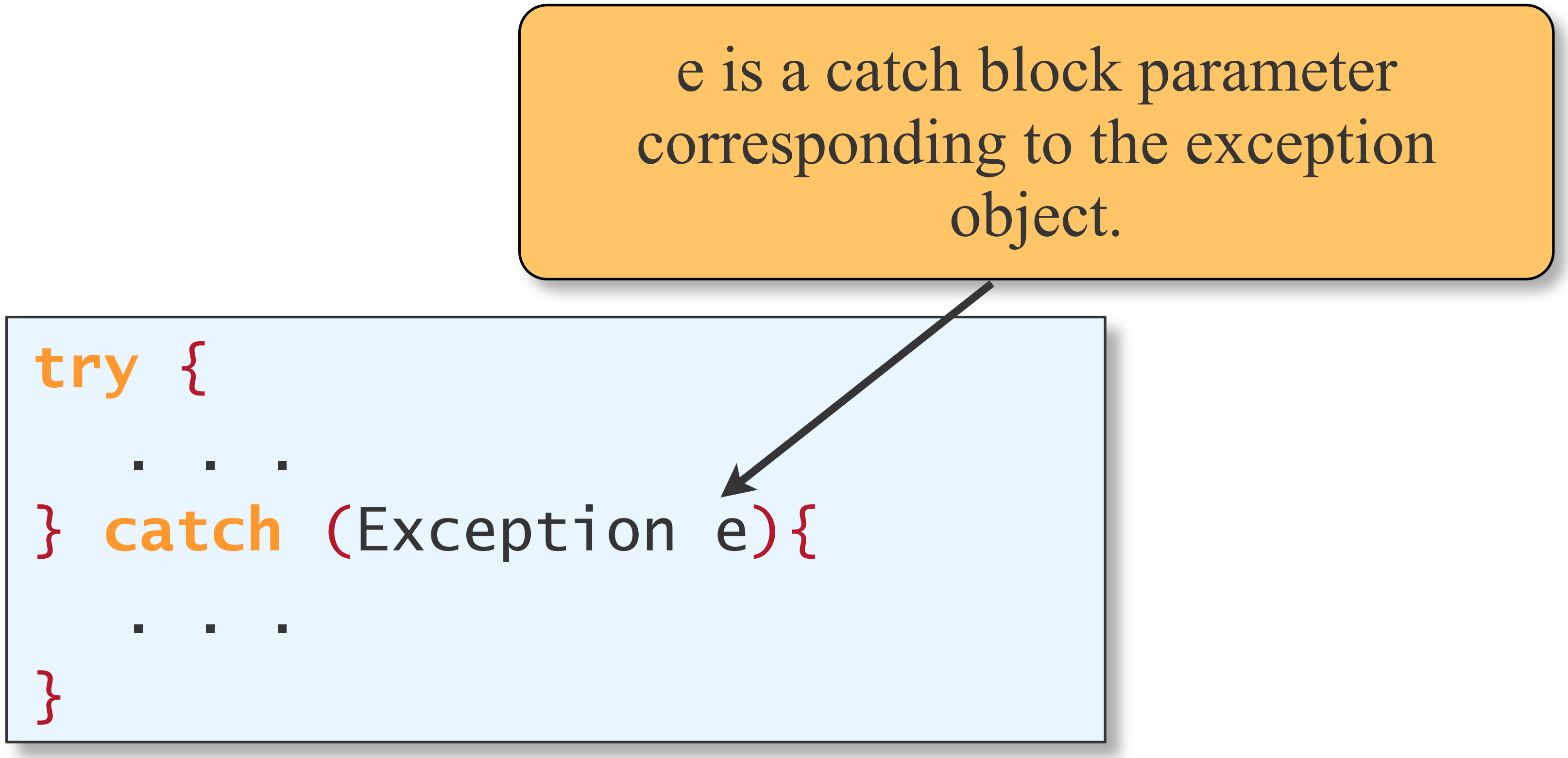
```
. . .
try{
   . . .
   stmt;
   . . .
} catch (Exception e){
   . . .
}
. . .
```

```
. . .
try{
   . . .
   stmt;
   . . .
} catch (Exception e){
   . . .
}
. . .
```

Exception is thrown when executing this statement.

Exception object

- An exception is thrown by creating an Exception object.
- The exception object is passed to the catch block as a parameter.
- It contains details about the actual exception that was thrown.



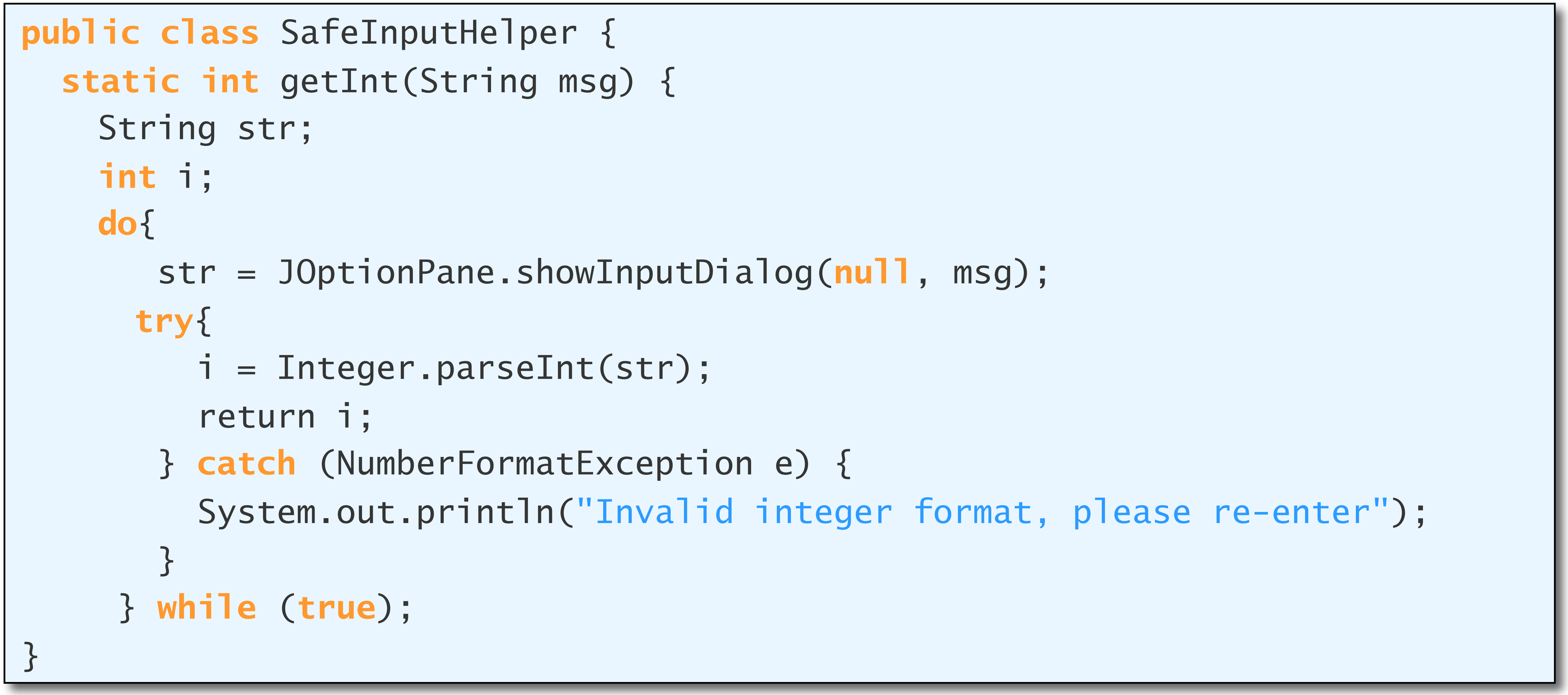
e is a catch block parameter corresponding to the exception object.

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

Exception object

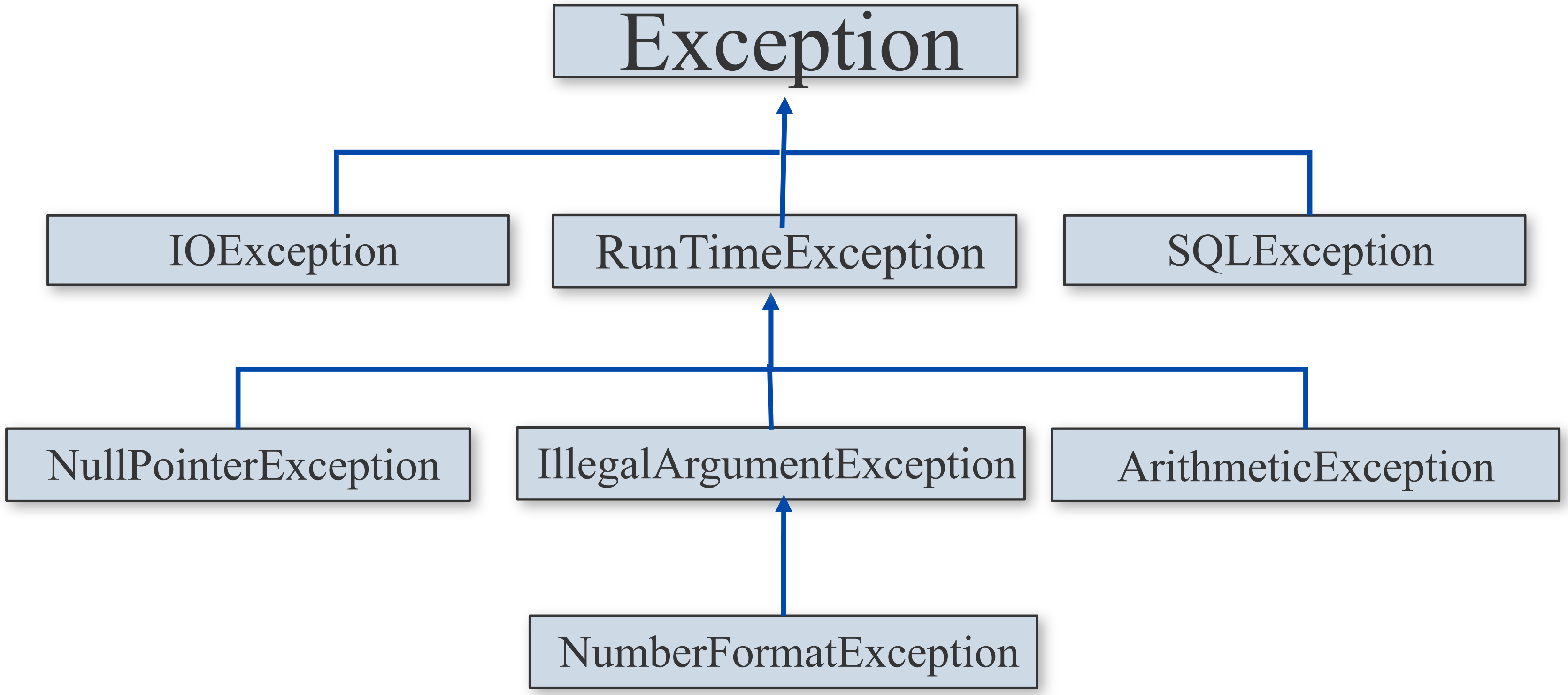
- The exception object contains details about the exception.
  - The `getMessage()` method simply returns a string of text that describes the exception.
  - The `printStackTrace()` method gives us the order (and line numbers) in which methods had been called when the exception took place.
    - In reverse order of the calls
    - The last method call is listed first, main is last.

SafeInputHelper



```java
public class SafeInputHelper {
  static int getInt(String msg) {
    String str;
    int i;
    do{
       str = JOptionPane.showInputDialog(null, msg);
      try{
         i = Integer.parseInt(str);
         return i;
       } catch (NumberFormatException e) {
         System.out.println("Invalid integer format, please re-enter");
       }
     } while (true);
}
```

The Exception Hierarchy



Many more.
See Java API

Multiple catch Blocks

- If more than one type of exception can take place, we may want to handle each one differently.
- A single try-catch statement can include multiple catch blocks, one for each type of exception.
- Only the first matching catch block is executed.
- Matching is based on the class of the exception.
- *Make sure to list classes lower in the hierarchy before listing classes higher up.*

Multiple catch Blocks

```java
try {
   . . .
   i = Integer.parseInt(inputStr);
   . . .
} catch (NumberFormatException e){
   . . . // code to handle NumberFormatExceptions.
} catch (NullPointerException e){
   . . . // code to handle NullPointerExceptions.
} catch (Exception e){
   . . . // code to handle all other exceptions.
}
```

Terminating a program

- It is possible to terminate a program at any point in its execution (maybe because a very serious error has occurred).
- This is achieved by calling

```
System.exit(0)
```

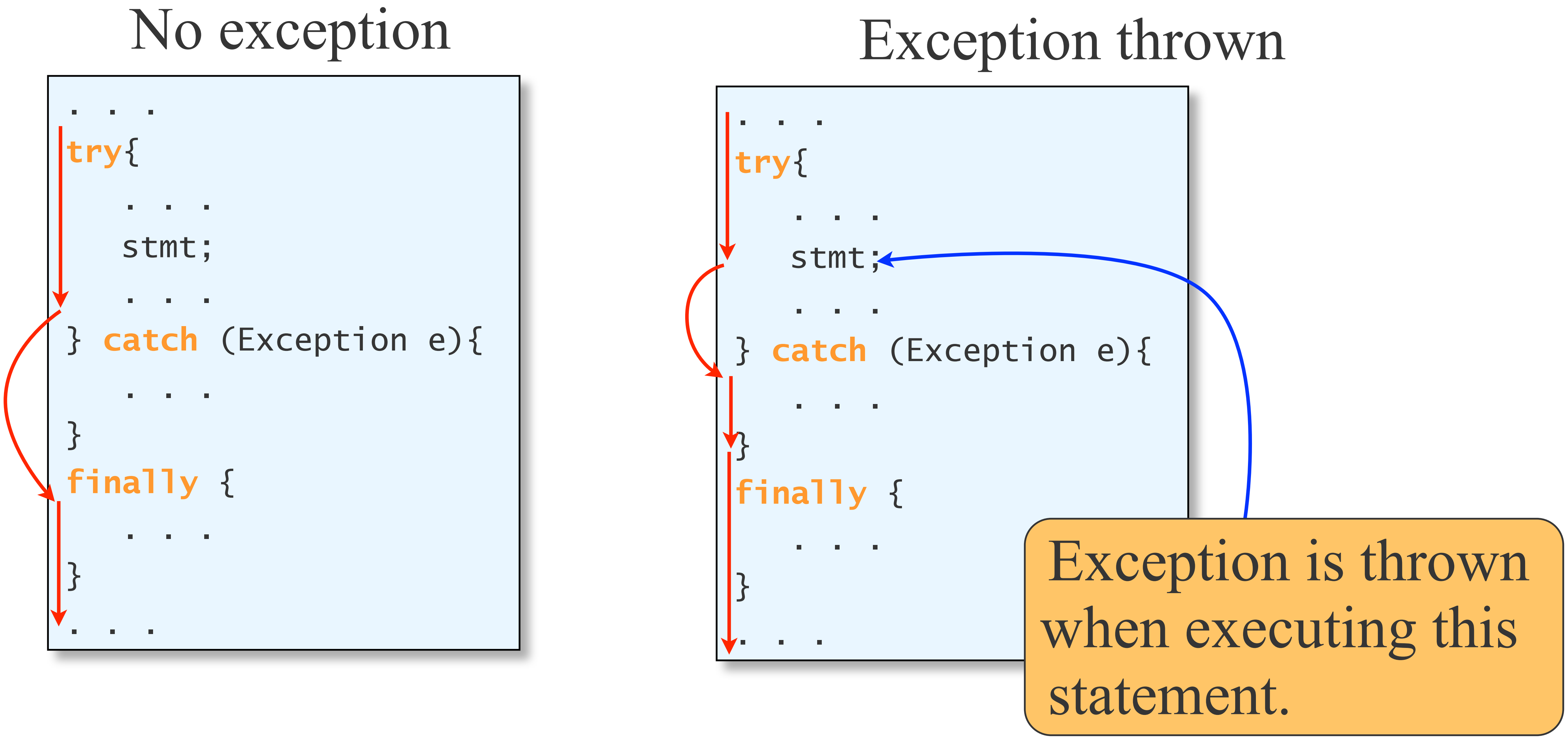
- This call takes any integer value as a parameter.
- The program is immediately terminated.

The finally Block

- There are situations where we need to take certain actions regardless of whether an exception is thrown or not.
- We place statements that must be executed regardless of exceptions, in the finally block.
- Commonly used to perform cleanup (e.g., closing disconnecting from a database, or closing a network connection)

Exception control-flow

finally block is always executed.



No exception

```
. . .
try{
   . . .
   stmt;
   . . .
} catch (Exception e){
   . . .
}
finally {
   . . .
}
. . .
```

Exception thrown

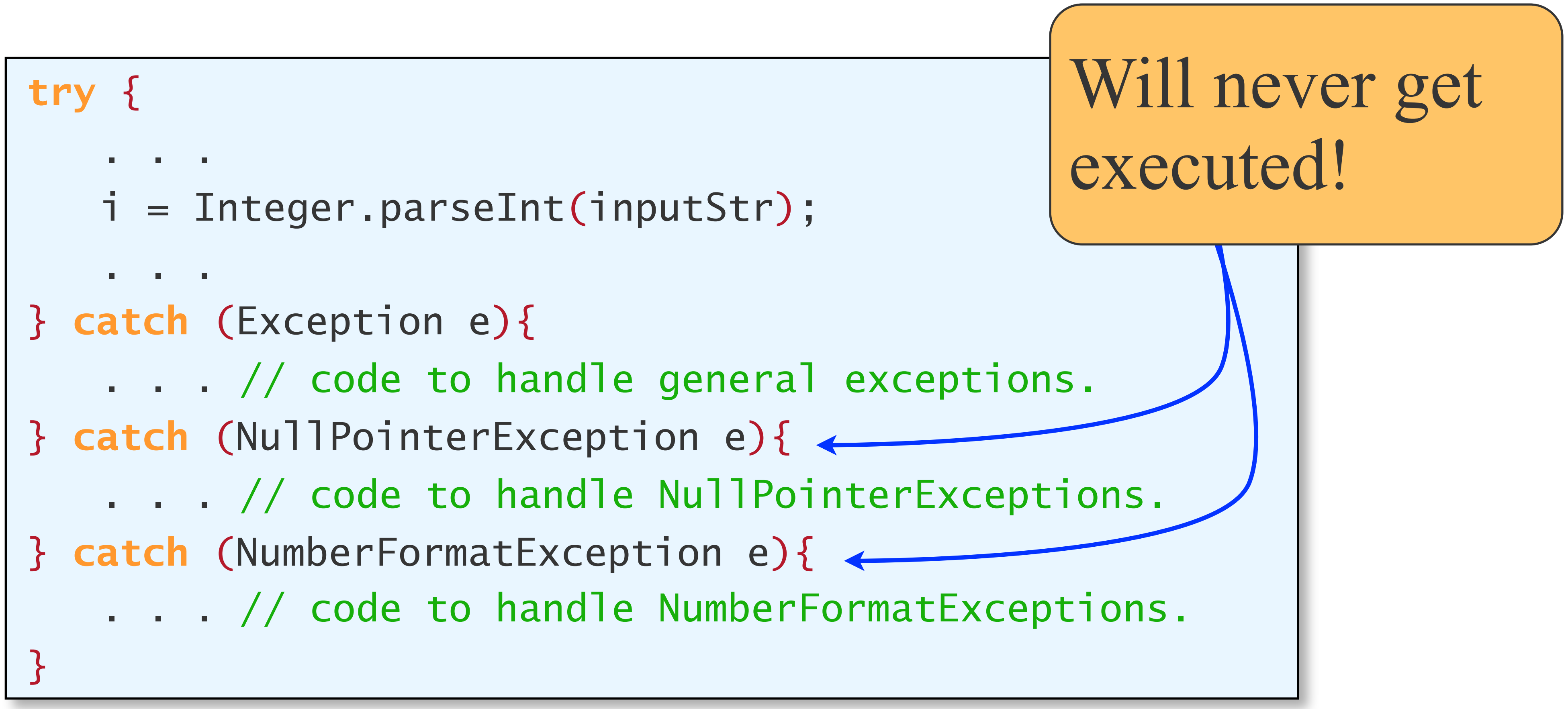
```
. . .
try{
   . . .
   stmt;
   . . .
} catch (Exception e){
   . . .
}
finally {
   . . .
}
. . .
```

Exception is thrown when executing this statement.

Salient points

- If multiple catch blocks are defined they are tested in order -- only the first that matches the thrown exception gets executed.
  - List them from more specific to general.
  - CAUTION: if A is a subclass of B, then an exception of class A is also an exception of class B!
- *Even if there is a return from the try or catch blocks, the finally block **is** executed before returning!*
- If no matching catch block is found for an exception, the finally block gets executed

Caution: order of catch blocks



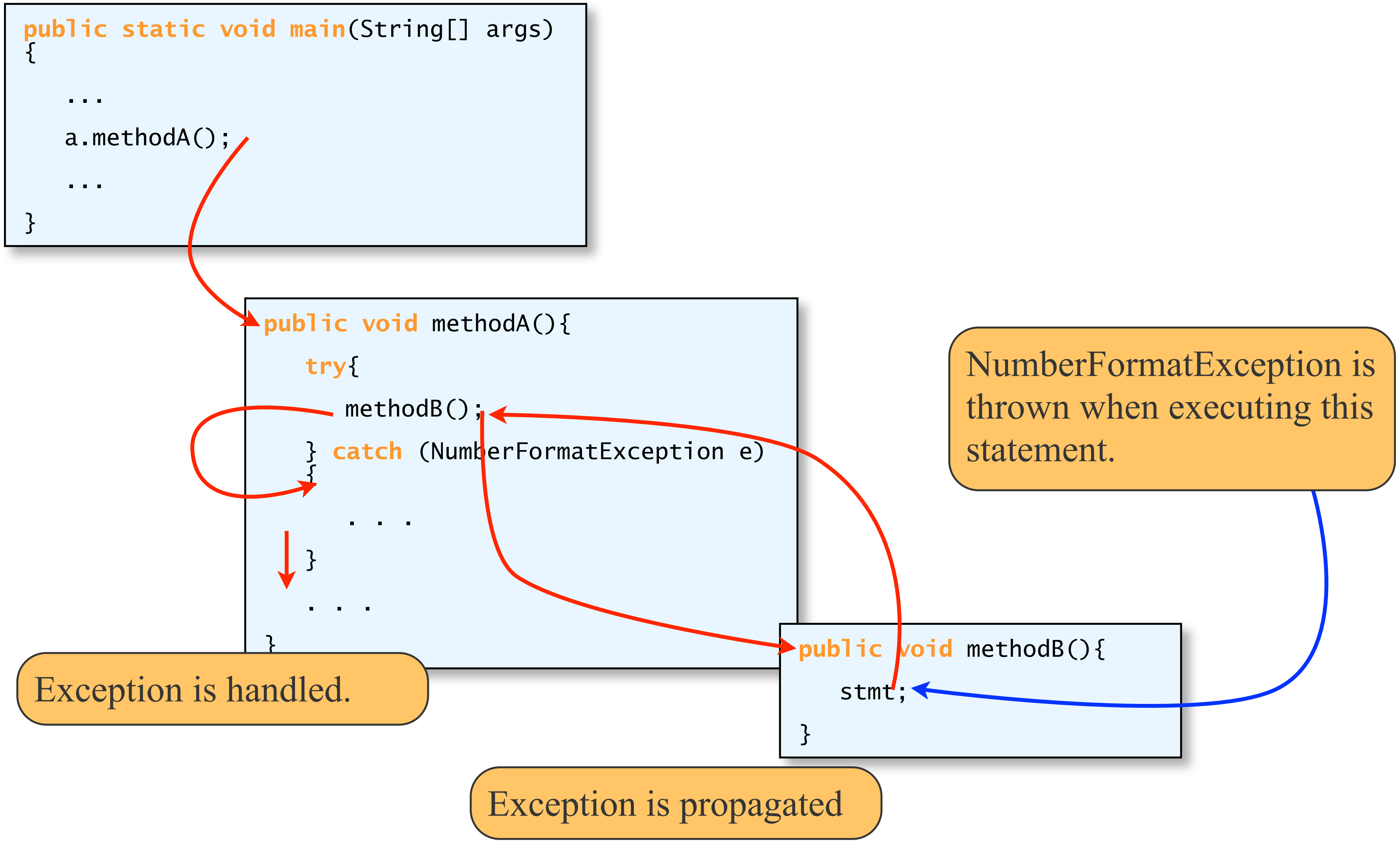
```
try {
   . . .
   i = Integer.parseInt(inputStr);
   . . .
} catch (Exception e){
   . . . // code to handle general exceptions.
} catch (NullPointerException e){
   . . . // code to handle NullPointerExceptions.
} catch (NumberFormatException e){
   . . . // code to handle NumberFormatExceptions.
}
```

Will never get executed!

Propagating exceptions

- If an exception occurs and there is no matching catch block, then the exception is **propagated**.
  - control passes to the calling method (like a return)
  - if the caller has no matching catch block, the same happens
  - eventually, if the main method does not handle the exception, the runtime system handles it.

Exception handling



```
public static void main(String[] args)
{
   ...
   a.methodA();
   ...
}
```

```
public void methodA(){
   try{
      methodB();
   } catch (NumberFormatException e)
   {
      . . .
   }
   . . .
}
```

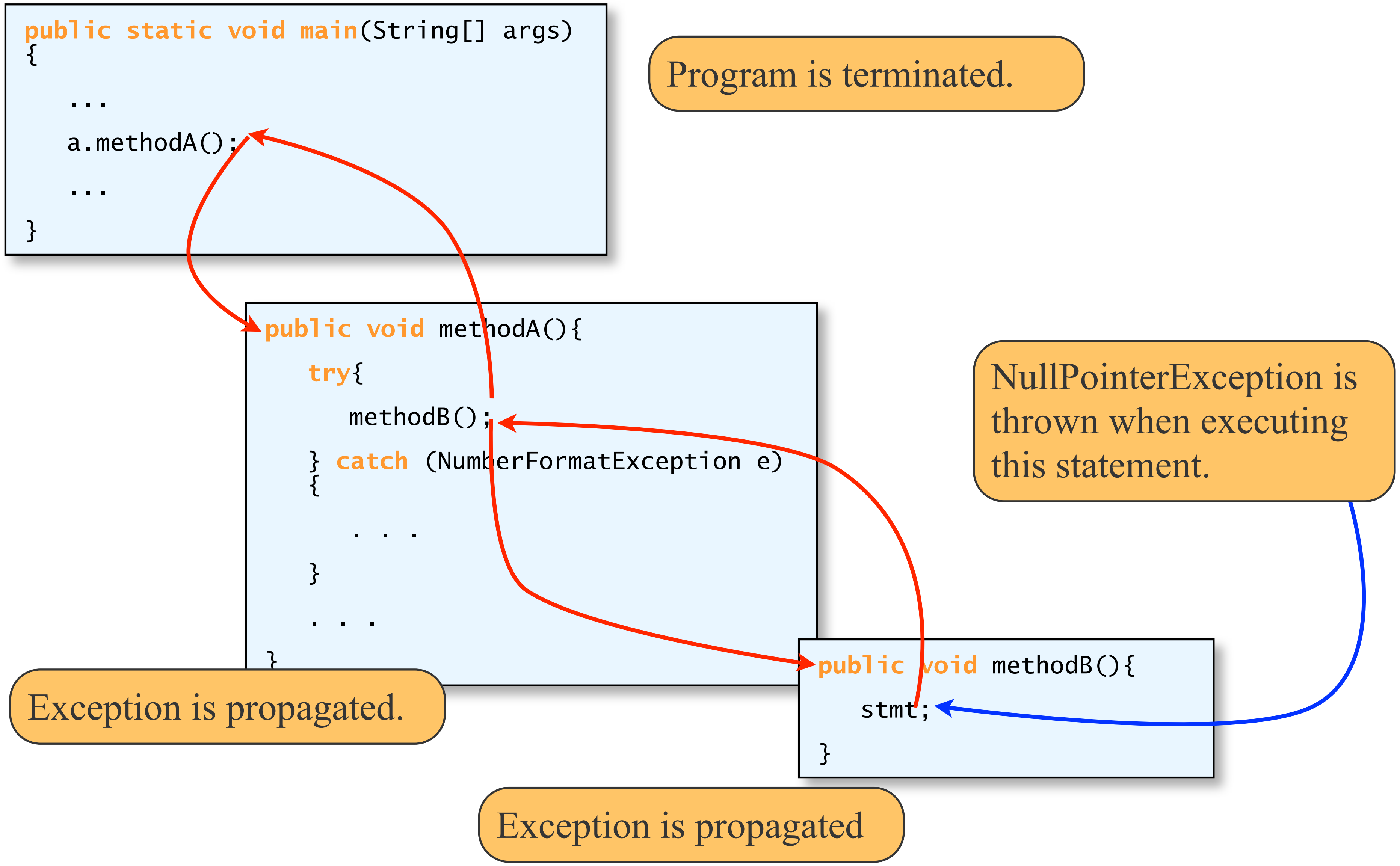
```
public void methodB(){
   stmt;
}
```

NumberFormatException is thrown when executing this statement.

Exception is handled.

Exception is propagated

Exception handling



```
public static void main(String[] args)
{
   ...
   a.methodA();
   ...
}
```

```
public void methodA(){
   try{
      methodB();
   } catch (NumberFormatException e)
   {
      . . .
   }
   . . .
}
```

```
public void methodB(){
   stmt;
}
```

Program is terminated.

NullPointerException is thrown when executing this statement.

Exception is propagated.

Exception is propagated

Types of exceptions

- Two main types of exceptions
  - Checked exceptions
  - Unchecked exceptions.
- Unchecked exceptions are those that can be thrown during the normal operation of the Java Virtual Machine
  - Captured under the RuntimeException class in the hierarchy.
  - NullPointerException, ArithmeticException, IndexOutOfBoundsException, etc.

Types of exceptions (cont.)

- Unchecked exceptions need not be explicitly handled (as we have done so far)
  - If unhandled, will lead to program termination.
- Checked exceptions must be explicitly handled by the program.
  - Any method that could result in a checked exception being thrown must either:
    - Handle it with a **try**-**catch** block, OR
    - Propagate and explicitly declare this possibility.

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Propagating Checked Exceptions

- A method that propagates an unchecked exception must declare this possibility:
  - the method header must include the reserved word **throws** followed by a list of the classes of exceptions that may be propagated
  - declaring runtime exceptions is optional

```
public int accessDB( ) throws SQLException {
   . . .
   // code that accesses some database
   . . .
}
```

Handling Unchecked Exceptions

`parseInt` throws NumberFormatException (see API).

```
void methodA( ){
   try {
      int i = Integer.parseInt(s);
   } catch (NumberFormatException e) {
     . . .
  }
}
```

Catcher

Propagator

```
void methodB( ) {
   int i = Integer.parseInt(s);
}
```

```
void methodB( ) throws  NumberFormatException {
   int i = Integer.parseInt(s);
}
```

Handling Checked Exceptions

`Scanner(File )` throws FileNotFoundException (see API).

```
void methodA( ){
   try {
      scanner = new Scanner(f);
   } catch (FileNotFoundException e) {
      . . .
   }
}
```

Catcher

Propagator

```
void methodB( ) throws  FileNotFoundException {
   scanner = new Scanner(f);
}
```

Throwing Exceptions

- We can throw an exception at any point in our code.
- To do this, we create an exception object and **throw** it.
- If this is a checked exception, we must declare that we throw this exception (unless we catch the exception).

```
public float squareRoot(float value) throws Exception {
   . . .
   if (value<0)
    throw new Exception ("Imaginary numbers not yet supported");
   . . .
}
```

Defining Custom Exceptions

- Should only need to do this if we want to capture extra information, or if you want to handle this class in a special fashion.
- In order to define a new exception class, we **must**:
  - Extend an exception class. Good idea to extend the Exception class.
  - Define a default constructor.
  - Call the parent’s constructor as the first call in the constructor for the new exception: `super(msg);`

Ascending Input Helper

- Let us assume that our application often needs to input several streams of integers in ascending order with a minimum jump between values.
  - each stream has its own starting point and minimum jump.
- Create a helper class to input such values: AscendingInputHelper
- This class throws a new type of exception that signals that the ascending rule was violated: AscendingException.

AscendingInputHelper

```
class AscendingInputHelper {
  int lastValue; // the previous input for this sequence
  int minimumIncrement; // the minimum increment required

  public AscendingInputHelper(int start, int minInc){
    lastValue = start;
    minimumIncrement = minInc;
  }
  // Propagate exception
  public  int getNextInt() throws AscendingException {
    int i;
    i = SafeInputHelper.getInt();   //Get the next integer from the user
    if(i< lastValue+minimumIncrement) //if invalid ascend, throw exception
      throw new AscendingException(i, lastValue, minimumIncrement);
    lastValue=i;
    return i;
  }
}
```

AscendingException

```java
public class AscendingException extends Exception {
  private int lastEntry, errorEntry, minimumIncrement;
  private static final String ERROR_MSG = "Invalid Ascending Sequence";

  public AscendingException(int badEntry, int last, int inc){
    this(AscendingException.ERROR_MSG, badEntry, last, inc);
  }
  public AscendingException (String msg, int badEntry, int last, int inc){
    super(msg);
    errorEntry = badEntry;
    lastEntry  = last;
    minimumIncrement = inc;
  }
  public int getLastEntry(){return lastEntry; }
  public int getErrorEntry(){return errorEntry; }
  public int getMinimumIncrement(){return minimumIncrement; }
}
```

Using AscendingInputHelper

```java
class TestAscendingInput {
  public static void main(String args[]) {
    int total=0, newValue;

    AscendingInputHelper ascInput = new AscendingInputHelper(0, 3);
    while(true){
      try {
          newValue = ascInput.getNextInt();
          total += newValue;
      } catch (AscendingException e) {
          JOptionPane.showMessageDialog(null, "Error with order of input\n" +
            e.getMessage() + "\nEntered value: " + e.getErrorEntry() +
            "\n Previous value: " + e.getLastEntry() +
            "\n Minimum Increment required: " + e.getMinimumIncrement());
          System.out.println("Total of valid inputs: " + total);
          System.exit(0);
      }
    }
  }
}
```

Assertions

- Exceptions handle unexpected behavior during execution.
- Sometimes programs fail due to logical errors in the code.
- Assertions are a mechanism available to detect logical errors.
- An assertion is essentially a sanity check regarding the state of data at a given point in the program.

Assertions

- The syntax for the **assert** statement is

```
assert <boolean expression>;
```

  where `<boolean expression>` represents the condition that must be true if the code is working correctly.

- If the expression results in **false**, an **AssertionError** (a subclass of **Error**) is thrown.

Sample Use #1

```
public double deposit(double amount) {
  double oldBalance = balance;
  balance += amount;
   assert balance > oldBalance;
}

public double withdraw(double amount) {
  double oldBalance = balance;
  balance -= amount;
   assert balance < oldBalance;
}
```

Second Form

- The assert statement may also take the form:

```
assert <boolean expression>: <expression>;
```

where `<expression>` represents the value passed as an argument to the constructor of the **AssertionError** class. The value serves as the detailed message of a thrown exception.

Sample Use #2

```
public double deposit(double amount) {

  double oldBalance = balance;

  balance += amount;

   assert balance > oldBalance :
     "Serious Error - balance did not " +
     " increase after deposit";
}
```

AscendingInputAssert

```
class AssendingInputAssert{
  public static void main(String args[]) {
    int minIncrement  = 3, lastValue = 0, newValue, total = 0;

    while(true){
      try{
        newValue = SafeInputHelper.getInt("Enter next value in
sequence");
        assert (newValue-lastValue)>=minIncrement;
        total += newValue;
        lastValue = newValue;
      } catch (AssertionError e) {
        JOptionPane.showMessageDialog(null, "Invalid increment:
terminating");
        System.out.println("Total of valid inputs = " + total);
        System.exit(0);
      }
    }
  }
}
```

Compiling Programs with Assertions

- Before Java 2 SDK 1.4, the word **assert** is a valid non-reserved identifier. In version 1.4 and after, the word **assert** is treated as a regular identifier to ensure compatibility.
- To enable the assertion mechanism, compile the source file using

```
javac –source 1.4 <source file>
```

Running Programs with Assertions

- To run the program with assertions enabled, use

```
java -ea <main class>
```

- If the `-ea` option is not provided, the program is executed without checking assertions.

Different Uses of Assertions

- *Precondition assertions* check for a condition that must be true before executing a method.
- *Postcondition assertions* check conditions that must be true after a method is executed.
- A *control-flow invariant* is a third type of assertion that is used to assert the control must flow to particular cases.