



# 5

## Flow Control, Exceptions, and Assertions

### CERTIFICATION OBJECTIVES

- Use if and switch Statements
  - Develop for, do, and while Loops  
Use break and continue Statements
  - Develop Code with Assertions
  - Use try, catch, and finally Statements
  - State the Effects of Exceptions
  - Recognize Common Exceptions
- ✓ Two-Minute Drill
- Q&A Self Test

**C**an you imagine trying to write code using a language that didn't give you a way to execute statements conditionally? Flow control is a key part of most any useful programming language, and Java offers several ways to do it. Some, like `if` statements and `for` loops, are common to most languages. But Java also throws in a couple of flow control features you might not have used before—exceptions and assertions.

The `if` statement and the `switch` statement are types of conditional/decision controls that allow your program to behave differently at a "fork in the road," depending on the result of a logical test. Java also provides three different looping constructs—`for`, `while`, and `do`—so you can execute the same code over and over again depending on some condition being true. Exceptions give you a clean, simple way to organize code that deals with problems that might crop up at runtime. Finally, the assertion mechanism, added to the language with version 1.4, gives you a way to do testing and debugging checks on conditions you expect to smoke out while developing, when you don't necessarily need or want the runtime overhead associated with exception handling.

With these tools, you can build a robust program that can handle any logical situation with grace. Expect to see a wide range of questions on the exam that include flow control as part of the question code, even on questions that aren't testing your knowledge of flow control.

## CERTIFICATION OBJECTIVE

### **if and switch Statements (Exam Objective 2.1)**

*2.1 Develop code that implements an if or switch statement; and identify legal argument types for these statements.*

The `if` and `switch` statements are commonly referred to as decision statements. When you use decision statements in your program, you're asking the program to evaluate a given expression to determine which course of action to take. We'll look at the `if` statement first.

## if-else Branching

The basic format of an `if` statement is as follows:

```
if (booleanExpression) {
    System.out.println("Inside if statement");
}
```

The expression in parentheses must evaluate to (a boolean) `true` or `false`. Typically you're testing something to see if it's true, and then running a code block (one or more statements) if it is true, and (optionally) another block of code if it isn't. The following code demonstrates a legal `if-else` statement:

```
if (x > 3) {
    System.out.println("x is greater than 3");
} else {
    System.out.println("x is not greater than 3");
}
```

The `else` block is optional, so you can also use the following:

```
if (x > 3) {
    y = 2;
}
z += 8;
a = y + x;
```

The preceding code will assign 2 to `y` if the test succeeds (meaning `x` really is greater than 3), but the other two lines will execute regardless. Even the curly braces are optional if you have only one statement to execute within the body of the conditional block. The following code example is legal (although not recommended for readability):

```
if (x > 3)    // bad practice, but seen on the exam
    y = 2;
z += 8;
a = y + x;
```

Sun considers it good practice to enclose blocks within curly braces, even if there's only one statement in the block. Be careful with code like the above, because you might think it should read as,

"If x is greater than 3, then set y to 2, z to z + 8, and a to y + x."

But the last two lines are going to execute no matter what! They aren't part of the conditional flow. You might find it even more misleading if the code were indented as follows:

```
if (x > 3)
    y = 2;
    z += 8;
    a = y + x;
```

You might have a need to nest `if-else` statements (although, again, it's not recommended for readability, so nested `if` tests should be kept to a minimum). You can set up an `if-else` statement to test for multiple conditions. The following example uses two conditions so that if the first test fails, we want to perform a second test before deciding what to do:

```
if (price < 300) {
    buyProduct();
} else {
    if (price < 400) {
        getApproval();
    }
    else {
        dontBuyProduct();
    }
}
```

This brings up the other `if-else` construct, the `if, else if, else`. The preceding code could (and should) be rewritten:

```
if (price < 300) {
    buyProduct();
} else if (price < 400) {
    getApproval();
} else {
    dontBuyProduct();
}
```

There are a couple of rules for using `else` and `else if`:

- You can have zero or one `else`'s for a given `if`, and it must come after any `else if`'s.
- You can have zero to many `else if`'s for a given `if` and they must come before the (optional) `else`.
- Once an `else if` succeeds, none of the remaining `else if` or `else`'s will be tested.

The following example shows code that is horribly formatted for the real world. As you've probably guessed, it's fairly likely that you'll encounter formatting like this on the exam. In any case, the code demonstrates the use of multiple `else if`'s:

```
int x = 1;
if ( x == 3 ) { }
else if (x < 4) {System.out.println("<4"); }
else if (x < 2) {System.out.println("<2"); }
else { System.out.println("else"); }
```

It produces the output:

```
<4
```

(Notice that even though the second `else if` is true, it is never reached.) Sometimes you can have a problem figuring out which `if` your `else` should pair with, as follows:

```
if (exam.done())
if (exam.getScore() < 0.61)
System.out.println("Try again.");
// Which if does this belong to?
else System.out.println("Java master!");
```

We intentionally left out the indenting in this piece of code so it doesn't give clues as to which `if` statement the `else` belongs to. Did you figure it out? Java law decrees that an `else` clause belongs to the innermost `if` statement to which it might possibly belong (in other words, the closest preceding `if` that doesn't have an `else`). In the case of the preceding example, the `else` belongs to the second `if` statement in the listing. With proper indenting, it would look like this:

```

if (exam.done())
    if (exam.getScore() < 0.61)
        System.out.println("Try again.");
    // Which if does this belong to?
    else
        System.out.println("Java master!");

```

Following our coding conventions by using curly braces, it would be even easier to read:

```

if (exam.done()) {
    if (exam.getScore() < 0.61) {
        System.out.println("Try again.");
    // Which if does this belong to?
    } else {
        System.out.println("Java master!");
    }
}

```

Don't get your hopes up about the exam questions being all nice and indented properly. Some exam takers even have a slogan for the way questions are presented on the exam: anything that can be made more confusing, will be.

Be prepared for questions that not only fail to indent nicely, but intentionally indent in a misleading way: Pay close attention for misdirection like the following:

```

if (exam.done())
    if (exam.getScore() < 0.61)
        System.out.println("Try again.");
    else
        System.out.println("Java master!"); // Hmmmmmm... now where does
                                              // it belong?

```

Of course, the preceding code is exactly the same as the previous two examples, except for the way it looks.

## Legal Expressions for if Statements

The expression in an if statement must be a boolean expression. Any expression that resolves to a boolean is fine, and some of the expressions can be complex.

Assume `doStuff()` returns `true`,

```

int y = 5;
int x = 2;

```

```

if ((x > 3) && (y < 2)) | doStuff() {
    System.out.println("true");
}

```

which prints

```
true
```

You can read the preceding code as, "If both `(x > 3)` and `(y < 2)` are `true`, or if the result of `doStuff()` is `true`, then print `true`." So basically, if just `doStuff()` alone is `true`, we'll still get `true`. If `doStuff()` is `false`, though, then both `(x > 3)` and `(y < 2)` will have to be `true` in order to print `true`. The preceding code is even more complex if you leave off one set of parentheses as follows,

```

int y = 5;
int x = 2;
if ((x > 3) && (y < 2) | doStuff()) {
    System.out.println("true");
}

```

which now prints...nothing! Because the preceding code (with one less set of parentheses) evaluates as though you were saying, "If `(x > 3)` is `true`, and either `(y < 2)` or the result of `doStuff()` is `true`, then print `true`." So if `(x > 3)` is not `true`, no point in looking at the rest of the expression." Because of the short-circuit `&&`, the expression is evaluated as though there were parentheses around `(y < 2) | doStuff()`. In other words, it is evaluated as a single expression before the `&&` and a single expression after the `&&`.

Remember that the only legal expression in an `if` test is a boolean. In some languages, `0 == false`, and `1 == true`. Not so in Java! The following code shows `if` statements that might look tempting, but are illegal, followed by legal substitutions:

```

int trueInt = 1;
int falseInt = 0;
if (trueInt)           // illegal
if (trueInt == true)   // illegal
if (1)                 // illegal
if (falseInt == false) // illegal
if (trueInt == 1)      // legal
if (falseInt == 0)     // legal

```

## exam

### Watch

One common mistake programmers make (and that can be difficult to spot), is assigning a boolean variable when you meant to test a boolean variable. Look out for code like the following:

```
boolean boo = false;
if (boo = true) { }
```

You might think one of three things:

1. The code compiles and runs fine, and the `if` test fails because `boo` is false.
2. The code won't compile because you're using an assignment (`=`) rather than an equality test (`==`).
3. The code compiles and runs fine and the `if` test succeeds because `boo` is SET to `true` (rather than TESTED for `true`) in the `if` argument!

Well, number 3 is correct. Pointless, but correct. Given that the result of any assignment is the value of the variable after the assignment, the expression `(boo = true)` has a result of `true`. Hence, the `if` test succeeds. But the only variable that can be assigned (rather than tested against something else) is a `boolean`; all other assignments will result in something non-boolean, so they're not legal, as in the following:

```
int x = 3;
if (x = 5) { } // Won't compile because x is not a boolean!
```

Because `if` tests require boolean expressions, you need to be really solid on both logical operators and `if` test syntax and semantics.

## switch Statements

A way to simulate the use of multiple `if` statements is with the `switch` statement. Take a look at the following `if-else` code, and notice how confusing it can be to have nested `if` tests, even just a few levels deep:

```
int x = 3;
if(x == 1) {
```



```

        System.out.println("x equals 1");
    }
    else if(x == 2) {
        System.out.println("x equals 2");
    }
    else if(x == 3) {
        System.out.println("x equals 3");
    }
    else {
        System.out.println("No idea what x is");
    }
}

```

Now let's see the same functionality represented in a switch construct:

```

int x = 3;
switch (x) {
    case 1:
        System.out.println("x is equal to 1");
        break;
    case 2:
        System.out.println("x is equal to 2");
        break;
    case 3:
        System.out.println("x is equal to 3");
        break;
    default:
        System.out.println("Still no idea what x is");
}

```

Note: The reason this switch statement emulates the nested ifs listed earlier is because of the break statements that were placed inside of the switch. In general, break statements are optional, and as we will see in a few pages, their inclusion or exclusion causes huge changes in how a switch statement will execute.

## Legal Expressions for switch and case

The general form of the switch statement is:

```

switch (expression) {
    case constant1: code block
    case constant2: code block
    default: code block
}

```

A `switch`'s expression must evaluate to a `char`, `byte`, `short`, `int`, or, as of Java 5, an `enum`. That means if you're not using an `enum`, only variables and values that can be automatically promoted (in other words, implicitly cast) to an `int` are acceptable. You won't be able to compile if you use anything else, including the remaining numeric types of `long`, `float`, and `double`.

A case constant must evaluate to the same type as the `switch` expression can use, with one additional—and big—constraint: the case constant must be a compile time constant! Since the case argument has to be resolved at compile time, that means you can use only a constant or `final` variable that is assigned a literal value. It is not enough to be `final`, it must be a compile time *constant*. For example:

```
final int a = 1;
final int b;
b = 2;
int x = 0;
switch (x) {
    case a:      // ok
    case b:      // compiler error
```

Also, the `switch` can only check for equality. This means that the other relational operators such as greater than are rendered unusable in a case. The following is an example of a valid expression using a method invocation in a `switch` statement. Note that for this code to be legal, the method being invoked on the object reference must return a value compatible with an `int`.

```
String s = "xyz";
switch (s.length()) {
    case 1:
        System.out.println("length is one");
        break;
    case 2:
        System.out.println("length is two");
        break;
    case 3:
        System.out.println("length is three");
        break;
    default:
        System.out.println("no match");
}
```

One other rule you might not expect involves the question, "What happens if I switch on a variable smaller than an `int`?" Look at the following switch:

```
byte g = 2;
switch(g) {
    case 23:
    case 128:
}
```

This code won't compile. Although the switch argument is legal—a byte is implicitly cast to an `int`—the second case argument (128) is too large for a byte, and the compiler knows it! Attempting to compile the preceding example gives you an error something like

```
Test.java:6: possible loss of precision
found   : int
required: byte
    case 128:
        ^
```

It's also illegal to have more than one case label using the same value. For example, the following block of code won't compile because it uses two cases with the same value of 80:

```
int temp = 90;
switch(temp) {
    case 80 : System.out.println("80");
    case 80 : System.out.println("80");    // won't compile!
    case 90 : System.out.println("90");
    default : System.out.println("default");
}
```

It is legal to leverage the power of boxing in a switch expression. For instance, the following is legal:

```
switch(new Integer(4)) {
    case 4: System.out.println("boxing is OK");
}
```

**exam****Watch**

**Look for any violation of the rules for `switch` and `case` arguments.**  
**For example, you might find illegal examples like the following snippets:**

```
switch(x) {
    case 0 {
        y = 7;
    }
}
```

```
switch(x) {
    0: { }
    1: { }
}
```

**In the first example, the `case` uses a curly brace and omits the colon.**  
**The second example omits the keyword `case`.**

## Break and Fall-Through in switch Blocks

We're finally ready to discuss the `break` statement, and more details about flow control within a `switch` statement. The most important thing to remember about the flow of execution through a `switch` statement is this:

**case constants are evaluated from the top down, and the first case constant that matches the `switch`'s expression is the execution *entry point*.**

In other words, once a case constant is matched, the JVM will execute the associated code block, and ALL subsequent code blocks (barring a `break` statement) too! The following example uses an enum in a case statement.

```
enum Color {red, green, blue}
class SwitchEnum {
    public static void main(String [] args) {
        Color c = Color.green;
        switch(c) {
```

```

        case red: System.out.print("red ");
        case green: System.out.print("green ");
        case blue: System.out.print("blue ");
        default: System.out.println("done");
    }
}

```

In this example `case green:` matched, so the JVM executed that code block and all subsequent code blocks to produce the output:

```
green blue done
```

Again, when the program encounters the keyword `break` during the execution of a `switch` statement, execution will immediately move out of the `switch` block to the next statement after the `switch`. If `break` is omitted, the program just keeps executing the remaining case blocks until either a `break` is found or the `switch` statement ends. Examine the following code:

```

int x = 1;
switch(x) {
    case 1: System.out.println("x is one");
    case 2: System.out.println("x is two");
    case 3: System.out.println("x is three");
}
System.out.println("out of the switch");

```

The code will print the following:

```

x is one
x is two
x is three
out of the switch

```

This combination occurs because the code didn't hit a `break` statement; execution just kept dropping down through each case until the end. This dropping down is actually called "fall-through," because of the way execution falls from one case to the next. Remember, the matching case is simply your entry point into the `switch` block! In other words, you must *not* think of it as, "Find the matching case, execute just that code, and get out." That's *not* how it works. If you do want that "just the matching code" behavior, you'll insert a `break` into each case as follows:

```

int x = 1;
switch(x) {
    case 1: {
        System.out.println("x is one"); break;
    }
    case 2: {
        System.out.println("x is two"); break;
    }
    case 3: {
        System.out.println("x is two"); break;
    }
}
System.out.println("out of the switch");

```

Running the preceding code, now that we've added the `break` statements, will print

```

x is one
out of the switch

```

and that's it. We entered into the `switch` block at case 1. Because it matched the `switch()` argument, we got the `println` statement, then hit the `break` and jumped to the end of the `switch`.

An interesting example of this fall-through logic is shown in the following code:

```

int x = someNumberBetweenOneAndTen;

switch (x) {
    case 2:
    case 4:
    case 6:
    case 8:
    case 10: {
        System.out.println("x is an even number"); break;
    }
}

```

This `switch` statement will print `x is an even number` or nothing, depending on whether the number is between one and ten and is odd or even. For example, if `x` is 4, execution will begin at case 4, but then fall down through 6, 8, and 10, where it prints and then breaks. The `break` at case 10, by the way, is not needed; we're already at the end of the `switch` anyway.

Note: Because fall-through is less than intuitive, Sun recommends that you add a comment like: `// fall through` when you use fall-through logic.

## The Default Case

What if, using the preceding code, you wanted to print "x is an odd number" if none of the cases (the even numbers) matched? You couldn't put it after the switch statement, or even as the last case in the switch, because in both of those situations it would always print `x is an odd number`. To get this behavior, you'll use the `default` keyword. (By the way, if you've wondered why there is a `default` keyword even though we don't use a modifier for default access control, now you'll see that the `default` keyword is used for a completely different purpose.) The only change we need to make is to add the default case to the preceding code:

```
int x = someNumberBetweenOneAndTen;

switch (x) {
    case 2:
    case 4:
    case 6:
    case 8:
    case 10: {
        System.out.println("x is an even number");
        break;
    }
    default: System.out.println("x is an odd number");
}
```

## exam

### Watch

**The default case doesn't have to come at the end of the switch. Look for it in strange places such as the following:**

```
int x = 2;
switch (x) {
    case 2: System.out.println("2");
    default: System.out.println("default");
    case 3: System.out.println("3");
    case 4: System.out.println("4");
}
```

**exam****Watch*****Running the preceding code prints***

```

2
default
3
4

```

***And if we modify it so that the only match is the default case:***

```

int x = 7;
switch (x) {
    case 2: System.out.println("2");
    default: System.out.println("default");
    case 3: System.out.println("3");
    case 4: System.out.println("4");
}

```

***Running the preceding code prints***

```

default
3
4

```

***The rule to remember is that `default` works just like any other case for fall-through!***

**EXERCISE 5-1****Creating a switch-case Statement**

Try creating a switch statement using a char value as the case. Include a default behavior if none of the char values match.

- Make sure a char variable is declared before the switch statement.
- Each case statement should be followed by a `break`.
- The default case can be located at the end, middle, or top.



**CERTIFICATION OBJECTIVE****Loops and Iterators (Exam Objective 2.2)**

*2.2 Develop code that implements all forms of loops and iterators, including the use of for, the enhanced for loop (for-each), do, while, labels, break, and continue; and explain the values taken by loop counter variables during and after loop execution.*

Java loops come in three flavors: `while`, `do`, and `for` (and as of Java 5, the `for` loop has two variations). All three let you repeat a block of code as long as some condition is true, or for a specific number of iterations. You're probably familiar with loops from other languages, so even if you're somewhat new to Java, these won't be a problem to learn.

**Using while Loops**

The `while` loop is good for scenarios where you don't know how many times a block or statement should repeat, but you want to continue looping as long as some condition is true. A `while` statement looks like this:

```
while (expression) {  
    // do stuff  
}  
  
or  
  
int x = 2;  
while(x == 2) {  
    System.out.println(x);  
    ++x;  
}
```

In this case, as in all loops, the expression (test) must evaluate to a `boolean` result. The body of the `while` loop will only execute if the expression (sometimes called the "condition") results in a value of `true`. Once inside the loop, the loop body will repeat until the condition is no longer met because it evaluates to `false`. In the previous example, program control will enter the loop body because `x` is equal to 2. However, `x` is incremented in the loop, so when the condition is checked again it will evaluate to `false` and exit the loop.

Any variables used in the expression of a `while` loop must be declared before the expression is evaluated. In other words, you can't say

```
while (int x = 2) { }    // not legal
```

Then again, why would you? Instead of testing the variable, you'd be declaring and initializing it, so it would always have the exact same value. Not much of a test condition!

The key point to remember about a `while` loop is that it might not ever run. If the test expression is `false` the first time the `while` expression is checked, the loop body will be skipped and the program will begin executing at the first statement *after* the `while` loop. Look at the following example:

```
int x = 8;
while (x > 8) {
    System.out.println("in the loop");
    x = 10;
}
System.out.println("past the loop");
```

Running this code produces

```
past the loop
```

Because the expression `(x > 8)` evaluates to `false`, none of the code within the `while` loop ever executes.

## Using do Loops

The `do` loop is similar to the `while` loop, except that the expression is not evaluated until after the `do` loop's code is executed. Therefore the code in a `do` loop is guaranteed to execute at least once. The following shows a `do` loop in action:

```
do {
    System.out.println("Inside loop");
} while(false);
```

The `System.out.println()` statement will print once, even though the expression evaluates to `false`. Remember, the `do` loop will always run the code in the loop body at least once. Be sure to note the use of the semicolon at the end of the `while` expression.

**exam****Watch**

**As with `if` tests, look for `while` loops (and the `while` test in a `do` loop) with an expression that does not resolve to a `boolean`. Take a look at the following examples of legal and illegal `while` expressions:**

```
int x = 1;
while (x) { }           // Won't compile; x is not a boolean
while (x = 5) { }       // Won't compile; resolves to 5
                        // (as the result of assignment)
while (x == 5) { }      // Legal, equality test
while (true) { }        // Legal
```

## Using for Loops

As of Java 5, the `for` loop took on a second structure. We'll call the old style of `for` loop the "basic `for` loop", and we'll call the new style of `for` loop the "enhanced `for` loop" (even though the Sun objective 2.2 refers to it as the `for-each`). Depending on what documentation you use (Sun's included), you'll see both terms, along with `for-in`. The terms `for-in`, `for-each`, and "enhanced `for`" all refer to the same Java construct.

The basic `for` loop is more flexible than the enhanced `for` loop, but the enhanced `for` loop was designed to make iterating through arrays and collections easier to code.

### The Basic for Loop

The `for` loop is especially useful for flow control when you already know how many times you need to execute the statements in the loop's block. The `for` loop declaration has three main parts, besides the body of the loop:

- Declaration and initialization of variables
- The `boolean` expression (conditional test)
- The iteration expression

The three `for` declaration parts are separated by semicolons. The following two examples demonstrate the `for` loop. The first example shows the parts of a `for` loop in a pseudocode form, and the second shows a typical example of a `for` loop.

```

for (/*Initialization*/ ; /*Condition*/ ; /* Iteration */) {
    /* loop body */
}

for (int i = 0; i<10; i++) {
    System.out.println("i is " + i);
}

```

### The Basic for Loop: Declaration and Initialization

The first part of the `for` statement lets you declare and initialize zero, one, or multiple variables of the same type inside the parentheses after the `for` keyword. If you declare more than one variable of the same type, then you'll need to separate them with commas as follows:

```
for (int x = 10, y = 3; y > 3; y++) { }
```

The declaration and initialization happens before anything else in a `for` loop. And whereas the other two parts—the boolean test and the iteration expression—will run with each iteration of the loop, the declaration and initialization happens just once, at the very beginning. You also must know that the scope of variables declared in the `for` loop ends with the `for` loop! The following demonstrates this:

```

for (int x = 1; x < 2; x++) {
    System.out.println(x); // Legal
}
System.out.println(x);    // Not Legal! x is now out of scope
                          // and can't be accessed.

```

If you try to compile this, you'll get something like this:

```

Test.java:19: cannot resolve symbol
symbol   : variable x
location: class Test
    System.out.println(x);
                      ^

```

### Basic for Loop: Conditional (boolean) Expression

The next section that executes is the conditional expression, which (like all other conditional tests) must evaluate to a `boolean` value. You can have only one

logical expression, but it can be very complex. Look out for code that uses logical expressions like this:

```
for (int x = 0; (((x < 10) && (y-- > 2)) | x == 3)); x++) { }
```

The preceding code is legal, but the following is not:

```
for (int x = 0; (x > 5), (y < 2); x++) { } // too many
                                           //expressions
```

The compiler will let you know the problem:

```
TestLong.java:20: ';' expected
for (int x = 0; (x > 5), (y < 2); x++) { }
                   ^
```

The rule to remember is this: *You can have only one test expression.*

In other words, you can't use multiple tests separated by commas, even though the other two parts of a `for` statement can have multiple parts.

## Basic for Loop: Iteration Expression

After each execution of the body of the `for` loop, the iteration expression is executed. This is where you get to say what you want to happen with each iteration of the loop. Remember that it always happens after the loop body runs! Look at the following:

```
for (int x = 0; x < 1; x++) {
    // body code that doesn't change the value of x
}
```

The preceding loop executes just once. The first time into the loop `x` is set to 0, then `x` is tested to see if it's less than 1 (which it is), and then the body of the loop executes. After the body of the loop runs, the iteration expression runs, incrementing `x` by 1. Next, the conditional test is checked, and since the result is now `false`, execution jumps to below the `for` loop and continues on.

**Keep in mind that barring a forced exit, evaluating the iteration expression and then evaluating the conditional expression are always the last two things that happen in a `for` loop!**

Examples of forced exits include a `break`, a `return`, a `System.exit()`, or an exception, which will all cause a loop to terminate abruptly, without running the iteration expression. Look at the following code:

```
static boolean doStuff() {
    for (int x = 0; x < 3; x++) {
        System.out.println("in for loop");
        return true;
    }
    return true;
}
```

Running this code produces

```
in for loop
```

The statement only prints once, because a `return` causes execution to leave not just the current iteration of a loop, but the entire method. So the iteration expression never runs in that case. Table 5-1 lists the causes and results of abrupt loop termination.

**TABLE 5-1** Causes of Early Loop Termination

Code in Loop	What Happens
<code>break</code>	Execution jumps immediately to the 1st statement after the <code>for</code> loop.
<code>return</code>	Execution jumps immediately back to the calling method.
<code>System.exit()</code>	All program execution stops; the VM shuts down.

**Basic for Loop: for Loop Issues**

None of the three sections of the `for` declaration are required! The following example is perfectly legal (although not necessarily good practice):

```
for( ; ; ) {
    System.out.println("Inside an endless loop");
}
```

In the preceding example, all the declaration parts are left out so the `for` loop will act like an endless loop. For the exam, it's important to know that with the absence

of the initialization and increment sections, the loop will act like a `while` loop. The following example demonstrates how this is accomplished:

```
int i = 0;

for (;i<10;) {
    i++;
    //do some other work
}
```

The next example demonstrates a `for` loop with multiple variables in play. A comma separates the variables, and they must be of the same type. Remember that the variables declared in the `for` statement are all local to the `for` loop, and can't be used outside the scope of the loop.

```
for (int i = 0, j = 0; (i<10) && (j<10); i++, j++) {
    System.out.println("i is " + i + " j is " + j);
}
```

## exam

### Watch

**Variable scope plays a large role in the exam. You need to know that a variable declared in the `for` loop can't be used beyond the `for` loop. But a variable only initialized in the `for` statement (but declared earlier) can be used beyond the loop. For example, the following is legal,**

```
int x = 3;
for (x = 12; x < 20; x++) { }
System.out.println(x);
```

### while this is not

```
for (int x = 3; x < 20; x++) { } System.out.println(x);
```

The last thing to note is that all three sections of the `for` loop are independent of each other. The three expressions in the `for` statement don't need to operate on the same variables, although they typically do. But even the iterator expression, which

many mistakenly call the "increment expression," doesn't need to increment or set anything; you can put in virtually any arbitrary code statements that you want to happen with each iteration of the loop. Look at the following:

```
int b = 3;
for (int a = 1; b != 1; System.out.println("iterate")) {
    b = b - a;
}
```

The preceding code prints

```
iterate
iterate
```

## exam

### Watch

**Many questions in the new (Java 5) exam list “Compilation fails” and “An exception occurs at runtime” as possible answers. This makes it more difficult because you can’t simply work through the behavior of the code. You must first make sure the code isn’t violating any fundamental rules that will lead to compiler error, and then look for possible exceptions. Only after you’ve satisfied those two, should you dig into the logic and flow of the code in the question.**

## The Enhanced for Loop (for Arrays)

The enhanced `for` loop, new to Java 5, is a specialized `for` loop that simplifies looping through an array or a collection. In this chapter we’re going to focus on using the enhanced `for` to loop through arrays. In Chapter 7 we’ll revisit the enhanced `for` as we discuss collections—where the enhanced `for` really comes into its own.

Instead of having *three* components, the enhanced `for` has *two*. Let’s loop through an array the basic (old) way, and then using the enhanced `for`:

```
int [] a = {1,2,3,4};
for(int x = 0; x < a.length; x++)    // basic for loop
    System.out.print(a[x]);
for(int n : a)                        // enhanced for loop
    System.out.print(n);
```



Which produces this output:

```
12341234
```

More formally, let's describe the enhanced `for` as follows:

```
for(declaration : expression)
```

The two pieces of the `for` statement are

- **declaration** The *newly declared* block variable, of a type compatible with the elements of the array you are accessing. This variable will be available within the `for` block, and its value will be the same as the current array element.
- **expression** This must evaluate to the array you want to loop through. This could be an array variable or a method call that returns an array. The array can be any type: primitives, objects, even arrays of arrays.

Using the above definitions, let's look at some legal and illegal enhanced `for` declarations:

```
int x;
long x2;
Long [] La = {4L, 5L, 6L};
long [] la = {7L, 8L, 9L};
int [][] twoDee = {{1,2,3}, {4,5,6}, {7,8,9}};
String [] sNums = {"one", "two", "three"};
Animal [] animals = {new Dog(), new Cat()};

// legal 'for' declarations
for(long y : la ) ;           // loop thru an array of longs
for(long lp : La) ;           // autoboxing the Long objects
                                // into longs
for(int[] n : twoDee) ;        // loop thru the array of arrays
for(int n2 : twoDee[2]) ;      // loop thru the 3rd sub-array
for(String s : sNums) ;        // loop thru the array of Strings
for(Object o : sNums) ;        // set an Object reference to
                                // each String
for(Animal a : animals) ;      // set an Animal reference to each
                                // element
```

```
// ILLEGAL 'for' declarations
for(x2 : la) ;           // x2 is already declared
for(int x2 : twoDee) ;    // can't stuff an array into an int
for(int x3 : la) ;        // can't stuff a long into an int
for(Dog d : animals) ;    // you might get a Cat!
```

The enhanced `for` loop assumes that, barring an early exit from the loop, you'll always loop through every element of the array. The following discussions of `break` and `continue` apply to both the basic and enhanced `for` loops.

## Using `break` and `continue`

The `break` and `continue` keywords are used to stop either the entire loop (`break`) or just the current iteration (`continue`). Typically if you're using `break` or `continue`, you'll do an `if` test within the loop, and if some condition becomes true (or false depending on the program), you want to get out immediately. The difference between them is whether or not you continue with a new iteration or jump to the first statement below the loop and continue from there.

### exam

#### Watch

**Remember,** `continue` statements must be inside a loop; otherwise, you'll get a compiler error. `break` statements must be used inside either a loop or `switch` statement. (Note: this does not apply to labeled `break` statements.).

The `break` statement causes the program to stop execution of the innermost loop and start processing the next line of code after the block.

The `continue` statement causes only the current iteration of the innermost loop to cease and the next iteration of the same loop to start if the condition of the loop is met. When using a `continue` statement with a `for` loop, you need to consider the effects that `continue` has on the loop iteration. Examine the following code:

```
for (int i = 0; i < 10; i++) {
    System.out.println("Inside loop");
    continue;
}
```

The question is, is this an endless loop? The answer is no. When the `continue` statement is hit, the iteration expression still runs! It runs just as though the current

iteration ended "in the natural way." So in the preceding example, `i` will still increment before the condition (`i < 10`) is checked again. Most of the time, a `continue` is used within an `if` test as follows:

```
for (int i = 0; i < 10; i++) {
    System.out.println("Inside loop");
    if (foo.doStuff() == 5) {
        continue;
    }
    // more loop code, that won't be reached when the above if
    // test is true
}
```

## Unlabeled Statements

Both the `break` statement and the `continue` statement can be unlabeled or labeled. Although it's far more common to use `break` and `continue` unlabeled, the exam expects you to know how labeled `break` and `continue` statements work. As stated before, a `break` statement (unlabeled) will exit out of the innermost looping construct and proceed with the next line of code beyond the loop block. The following example demonstrates a `break` statement:

```
boolean problem = true;
while (true) {
    if (problem) {
        System.out.println("There was a problem");
        break;
    }
}
// next line of code
```

In the previous example, the `break` statement is unlabeled. The following is an example of an unlabeled `continue` statement:

```
while (!EOF) {
    //read a field from a file
    if (wrongField) {
        continue;    // move to the next field in the file
    }
    // otherwise do other stuff with the field
}
```

In this example, a file is being read one field at a time. When an error is encountered, the program moves to the next field in the file and uses the `continue` statement to go back into the loop (if it is not at the end of the file) and keeps reading the various fields. If the `break` command were used instead, the code would stop reading the file once the error occurred and move on to the next line of code after the loop. The `continue` statement gives you a way to say, "This particular iteration of the loop needs to stop, but not the whole loop itself. I just don't want the rest of the code in this iteration to finish, so do the iteration expression and then start over with the test, and don't worry about what was below the `continue` statement."

## Labeled Statements

Although many statements in a Java program can be labeled, it's most common to use labels with loop statements like `for` or `while`, in conjunction with `break` and `continue` statements. A label statement must be placed just before the statement being labeled, and it consists of a valid identifier that ends with a colon (:).

You need to understand the difference between labeled and unlabeled `break` and `continue`. The labeled varieties are needed only in situations where you have a nested loop, and need to indicate which of the nested loops you want to break from, or from which of the nested loops you want to continue with the next iteration. A `break` statement will exit out of the labeled loop, as opposed to the innermost loop, if the `break` keyword is combined with a label. An example of what a label looks like is in the following code:

```
foo:
    for (int x = 3; x < 20; x++) {
        while(y > 7) {
            y--;
        }
    }
```

The label must adhere to the rules for a valid variable name and should adhere to the Java naming convention. The syntax for the use of a label name in conjunction with a `break` statement is the `break` keyword, then the label name, followed by a semicolon. A more complete example of the use of a labeled `break` statement is as follows:

```
boolean isTrue = true;
outer:
    for(int i=0; i<5; i++) {
        while (isTrue) {
```

```

        System.out.println("Hello");
        break outer;
    } // end of inner while loop
    System.out.println("Outer loop."); // Won't print
} // end of outer for loop
System.out.println("Good-Bye");

```

Running this code produces

```

Hello
Good-Bye

```

In this example the word `Hello` will be printed one time. Then, the labeled `break` statement will be executed, and the flow will exit out of the loop labeled `outer`. The next line of code will then print out `Good-Bye`. Let's see what will happen if the `continue` statement is used instead of the `break` statement. The following code example is similar to the preceding one, with the exception of substituting `continue` for `break`:

```

outer:
    for (int i=0; i<5; i++) {
        for (int j=0; j<5; j++) {
            System.out.println("Hello");
            continue outer;
        } // end of inner loop
        System.out.println("outer"); // Never prints
    }
System.out.println("Good-Bye");

```

Running this code produces

```

Hello
Hello
Hello
Hello
Hello
Good-Bye

```

In this example, `Hello` will be printed five times. After the `continue` statement is executed, the flow continues with the next iteration of the loop identified with the label. Finally, when the condition in the outer loop evaluates to `false`, this loop will finish and `Good-Bye` will be printed.

**EXERCISE 5-2****Creating a Labeled while Loop**

Try creating a labeled `while` loop. Make the label `outer` and provide a condition to check whether a variable `age` is less than or equal to 21. Within the loop, increment `age` by one. Every time the program goes through the loop, check whether `age` is 16. If it is, print the message "get your driver's license" and continue to the outer loop. If not, print "Another year."

- The outer label should appear just before the `while` loop begins.
- Make sure `age` is declared outside of the `while` loop.

**exam****Watch**

**Labeled `continue` and `break` statements must be inside the loop that has the same label name; otherwise, the code will not compile.**

**CERTIFICATION OBJECTIVE****Handling Exceptions (Exam Objectives 2.4 and 2.5)**

*2.4 Develop code that makes use of exceptions and exception handling clauses (`try`, `catch`, `finally`), and declares methods and overriding methods that throw exceptions.*

*2.5 Recognize the effect of an exception arising at a specific point in a code fragment. Note that the exception may be a runtime exception, a checked exception, or an error.*

An old maxim in software development says that 80 percent of the work is used 20 percent of the time. The 80 percent refers to the effort required to check and handle errors. In many languages, writing program code that checks for and deals with errors is tedious and bloats the application source into confusing spaghetti.

Still, error detection and handling may be the most important ingredient of any robust application. Java arms developers with an elegant mechanism for handling errors that produces efficient and organized error-handling code: exception handling.

Exception handling allows developers to detect errors easily without writing special code to test return values. Even better, it lets us keep exception-handling code cleanly separated from the exception-generating code. It also lets us use the same exception-handling code to deal with a range of possible exceptions.

The exam has three objectives covering exception handling. We'll cover the first two in this section, and in the next section we'll cover those aspects of exception handling that are new to the exam as of Java 5.

## Catching an Exception Using try and catch

Before we begin, let's introduce some terminology. The term "exception" means "exceptional condition" and is an occurrence that alters the normal program flow. A bunch of things can lead to exceptions, including hardware failures, resource exhaustion, and good old bugs. When an exceptional event occurs in Java, an exception is said to be "thrown." The code that's responsible for doing something about the exception is called an "exception handler," and it "catches" the thrown exception.

Exception handling works by transferring the execution of a program to an appropriate exception handler when an exception occurs. For example, if you call a method that opens a file but the file cannot be opened, execution of that method will stop, and code that you wrote to deal with this situation will be run. Therefore, we need a way to tell the JVM what code to execute when a certain exception happens. To do this, we use the `try` and `catch` keywords. The `try` is used to define a block of code in which exceptions may occur. This block of code is called a guarded region (which really means "risky code goes here"). One or more `catch` clauses match a specific exception (or group of exceptions—more on that later) to a block of code that handles it. Here's how it looks in pseudocode:

```
1. try {
2.     // This is the first line of the "guarded region"
3.     // that is governed by the try keyword.
4.     // Put code here that might cause some kind of exception.
5.     // We may have many code lines here or just one.
6. }
7. catch(MyFirstException) {
8.     // Put code here that handles this exception.
```

```

9.    // This is the next line of the exception handler.
10.   // This is the last line of the exception handler.
11.  }
12.  catch(MySecondException) {
13.    // Put code here that handles this exception
14.  }
15.
16. // Some other unguarded (normal, non-risky) code begins here

```

In this pseudocode example, lines 2 through 5 constitute the guarded region that is governed by the `try` clause. Line 7 is an exception handler for an exception of type `MyFirstException`. Line 12 is an exception handler for an exception of type `MySecondException`. Notice that the `catch` blocks immediately follow the `try` block. This is a requirement; if you have one or more `catch` blocks, they must immediately follow the `try` block. Additionally, the `catch` blocks must all follow each other, without any other statements or blocks in between. Also, the order in which the `catch` blocks appear matters, as we'll see a little later.

Execution of the guarded region starts at line 2. If the program executes all the way past line 5 with no exceptions being thrown, execution will transfer to line 15 and continue downward. However, if at any time in lines 2 through 5 (the `try` block) an exception is thrown of type `MyFirstException`, execution will immediately transfer to line 7. Lines 8 through 10 will then be executed so that the entire `catch` block runs, and then execution will transfer to line 15 and continue.

Note that if an exception occurred on, say, line 3 of the `try` block, the rest of the lines in the `try` block (4 and 5) would never be executed. Once control jumps to the `catch` block, it never returns to complete the balance of the `try` block. This is exactly what you want, though. Imagine your code looks something like this pseudocode:

```

try {
    getTheFileFromOverNetwork
    readFromTheFileAndPopulateTable
}
catch(CantGetFileFromNetwork) {
    displayNetworkErrorMessage
}

```

The preceding pseudocode demonstrates how you typically work with exceptions. Code that's dependent on a risky operation (as populating a table with file data is dependent on getting the file from the network) is grouped into a `try` block in such



a way that if, say, the first operation fails, you won't continue trying to run other code that's also guaranteed to fail. In the pseudocode example, you won't be able to read from the file if you can't get the file off the network in the first place.

One of the benefits of using exception handling is that code to handle any particular exception that may occur in the governed region needs to be written only once. Returning to our earlier code example, there may be three different places in our `try` block that can generate a `MyFirstException`, but wherever it occurs it will be handled by the same `catch` block (on line 7). We'll discuss more benefits of exception handling near the end of this chapter.

## Using finally

Although `try` and `catch` provide a terrific mechanism for trapping and handling exceptions, we are left with the problem of how to clean up after ourselves if an exception occurs. Because execution transfers out of the `try` block as soon as an exception is thrown, we can't put our cleanup code at the bottom of the `try` block and expect it to be executed if an exception occurs. Almost as bad an idea would be placing our cleanup code in each of the `catch` blocks—let's see why.

Exception handlers are a poor place to clean up after the code in the `try` block because each handler then requires its own copy of the cleanup code. If, for example, you allocated a network socket or opened a file somewhere in the guarded region, each exception handler would have to close the file or release the socket. That would make it too easy to forget to do cleanup, and also lead to a lot of redundant code. To address this problem, Java offers the `finally` block.

A `finally` block encloses code that is always executed at some point after the `try` block, whether an exception was thrown or not. Even if there is a `return` statement in the `try` block, the `finally` block executes right after the `return` statement is encountered, and before the `return` executes!

This is the right place to close your files, release your network sockets, and perform any other cleanup your code requires. If the `try` block executes with no exceptions, the `finally` block is executed immediately after the `try` block completes. If there was an exception thrown, the `finally` block executes immediately after the proper `catch` block completes. Let's look at another pseudocode example:

```
1: try {
2:   // This is the first line of the "guarded region".
3: }
4: catch(MyFirstException) {
```

```

5:    // Put code here that handles this exception
6: }
7: catch(MySecondException) {
8:    // Put code here that handles this exception
9: }
10: finally {
11:    // Put code here to release any resource we
12:    // allocated in the try clause.
13: }
14:
15: // More code here

```

As before, execution starts at the first line of the `try` block, line 2. If there are no exceptions thrown in the `try` block, execution transfers to line 11, the first line of the `finally` block. On the other hand, if a `MySecondException` is thrown while the code in the `try` block is executing, execution transfers to the first line of that exception handler, line 8 in the `catch` clause. After all the code in the `catch` clause is executed, the program moves to line 11, the first line of the `finally` clause. Repeat after me: `finally` always runs! OK, we'll have to refine that a little, but for now, start burning in the idea that `finally` always runs. If an exception is thrown, `finally` runs. If an exception is not thrown, `finally` runs. If the exception is caught, `finally` runs. If the exception is not caught, `finally` runs. Later we'll look at the few scenarios in which `finally` might not run or complete.

Remember, `finally` clauses are not required. If you don't write one, your code will compile and run just fine. In fact, if you have no resources to clean up after your `try` block completes, you probably don't need a `finally` clause. Also, because the compiler doesn't even require `catch` clauses, sometimes you'll run across code that has a `try` block immediately followed by a `finally` block. Such code is useful when the exception is going to be passed back to the calling method, as explained in the next section. Using a `finally` block allows the cleanup code to execute even when there isn't a `catch` clause.

The following legal code demonstrates a `try` with a `finally` but no `catch`:

```

try {
    // do stuff
} finally {
    //clean up
}

```

The following legal code demonstrates a `try`, `catch`, and `finally`:

```

try {
    // do stuff
} catch (SomeException ex) {
    // do exception handling
} finally {
    // clean up
}

```

The following ILLEGAL code demonstrates a try without a catch or finally:

```

try {
    // do stuff
}
// need a catch or finally here
System.out.println("out of try block");

```

The following ILLEGAL code demonstrates a misplaced catch block:

```

try {
    // do stuff
}
// can't have code between try/catch
System.out.println("out of try block");
catch(Exception ex) { }

```

## exam

### Watch

***It is illegal to use a try clause without either a catch clause or a finally clause. A try clause by itself will result in a compiler error. Any catch clauses must immediately follow the try block. Any finally clause must immediately follow the last catch clause (or it must immediately follow the try block if there is no catch). It is legal to omit either the catch clause or the finally clause, but not both.***

## exam

### Watch

**You can't sneak any code in between the `try`, `catch`, or `finally` blocks.**

**The following won't compile:**

```
try {
    // do stuff
}
System.out.print("below the try"); //Illegal!
catch(Exception ex) { }
```

## Propagating Uncaught Exceptions

Why aren't `catch` clauses required? What happens to an exception that's thrown in a `try` block when there is no `catch` clause waiting for it? Actually, there's no requirement that you code a `catch` clause for every possible exception that could be thrown from the corresponding `try` block. In fact, it's doubtful that you could accomplish such a feat! If a method doesn't provide a `catch` clause for a particular exception, that method is said to be "ducking" the exception (or "passing the buck").

So what happens to a ducked exception? Before we discuss that, we need to briefly review the concept of the call stack. Most languages have the concept of a method stack or a call stack. Simply put, the call stack is the chain of methods that your program executes to get to the current method. If your program starts in method `main()` and `main()` calls method `a()`, which calls method `b()`, which in turn calls method `c()`, the call stack consists of the following:

```
c
b
a
main
```

We will represent the stack as growing upward (although it can also be visualized as growing downward). As you can see, the last method called is at the top of the stack, while the first calling method is at the bottom. The method at the very top of the stack trace would be the method you were currently executing. If we move back down the call stack, we're moving from the current method to the previously called method. Figure 5-1 illustrates a way to think about how the call stack in Java works.

**FIGURE 5-1**

The Java method  
call stack

1) The call stack while method3() is running.

4	method3()	method2 invokes method3
3	method2()	method1 invokes method2
2	method1()	main invokes method1
1	main()	main begins

The order in which methods are put on the call stack

2) The call stack after method3() completes

Execution returns to method2()

1	method2()	method2() will complete
2	method1()	method1() will complete
3	main()	main() will complete and the JVM will exit

The order in which methods complete

Now let's examine what happens to ducked exceptions. Imagine a building, say, five stories high, and at each floor there is a deck or balcony. Now imagine that on each deck, one person is standing holding a baseball mitt. Exceptions are like balls dropped from person to person, starting from the roof. An exception is first thrown from the top of the stack (in other words, the person on the roof), and if it isn't caught by the same person who threw it (the person on the roof), it drops down the call stack to the previous method, which is the person standing on the deck one floor down. If not caught there, by the person one floor down, the exception/ball again drops down to the previous method (person on the next floor down), and so on until it is caught or until it reaches the very bottom of the call stack. This is called exception propagation.

If an exception reaches the bottom of the call stack, it's like reaching the bottom of a very long drop; the ball explodes, and so does your program. An exception that's never caught will cause your application to stop running. A description (if one is available) of the exception will be displayed, and the call stack will be "dumped." This helps you debug your application by telling you what exception was thrown, from what method it was thrown, and what the stack looked like at the time.

**exam****Watch**

**You can keep throwing an exception down through the methods on the stack. But what about when you get to the `main()` method at the bottom? You can throw the exception out of `main()` as well. This results in the Java Virtual Machine (JVM) halting, and the stack trace will be printed to the output.**

**The following code throws an exception,**

```
class TestEx {
    public static void main (String [] args) {
        doStuff();
    }
    static void doStuff() {
        doMoreStuff();
    }
    static void doMoreStuff() {
        int x = 5/0;    // Can't divide by zero!
                       // ArithmeticException is thrown here
    }
}
```

**which prints out a stack trace something like,**

```
%java TestEx
Exception in thread "main" java.lang.ArithmeticException: /
by zero
at TestEx.doMoreStuff(TestEx.java:10)
at TestEx.doStuff(TestEx.java:7)
at TestEx.main(TestEx.java:3)
```

**EXERCISE 5-3****Propagating and Catching an Exception**

In this exercise you're going to create two methods that deal with exceptions. One of the methods is the `main()` method, which will call another method. If an exception is thrown in the other method, `main()` must deal with it. A `finally` statement will be included to indicate that the program has completed. The method that `main()`

will call will be named `reverse`, and it will reverse the order of the characters in a `String`. If the `String` contains no characters, `reverse` will propagate an exception up to the `main()` method.

- Create a class called `Propagate` and a `main()` method, which will remain empty for now.
- Create a method called `reverse`. It takes an argument of a `String` and returns a `String`.
- In `reverse`, check if the `String` has a length of 0 by using the `String.length()` method. If the length is 0, the `reverse` method will throw an exception.
- Now include the code to reverse the order of the `String`. Because this isn't the main topic of this chapter, the reversal code has been provided, but feel free to try it on your own.

```
String reverseStr = "";
for(int i=s.length()-1;i>=0;--i) {
    reverseStr += s.charAt(i);
}
return reverseStr;
```

- Now in the `main()` method you will attempt to call this method and deal with any potential exceptions. Additionally, you will include a `finally` statement that displays when `main()` has finished.

## Defining Exceptions

We have been discussing exceptions as a concept. We know that they are thrown when a problem of some type happens, and we know what effect they have on the flow of our program. In this section we will develop the concepts further and use exceptions in functional Java code. Earlier we said that an exception is an occurrence that alters the normal program flow. But because this is Java, anything that's not a primitive must be...an object. Exceptions are no, well, exception to this rule. Every exception is an instance of a class that has class `Exception` in its inheritance hierarchy. In other words, exceptions are always some subclass of `java.lang.Exception`.

When an exception is thrown, an object of a particular `Exception` subtype is instantiated and handed to the exception handler as an argument to the `catch` clause. An actual `catch` clause looks like this:

```
try {
    // some code here
}
catch (ArrayIndexOutOfBoundsException e) {
    e.printStackTrace();
}
```

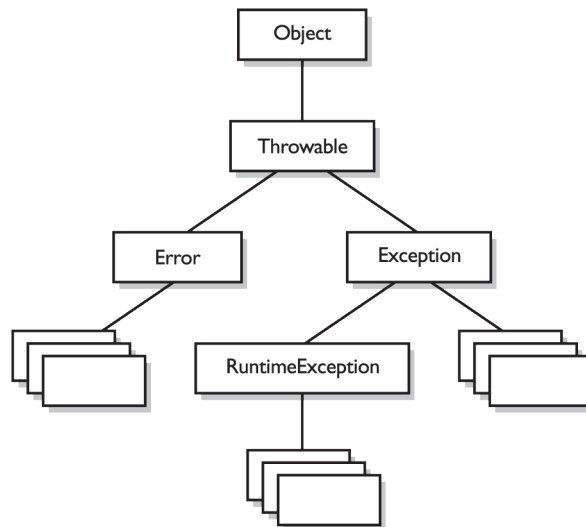
In this example, `e` is an instance of the `ArrayIndexOutOfBoundsException` class. As with any other object, you can call its methods.

## Exception Hierarchy

All exception classes are subtypes of class `Exception`. This class derives from the class `Throwable` (which derives from the class `Object`). Figure 5-2 shows the hierarchy for the exception classes.

**FIGURE 5-2**

Exception class hierarchy



As you can see, there are two subclasses that derive from `Throwable`: `Exception` and `Error`. Classes that derive from `Error` represent unusual situations that are not caused by program errors, and indicate things that would not normally happen



during program execution, such as the JVM running out of memory. Generally, your application won't be able to recover from an `Error`, so you're not required to handle them. If your code does not handle them (and it usually won't), it will still compile with no trouble. Although often thought of as exceptional conditions, `Errors` are technically not exceptions because they do not derive from class `Exception`.

In general, an exception represents something that happens not as a result of a programming error, but rather because some resource is not available or some other condition required for correct execution is not present. For example, if your application is supposed to communicate with another application or computer that is not answering, this is an exception that is not caused by a bug. Figure 5-2 also shows a subtype of `Exception` called `RuntimeException`. These exceptions are a special case because they sometimes do indicate program errors. They can also represent rare, difficult-to-handle exceptional conditions. Runtime exceptions are discussed in greater detail later in this chapter.

Java provides many exception classes, most of which have quite descriptive names. There are two ways to get information about an exception. The first is from the type of the exception itself. The next is from information that you can get from the exception object. Class `Throwable` (at the top of the inheritance tree for exceptions) provides its descendants with some methods that are useful in exception handlers. One of these is `printStackTrace()`. As expected, if you call an exception object's `printStackTrace()` method, as in the earlier example, a stack trace from where the exception occurred will be printed.

We discussed that a call stack builds upward with the most recently called method at the top. You will notice that the `printStackTrace()` method prints the most recently entered method first and continues down, printing the name of each method as it works its way down the call stack (this is called unwinding the stack) from the top.

## exam

### Watch

**For the exam, it is not necessary to know any of the methods contained in the `Throwable` classes, including `Exception` and `Error`. You are expected to know that `Exception`, `Error`, `RuntimeException`, and `Throwable` types can all be thrown using the `throw` keyword, and can all be caught (although you rarely will catch anything other than `Exception` subtypes).**

## Handling an Entire Class Hierarchy of Exceptions

We've discussed that the `catch` keyword allows you to specify a particular type of exception to catch. You can actually catch more than one type of exception in a single `catch` clause. If the exception class that you specify in the `catch` clause has no subclasses, then only the specified class of exception will be caught. However, if the class specified in the `catch` clause does have subclasses, any exception object that subclasses the specified class will be caught as well.

For example, class `IndexOutOfBoundsException` has two subclasses, `ArrayIndexOutOfBoundsException` and `StringIndexOutOfBoundsException`. You may want to write one exception handler that deals with exceptions produced by either type of boundary error, but you might not be concerned with which exception you actually have. In this case, you could write a `catch` clause like the following:

```
try {
    // Some code here that can throw a boundary exception
}
catch (IndexOutOfBoundsException e) {
    e.printStackTrace();
}
```

If any code in the `try` block throws `ArrayIndexOutOfBoundsException` or `StringIndexOutOfBoundsException`, the exception will be caught and handled. This can be convenient, but it should be used sparingly. By specifying an exception class's superclass in your `catch` clause, you're discarding valuable information about the exception. You can, of course, find out exactly what exception class you have, but if you're going to do that, you're better off writing a separate `catch` clause for each exception type of interest.



***Resist the temptation to write a single catchall exception handler such as the following:***

```
try {
    // some code
}
catch (Exception e) {
    e.printStackTrace();
}
```

***This code will catch every exception generated. Of course, no single exception handler can properly handle every exception, and programming in this way defeats the design objective. Exception handlers that trap many errors at once will probably reduce the reliability of your program because it's likely that an exception will be caught that the handler does not know how to handle.***

## Exception Matching

If you have an exception hierarchy composed of a superclass exception and a number of subtypes, and you're interested in handling one of the subtypes in a special way but want to handle all the rest together, you need write only two catch clauses.

When an exception is thrown, Java will try to find (by looking at the available catch clauses from the top down) a catch clause for the exception type. If it doesn't find one, it will search for a handler for a supertype of the exception. If it does not find a catch clause that matches a supertype for the exception, then the exception is propagated down the call stack. This process is called exception matching. Let's look at an example:

```

1: import java.io.*;
2: public class ReadData {
3:     public static void main(String args[]) {
4:         try {
5:             RandomAccessFile raf =
6:                 new RandomAccessFile("myfile.txt", "r");
7:             byte b[] = new byte[1000];
8:             raf.readFully(b, 0, 1000);
9:         }
10:        catch(FileNotFoundException e) {
11:            System.err.println("File not found");
12:            System.err.println(e.getMessage());
13:            e.printStackTrace();
14:        }
15:        catch(IOException e) {
16:            System.err.println("IO Error");
17:            System.err.println(e.toString());
18:            e.printStackTrace();
19:        }
20:    }
21: }
```

This short program attempts to open a file and to read some data from it. Opening and reading files can generate many exceptions, most of which are some type of `IOException`. Imagine that in this program we're interested in knowing only whether the exact exception is a `FileNotFoundException`. Otherwise, we don't care exactly what the problem is.

`FileNotFoundException` is a subclass of `IOException`. Therefore, we could handle it in the catch clause that catches all subtypes of `IOException`, but then we would have to test the exception to determine whether it was a `FileNotFoundException`. Instead, we coded a special exception handler for the `FileNotFoundException` and a separate exception handler for all other `IOException` subtypes.

If this code generates a `FileNotFoundException`, it will be handled by the catch clause that begins at line 10. If it generates another `IOException`—perhaps `EOFException`, which is a subclass of `IOException`—it will be handled by the catch clause that begins at line 15. If some other exception is generated, such as a runtime exception of some type, neither catch clause will be executed and the exception will be propagated down the call stack.

Notice that the catch clause for the `FileNotFoundException` was placed above the handler for the `IOException`. This is really important! If we do it the opposite way, the program will not compile. The handlers for the most specific exceptions must always be placed above those for more general exceptions. The following will not compile:

```
try {
    // do risky IO things
} catch (IOException e) {
    // handle general IOExceptions
} catch (FileNotFoundException ex) {
    // handle just FileNotFoundException
}
```

You'll get a compiler error something like this:

```
TestEx.java:15: exception java.io.FileNotFoundException has
already been caught
} catch (FileNotFoundException ex) {
^
```

If you think back to the people with baseball mitts (in the section "Propagating Uncaught Exceptions,") imagine that the most general mitts are the largest, and can thus catch many different kinds of balls. An `IOException` mitt is large enough

and flexible enough to catch any type of `IOException`. So if the person on the fifth floor (say, Fred) has a big 'ol `IOException` mitt, he can't help but catch a `FileNotFoundException` ball with it. And if the guy (say, Jimmy) on the second floor is holding a `FileNotFoundException` mitt, that `FileNotFoundException` ball will never get to him, since it will always be stopped by Fred on the fifth floor, standing there with his big-enough-for-any-`IOException` mitt.

So what do you do with exceptions that are siblings in the class hierarchy? If one Exception class is not a subtype or supertype of the other, then the order in which the catch clauses are placed doesn't matter.

## Exception Declaration and the Public Interface

So, how do we know that some method throws an exception that we have to catch? Just as a method must specify what type and how many arguments it accepts and what is returned, the exceptions that a method can throw must be *declared* (unless the exceptions are subclasses of `RuntimeException`). The list of thrown exceptions is part of a method's public interface. The `throws` keyword is used as follows to list the exceptions that a method can throw:

```
void myFunction() throws MyException1, MyException2 {
    // code for the method here
}
```

This method has a `void` return type, accepts no arguments, and declares that it can throw one of two types of exceptions: either type `MyException1` or type `MyException2`. (Just because the method declares that it throws an exception doesn't mean it always will. It just tells the world that it might.)

Suppose your method doesn't directly throw an exception, but calls a method that does. You can choose not to handle the exception yourself and instead just declare it, as though it were your method that actually throws the exception. If you do declare the exception that your method might get from another method, and you don't provide a `try/catch` for it, then the method will propagate back to the method that called your method, and either be caught there or continue on to be handled by a method further down the stack.

Any method that might throw an exception (unless it's a subclass of `RuntimeException`) must declare the exception. That includes methods that aren't actually throwing it directly, but are "ducking" and letting the exception pass down to the next method in the stack. If you "duck" an exception, it is just as if you were the one actually throwing the exception. `RuntimeException` subclasses are

exempt, so the compiler won't check to see if you've declared them. But all non-`RuntimeException`s are considered "checked" exceptions, because the compiler checks to be certain you've acknowledged that "bad things could happen here."

Remember this:

*Each method must either handle all checked exceptions by supplying a catch clause or list each unhandled checked exception as a thrown exception.*

This rule is referred to as Java's "handle or declare" requirement. (Sometimes called "catch or declare.")

## exam

### Watch

**Look for code that invokes a method declaring an exception, where the calling method doesn't handle or declare the checked exception. The following code (which uses the `throw` keyword to throw an exception manually - more on this next) has two big problems that the compiler will prevent:**

```
void doStuff() {
    doMore();
}
void doMore() {
    throw new IOException();
}
```

**First, the `doMore()` method throws a checked exception, but does not declare it! But suppose we fix the `doMore()` method as follows:**

```
void doMore() throws IOException { ... }
```

**The `doStuff()` method is still in trouble because it, too, must declare the `IOException`, unless it handles it by providing a `try/catch`, with a `catch` clause that can take an `IOException`.**

Again, some exceptions are exempt from this rule. An object of type `RuntimeException` may be thrown from any method without being specified as part of the method's public interface (and a handler need not be present). And even if a method does declare a `RuntimeException`, the calling method is under no obligation to handle or declare it. `RuntimeException`, `Error`, and all of their subtypes are unchecked exceptions and unchecked exceptions do not have to be specified or handled. Here is an example:

```
import java.io.*;
class Test {
    public int myMethod1() throws EOFException {
        return myMethod2();
    }
    public int myMethod2() throws EOFException {
        // code that actually could throw the exception goes here
        return 1;
    }
}
```

Let's look at `myMethod1()`. Because `EOFException` subclasses `IOException` and `IOException` subclasses `Exception`, it is a checked exception and must be declared as an exception that may be thrown by this method. But where will the exception actually come from? The public interface for method `myMethod2()` called here declares that an exception of this type can be thrown. Whether that method actually throws the exception itself or calls another method that throws it is unimportant to us; we simply know that we have to either catch the exception or declare that we throw it. The method `myMethod1()` does not catch the exception, so it declares that it throws it. Now let's look at another legal example, `myMethod3()`.

```
public void myMethod3() {
    // code that could throw a NullPointerException goes here
}
```

According to the comment, this method can throw a `NullPointerException`. Because `RuntimeException` is the superclass of `NullPointerException`, it is an unchecked exception and need not be declared. We can see that `myMethod3()` does not declare any exceptions.

Runtime exceptions are referred to as *unchecked* exceptions. All other exceptions are *checked* exceptions, and they don't derive from `java.lang.RuntimeException`. A checked exception must be caught somewhere in your code. If you invoke a method that throws a checked exception but you don't catch the checked exception

somewhere, your code will not compile. That's why they're called checked exceptions; the compiler checks to make sure that they're handled or declared. A number of the methods in the Java 2 Standard Edition libraries throw checked exceptions, so you will often write exception handlers to cope with exceptions generated by methods you didn't write.

You can also throw an exception yourself, and that exception can be either an existing exception from the Java API or one of your own. To create your own exception, you simply subclass `Exception` (or one of its subclasses) as follows:

```
class MyException extends Exception { }
```

And if you throw the exception, the compiler will guarantee that you declare it as follows:

```
class TestEx {
    void doStuff() {
        throw new MyException(); // Throw a checked exception
    }
}
```

The preceding code upsets the compiler:

```
TestEx.java:6: unreported exception MyException; must be caught
or
declared to be thrown
    throw new MyException();
    ^
```

## exam

### Watch

**When an object of a subtype of `Exception` is thrown, it must be handled or declared. These objects are called checked exceptions, and include all exceptions except those that are subtypes of `RuntimeException`, which are unchecked exceptions. Be ready to spot methods that don't follow the "handle or declare" rule, such as**

```
class MyException extends Exception {
    void someMethod () {
        doStuff();
    }
}
```



**exam****Watch**

```

void doStuff() throws MyException {
    try {
        throw new MyException();
    }
    catch(MyException me) {
        throw me;
    }
}

```

**You need to recognize that this code won't compile. If you try, you'll get**

```

MyException.java:3: unreported exception MyException; must
be caught or declared to be thrown
doStuff();
    ^

```

**Notice that** `someMethod()` **fails to either handle or declare the exception that can be thrown by** `doStuff()`.

You need to know how an `Error` compares with checked and unchecked exceptions. Objects of type `Error` are not `Exception` objects, although they do represent exceptional conditions. Both `Exception` and `Error` share a common superclass, `Throwable`, thus both can be thrown using the `throw` keyword. When an `Error` or a subclass of `Error` is thrown, it's unchecked. You are not required to catch `Error` objects or `Error` subtypes. You can also throw an `Error` yourself (although other than `AssertionError` you probably won't ever want to), and you can catch one, but again, you probably won't. What, for example, would you actually do if you got an `OutOfMemoryError`? It's not like you can tell the garbage collector to run; you can bet the JVM fought desperately to save itself (and reclaimed all the memory it could) by the time you got the error. In other words, don't expect the JVM at that point to say, "Run the garbage collector? Oh, thanks so much for telling me. That just never occurred to me. Sure, I'll get right on it." Even better, what would you do if a `VirtualMachineError` arose? Your program is toast by the time you'd catch the `Error`, so there's really no point in trying to catch one of these babies. Just remember, though, that you can! The following compiles just fine:

```

class TestEx {
    public static void main (String [] args) {
        badMethod();
    }
    static void badMethod() { // No need to declare an Error
        doStuff()
    }
    static void doStuff() { //No need to declare an Error
        try {
            throw new Error();
        }
        catch(Error me) {
            throw me; // We catch it, but then rethrow it
        }
    }
}

```

If we were throwing a checked exception rather than `Error`, then the `doStuff()` method would need to declare the exception. But remember, since `Error` is not a subtype of `Exception`, it doesn't need to be declared. You're free to declare it if you like, but the compiler just doesn't care one way or another when or how the `Error` is thrown, or by whom.



***Because Java has checked exceptions, it's commonly said that Java forces developers to handle exceptions. Yes, Java forces us to write exception handlers for each exception that can occur during normal operation, but it's up to us to make the exception handlers actually do something useful. We know software managers who melt down when they see a programmer write:***

```

try {
    callBadMethod();
} catch (Exception ex) { }

```

***Notice anything missing? Don't "eat" the exception by catching it without actually handling it. You won't even be able to tell that the exception occurred, because you'll never see the stack trace.***

## Rethrowing the Same Exception

Just as you can throw a new exception from a catch clause, you can also throw the same exception you just caught. Here's a catch clause that does this:

```
catch(IOException e) {
    // Do things, then if you decide you can't handle it...
    throw e;
}
```

All other `catch` clauses associated with the same `try` are ignored, if a `finally` block exists, it runs, and the exception is thrown back to the calling method (the next method down the call stack). If you throw a checked exception from a `catch` clause, you must also declare that exception! In other words, you must handle *and* declare, as opposed to handle *or* declare. The following example is illegal:

```
public void doStuff() {
    try {
        // risky IO things
    } catch(IOException ex) {
        // can't handle it
        throw ex; // Can't throw it unless you declare it
    }
}
```

In the preceding code, the `doStuff()` method is clearly able to throw a checked exception—in this case an `IOException`—so the compiler says, "Well, that's just peachy that you have a `try/catch` in there, but it's not good enough. If you might rethrow the `IOException` you catch, then you must declare it!"

## EXERCISE 5-4

### Creating an Exception

In this exercise we attempt to create a custom exception. We won't put in any new methods (it will have only those inherited from `Exception`), and because it extends `Exception`, the compiler considers it a checked exception. The goal of the program is to determine whether a command-line argument, representing a particular food (as a string), is considered bad or OK.

- Let's first create our exception. We will call it `BadFoodException`. This exception will be thrown when a bad food is encountered.
- Create an enclosing class called `MyException` and a `main()` method, which will remain empty for now.

- Create a method called `checkFood()`. It takes a `String` argument and throws our exception if it doesn't like the food it was given. Otherwise, it tells us it likes the food. You can add any foods you aren't particularly fond of to the list.
  - Now in the `main()` method, you'll get the command-line argument out of the `String` array, and then pass that `String` on to the `checkFood()` method. Because it's a checked exception, the `checkFood()` method must declare it, and the `main()` method must handle it (using a `try/catch`). Do not have `main()` declare the exception, because if `main()` ducks the exception, who else is back there to catch it?
  - As nifty as exception handling is, it's still up to the developer to make proper use of it. Exception handling makes organizing our code and signaling problems easy, but the exception handlers still have to be written. You'll find that even the most complex situations can be handled, and your code will be reusable, readable, and maintainable.
- 

## CERTIFICATION OBJECTIVE

### Common Exceptions and Errors

*2.6 Recognize situations that will result in any of the following being thrown: `ArrayIndexOutOfBoundsException`, `ClassCastException`, `IllegalArgumentException`, `IllegalStateException`, `NullPointerException`, `NumberFormatException`, `AssertionError`, `ExceptionInInitializerError`, `StackOverflowError`, or `NoClassDefFoundError`. Understand which of these are thrown by the virtual machine and recognize situations in which others should be thrown programmatically.*

Exception handling is another area that the exam creation team decided to expand for the SCJP 5 exam. This section discusses the aspects of exceptions that were added for this new version. The intention of Objective 2.6 is to make sure that you are familiar with some of the most common exceptions and errors you'll encounter as a Java programmer.

**exam****Watch**

*The questions from this section are likely to be along the lines of, "Here's some code that just did something bad, which exception will be thrown?"*

*Throughout the exam, questions will present some code and ask you to determine whether the code will run, or whether an exception will be thrown. Since these questions are so common, understanding the causes for these exceptions is critical to your success.*

This is another one of those objectives that will turn up all through the real exam (does "An exception is thrown at runtime" ring a bell?), so make sure this section gets a lot of your attention.

## Where Exceptions Come From

Jump back a page and take a look at the last sentence of Objective 2.6. It's important to understand what causes exceptions and errors, and where they come from. For the purposes of exam preparation, let's define two broad categories of exceptions and errors:

- **JVM exceptions** Those exceptions or errors that are either exclusively or most logically thrown by the JVM.
- **Programmatic exceptions** Those exceptions that are thrown explicitly by application and/or API programmers.

## JVM Thrown Exceptions

Let's start with a very common exception, the `NullPointerException`. As we saw in Chapter 3, this exception occurs when you attempt to access an object using a reference variable with a current value of `null`. There's no way that the compiler can hope to find these problems before runtime. Let's look at the following:

```
class NPE {  
    static String s;
```

```

    public static void main(String [] args) {
        System.out.println(s.length());
    }
}

```

Surely, the compiler can find the problem with that tiny little program! Nope, you're on your own. The code will compile just fine, and the JVM will throw a `NullPointerException` when it tries to invoke the `length()` method.

Earlier in this chapter we discussed the call stack. As you recall, we used the convention that `main()` would be at the bottom of the call stack, and that as `main()` invokes another method, and that method invokes another, and so on, the stack grows upward. Of course the stack resides in memory, and even if your OS gives you a gigabyte of RAM for your program, it's still a finite amount. It's possible to grow the stack so large that the OS runs out of space to store the call stack. When this happens you get (wait for it...), a `StackOverflowError`. The most common way for this to occur is to create a recursive method. A recursive method is one that invokes itself in the method body. While that may sound weird, it's a very common and useful technique for such things as searching and sorting algorithms. Take a look at this code:

```

void go() {    // recursion gone bad
    go();
}

```

As you can see, if you ever make the mistake of invoking the `go()` method, your program will fall into a black hole; `go()` invoking `go()` invoking `go()`, until, no matter how much memory you have, you'll get a `StackOverflowError`. Again, only the JVM knows when this moment occurs, and the JVM will be the source of this error.

## Programmatically thrown exceptions

Now let's look at programmatically thrown exceptions. Remember we defined "programmatically" as meaning something like this

"Created by an application and/or API developer."

For instance, many classes in the Java API have methods that take `String` arguments, and convert these `Strings` into numeric primitives. A good example of these classes are the so-called "wrapper classes" that we studied in Chapter 3.

At some point long ago, some programmer wrote the `java.lang.Integer` class, and created methods like `parseInt()` and `valueOf()`. That programmer wisely decided that if one of these methods was passed a `String` that could not be converted into a number, the method should throw a `NumberFormatException`. The partially implemented code might look something like this:

```
int parseInt(String s) throws NumberFormatException {
    boolean parseSuccess = false;
    int result = 0;
    // do complicated parsing
    if (!parseSuccess) // if the parsing failed
        throw new NumberFormatException();
    return result;
}
```

Other examples of programmatic exceptions include an `AssertionError` (okay, it's not an exception, but it IS thrown programmatically), and throwing an `IllegalArgumentException`. In fact, our mythical API developer could have used `IllegalArgumentException` for her `parseInt()` method. But it turns out that `NumberFormatException` extends `IllegalArgumentException`, and is a little more precise, so in this case, using `NumberFormatException` supports the notion we discussed earlier: that when you have an exception hierarchy, you should use the most precise exception that you can.

Of course, as we discussed earlier, you can also make up your very own special, custom exceptions, and throw them whenever you want to. These homemade exceptions also fall into the category of "programmatically thrown exceptions."

## **A Summary of the Exam's Exceptions and Errors**

Objective 2.6 lists ten specific exceptions and errors. In this section we discussed the `StackOverflowError`. The other nine exceptions and errors listed in the objective are covered elsewhere in this book. Table 5-2 summarizes this list and provides chapter references to the exceptions and errors we did not discuss here.

**TABLE 5-2** Descriptions and Sources of Common Exceptions.

Exception (Chapter Location)	Description	Typically Thrown
<b>ArrayIndexOutOfBoundsException</b> (Chapter 3, "Assignments")	Thrown when attempting to access an array with an invalid index value (either negative or beyond the length of the array).	By the JVM
<b>ClassCastException</b> (Chapter 2, "Object Orientation")	Thrown when attempting to cast a reference variable to a type that fails the IS-A test.	By the JVM
<b>IllegalArgumentException</b> (Chapter 3, "Assignments")	Thrown when a method receives an argument formatted differently than the method expects.	Programmatically
<b>IllegalStateException</b> (Chapter 6, "Formatting")	Thrown when the state of the environment doesn't match the operation being attempted, e.g., using a Scanner that's been closed.	Programmatically
<b>NullPointerException</b> (Chapter 3, "Assignments")	Thrown when attempting to access an object with a reference variable whose current value is <code>null</code> .	By the JVM
<b>NumberFormatException</b> (Chapter 6, "Formatting")	Thrown when a method that converts a String to a number receives a String that it cannot convert.	Programmatically
<b>AssertionError</b> (This chapter)	Thrown when a statement's boolean test returns <code>false</code> .	Programmatically
<b>ExceptionInInitializerError</b> (Chapter 3, "Assignments")	Thrown when attempting to initialize a static variable or an initialization block.	By the JVM
<b>StackOverflowError</b> (This chapter)	Typically thrown when a method recurses too deeply. (Each invocation is added to the stack.)	By the JVM
<b>NoClassDefFoundError</b> (Chapter 10, "Development")	Thrown when the JVM can't find a class it needs, because of a command-line error, a classpath issue, or a missing <code>.class</code> file.	By the JVM



**CERTIFICATION OBJECTIVE**

## Working with the Assertion Mechanism (Exam Objective 2.3)

*2.3 Develop code that makes use of assertions, and distinguish appropriate from inappropriate uses of assertions.*

You know you're not supposed to make assumptions, but you can't help it when you're writing code. You put them in comments:

```
if (x > 2 && y) {  
    // do something  
} else if (x < 2 || y) {  
    // do something  
} else {  
    // x must be 2  
    // do something else  
}
```

You write print statements with them:

```
while (true) {  
    if (x > 2) {  
        break;  
    }  
    System.out.print("If we got here " +  
                    "something went horribly wrong");  
}
```

Added to the Java language beginning with version 1.4, assertions let you test your assumptions during development, without the expense (in both your time and program overhead) of writing exception handlers for exceptions that you assume will never happen once the program is out of development and fully deployed.

Starting with exam 310-035 (version 1.4 of the Sun Certified Java Programmer exam) and continuing with the current exam 310-055 (version 5), you're expected to know the basics of how assertions work, including how to enable them, how to use them, and how *not* to use them.

## Assertions Overview

Suppose you assume that a number passed into a method (say, `methodA()`) will never be negative. While testing and debugging, you want to validate your assumption, but you don't want to have to strip out `print` statements, runtime exception handlers, or `if/else` tests when you're done with development. But leaving any of those in is, at the least, a performance hit. Assertions to the rescue! Check out the following code:

```
private void methodA(int num) {
    if (num >= 0) {
        useNum(num + x);
    } else { // num must be < 0
        // This code should never be reached!
        System.out.println("Yikes! num is a negative number! "
            + num);
    }
}
```

Because you're so certain of your assumption, you don't want to take the time (or program performance hit) to write exception-handling code. And at runtime, you don't want the `if/else` either because if you do reach the `else` condition, it means your earlier logic (whatever was running prior to this method being called) is flawed.

Assertions let you test your assumptions during development, but the assertion code basically evaporates when the program is deployed, leaving behind no overhead or debugging code to track down and remove. Let's rewrite `methodA()` to validate that the argument was not negative:

```
private void methodA(int num) {
    assert (num>=0); // throws an AssertionError
                  // if this test isn't true
    useNum(num + x);
}
```

Not only do assertions let your code stay cleaner and tighter, but because assertions are inactive unless specifically "turned on" (enabled), the code will run as though it were written like this:

```
private void methodA(int num) {
    useNum(num + x); // we've tested this;
                  // we now know we're good here
}
```

Assertions work quite simply. You always assert that something is `true`. If it is, no problem. Code keeps running. But if your assertion turns out to be wrong (`false`), then a stop-the-world `AssertionError` is thrown (that you should never, ever handle!) right then and there, so you can fix whatever logic flaw led to the problem.

Assertions come in two flavors: *really simple* and *simple*, as follows:

Really simple:

```
private void doStuff() {
    assert (y > x);
    // more code assuming y is greater than x
}
```

Simple:

```
private void doStuff() {
    assert (y > x): "y is " + y + " x is " + x;
    // more code assuming y is greater than x
}
```

The difference between the two is that the simple version adds a second expression, separated from the first (boolean expression) by a colon, this expression's string value is added to the stack trace. Both versions throw an immediate `AssertionError`, but the simple version gives you a little more debugging help while the really simple version simply tells you only that your assumption was false.



***Assertions are typically enabled when an application is being tested and debugged, but disabled when the application is deployed. The assertions are still in the code, although ignored by the JVM, so if you do have a deployed application that starts misbehaving, you can always choose to enable assertions in the field for additional testing.***

## Assertion Expression Rules

Assertions can have either one or two expressions, depending on whether you're using the "simple" or the "really simple." The first expression must always result in a boolean value! Follow the same rules you use for `if` and `while` tests. The whole point is to assert `aTest`, which means you're asserting that `aTest` is `true`. If it is `true`, no problem. If it's not `true`, however, then your assumption was wrong and you get an `AssertionError`.

The second expression, used only with the simple version of an `assert` statement, can be anything that results in a value. Remember, the second expression is used to generate a `String` message that displays in the stack trace to give you a little more debugging information. It works much like `System.out.println()` in that you can pass it a primitive or an object, and it will convert it into a `String` representation. It must resolve to a value!

The following code lists legal and illegal expressions for both parts of an `assert` statement. Remember, `expression2` is used only with the simple `assert` statement, where the second expression exists solely to give you a little more debugging detail:

```
void noReturn() { }
int aReturn() { return 1; }
void go() {
    int x = 1;
    boolean b = true;

    // the following six are legal assert statements
    assert(x == 1);
    assert(b);
    assert true;
    assert(x == 1) : x;
    assert(x == 1) : aReturn();
    assert(x == 1) : new ValidAssert();

    // the following six are ILLEGAL assert statements
    assert(x = 1); // none of these are booleans
    assert(x);
    assert 0;
    assert(x == 1) : ; // none of these return a value
    assert(x == 1) : noReturn();
    assert(x == 1) : ValidAssert va;
}
```

## exam

### Watch

**If you see the word “expression” in a question about assertions, and the question doesn’t specify whether it means *expression1* (the boolean test) or *expression2* (the value to print in the stack trace), then always assume the word “expression” refers to *expression1*, the boolean test. For example, consider the following question:**

**exam****Watch**

**An assert expression must result in a `boolean` value, true or false?**

**Assume that the word 'expression' refers to expression1 of an assert, so the question statement is correct. If the statement were referring to expression2, however, the statement would not be correct, since expression2 can have a result of any value, not just a `boolean`.**

## Enabling Assertions

If you want to use assertions, you have to think first about how to compile with assertions in your code, and then about how to run with assertions enabled. Both require version 1.4 or greater, and that brings us to the first issue: how to compile with assertions in your code.

### Identifier vs. Keyword

Prior to version 1.4, you might very well have written code like this:

```
int assert = getInitialValue();
if (assert == getActualResult()) {
    // do something
}
```

Notice that in the preceding code, `assert` is used as an identifier. That's not a problem prior to 1.4. But you cannot use a keyword/reserved word as an identifier, and beginning with version 1.4, `assert` is a keyword. The bottom line is this:

You can use `assert` as a keyword or as an identifier, but not both.



**If for some reason you're using a Java 1.4 compiler, and if you're using `assert` as a keyword (in other words, you're actually trying to `assert` something in your code), then you must explicitly enable assertion-awareness at compile time, as follows:**

```
javac -source 1.4 com/geeksanonymous/TestClass.java
```

***You can read that as "compile the class TestClass, in the directory com/geeksanonymous, and do it in the 1.4 way, where assert is a keyword."***

## Use Version 5 of java and javac

As far as the exam is concerned, you'll ALWAYS be using version 5 of the Java compiler (javac), and version 5 of the Java application launcher (java). You might see questions about older versions of source code, but those questions will always be in the context of compiling and launching old code with the current versions of javac and java.

## Compiling Assertion-Aware Code

The Java 5 compiler will use the `assert` keyword by default. Unless you tell it otherwise, the compiler will generate an error message if it finds the word `assert` used as an identifier. However, you can tell the compiler that you're giving it an old piece of code to compile, and that it should pretend to be an old compiler! (More about compiler commands in Chapter 10.) Let's say you've got to make a quick fix to an old piece of 1.3 code that uses `assert` as an identifier. At the command line you can type

```
javac -source 1.3 OldCode.java
```

The compiler will issue warnings when it discovers the word `assert` used as an identifier, but the code will compile and execute. Suppose you tell the compiler that your code is version 1.4 or later, for instance:

```
javac -source 1.4 NotQuiteSoOldCode.java
```

In this case, the compiler will issue errors when it discovers the word `assert` used as an identifier.

If you want to tell the compiler to use Java 5 rules you can do one of three things: omit the `-source` option, which is the default, or add one of two source options:

```
-source 1.5 or -source 5. (See how clear Sun is about 1.5 vs. 5?)
```

If you want to use `assert` as an identifier in your code, you **MUST** compile using the `-source 1.3` option. Table 5-3 summarizes how the Java 5 compiler will react to `assert` as either an identifier or a keyword.

**TABLE 5-3** Using Java 5 to Compile Code That Uses `assert` as an Identifier or a Keyword

Command Line	If <code>assert</code> Is an Identifier	If <code>assert</code> Is a Keyword
<code>javac -source 1.3 TestAsserts.java</code>	Code compiles with warnings.	Compilation fails.
<code>javac -source 1.4 TestAsserts.java</code>	Compilation fails.	Code compiles.
<code>javac -source 1.5 TestAsserts.java</code>	Compilation fails.	Code compiles.
<code>javac -source 5 TestAsserts.java</code>	Compilation fails.	Code compiles.
<code>javac TestAsserts.java</code>	Compilation fails.	Code compiles.

## Running with Assertions

Here's where it gets cool. Once you've written your assertion-aware code (in other words, code that uses `assert` as a keyword, to actually perform assertions at runtime), you can choose to enable or disable your assertions at runtime! Remember, assertions are disabled by default.

## Enabling Assertions at Runtime

You enable assertions at runtime with

```
java -ea com.geeksanonymous.TestClass
```

or

```
java -enableassertions com.geeksanonymous.TestClass
```

The preceding command-line switches tell the JVM to run with assertions enabled.

## Disabling Assertions at Runtime

You must also know the command-line switches for disabling assertions,

```
java -da com.geeksanonymous.TestClass
```

or

```
java -disableassertions com.geeksanonymous.TestClass
```

Because assertions are disabled by default, using the disable switches might seem unnecessary. Indeed, using the switches the way we do in the preceding example just gives you the default behavior (in other words, you get the same result regardless of whether you use the disabling switches). But...you can also selectively enable and disable assertions in such a way that they're enabled for some classes and/or packages, and disabled for others, while a particular program is running.

## Selective Enabling and Disabling

The command-line switches for assertions can be used in various ways:

- **With no arguments (as in the preceding examples)** Enables or disables assertions in all classes, except for the system classes.
- **With a package name** Enables or disables assertions in the package specified, and any packages below this package in the same directory hierarchy (more on that in a moment).
- **With a class name** Enables or disables assertions in the class specified.

You can combine switches to, say, disable assertions in a single class, but keep them enabled for all others, as follows:

```
java -ea -da:com.geeksanonymous.Foo
```

The preceding command line tells the JVM to enable assertions in general, but disable them in the class `com.geeksanonymous.Foo`. You can do the same selectivity for a package as follows:

```
java -ea -da:com.geeksanonymous...
```

The preceding command line tells the JVM to enable assertions in general, but disable them in the package `com.geeksanonymous`, and all of its subpackages! You may not be familiar with the term subpackages, since there wasn't much use of that term prior to assertions. A subpackage is any package in a subdirectory of the named package. For example, look at the following directory tree:



```

com
|_geeksanonymous
    |_Foo
    |_twelvesteps
        |_StepOne
        |_StepTwo

```

This tree lists three directories,

```

com
geeksanonymous
twelvesteps
and three classes:
com.geeksanonymous.Foo
com.geeksanonymous.twelvesteps.StepOne
com.geeksanonymous.twelvesteps.StepTwo

```

The subpackage of `com.geeksanonymous` is the `twelvesteps` package. Remember that in Java, the `com.geeksanonymous.twelvesteps` package is treated as a completely distinct package that has no relationship with the packages above it (in this example, the `com.geeksanonymous` package), except they just happen to share a couple of directories. Table 5-4 lists examples of command-line switches for enabling and disabling assertions.

**TABLE 5-4** Assertion Command-Line Switches

Command-Line Example	What It Means
<pre>java -ea java -enableassertions</pre>	Enable assertions.
<pre>java -da java -disableassertions</pre>	Disable assertions (the default behavior of 1.5).
<pre>java -ea:com.foo.Bar</pre>	Enable assertions in class <code>com.foo.Bar</code> .
<pre>java -ea:com.foo...</pre>	Enable assertions in package <code>com.foo</code> and any of its subpackages.
<pre>java -ea -dsa</pre>	Enable assertions in general, but disable assertions in system classes.
<pre>java -ea -da:com.foo...</pre>	Enable assertions in general, but disable assertions in package <code>com.foo</code> and any of its subpackages.

## Using Assertions Appropriately

Not all legal uses of assertions are considered appropriate. As with so much of Java, you can abuse the intended use of assertions, despite the best efforts of Sun's Java engineers to discourage you from doing so. For example, you're never supposed to handle an assertion failure. That means you shouldn't catch it with a `catch` clause and attempt to recover. Legally, however, `AssertionError` is a subclass of `Throwable`, so it can be caught. But just don't do it! If you're going to try to recover from something, it should be an exception. To discourage you from trying to substitute an assertion for an exception, the `AssertionError` doesn't provide access to the object that generated it. All you get is the `String` message.

So who gets to decide what's appropriate? Sun. The exam uses Sun's "official" assertion documentation to define appropriate and inappropriate uses.

### Don't Use Assertions to Validate Arguments to a Public Method

The following is an inappropriate use of assertions:

```
public void doStuff(int x) {
    assert (x > 0);           // inappropriate !
    // do things with x
}
```

## exam

### Watch

***If you see the word "appropriate" on the exam, do not mistake that for "legal." "Appropriate" always refers to the way in which something is supposed to be used, according to either the developers of the mechanism or best practices officially embraced by Sun. If you see the word "correct" in the context of assertions, as in, "Line 3 is a correct use of assertions," you should also assume that correct is referring to how assertions SHOULD be used rather than how they legally COULD be used.***

A `public` method might be called from code that you don't control (or from code you have never seen). Because `public` methods are part of your interface to the outside world, you're supposed to guarantee that any constraints on the arguments will be enforced by the method itself. But since assertions aren't guaranteed to actually run (they're typically disabled in a deployed application), the enforcement won't happen if assertions aren't enabled. You don't want publicly accessible code that works only conditionally, depending on whether assertions are enabled.

If you need to validate public method arguments, you'll probably use exceptions to throw, say, an `IllegalArgumentException` if the values passed to the public method are invalid.

### **Do Use Assertions to Validate Arguments to a Private Method**

If you write a private method, you almost certainly wrote (or control) any code that calls it. When you assume that the logic in code calling your private method is correct, you can test that assumption with an assertion as follows:

```
private void doMore(int x) {
    assert (x > 0);
    // do things with x
}
```

The only difference that matters between the preceding example and the one before it is the access modifier. So, do enforce constraints on private methods' arguments, but do not enforce constraints on public methods. You're certainly free to compile assertion code with an inappropriate validation of public arguments, but for the exam (and real life) you need to know that you shouldn't do it.

### **Don't Use Assertions to Validate Command-Line Arguments**

This is really just a special case of the "Do not use assertions to validate arguments to a public method" rule. If your program requires command-line arguments, you'll probably use the exception mechanism to enforce them.

### **Do Use Assertions, Even in Public Methods, to Check for Cases that You Know Are Never, Ever Supposed to Happen**

This can include code blocks that should never be reached, including the default of a switch statement as follows:

```
switch(x) {
    case 1: y = 3;
    case 2: y = 9;
    case 3: y = 27;
    default: assert false; // We're never supposed to get here!
}
```

If you assume that a particular code block won't be reached, as in the preceding example where you assert that `x` must be either 2, 3, or 4, then you can use `assert false` to cause an `AssertionError` to be thrown immediately if you ever do reach that code. So in the switch example, we're not performing a boolean test—we've

already asserted that we should never be there, so just getting to that point is an automatic failure of our assertion/assumption.

### Don't Use Assert Expressions that Can Cause Side Effects!

The following would be a very bad idea:

```
public void doStuff() {
    assert (modifyThings());
    // continues on
}
public boolean modifyThings() {
    y = x++;
    return true;
}
```

The rule is, an `assert` expression should leave the program in the same state it was in before the expression! Think about it. `assert` expressions aren't guaranteed to always run, so you don't want your code to behave differently depending on whether assertions are enabled. Assertions must not cause any side effects. If assertions are enabled, the only change to the way your program runs is that an `AssertionError` can be thrown if one of your assertions (think: *assumptions*) turns out to be false.



***Using assertions that cause side effects can cause some of the most maddening and hard-to-find bugs known to man! When a hot tempered Q.A. analyst is screaming at you that your code doesn't work, trotting out the old "well it works on MY machine" excuse won't get you very far.***

## CERTIFICATION SUMMARY

This chapter covered a lot of ground, all of which involves ways of controlling your program flow, based on a conditional test. First you learned about `if` and `switch` statements. The `if` statement evaluates one or more expressions to a `boolean` result. If the result is `true`, the program will execute the code in the block that is encompassed by the `if`. If an `else` statement is used and the `if` expression evaluates to `false`, then the code following the `else` will be performed. If no `else` block is defined, then none of the code associated with the `if` statement will execute.

You also learned that the `switch` statement can be used to replace multiple `if-else` statements. The `switch` statement can evaluate integer primitive types that can be implicitly cast to an `int` (those types are `byte`, `short`, `int`, and `char`), or it can evaluate `enums`.

At runtime, the JVM will try to find a match between the expression in the `switch` statement and a constant in a corresponding `case` statement. If a match is found, execution will begin at the matching case, and continue on from there, executing code in all the remaining case statements until a `break` statement is found or the end of the `switch` statement occurs. If there is no match, then the default case will execute, if there is one.

You've learned about the three looping constructs available in the Java language. These constructs are the `for` loop (including the basic `for` and the enhanced `for` which is new to Java 5), the `while` loop, and the `do` loop. In general, the `for` loop is used when you know how many times you need to go through the loop. The `while` loop is used when you do not know how many times you want to go through, whereas the `do` loop is used when you need to go through at least once. In the `for` loop and the `while` loop, the expression will have to evaluate to `true` to get inside the block and will check after every iteration of the loop. The `do` loop does not check the condition until after it has gone through the loop once. The major benefit of the `for` loop is the ability to initialize one or more variables and increment or decrement those variables in the `for` loop definition.

The `break` and `continue` statements can be used in either a labeled or unlabeled fashion. When unlabeled, the `break` statement will force the program to stop processing the innermost looping construct and start with the line of code following the loop. Using an unlabeled `continue` command will cause the program to stop execution of the current iteration of the innermost loop and proceed with the next iteration. When a `break` or a `continue` statement is used in a labeled manner, it will perform in the same way, with one exception: the statement will not apply to the innermost loop; instead, it will apply to the loop with the label. The `break` statement is used most often in conjunction with the `switch` statement. When there is a match between the `switch` expression and the case constant, the code following the case constant will be performed. To stop execution, a `break` is needed.

You've seen how Java provides an elegant mechanism in exception handling. Exception handling allows you to isolate your error-correction code into separate blocks so that the main code doesn't become cluttered by error-checking code. Another elegant feature allows you to handle similar errors with a single error-handling block, without code duplication. Also, the error handling can be deferred to methods further back on the call stack.

You learned that Java's `try` keyword is used to specify a guarded region—a block of code in which problems might be detected. An exception handler is the code that is executed when an exception occurs. The handler is defined by using Java's `catch` keyword. All `catch` clauses must immediately follow the related `try` block. Java also provides the `finally` keyword. This is used to define a block of code that is always executed, either immediately after a `catch` clause completes or immediately after

the associated `try` block in the case that no exception was thrown (or there was a `try` but no `catch`). Use `finally` blocks to release system resources and to perform any cleanup required by the code in the `try` block. A `finally` block is not required, but if there is one it must immediately follow the `catch`. (If there is no `catch` block, the `finally` block must immediately follow the `try` block.) It is guaranteed to be called except in the cases where the `try` or `catch` code issues a `System.exit()`.

An exception object is an instance of class `Exception` or one of its subclasses. The `catch` clause takes, as a parameter, an instance of an object of a type derived from the `Exception` class. Java requires that each method either catches any checked exception it can throw or else declares that it throws the exception. The exception declaration is part of the method's public interface. To declare that an exception may be thrown, the `throws` keyword is used in a method definition, along with a list of all checked exceptions that might be thrown.

Runtime exceptions are of type `RuntimeException` (or one of its subclasses). These exceptions are a special case because they do not need to be handled or declared, and thus are known as "unchecked" exceptions. Errors are of type `java.lang.Error` or its subclasses, and like runtime exceptions, they do not need to be handled or declared. Checked exceptions include any exception types that are not of type `RuntimeException` or `Error`. If your code fails to either handle a checked exception or declare that it is thrown, your code won't compile. But with unchecked exceptions or objects of type `Error`, it doesn't matter to the compiler whether you declare them or handle them, do nothing about them, or do some combination of declaring and handling. In other words, you're free to declare them and handle them, but the compiler won't care one way or the other. It's not good practice to handle an `Error`, though, because you can rarely recover from one.

Exceptions can be generated by the JVM, or by a programmer.

Assertions, added to the language in version 1.4, are a useful debugging tool. You learned how you can use them for testing, by enabling them, but keep them disabled when the application is deployed. If you have older Java code that uses the word `assert` as an identifier, then you won't be able to use assertions, and you must recompile your older code using the `-source 1.3` flag. Remember that as of Java 5, assertions are compiled as a keyword by default, but must be enabled explicitly at runtime.

You learned how `assert` statements always include a boolean expression, and if the expression is `true` the code continues on, but if the expression is `false`, an `AssertionError` is thrown. If you use the two-expression `assert` statement, then the second expression is evaluated, converted to a `String` representation and inserted into the stack trace to give you a little more debugging info. Finally, you saw why assertions should not be used to enforce arguments to `public` methods, and why `assert` expressions must not contain side effects!



## TWO-MINUTE DRILL

Here are some of the key points from each certification objective in this chapter. You might want to loop through them several times.

### Writing Code Using `if` and `switch` Statements (Obj. 2.1)

- ❑ The only legal expression in an `if` statement is a boolean expression, in other words an expression that resolves to a boolean or a boolean variable.
- ❑ Watch out for boolean assignments (`=`) that can be mistaken for boolean equality (`==`) tests:

```
boolean x = false;  
if (x = true) { } // an assignment, so x will always be true!
```

- ❑ Curly braces are optional for `if` blocks that have only one conditional statement. But watch out for misleading indentations.
- ❑ `switch` statements can evaluate only to `enums` or the `byte`, `short`, `int`, and `char` data types. You can't say,

```
long s = 30;  
switch(s) { }
```

- ❑ The case constant must be a literal or `final` variable, or a constant expression, including an `enum`. You cannot have a case that includes a non-final variable, or a range of values.
- ❑ If the condition in a `switch` statement matches a case constant, execution will run through all code in the `switch` following the matching case statement until a `break` statement or the end of the `switch` statement is encountered. In other words, the matching case is just the entry point into the case block, but unless there's a `break` statement, the matching case is not the only case code that runs.
- ❑ The `default` keyword should be used in a `switch` statement if you want to run some code when none of the case values match the conditional value.
- ❑ The default block can be located anywhere in the `switch` block, so if no case matches, the default block will be entered, and if the default does not contain a `break`, then code will continue to execute (fall-through) to the end of the `switch` or until the `break` statement is encountered.

## Writing Code Using Loops (Objective 2.2)

- ❑ A basic `for` statement has three parts: declaration and/or initialization, boolean evaluation, and the iteration expression.
- ❑ If a variable is incremented or evaluated within a basic `for` loop, it must be declared before the loop, or within the `for` loop declaration.
- ❑ A variable declared (not just initialized) within the basic `for` loop declaration cannot be accessed outside the `for` loop (in other words, code below the `for` loop won't be able to use the variable).
- ❑ You can initialize more than one variable of the same type in the first part of the basic `for` loop declaration; each initialization must be separated by a comma.
- ❑ An enhanced `for` statement (new as of Java 5), has two parts, the *declaration* and the *expression*. It is used only to loop through arrays or collections.
- ❑ With an enhanced `for`, the *expression* is the array or collection through which you want to loop.
- ❑ With an enhanced `for`, the *declaration* is the block variable, whose type is compatible with the elements of the array or collection, and that variable contains the value of the element for the given iteration.
- ❑ You cannot use a number (old C-style language construct) or anything that does not evaluate to a `boolean` value as a condition for an `if` statement or looping construct. You can't, for example, say `if (x)`, unless `x` is a `boolean` variable.
- ❑ The `do` loop will enter the body of the loop at least once, even if the test condition is not met.

## Using `break` and `continue` (Objective 2.2)

- ❑ An unlabeled `break` statement will cause the current iteration of the innermost looping construct to stop and the line of code following the loop to run.
- ❑ An unlabeled `continue` statement will cause: the current iteration of the innermost loop to stop, the condition of that loop to be checked, and if the condition is met, the loop to run again.
- ❑ If the `break` statement or the `continue` statement is labeled, it will cause similar action to occur on the labeled loop, not the innermost loop.



## Handling Exceptions (Objectives 2.4, 2.5, and 2.6)

- ❑ Exceptions come in two flavors: checked and unchecked.
- ❑ Checked exceptions include all subtypes of `Exception`, excluding classes that extend `RuntimeException`.
- ❑ Checked exceptions are subject to the handle or declare rule; any method that might throw a checked exception (including methods that invoke methods that can throw a checked exception) must either declare the exception using `throws`, or handle the exception with an appropriate `try/catch`.
- ❑ Subtypes of `Error` or `RuntimeException` are unchecked, so the compiler doesn't enforce the handle or declare rule. You're free to handle them, or to declare them, but the compiler doesn't care one way or the other.
- ❑ If you use an optional `finally` block, it will always be invoked, regardless of whether an exception in the corresponding `try` is thrown or not, and regardless of whether a thrown exception is caught or not.
- ❑ The only exception to the `finally`-will-always-be-called rule is that a `finally` will not be invoked if the JVM shuts down. That could happen if code from the `try` or `catch` blocks calls `System.exit()`.
- ❑ Just because `finally` is invoked does not mean it will complete. Code in the `finally` block could itself raise an exception or issue a `System.exit()`.
- ❑ **Uncaught exceptions propagate back through the call stack**, starting from the method where the exception is thrown and ending with either the first method that has a corresponding catch for that exception type or a JVM shutdown (which happens if the exception gets to `main()`, and `main()` is "ducking" the exception by declaring it).
- ❑ You can create your own exceptions, normally by extending `Exception` or one of its subtypes. Your exception will then be considered a checked exception, and the compiler will enforce the handle or declare rule for that exception.
- ❑ All `catch` blocks must be ordered from most specific to most general. If you have a `catch` clause for both `IOException` and `Exception`, you must put the `catch` for `IOException` first in your code. Otherwise, the `IOException` would be caught by `catch(Exception e)`, because a `catch` argument can catch the specified exception or any of its subtypes! The compiler will stop you from defining `catch` clauses that can never be reached.
- ❑ Some exceptions are created by programmers, some by the JVM.

### Working with the Assertion Mechanism (Objective 2.3)

- ❑ Assertions give you a way to test your assumptions during development and debugging.
- ❑ **Assertions are typically enabled during testing but disabled during deployment.**
- ❑ You can use `assert` as a keyword (as of version 1.4) or an identifier, but not both together. To compile older code that uses `assert` as an identifier (for example, a method name), use the `-source 1.3` command-line flag to `javac`.
- ❑ Assertions are disabled at runtime by default. To enable them, use a command-line flag `-ea` or `-enableassertions`.
- ❑ Selectively disable assertions by using the `-da` or `-disableassertions` flag.
- ❑ If you enable or disable assertions using the flag without any arguments, you're enabling or disabling assertions in general. You can combine enabling and disabling switches to have assertions enabled for some classes and/or packages, but not others.
- ❑ You can enable and disable assertions on a class-by-class basis, using the following syntax:  

```
java -ea -da:MyClass TestClass
```
- ❑ You can enable and disable assertions on a package-by-package basis, and any package you specify also includes any subpackages (packages further down the directory hierarchy).
- ❑ Do not use assertions to validate arguments to `public` methods.
- ❑ Do not use `assert` expressions that cause side effects. Assertions aren't guaranteed to always run, and you don't want behavior that changes depending on whether assertions are enabled.
- ❑ Do use assertions—even in `public` methods—to validate that a particular code block will never be reached. You can use `assert false;` for code that should never be reached, so that an assertion error is thrown immediately if the `assert` statement is executed.

## SELF TEST

1. Given the following code:

```
public class OrtegorumFunction {
    public int computeDiscontinuous(int x) {
        int r = 1;
        r += x;
        if ((x > 4) && (x < 10)) {
            r += 2 * x;
        } else (x <= 4) {
            r += 3 * x;
        } else {
            r += 4 * x;
        }
        r += 5 * x;
        return r;
    }

    public static void main(String [] args) {
        OrtegorumFunction o = new OrtegorumFunction();
        System.out.println("OF(11) is: " + o.computeDiscontinuous(11));
    }
}
```

What is the result?

- A. OF(11) is: 45
  - B. OF(11) is: 56
  - C. OF(11) is: 89
  - D. OF(11) is: 111
  - E. Compilation fails.
  - F. An exception is thrown at runtime.
2. Given two files:

```
1. class One {
2.     public static void main(String[] args) {
3.         int assert = 0;
4.     }
5. }
```

```
1. class Two {
2.     public static void main(String[] args) {
```

```

3.     assert(false);
4.     }
5. }

```

And the four command-line invocations:

```

javac -source 1.3 One.java
javac -source 1.4 One.java
javac -source 1.3 Two.java
javac -source 1.4 Two.java

```

What is the result? (Choose all that apply.)

- A. Only one compilation will succeed.
- B. Exactly two compilations will succeed.
- C. Exactly three compilations will succeed.
- D. All four compilations will succeed.
- E. No compiler warnings will be produced.
- F. At least one compiler warning will be produced.

3. Given:

```

import java.io.*;
class Master {
    String doFileStuff() throws FileNotFoundException { return "a"; }
}
class Slave extends Master {
    public static void main(String[] args) {
        String s = null;
        try { s = new Slave().doFileStuff();
        } catch ( Exception x) {
            s = "b"; }
        System.out.println(s);
    }
    // insert code here
}

```

Which, inserted independently at // insert code here, will compile, and produce the output b? (Choose all that apply.)

- A. String doFileStuff() { return "b"; }
- B. String doFileStuff() throws IOException { return "b"; }
- C. String doFileStuff(int x) throws IOException { return "b"; }
- D. String doFileStuff() throws FileNotFoundException { return "b"; }

- E. `String doFileStuff()` throws `NumberFormatException` { `return "b";` }
- F. `String doFileStuff()` throws `NumberFormatException`,  
`FileNotFoundException` { `return "b";` }

**4.** Given:

```
class Input {
    public static void main(String[] args) {
        String s = "-";
        try {
            doMath(args[0]);
            s += "t ";           // line 6
        }
        finally { System.out.println(s += "f "); }
    }
    public static void doMath(String a) {
        int y = 7 / Integer.parseInt(a);
    }
}
```

And the command-line invocations:

```
java Input
java Input 0
```

Which are true? (Choose all that apply.)

- A. Line 6 is executed exactly 0 times.
- B. Line 6 is executed exactly 1 time.
- C. Line 6 is executed exactly 2 times.
- D. The `finally` block is executed exactly 0 times.
- E. The `finally` block is executed exactly 1 time.
- F. The `finally` block is executed exactly 2 times.
- G. Both invocations produce the same exceptions.
- H. Each invocation produces a different exception.

**5.** Given:

```
1. class Crivitch {
2.     public static void main(String [] args) {
3.         int x = 0;
4.         // insert code here
5.         do { } while (x++ < y);
6.         System.out.println(x);
7.     }
8. }
```

Which, inserted at line 4, produces the output 12?

- A. `int y = x;`
- B. `int y = 10;`
- C. `int y = 11;`
- D. `int y = 12;`
- E. `int y = 13;`
- F. None of the above will allow compilation to succeed.

6. Given:

```
class Plane {
    static String s = "-";
    public static void main(String[] args) {
        new Plane().s1();
        System.out.println(s);
    }
    void s1() {
        try { s2(); }
        catch (Exception e) { s += "c"; }
    }
    void s2() throws Exception {
        s3(); s += "2";
        s3(); s += "2b";
    }
    void s3() throws Exception {
        throw new Exception();
    }
}
```

What is the result?

- A. -
- B. -c
- C. -c2
- D. -2c
- E. -c22b
- F. -2c2b
- G. -2c2bc
- H. Compilation fails.

**7.** Given:

```
try { int x = Integer.parseInt("two"); }
```

Which could be used to create an appropriate catch block? (Choose all that apply.)

- A. `ClassCastException`
- B. `IllegalStateException`
- C. `NumberFormatException`
- D. `IllegalArgumentException`
- E. `ExceptionInInitializerError`
- F. `ArrayIndexOutOfBoundsException`

**8.** Given:

```
1. class Ping extends Utils {
2.     public static void main(String [] args) {
3.         Utils u = new Ping();
4.         System.out.print(u.getInt(args[0]));
5.     }
6.     int getInt(String arg) {
7.         return Integer.parseInt(arg);
8.     }
9. }
10. class Utils {
11.     int getInt(String x) throws Exception { return 7; }
12. }
```

And the following three possible changes:

- C1. Declare that `main()` throws an `Exception`.
- C2. Declare that `Ping.getInt()` throws an `Exception`.
- C3. Wrap the invocation of `getInt()` in a `try / catch` block.

Which change(s) allow the code to compile? (Choose all that apply.)

- A. Just C1 is sufficient.
- B. Just C2 is sufficient.
- C. Just C3 is sufficient.
- D. Both C1 and C2 are required.
- E. Both C1 and C3 are required.
- F. Both C2 and C3 are required.
- G. All three changes are required.

9. Given:

```
class Swill {
    public static void main(String[] args) {
        String s = "-";
        switch(TimeZone.CST) {
            case EST: s += "e";
            case CST: s += "c";
            case MST: s += "m";
            default: s += "X";
            case PST: s += "p";
        }
        System.out.println(s);
    }
}
enum TimeZone {EST, CST, MST, PST }
```

What is the result?

- A. -c
- B. -x
- C. -cm
- D. -cmp
- E. -cmXp
- F. Compilation fails.
- G. An exception is thrown at runtime.

10. Given:

```
class Circus {
    public static void main(String[] args) {
        int x = 9;
        int y = 6;
        for(int z = 0; z < 6; z++, y--) {
            if(x > 2) x--;
            label:
            if(x > 5) {
                System.out.print(x + " ");
                --x;
                continue label;
            }
        }
    }
}
```



```

        }
        x--;
    }
}

```

What is the result?

- A. 8
- B. 8 7
- C. 8 7 6
- D. Compilation fails.
- E. An exception is thrown at runtime.

11. Which are true? (Choose all that apply.)

- A. It is appropriate to use assertions to validate arguments to methods marked `public`.
- B. It is appropriate to catch and handle assertion errors.
- C. It is NOT appropriate to use assertions to validate command-line arguments.
- D. It is appropriate to use assertions to generate alerts when you reach code that should not be reachable.
- E. It is NOT appropriate for assertions to change a program's state.

12. Given:

```

1. class Loopy {
2.     public static void main(String[] args) {
3.         int[] x = {7,6,5,4,3,2,1};
4.         // insert code here
5.         System.out.print(y + " ");
6.     }
7. }
8. }

```

Which, inserted independently at line 4, compiles? (Choose all that apply.)

- A. `for(int y : x) {`
- B. `for(x : int y) {`
- C. `int y = 0; for(y : x) {`
- D. `for(int y=0, z=0; z<x.length; z++) { y = x[z];`
- E. `for(int y=0, int z=0; z<x.length; z++) { y = x[z];`
- F. `int y = 0; for(int z=0; z<x.length; z++) { y = x[z];`

13. Given:

```

1. class Ring {
2.     final static int x2 = 7;
3.     final static Integer x4 = 8;
4.     public static void main(String[] args) {
5.         Integer x1 = 5;
6.         String s = "a";
7.         if(x1 < 9) s += "b";
8.         switch(x1) {
9.             case 5: s += "c";
10.            case x2: s += "d";
11.            case x4: s += "e";
12.        }
13.        System.out.println(s);
14.    }
15. }
```

What is the result?

- A. abc
- B. abcde
- C. Compilation fails due only to an error on line 7.
- D. Compilation fails due only to an error on line 8.
- E. Compilation fails due only to an error on line 10.
- F. Compilation fails due only to an error on line 11.
- G. Compilation fails due to errors on multiple lines.

**14.** Given:

```

class Emu {
    static String s = "-";
    public static void main(String[] args) {
        try {
            throw new Exception();
        } catch (Exception e) {
            try {
                try { throw new Exception(); }
                catch (Exception ex) { s += "ic "; }
                throw new Exception();
            }
            catch (Exception x) { s += "mc "; }
            finally { s += "mf "; }
        } finally { s += "of "; }
        System.out.println(s);
    } }

```

What is the result?

- A. -ic of
- B. -mf of
- C. -mc mf
- D. -ic mf of
- E. -ic mc mf of
- F. -ic mc of mf
- G. Compilation fails.

**15.** Given:

```

class Mineral { }
class Gem extends Mineral { }
class Miner {
    static int x = 7;
    static String s = null;
    public static void getWeight(Mineral m) {
        int y = 0 / x;
        System.out.print(s + " ");
    }
    public static void main(String[] args) {
        Mineral[] ma = {new Mineral(), new Gem()};
    }
}

```

```
        for(Object o : ma)
            getWeight((Mineral) o);
    }
}
```

And the command-line invocation:

```
java Miner.java
```

What is the result?

- A. null
  - B. null null
  - C. A `ClassCastException` is thrown.
  - D. A `NullPointerException` is thrown.
  - E. A `NoClassDefFoundError` is thrown.
  - F. An `ArithmeticException` is thrown.
  - G. An `IllegalArgumentException` is thrown.
  - H. An `ArrayIndexOutOfBoundsException` is thrown.
16. Which are most typically thrown by an API developer or an application developer as opposed to being thrown by the JVM? (Choose all that apply.)
- A. `ClassCastException`
  - B. `IllegalStateException`
  - C. `NumberFormatException`
  - D. `IllegalArgumentException`
  - E. `ExceptionInInitializerError`

# SELF TEST ANSWERS

1. Given the following code:

```
public class OrtegorumFunction {
    public int computeDiscontinuous(int x) {
        int r = 1;
        r += x;
        if ((x > 4) && (x < 10)) {
            r += 2 * x;
        } else (x <= 4) {
            r += 3 * x;
        } else {
            r += 4 * x;
        }
        r += 5 * x;
        return r;
    }

    public static void main(String [] args) {
        OrtegorumFunction o = new OrtegorumFunction();
        System.out.println("OF(11) is: " + o.computeDiscontinuous(11));
    } }
```

What is the result?

- A. OF(11) is: 45
- B. OF(11) is: 56
- C. OF(11) is: 89
- D. OF(11) is: 111
- E. Compilation fails.
- F. An exception is thrown at runtime.

Answer:

- ☒ E is correct. The if statement is illegal. The if-else-else must be changed to if-else if-else, which would result in OF(11) is: 111.
- ☒ A, B, C, D, and F are incorrect based on the above. (Objective 2.1)

2. Given two files:

```
1. class One {
2.     public static void main(String[] args) {
3.         int assert = 0;
4.     }
5. }
```

```

1. class Two {
2.     public static void main(String[] args) {
3.         assert(false);
4.     }
5. }

```

And the four command-line invocations:

```

javac -source 1.3 One.java
javac -source 1.4 One.java
javac -source 1.3 Two.java
javac -source 1.4 Two.java

```

What is the result? (Choose all that apply.)

- A. Only one compilation will succeed.
- B. Exactly two compilations will succeed.
- C. Exactly three compilations will succeed.
- D. All four compilations will succeed.
- E. No compiler warnings will be produced.
- F. At least one compiler warning will be produced.

Answer:

- ☒ **B** and **F** are correct. Class One will compile (and issue a warning) using the 1.3 flag, and class Two will compile using the 1.4 flag.
- ☒ **A**, **C**, **D**, and **E** are incorrect based on the above. (Objective 2.3)

**3.** Given:

```

import java.io.*;
class Master {
    String doFileStuff() throws FileNotFoundException { return "a"; }
}
class Slave extends Master {
    public static void main(String[] args) {
        String s = null;
        try { s = new Slave().doFileStuff();
        } catch ( Exception x) {
            s = "b"; }
        System.out.println(s);
    }
    // insert code here
}

```

Which, inserted independently at `// insert code here`, will compile, and produce the output `b`? (Choose all that apply.)

- A. `String doFileStuff() { return "b"; }`
- B. `String doFileStuff() throws IOException { return "b"; }`
- C. `String doFileStuff(int x) throws IOException { return "b"; }`
- D. `String doFileStuff() throws FileNotFoundException { return "b"; }`
- E. `String doFileStuff() throws NumberFormatException { return "b"; }`
- F. `String doFileStuff() throws NumberFormatException,  
FileNotFoundException { return "b"; }`

Answer:

- ☒ A, D, E, and F are correct. It's okay for an overriding method to throw the same exceptions, narrower exceptions, or no exceptions. And it's okay for the overriding method to throw any runtime exceptions.
- ☒ B is incorrect, because the overriding method is trying to throw a broader exception. C is incorrect. This method doesn't override, so the output is `a`. (Objective 2.4)

4. Given:

```
class Input {
    public static void main(String[] args) {
        String s = "-";
        try {
            doMath(args[0]);
            s += "t ";           // line 6
        }
        finally { System.out.println(s += "f "); }
    }
    public static void doMath(String a) {
        int y = 7 / Integer.parseInt(a);
    }
}
```

And the command-line invocations:

```
java Input
java Input 0
```

Which are true? (Choose all that apply.)

- A. Line 6 is executed exactly 0 times.
- B. Line 6 is executed exactly 1 time.
- C. Line 6 is executed exactly 2 times.

- D. The `finally` block is executed exactly 0 times.
- E. The `finally` block is executed exactly 1 time.
- F. The `finally` block is executed exactly 2 times.
- G. Both invocations produce the same exceptions.
- H. Each invocation produces a different exception.

Answer:

- ☒ **A, F, and H** are correct. Since both invocations throw exceptions, line 6 is never reached. Since both exceptions occurred within a `try` block, the `finally` block will always execute. The first invocation throws an `ArrayIndexOutOfBoundsException`, and the second invocation throws an `ArithmeticException` for the attempt to divide by zero.
- ☒ **B, C, D, E, and G** are incorrect based on the above. (Objective 2.5)

**5.** Given:

```

1. class Crivitch {
2.     public static void main(String [] args) {
3.         int x = 0;
4.         // insert code here
5.         do { } while (x++ < y);
6.         System.out.println(x);
7.     }
8. }
```

Which, inserted at line 4, produces the output 12?

- A. `int y = x;`
- B. `int y = 10;`
- C. `int y = 11;`
- D. `int y = 12;`
- E. `int y = 13;`
- F. None of the above will allow compilation to succeed.

Answer:

- ☒ **C** is correct. `x` reaches the value of 11, at which point the `while` test fails. `x` is then incremented (after the comparison test!), and the `println()` method runs.
- ☒ **A, B, D, E, and F** are incorrect based on the above. (Objective 2.2)



6. Given:

```
class Plane {
    static String s = "-";
    public static void main(String[] args) {
        new Plane().s1();
        System.out.println(s);
    }
    void s1() {
        try { s2(); }
        catch (Exception e) { s += "c"; }
    }
    void s2() throws Exception {
        s3(); s += "2";
        s3(); s += "2b";
    }
    void s3() throws Exception {
        throw new Exception();
    } }
}
```

What is the result?

- A. -
- B. -c
- C. -c2
- D. -2c
- E. -c22b
- F. -2c2b
- G. -2c2bc
- H. Compilation fails.

Answer:

- ☒ **B** is correct. Once `s3()` throws the exception to `s2()`, `s2()` throws it to `s1()`, and no more of `s2()`'s code will be executed.
- ☒ **A, C, D, E, F, G, and H** are incorrect based on the above. (Objective 2.5)

7. Given:

```
try { int x = Integer.parseInt("two"); }
```

Which could be used to create an appropriate catch block? (Choose all that apply.)

- A. `ClassCastException`
- B. `IllegalStateException`
- C. `NumberFormatException`

- D. `IllegalArgumentException`
- E. `ExceptionInInitializerError`
- F. `ArrayIndexOutOfBoundsException`

Answer:

- ☒ C and D are correct. `Integer.parseInt` can throw a `NumberFormatException`, and `IllegalArgumentException` is its superclass (i.e., a broader exception).
- ☒ A, B, E, and F are not in `NumberFormatException`'s class hierarchy. (Objective 2.6)

8. Given:

```

1. class Ping extends Utils {
2.     public static void main(String [] args) {
3.         Utils u = new Ping();
4.         System.out.print(u.getInt(args[0]));
5.     }
6.     int getInt(String arg) {
7.         return Integer.parseInt(arg);
8.     }
9. }
10. class Utils {
11.     int getInt(String x) throws Exception { return 7; }
12. }
```

And the following three possible changes:

- C1. Declare that `main()` throws an `Exception`.
- C2. Declare that `Ping.getInt()` throws an `Exception`.
- C3. Wrap the invocation of `getInt()` in a `try / catch` block.

Which change(s) allow the code to compile? (Choose all that apply.)

- A. Just C1 is sufficient.
- B. Just C2 is sufficient.
- C. Just C3 is sufficient.
- D. Both C1 and C2 are required.
- E. Both C1 and C3 are required.
- F. Both C2 and C3 are required.
- G. All three changes are required.

Answer:

- ☒ **A** and **C** are correct. Remember that line 4 is making a polymorphic call so the compiler knows that an exception might be thrown. If C1 is implemented the exception has been sufficiently declared, and if C3 is implemented the exception has been sufficiently handled. C2 is not necessary in either case.
- ☒ **B, D, E, F, and G** are incorrect based on the above. (Objective 2.4)

**9.** Given:

```
class Swill {
    public static void main(String[] args) {
        String s = "-";
        switch(TimeZone.CST) {
            case EST: s += "e";
            case CST: s += "c";
            case MST: s += "m";
            default: s += "X";
            case PST: s += "p";
        }
        System.out.println(s);
    }
}
enum TimeZone {EST, CST, MST, PST }
```

What is the result?

- A.** -c
- B.** -x
- C.** -cm
- D.** -cmp
- E.** -cmXp
- F.** Compilation fails.
- G.** An exception is thrown at runtime.

Answer:

- ☒ **E** is correct. It's legal to use enums in a switch, and normal switch fall-through logic applies; i.e., once a match is made the switch has been entered, and all remaining blocks will run if no break statement is encountered. Note: default doesn't have to be last.
- ☒ **A, B, C, D, and F** are incorrect based on the above. (Objective 2.1)

10. Given:

```
class Circus {
    public static void main(String[] args) {
        int x = 9;
        int y = 6;
        for(int z = 0; z < 6; z++, y--) {
            if(x > 2) x--;
            label:
                if(x > 5) {
                    System.out.print(x + " ");
                    --x;
                    continue label;
                }
            x--;
        }
    }
}
```

What is the result?

- A. 8
- B. 8 7
- C. 8 7 6
- D. Compilation fails.
- E. An exception is thrown at runtime.

Answer:

- ☒ D is correct. A labeled `continue` works *only* with loops. In this case, although the label is legal, `label` is not a label on a loop statement, it's a label on an `if` statement.
- ☒ A, B, C, and E are incorrect based on the above. (Objective 2.2)

11. Which are true? (Choose all that apply.)

- A. It is appropriate to use assertions to validate arguments to methods marked `public`.
- B. It is appropriate to catch and handle assertion errors.
- C. It is NOT appropriate to use assertions to validate command-line arguments.
- D. It is appropriate to use assertions to generate alerts when you reach code that should not be reachable.
- E. It is NOT appropriate for assertions to change a program's state.

Answer:

- ☒ **C, D, and E** are correct statements.
- ☒ **A** is incorrect. It is acceptable to use assertions to test the arguments of `private` methods. **B** is incorrect. While assertion errors can be caught, Sun discourages you from doing so. (Objective 2.3)

**12.** Given:

```

1. class Loopy {
2.     public static void main(String[] args) {
3.         int[] x = {7,6,5,4,3,2,1};
4.         // insert code here
5.         System.out.print(y + " ");
6.     }
7. } }
```

Which, inserted independently at line 4, compiles? (Choose all that apply.)

- A.** `for(int y : x) {`
- B.** `for(x : int y) {`
- C.** `int y = 0; for(y : x) {`
- D.** `for(int y=0, z=0; z<x.length; z++) { y = x[z];`
- E.** `for(int y=0, int z=0; z<x.length; z++) { y = x[z];`
- F.** `int y = 0; for(int z=0; z<x.length; z++) { y = x[z];`

Answer:

- ☒ **A, D, and F** are correct. **A** is an example of the enhanced `for` loop. **D** and **F** are examples of the basic `for` loop.
- ☒ **B** is incorrect because its operands are swapped. **C** is incorrect because the enhanced `for` must declare its first operand. **E** is incorrect syntax to declare two variables in a `for` statement. (Objective 2.2)

**13.** Given:

```

1. class Ring {
2.     final static int x2 = 7;
3.     final static Integer x4 = 8;
4.     public static void main(String[] args) {
5.         Integer x1 = 5;
6.         String s = "a";
```

```

7.      if(x1 < 9) s += "b";
8.      switch(x1) {
9.          case 5: s += "c";
10.         case x2: s += "d";
11.         case x4: s += "e";
12.     }
13.     System.out.println(s);
14. }
15. }

```

What is the result?

- A. abc
- B. abcde
- C. Compilation fails due only to an error on line 7.
- D. Compilation fails due only to an error on line 8.
- E. Compilation fails due only to an error on line 10.
- F. Compilation fails due only to an error on line 11.
- G. Compilation fails due to errors on multiple lines.

Answer:

- ☒ **F** is correct. A `switch` statement requires its case expressions to be constants, and wrapper variables (even `final static` ones) aren't considered constants. The rest of the code is correct.
- ☒ **A, B, C, D, E, and G** are incorrect based on the above. (Objective 2.1)

**14.** Given:

```

class Emu {
    static String s = "-";
    public static void main(String[] args) {
        try {
            throw new Exception();
        } catch (Exception e) {
            try {
                try { throw new Exception(); }
                catch (Exception ex) { s += "ic "; }
                throw new Exception(); }
            catch (Exception x) { s += "mc "; }
            finally { s += "mf "; }
        } finally { s += "of "; }
        System.out.println(s);
    } }

```

What is the result?

- A. -ic of
- B. -mf of
- C. -mc mf
- D. -ic mf of
- E. -ic mc mf of
- F. -ic mc of mf
- G. Compilation fails.

Answer:

- ☒ E is correct. There is no problem nesting try / catch blocks. As is normal, when an exception is thrown, the code in the catch block runs, then the code in the finally block runs.
- ☒ A, B, C, D, and F are incorrect based on the above.  
(Objective 2.5)

**15.** Given:

```
class Mineral { }
class Gem extends Mineral { }
class Miner {
    static int x = 7;
    static String s = null;
    public static void getWeight(Mineral m) {
        int y = 0 / x;
        System.out.print(s + " ");
    }
    public static void main(String[] args) {
        Mineral[] ma = {new Mineral(), new Gem()};
        for(Object o : ma)
            getWeight((Mineral) o);
    }
}
```

And the command-line invocation:

```
java Miner.java
```

What is the result?

- A. `null`
- B. `null null`
- C. A `ClassCastException` is thrown.
- D. A `NullPointerException` is thrown.
- E. A `NoClassDefFoundError` is thrown.
- F. An `ArithmeticException` is thrown.
- G. An `IllegalArgumentException` is thrown.
- H. An `ArrayIndexOutOfBoundsException` is thrown.

Answer:

- ☒ E is correct. The invocation should be `java Miner`, in which case `null null` would be produced.
- ☒ A, B, C, D, F, G, and H are incorrect based on the above.  
(Objective 2.6)

**16.** Which are most typically thrown by an API developer or an application developer as opposed to being thrown by the JVM? (Choose all that apply.)

- A. `ClassCastException`
- B. `IllegalStateException`
- C. `NumberFormatException`
- D. `IllegalArgumentException`
- E. `ExceptionInInitializerError`

Answer:

- ☒ B, C, and D are correct. B is typically used to report an environment problem such as trying to access a resource that's closed. C is often thrown in API methods that attempt to convert poorly formed String arguments to numeric values. D is often thrown in API methods that receive poorly formed arguments.
- ☒ A and E are thrown by the JVM.  
(Objective 2.6)