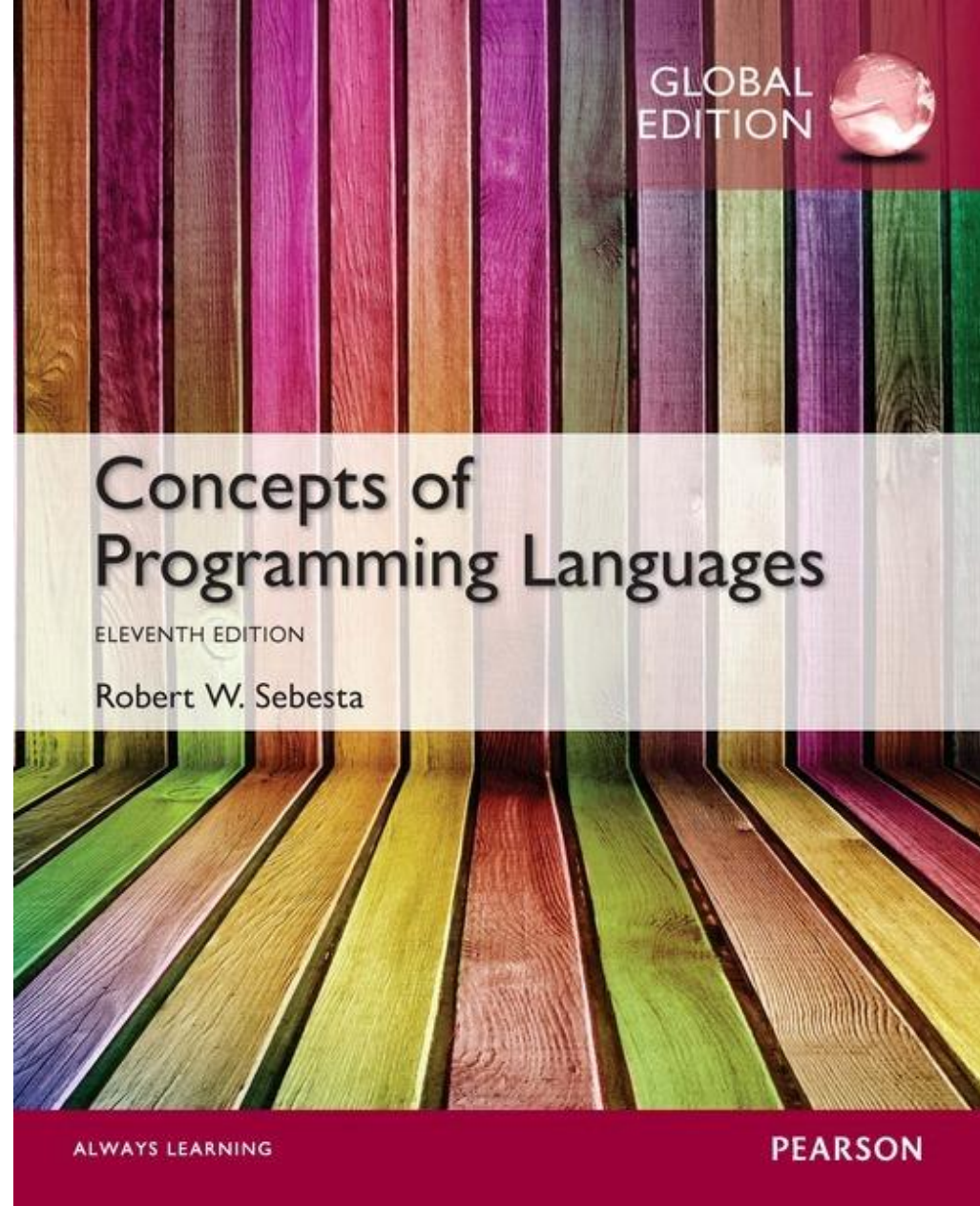


# Chapter 14

## Exception Handling and Event Handling



# Chapter 14 Topics

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- Introduction to Exception Handling
- Exception Handling in C++
- Exception Handling in Java
- Exception Handling in Python and Ruby
- Introduction to Event Handling
- Event Handling with Java
- Event Handling in C#

# Introduction to Exception Handling

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- In a language without exception handling
  - When an exception occurs, control goes to the operating system, where a message is displayed and the program is terminated
- In a language with exception handling
  - Programs are allowed to trap some exceptions, thereby providing the possibility of fixing the problem and continuing

# Basic Concepts

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- Many languages allow programs to trap input/output errors (including EOF)
- An *exception* is any unusual event, either erroneous or not, detectable by either hardware or software, that may require special processing
- The special processing that may be required after detection of an exception is called *exception handling*
- The exception handling code unit is called an *exception handler*

# Exception Handling Alternatives

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- An exception is raised when its associated event occurs
- A language that does not have exception handling capabilities can still define, detect, raise, and handle exceptions (user defined, software detected)
- Alternatives:
  - Send an auxiliary parameter or use the return value to indicate the return status of a subprogram.
    - Immediately upon return from the called unit, the caller tests the status variable. If the value indicates that an exception has occurred, the handler, which may reside in the calling unit, can be enacted. Many of the C standard library functions use a variant of this approach: The return values are used as error indicators.

# Exception Handling Alternatives

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- Alternatives (cont.):
  - Pass a label parameter to all subprograms (error return is to the passed label)
    - Of course, this approach is possible only in languages that allow labels to be used as parameters. This is a common use of label parameters in Fortran.
  - Pass an exception handling subprogram to all subprograms
    - In this case, the handler subprogram is provided by the caller, but the called unit calls the handler when an exception is raised. One problem with this approach is that one is required to send a handler subprogram with every call to every subprogram that takes a handler subprogram as a parameter, whether it is needed or not.

# Advantages of Built-in Exception Handling

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- Error detection code is tedious to write and it clutters the program
  - Ex:

```
if (row >= 0 && row < 10 && col >= 0 && col < 20)
    sum += mat[row][col];
else
    System.out.println("Index range error on mat");
```
- Exception handling encourages programmers to consider many different possible errors
- Exception propagation allows a high level of reuse of exception handling code

# Design Issues

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- How and where are exception handlers specified and what is their scope?
- How is an exception occurrence bound to an exception handler?
- Can information about the exception be passed to the handler?
- Where does execution continue, if at all, after an exception handler completes its execution? (continuation vs. resumption)
- Is some form of finalization provided?

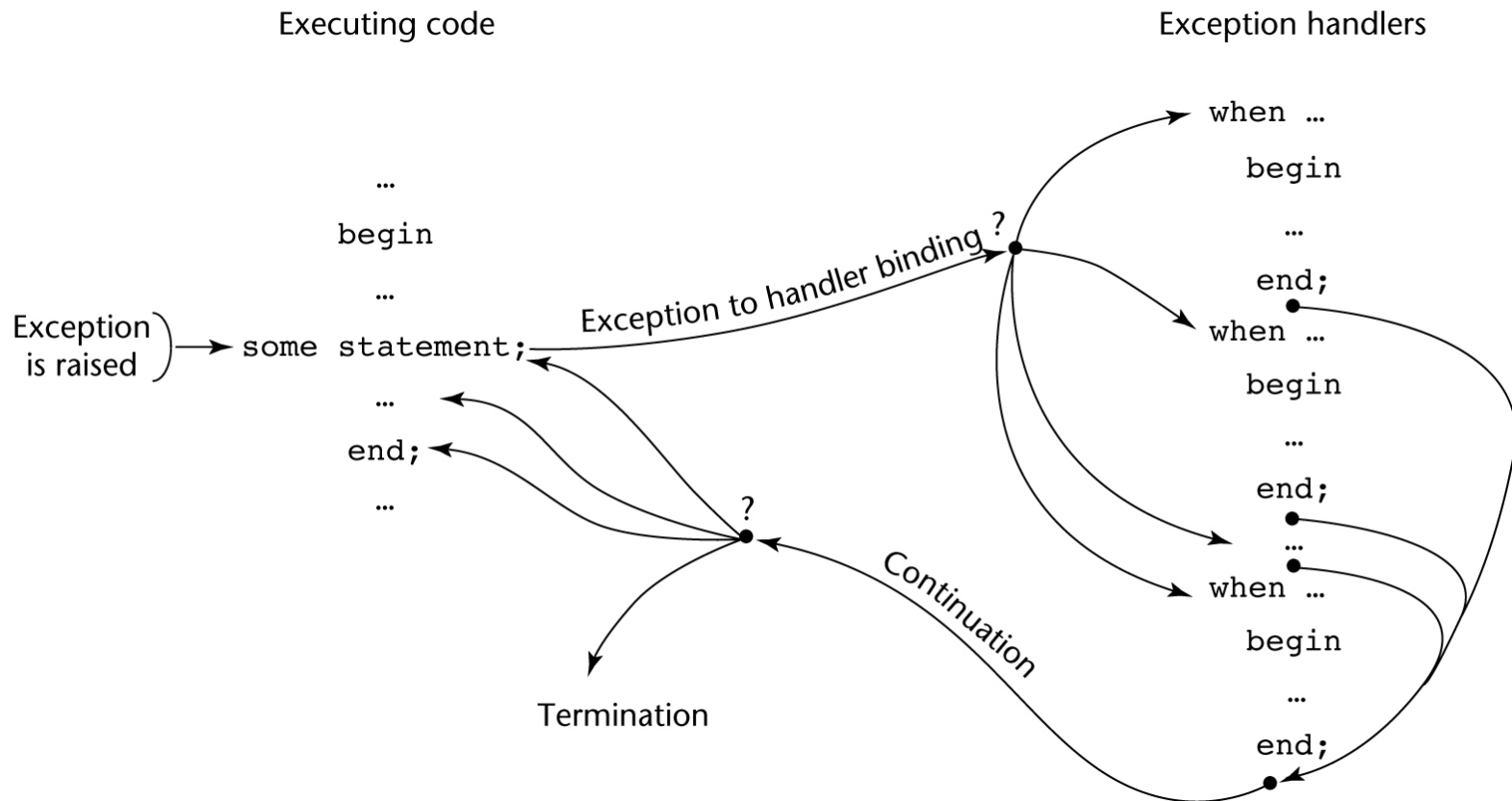


# Design Issues (continued)

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- How are user-defined exceptions specified?
- Should there be default exception handlers for programs that do not provide their own?
- Can predefined exceptions be explicitly raised?
- Are hardware-detectable errors treated as exceptions that can be handled?
- Are there any predefined exceptions?
- How can exceptions be disabled, if at all?

# Exception Handling Control Flow



# Exception Handling in C++

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- Added to C++ in 1990
- Design is based on that of CLU, Ada, and ML

# C++ Exception Handlers

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- Exception Handlers Form:

```
try {  
    -- code that is expected to raise an exception  
}  
catch (formal parameter) {  
    -- handler code  
}  
  
...  
catch (formal parameter) {  
    -- handler code  
}
```

# The catch Function

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- **catch** is the name of all handlers—it is an overloaded name, so the formal parameter of each must be unique
- The formal parameter need not have a variable
  - It can be simply a type name to distinguish the handler it is in from others
- The formal parameter can be used to transfer information to the handler
- The formal parameter can be an ellipsis, in which case it handles all exceptions not yet handled

# Throwing Exceptions

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- Exceptions are all raised explicitly by the statement:

**throw** [ *expression* ] ;

- The brackets are metasympols
- A **throw** without an operand can only appear in a handler; when it appears, it simply re-raises the exception, which is then handled elsewhere
- The type of the expression disambiguates the intended handler

# Unhandled Exceptions

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- An unhandled exception is propagated to the caller of the function in which it is raised
- This propagation continues to the main function
- If no handler is found, the default handler is called

# Continuation

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- After a handler completes its execution, control flows to the first statement after the last handler in the sequence of handlers of which it is an element
- Other design choices
  - All exceptions are user-defined
  - Exceptions are neither specified nor declared
  - The default handler, `unexpected`, simply terminates the program; `unexpected` can be redefined by the user
  - Functions can list the exceptions they may raise
  - Without a specification, a function can raise any exception (the `throw` clause)



# Evaluation

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- There are no predefined exceptions
- It is odd that exceptions are not named and that hardware- and system software-detectable exceptions cannot be handled
- Binding exceptions to handlers through the type of the parameter certainly does not promote readability

# Exception Handling in Java

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- Based on that of C++, but more in line with OOP philosophy
- All exceptions are objects of classes that are descendants of the `Throwable` class

# Classes of Exceptions

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- The Java library includes two subclasses of `Throwable` :
  - `Error`
    - Thrown by the Java interpreter for events such as heap overflow
    - Never handled by user programs
  - `Exception`
    - User-defined exceptions are usually subclasses of this
    - Has two predefined subclasses, `IOException` and `RuntimeException` (e.g., `ArrayIndexOutOfBoundsException` and `NullPointerException`)

# Java Exception Handlers

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- Like those of C++, except every **catch** requires a named parameter and all parameters must be descendants of `Throwable`
- Syntax of **try** clause is exactly that of C++
- Exceptions are thrown with **throw**, as in C++, but often the **throw** includes the **new** operator to create the object, as in:  
**throw new** `MyException()` ;

# Binding Exceptions to Handlers

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- Binding an exception to a handler is simpler in Java than it is in C++
  - An exception is bound to the first handler with a parameter is the same class as the thrown object or an ancestor of it
- An exception can be handled and rethrown by including a **throw** in the handler (a handler could also throw a different exception)

# Continuation

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- If no handler is found in the `try` construct, the search is continued in the nearest enclosing `try` construct, etc.
- If no handler is found in the method, the exception is propagated to the method's caller
- If no handler is found (all the way to `main`), the program is terminated
- To insure that all exceptions are caught, a handler can be included in any `try` construct that catches all exceptions
  - Simply use an `Exception` class parameter
  - Of course, it must be the last in the `try` construct

# Checked and Unchecked Exceptions

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- The Java `throws` clause is quite different from the `throw` clause of C++
- Exceptions of class `Error` and `RuntimeException` and all of their descendants are called **unchecked exceptions**; all other exceptions are called **checked exceptions**
  - Unchecked exceptions are never a concern of the compiler. The reason why exceptions of the classes `Error` and `RuntimeException` and their descendants are unchecked is that any method could throw them. A program can catch unchecked exceptions, but it is not required.
- Checked exceptions that may be thrown by a method must be either:
  - Listed in the `throws` clause, or
  - Handled in the method

# Other Design Choices

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- A method cannot declare more exceptions in its **throws** clause than the method it overrides
- A method that calls a method that lists a particular checked exception in its **throws** clause has three alternatives for dealing with that exception:
  - Catch and handle the exception
  - Catch the exception and throw an exception that is listed in its own **throws** clause
  - Declare it in its **throws** clause and do not handle it



# The `finally` Clause

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- Can appear at the end of a try construct
- Form:

```
finally {  
    ...  
}
```

- Purpose: To specify code that is to be executed, regardless of what happens in the `try` construct

# Example

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- A try construct with a finally clause can be used outside exception handling

```
try {  
    for (index = 0; index < 100; index++) {  
        ...  
        if (...) {  
            return;  
        } /** end of if  
    } /** end of try clause  
    finally {  
        ...  
    } /** end of try construct
```

# Assertions

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- Statements in the program declaring a boolean expression regarding the current state of the computation
- When evaluated to true nothing happens
- When evaluated to false an `AssertionError` exception is thrown
- Can be disabled during runtime without program modification or recompilation
- Two forms
  - `assert condition;`
  - `assert condition: expression;`

# Evaluation

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- The types of exceptions makes more sense than in the case of C++
- The **throws** clause is better than that of C++ (The **throw** clause in C++ says little to the programmer)
- The **finally** clause is often useful
- The Java interpreter throws a variety of exceptions that can be handled by user programs

# Exception Handling in Python

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- Exceptions are objects; the base class is `BaseException`
- All predefined and user-defined exceptions are derived from `Exception`
- Predefined subclasses of `Exception` are `ArithmeticError` (subclasses are `OverflowError`, `ZeroDivisionError`, and `FloatingPointError`) and `LookupError` (subclasses are `IndexError` and `KeyError`)

# Exception Handling in Python

(continued)

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**try:**

- The **try** block

**except** Exception1:

- Handler for Exception1

**except** Exception2:

- Handler for Exception2

...

**else:**

- The **else** block (no exception is raised)

**finally:**

- the **finally** block (do it no matter what)

# Exception Handling in Python

(continued)

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- Handlers handle the named exception plus all subclasses of that exception, so if the named exception is `Exception`, it handles all predefined and user-defined exceptions
- Unhandled exceptions are propagated to the nearest enclosing try block; if no handler is found, the default handler is called
- `Raise IndexError` creates an instance
- The raised exception object can be gotten:  

```
except Exception as ex_obj:
```

# Exception Handling in Python

(continued)

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- The `assert` statement tests its Boolean expression (first parameter) and sends its second parameter to the constructor for the exception object to be raised

```
assert test, data
```



# Exception Handling in Ruby

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- Exceptions are objects
- There are many predefined exceptions
- All exceptions that are user handled are either `StandardError` class or a subclass of it
- `StandardError` is derived from `Exception`, which has two methods, `message` and `backtrace`
- Exceptions can be raised with `raise`, which often has the form:

```
raise "bad parameter" if count == 0
```

# Exception Handling in Ruby (continued)

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- Handlers are placed at the end of a begin–end block of code; introduced by `rescue`

`begin`

– Statements in the block

`rescue`

– Handler

`end`

- The block could include `else` and/or `ensure` clauses, which are like `else` and `finally` in Java

# Exception Handling in Ruby (continued)

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- Unlike the other languages we have discussed, in Ruby the code that raised an exception can be rerun by placing a `retry` statement at the end of the handler

# Introduction to Event Handling

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- An *event* is a notification that something specific has occurred, such as a mouse click on a graphical button
- The *event handler* is a segment of code that is executed in response to an event

# Java Swing GUI Components

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- Text box is an object of class `JTextField`
- Radio button is an object of class `JRadioButton`
- Applet's display is a frame, a multilayered structure
- Content pane is one layer, where applets put output
- GUI components can be placed in a frame
- Layout manager objects are used to control the placement of components

# The Java Event Model

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- User interactions with GUI components create events that can be caught by event handlers, called *event listeners*
- An event generator tells a listener of an event by sending a message
- An interface is used to make event-handling methods conform to a standard protocol
- A class that implements a listener must implement an interface for the listener

# The Java Event Model (continued)

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- One class of events is `ItemEvent`, which is associated with the event of clicking a checkbox, a radio button, or a list item
- The `ItemListener` interface prescribes a method, `itemStateChanged`, which is a handler for `ItemEvent` events
- The listener is created with `addItemListener`

# Event Handling in C#

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- Event handling in C# (and the other .NET languages) is similar to that in Java
- .NET has two approaches, Windows Forms and Windows Presentation Foundation—we cover only the former (which is the original approach)
- An application subclasses the `Form` predefined class (defined in `System.Windows.Forms`)
- There is no need to create a frame or panel in which to place the GUI components
- `Label` objects are used to place text in the window
- Radio buttons are objects of the `RadioButton` class



# Event Handling in C# (continued)

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- Components are positioned by assigning a new `Point` object to the `Location` property of the component

```
private RadioButton plain = new RadioButton();  
plain.Location = new Point(100, 300);  
plain.Text = "Plain";  
controls.Add(plain);
```

- All C# event handlers have the same protocol, the return type is `void` and the two parameters are of types `object` and `EventArgs`

# Event Handling in C# (continued)

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- An event handler can have any name
- A radio button is tested with the Boolean Checked property of the button

```
private void rb_CheckedChanged (object o,  
                                EventArgs e) {  
    if (plain.Checked) ...  
    ...  
}
```

- To register an event, a new `EventHandler` object must be created and added to the predefined delegate for the event

# Event Handling in C# (continued)

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- When a radio button changes from unchecked to checked, the `CheckedChanged` event is raised
- The associated delegate is referenced by the name of the event
- If the handler was named `rb_CheckedChanged`, we could register it on the radio button named `plain` with:

```
plain.CheckedChanged +=  
    new EventHandler (rb_CheckedChanged) ;
```

# Summary

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- Ada provides extensive exception-handling facilities with a comprehensive set of built-in exceptions.
- C++ includes no predefined exceptions
- Exceptions are bound to handlers by connecting the type of expression in the `throw` statement to that of the formal parameter of the `catch` function
- Java exceptions are similar to C++ exceptions except that a Java exception must be a descendant of the `Throwable` class. Additionally Java includes a `finally` clause
- An event is a notification that something has occurred that requires handling by an event handler
- Java event handling is defined on the Swing components
- C# event handling is the .NET model, which is similar to the Java model