Chapter 3
Control Statements (Part Ⅱ)

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Objectives

- To use `for` and `do...while` statements
- To use `switch` statement
- To use `continue` and `break` statements
- To use logical operators
- Structured programming

Counter-Controlled Repetition with `while`

```
public class WhileCounter {

    public static void main(String[] args) {

        int counter = 1;

        while ( counter <= 10 ) {

            System.out.printf("%d", counter);

            ++counter;

        }

        System.out.println();

    }

}
```

Control variable (loop counter)

Loop continuation condition

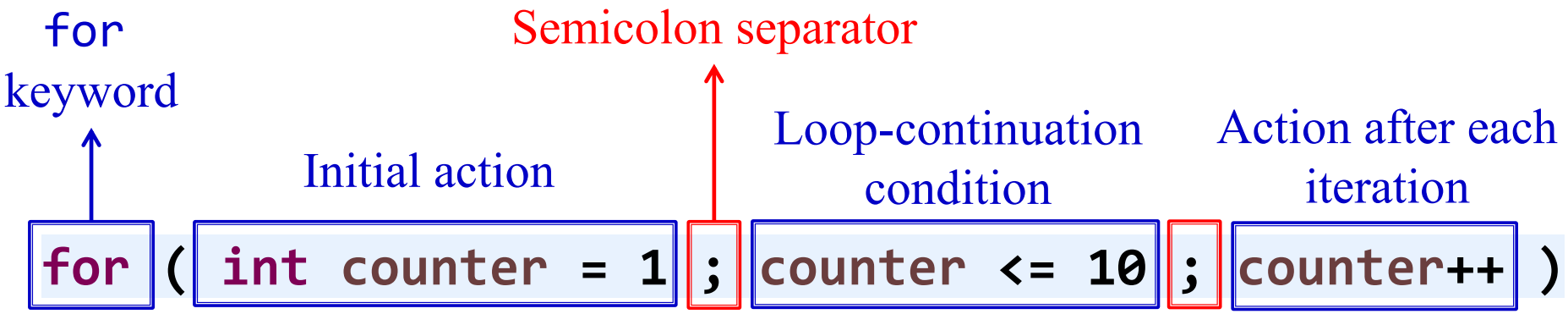
Actions (e.g., counter increment or decrement) after each iteration

The for Repetition Statement

- Specifies the counter-controlled-repetition details in one line

```
public class ForCounter {
    public static void main(String[] args) {
        for(int counter = 1; counter <= 10; counter++) {
            System.out.printf("%d", counter);
        }
        System.out.println();
    }
}
```

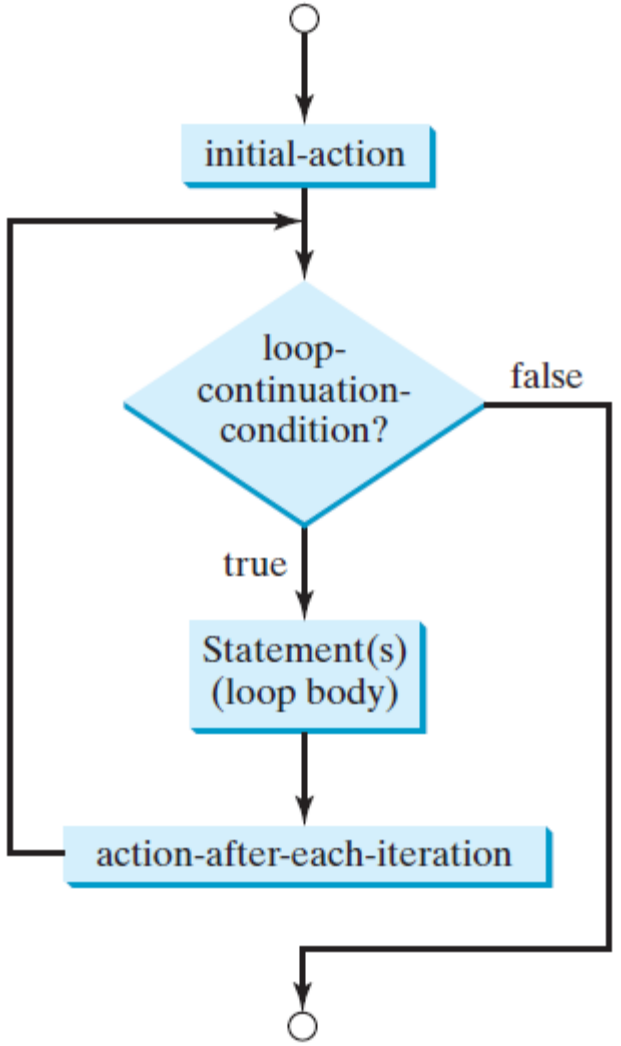
The for Repetition Statement




```
{

      // Statements

}
```

The for Repetition Statement

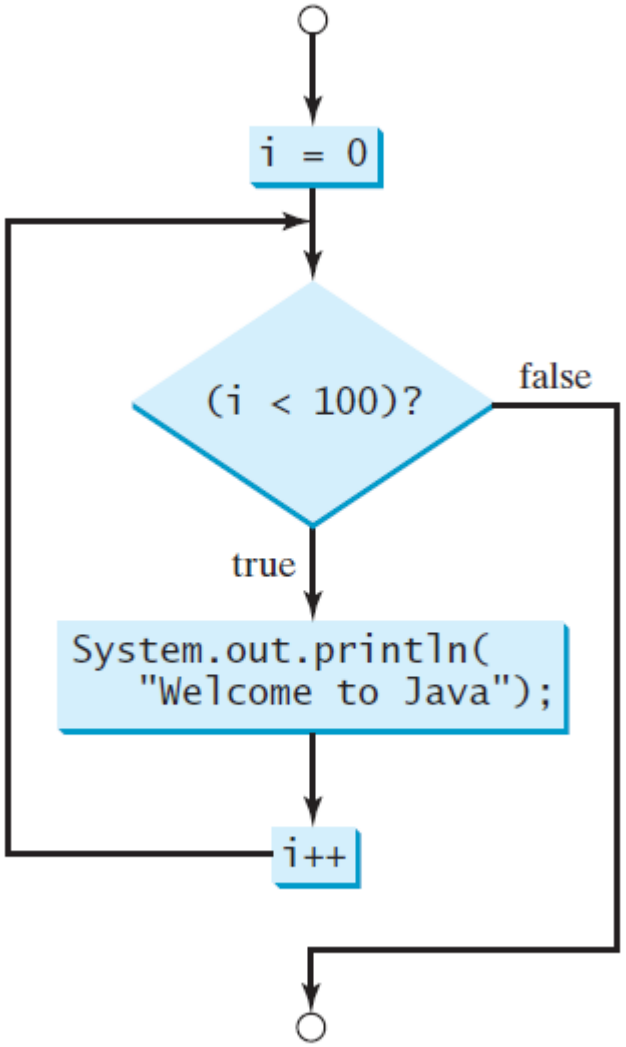
```
for (initial-action; loop-continuation-condition;
     action-after-each-iteration) {
  // Loop body;
  Statement(s);
}
```



The for Repetition Statement

```
int i;
for (i = 0; i < 100; i++) {
  System.out.println("Welcome to Java!");
}
```

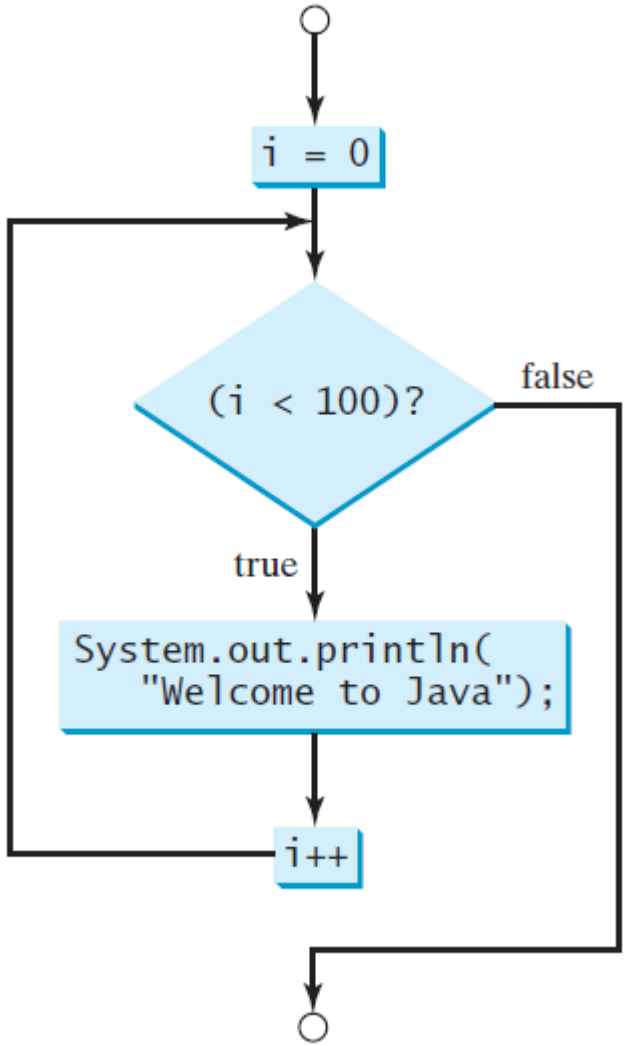
```
for (int i = 0; i < 100; i++) {
  System.out.println("Welcome to Java!");
}
```



The for Repetition Statement

```
int i;
for(i = 0; i < 100; i++) {
    // i can be used here
}
// i can also be used after the loop
// until the end of the enclosing block
```

```
for(int i = 0; i < 100; i++) {
    // i can only be used
    // in the loop body
}
```



Boundary Values

```
for(int counter = 0; counter < 10; counter++) {
    // loop how many times?
}

for(int counter = 0; counter <= 10; counter++) {
    // loop how many times?
}

for(int counter = 1; counter <= 10; counter++) {
    // loop how many times?
}
```

More on for Repetition Statement

- If the *loop-continuation condition* is omitted, the condition is always true, thus creating an infinite loop.

```
for(int i = 0; ; i++) {
    System.out.println("infinite loop");
}
```

- You might omit the *initialization* expression if the program initializes the control variable before the loop.

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

=

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

More on for Repetition Statement

- You might omit the *action-after-each-iteration* if the program calculates it with statements in the loop's body or no action is needed.

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

```
Scanner sc = new Scanner(System.in);
int input = sc.nextInt();
for( ; input > 0; ) {
  System.out.println(input);
  input = sc.nextInt();
}
sc.close();
```

More on for Repetition Statement

- The *action-after-each-iteration* expression in a `for` acts as if it were a standalone statement at the end of the `for`'s body, so

```
counter = counter + 1
counter += 1
++counter
counter++
```

are equivalent increment expressions in a `for` statement.

More on for Repetition Statement

- The *initialization* and *action-after-each-iteration* expressions can contain multiple expressions separated by commas.

```
int total = 0;
for (int i = 2; i <= 10; total += i, i += 2) {
    System.out.println(total);
} // what's the output?
```

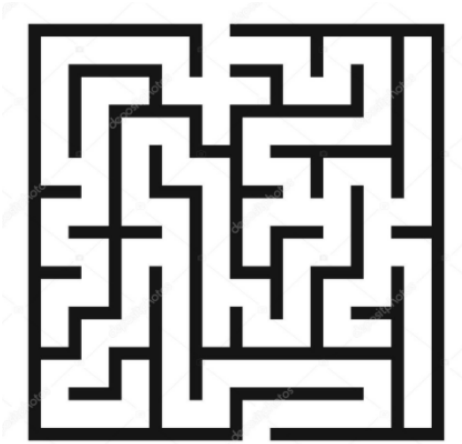
=

```
int total = 0, i = 2;
while (i <= 10) {
    System.out.println(total);
    total += i;
    i += 2;
}
```

Using `for` or `while` loop?

- Typically, `for` statements are used for counter-controlled repetition and `while` statements for sentinel-controlled repetition

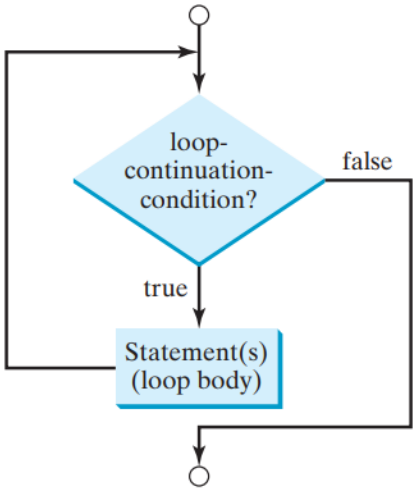
```
The required Reverse Pyramid pattern containing 8 rows is:

Row # 1 contains 8 stars :  * * * * * * * *
Row # 2 contains 7 stars :  * * * * * * *
Row # 3 contains 6 stars :  * * * * * *
Row # 4 contains 5 stars :  * * * * *
Row # 5 contains 4 stars :  * * * *
Row # 6 contains 3 stars :  * * *
Row # 7 contains 2 stars :  * *
Row # 8 contains 1 stars :  *
```



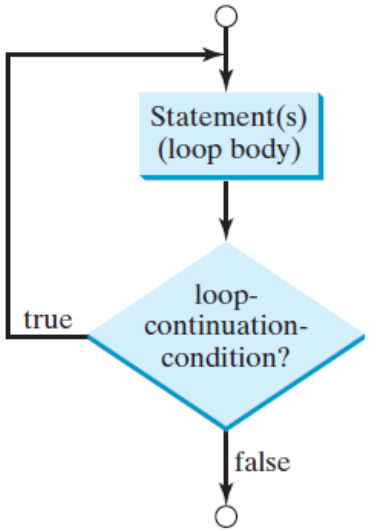
The do…while repetition statement

- **do…while** is similar to **while** except that it executes the loop body first and then checks the loop continuation condition.

```
while (loop-continuation-condition) {
  // Loop body
  Statement(s);
}
```




```
do {
  // Loop body;
  Statement(s);
} while (loop-continuation-condition);
```



do…while vs while

```
int num = 0;
while(num>5){
   System.out.println("num > 5");
}
```

`while`: Condition is tested at the beginning of the loop

```
int num = 0;
do{
   System.out.println("num > 5");
}while(num>5);
```

Don't forget the semicolon

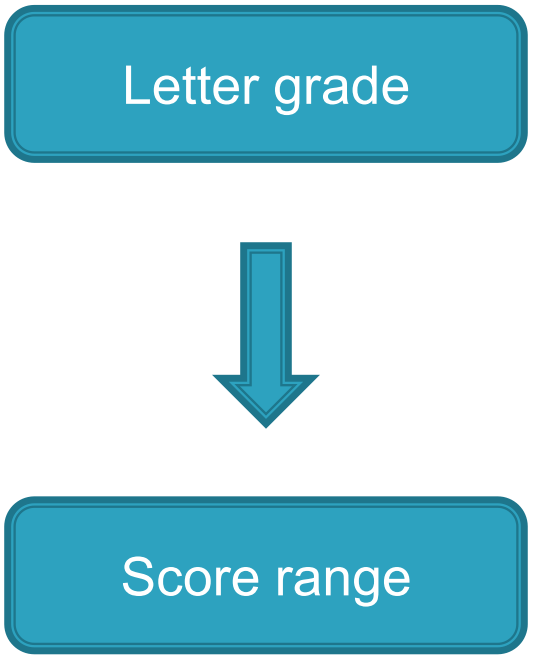
`do…while`: Condition is tested at the end of the loop; body will be executed at least once

Objectives

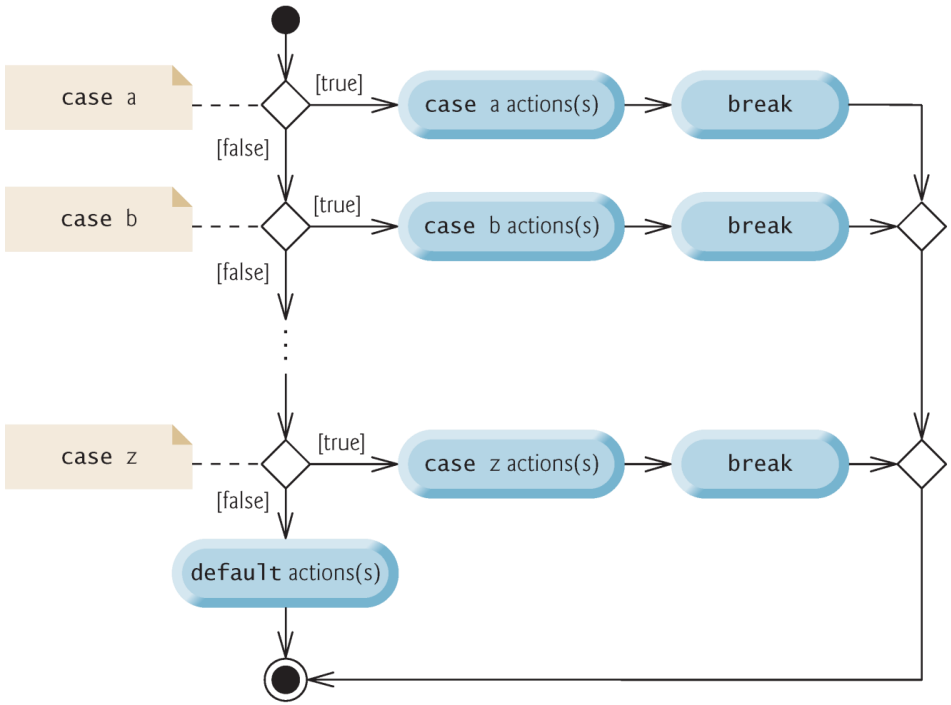
- To use `for` and `do…while` statements
- To use `switch` statement
- To use `continue` and `break` statements
- To use logical operators
- Structured programming

Recall the `if…else` statement

```
if(studentGrade == 'A') {
    System.out.println("90 - 100");
} else if(studentGrade == 'B') {
    System.out.println("80 - 89");
} else if(studentGrade == 'C') {
    System.out.println("70 - 79");
} else if(studentGrade == 'D') {
    System.out.println("60 - 69");
} else {
    System.out.println("score < 60");
}
```



The switch Multiple-Selection Statement




```
switch (studentGrade) {
    case 'A':
        System.out.println("90 - 100");
        break;
    case 'B':
        System.out.println("80 - 89");
        break;
    case 'C':
        System.out.println("70 - 79");
        break;
    case 'D':
        System.out.println("60 - 69");
        break;
    default:
        System.out.println("score < 60");
}
```

The `switch` Multiple-Selection Statement

```
switch (switch-expression) {
         case value1: statement(s)1;
                      break;
         case value2: statement(s)2;
                      break;
         ...
         case valueN: statement(s)N;
                      break;
         default: statement(s)-for-default;
}
```

The switch-expression must yield a value of char, byte, short, int, or String type and must always be enclosed in parentheses.

```
switch (studentGrade) {
    case 'A':
        System.out.println("90 - 100");
        break;
    case 'B':
        System.out.println("80 - 89");
        break;
    case 'C':
        System.out.println("70 - 79");
        break;
    case 'D':
        System.out.println("60 - 69");
        break;
    default:
        System.out.println("score < 60");
}
```

The switch Multiple-Selection Statement

```
switch (switch-expression) {
         case value1: statement(s)1;
                      break;
         case value2: statement(s)2;
                      break;
         ...
         case valueN: statement(s)N;
                      break;
         default: statement(s)-for-default;
}
```

- The value1, . . ., and valueN must have the same data type as the value of the switch expression.
- value1, . . ., and valueN are constant expressions, meaning that they cannot contain variables, such as 1 + x

```
switch (studentGrade) {
    case 'A':
        System.out.println("90 - 100");
        break;
    case 'B':
        System.out.println("80 - 89");
        break;
    case 'C':
        System.out.println("70 - 79");
        break;
    case 'D':
        System.out.println("60 - 69");
        break;
    default:
        System.out.println("score < 60");
}
```

The switch Multiple-Selection Statement

```
switch (grade) {
    case 90 <= grade: X
        System.out.println("A Level");
        break;
    case …:…
}
```

- The value1, . . ., and valueN must have the same data type as the value of the switch expression.
- value1, . . ., and valueN are constant expressions, meaning that they cannot contain variables, such as 1 + x

```
switch (studentGrade) {
    case 'A':
        System.out.println("90 - 100");
        break;
    case 'B':
        System.out.println("80 - 89");
        break;
    case 'C':
        System.out.println("70 - 79");
        break;
    case 'D':
        System.out.println("60 - 69");
        break;
    default:
        System.out.println("score < 60");
}
```

The switch Multiple-Selection Statement

```
switch (switch-expression) {
         case value1: statement(s)1;
                      break;
         case value2: statement(s)2;
                      break;
         ...
         case valueN: statement(s)N;
                      break;
         default: statement(s)-for-default;
}
```

When the value in a case statement matches the value of the switch-expression, the statements starting from this case are executed until either a break statement or the end of the switch statement is reached.
The keyword break is optional. The break statement immediately ends the switch statement.

```
switch (studentGrade) {
    case 'A':
        System.out.println("90 - 100");
        break;
    case 'B':
        System.out.println("80 - 89");
        break;
    case 'C':
        System.out.println("70 - 79");
        break;
    case 'D':
        System.out.println("60 - 69");
        break;
    default:
        System.out.println("score < 60");
}
```

The switch Multiple-Selection Statement

```
switch (switch-expression) {
         case value1: statement(s)1;
                      break;
         case value2: statement(s)2;
                      break;
         ...
         case valueN: statement(s)N;
                      break;
         default: statement(s)-for-default;
}
```

The default case, which is optional, can be used to perform actions when none of the specified cases matches the switch-expression.

If no match occurs and there is no default case, program simply continues with the first statement after switch.

```
switch (studentGrade) {
    case 'A':
        System.out.println("90 - 100");
        break;
    case 'B':
        System.out.println("80 - 89");
        break;
    case 'C':
        System.out.println("70 - 79");
        break;
    case 'D':
        System.out.println("60 - 69");
        break;
    default:
        System.out.println("score < 60");
}
```

Using break in switch

```
switch (studentGrade) {
    case 'A':
        System.out.println("90 - 100");
        break;
    case 'B':
        System.out.println("80 - 89");
        break;
    case 'C':
        System.out.println("70 - 79");
        break;
    case 'D':
        System.out.println("60 - 69");
        break;
    default:
        System.out.println("score < 60");
}
```

- **Falling through:** Without break, the statements for a matching case and subsequent cases execute until a break or the end of the switch is encountered.

If `studentGrade == 'A'`, then output is

90 – 100
80 – 89
70 – 79

Using break in switch

```
switch (studentGrade) {
    case 'A':
        System.out.println("90 - 100");
        break;
    case 'B':
        System.out.println("80 - 89");
        break;
    case 'C':
        System.out.println("70 - 79");
        break;
    case 'D':
        System.out.println("60 - 69");
        break;
    default:
        System.out.println("score < 60");
}
```

- **Falling through:** Without break, the statements for a matching case and subsequent cases execute until a break or the end of the switch is encountered.

If `studentGrade == 'A'`, then output is

90 – 100
80 – 89
70 – 79
60 – 69
score < 60

Using break in switch

```
switch (studentGrade) {
    case 'A':
        System.out.println("90 - 100");
        break;
    case 'B':
        System.out.println("80 - 89");
        break;
    case 'C':
        System.out.println("70 - 79");
        break;
    case 'D':
        System.out.println("60 - 69");
        break;
    default:
        System.out.println("score < 60");
}
```

- **Falling through:** Without break, the statements for a matching case and subsequent cases execute until a break or the end of the switch is encountered.

If `studentGrade == 'C'`, then output is

70 – 79
60 – 69
score < 60

Using break in switch

```
switch (studentGrade) {
    case 'A':
        System.out.println("90 - 100");
        break;
    case 'B':
        System.out.println("80 - 89");
        break;
    case 'C':
        System.out.println("70 - 79");
        break;
    case 'D':
        System.out.println("60 - 69");
        break;
    default:
        System.out.println("score < 60");
}
```

- **Falling through:** Without break, the statements for a matching case and subsequent cases execute until a break or the end of the switch is encountered.

To avoid programming errors and improve code maintainability, it is a good idea to put a comment in a case clause if break is purposely omitted.

switch vs if…else

- if…else
  - Can test expressions based on ranges of values or conditions; Better for conditions that result into a boolean
- switch
  - Better for fixed data values, e.g., int, char, String

```
if ( studentGrade >= 90 )
   System.out.println( "A" );
else if ( studentGrade >= 80 )
   System.out.println( "B" );
else if ( studentGrade >= 70 )
   System.out.println( "C" );
else if ( studentGrade >= 60 )
   System.out.println( "D" );
else
   System.out.println( "F" );
```

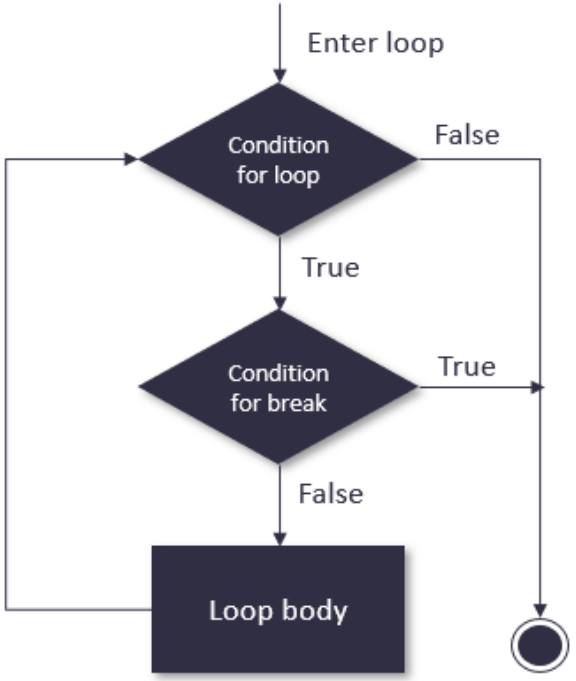
```
switch (studentGrade) {
    case 'A':
        System.out.println("90 - 100");
        break;
    case 'B':
        System.out.println("80 - 89");
        break;
    case 'C':
        System.out.println("70 - 79");
        break;
    case 'D':
        System.out.println("60 - 69");
        break;
    default:
        System.out.println("score < 60");
}
```

Objectives

- To use `for` and `do…while` statements
- To use `switch` statement
- To use `continue` and `break` statements
- To use logical operators
- Structured programming

The break Statement

- The **break** statement, when executed in a `while`, `for`, `do…while` or `switch`, causes **immediate exit** from that statement.
- Execution continues with the first statement after the control statement.
- Common uses of the `break` statement are to escape early from a loop or to skip the remainder of a `switch`.



break: jump out of the loop

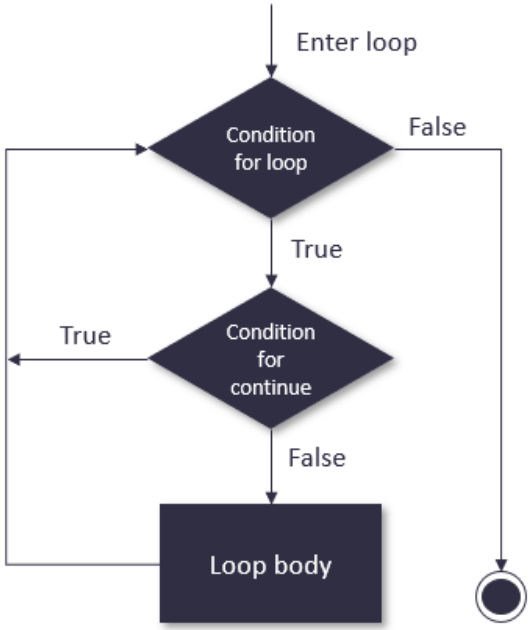
The break Statement

```
public class BreakTest {
    public static void main(String[] args) {
        int count;
        for(count = 1; count <= 10; count++) { // loop 10 times
            if(count == 5) {
                break; // terminate loop if count == 5
            }
            System.out.printf("%d ", count);
        }

        System.out.printf("\nBroke out of loop at count = %d\n", count);
    }
}
```

```
1 2 3 4

Broke out of loop at count = 5
```

The `continue` Statement

- The `continue` statement, when executed in a `while`, `for` or `do…while`, skips the remaining statements in the loop body and proceeds with the next iteration of the loop.
- In `while` and `do…while` statements, the program evaluates the loop-continuation test immediately after the `continue` statement executes.
- In a `for` statement, the action-after-iteration expression executes, then the program evaluates the loop-continuation test.



`continue`: skip one iteration if a condition is satisfied, then continue with the next iteration

The continue Statement

```
public class ContinueTest {
  public static void main(String[] args) {
    for(int count = 1; count <= 10; count++) { // loop 10 times
      if(count == 5) {
        continue; // skip remaining code in the loop if count == 5
      }
      System.out.printf("%d ", count);
    }
    System.out.println("\nUsed continue to skip printing 5");
  }
}
```

```
1 2 3 4 6 7 8 9 10
Used continue to skip printing 5
```

What's the output?

```
int count = 1;
while(count<=10){
    if(count == 5) {
        continue;
    }
    count++;
    System.out.printf("%d ", count);
}
```


Objectives

- To use `for` and `do…while` statements
- To use `switch` statement
- To use `continue` and `break` statements
- To use logical operators (逻辑运算符)
- Structured programming

Logical Operators

- The logical operators !, &&, ||, and ^ can be used to create a compound Boolean expression.

TABLE 3.3 Boolean Operators

Operator	*Name*	*Description*
!	not	logical negation
&&	and	logical conjunction
||	or	logical disjunction
^	exclusive or	logical exclusion

The ! Operator

- ! (also known as **logical negation** or **logical complement**) unary operator "reverses" the value of a condition.

TABLE 3.4 Truth Table for Operator !

p	!p	*Example (assume* `age = 24, weight = 140`*)*
`true`	`false`	`!(age > 18)` is `false`, because `(age > 18)` is `true`.
`false`	`true`	`!(weight == 150)` is `true`, because `(weight == 150)` is `false`.

The && Operator

- && ensures that two conditions on its left- and right-hand sides are *both true* before choosing a certain path of execution.

TABLE 3.5 Truth Table for Operator &&

p_1	p_2	p_1 && p_2	*Example (assume* `age = 24, weight = 140`*)*
`false`	`false`	`false`	
`false`	`true`	`false`	`(age > 28) && (weight <= 140)` is `true`, because `(age > 28)` is `false`.
`true`	`false`	`false`	
`true`	`true`	`true`	`(age > 18) && (weight >= 140)` is `true`, because `(age > 18)` and `(weight >= 140)` are both `true`.

The || Operator

- || ensures that *either or both* of two conditions are true before choosing a certain path of execution

TABLE 3.6 Truth Table for Operator ||

p_1	p_2	p_1 || p_2	*Example (assume* `age = 24, weight = 140`*)*
`false`	`false`	`false`	`(age > 34) || (weight >= 150)` is `false`, because `(age > 34)` and `(weight >= 150)` are both `false`.
`false`	`true`	`true`	
`true`	`false`	`true`	`(age > 18) || (weight < 140)` is `true`, because `(age > 18)` is `true`.
`true`	`true`	`true`	

The || Operator

- Operator && has a higher precedence than operator ||
- Both operators associate from left to right

```
a && b || c
```

Evaluate first (precedence)

```
a || b || c
```

Evaluate first (associativity)

Short-circuit evaluation of && and || (短路求值)

- The expression containing && or || operators are evaluated only until it's known whether the condition is true or false.

- `( gender == 'M' ) &&` `( age >= 65 )`

  Evaluation stops if the first part is false, the whole expression's value is false

- `( gender == 'F' ) ||` `( age >= 65 )`

  Evaluation stops if the first part is true, the whole expression's value is true

The & and | operators

- The **boolean logical AND** (**&**) and **boolean logical inclusive OR (|)** operators are identical to the && and || operators, except that the & and | operators *always evaluate both of their operands*

- This is useful if the operand at the right-hand side of & or | has a required **side effect (副作用)**—a modification of a variable's value

Example: || vs. |

```
int b = 0, c = 0;
if(true || b == (c = 6)) {
    System.out.println(c); // what's c's value?
}
```

Prints 0

```
int b = 0, c = 0;
if(true | b == (c = 6)) {
    System.out.println(c); // what's c's value?
}
```

Prints 6

The ^ operator

- A simple condition containing the **boolean logical exclusive OR** (^) operator is `true` *if and only if* one of its operands is `true` and the other is `false`

TABLE 3.7 Truth Table for Operator ^

p_1	p_2	p_1 ^ p_2	*Example (assume* `age = 24, weight = 140`*)*
`false`	`false`	`false`	`(age > 34) ^ (weight > 140)` is `false`, because `(age > 34)` and `(weight > 140)` are both `false`.
`false`	`true`	`true`	`(age > 34) ^ (weight >= 140)` is `true`, because `(age > 34)` is `false` but `(weight >= 140)` is `true`.
`true`	`false`	`true`	
`true`	`true`	`false`	

Bitwise Operators

- &, | and ^ are also **bitwise operators** when applied to integral operands.

```
a = 5 = 0101 (In Binary)
b = 7 = 0111 (In Binary)

Bitwise AND Operation of 5 and 7
  0101
& 0111
 ________
  0101  = 5 (In decimal)
```

```
int a = 5;
int b = 7;

// bitwise and
// 0101 & 0111=0101 = 5
System.out.println("a&b = " + (a & b));

// bitwise or
// 0101 | 0111=0111 = 7
System.out.println("a|b = " + (a | b));
```

https://www.geeksforgeeks.org/bitwise-operators-in-java/

Bitwise Operators

- &, | and ^ are also **bitwise operators** when applied to integral operands.

```
a = 5 = 0101 (In Binary)
b = 7 = 0111 (In Binary)

Bitwise OR Operation of 5 and 7
  0101
| 0111
 ________
  0111  = 7 (In decimal)
```

```
int a = 5;
int b = 7;

// bitwise and
// 0101 & 0111=0101 = 5
System.out.println("a&b = " + (a & b));

// bitwise or
// 0101 | 0111=0111 = 7
System.out.println("a|b = " + (a | b));
```

https://www.geeksforgeeks.org/bitwise-operators-in-java/

The Operators Introduced So Far

Precedence

Operators	Associativity	Type
++ --	right to left	unary postfix
++ -- + - ! (*type*)	right to left	unary prefix
* / %	left to right	multiplicative
+ -	left to right	additive
< <= > >=	left to right	relational
== !=	left to right	equality
&	left to right	boolean logical AND
^	left to right	boolean logical exclusive OR
|	left to right	boolean logical inclusive OR
&&	left to right	conditional AND
||	left to right	conditional OR
?:	right to left	conditional
= += -= *= /= %=	right to left	assignment

Associativity is not relevant for some operators.
For example, `x <= y <= z` and `x++--` and ++x++ are invalid expressions in Java.

General Rules

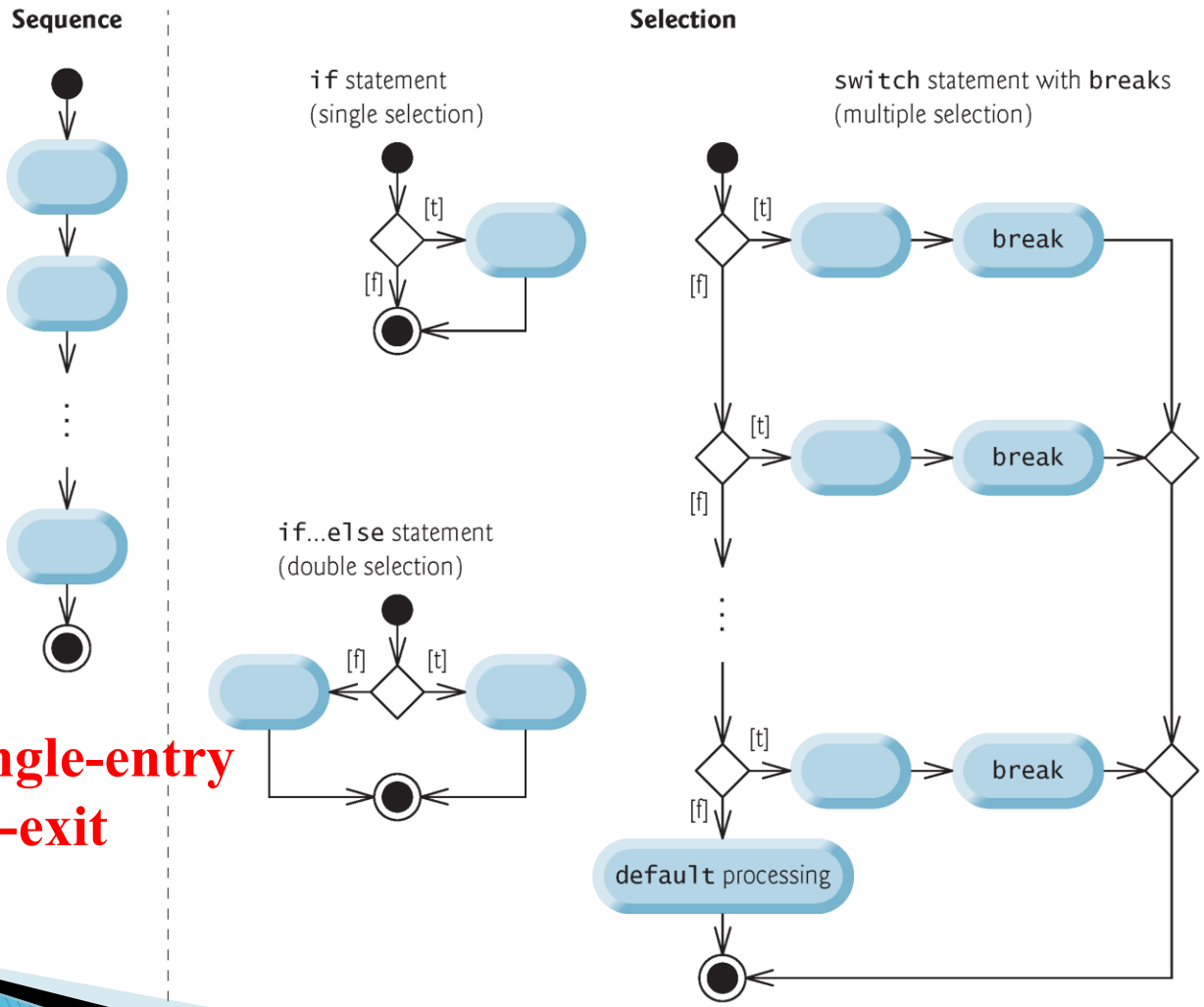
- The operators in expressions are evaluated in the order determined by the rules of parentheses, operator precedence, and operator associativity.
- Parentheses can be used to force the order of evaluation to occur in any sequence.
- Operators with higher precedence are evaluated earlier. For operators of the same precedence, their associativity determines the order of evaluation.
- All binary operators except assignment operators are left-associative; assignment operators are right-associative

When in doubt, use () or simply use multiple statements!

Objectives

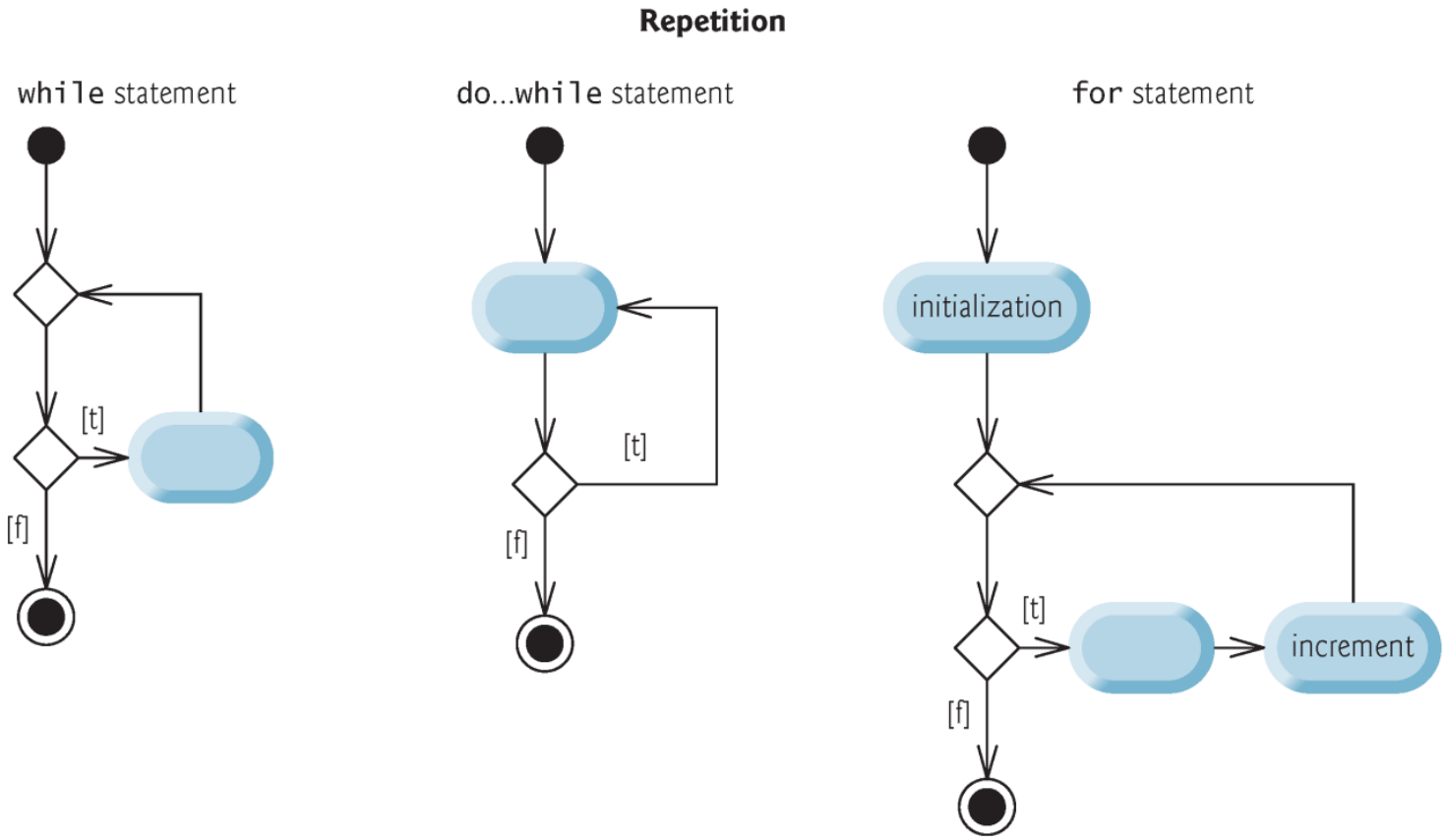
- To use `for` and `do…while` statements
- To use `switch` statement
- To use `continue` and `break` statements
- To use logical operators (逻辑运算符)
- Structured programming

Control Structures Summary



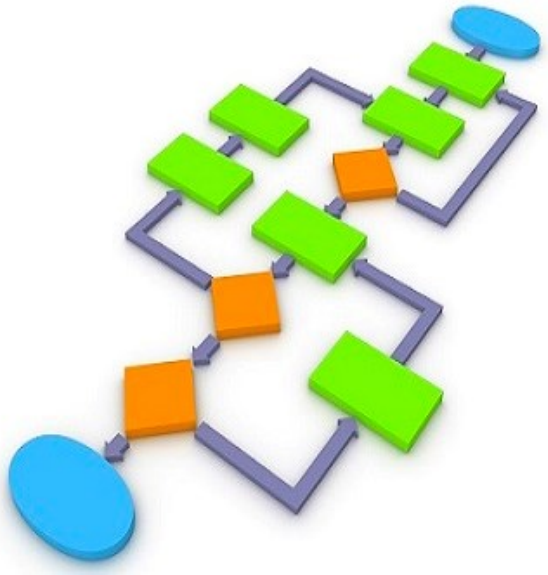
Always single-entry and single-exit

Control Structures Summary



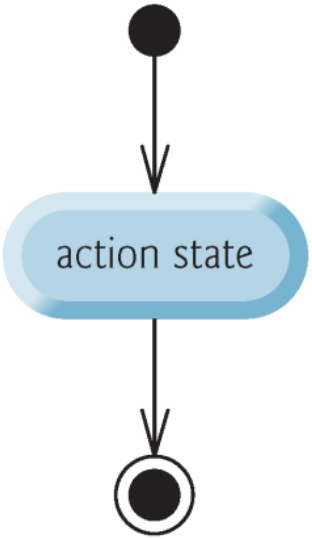
Structured Programming Summary

- **Böhm-Jacopini Theorem:** Only three forms of control are needed to implement any algorithm:
  - Sequence
  - Selection
  - Repetition



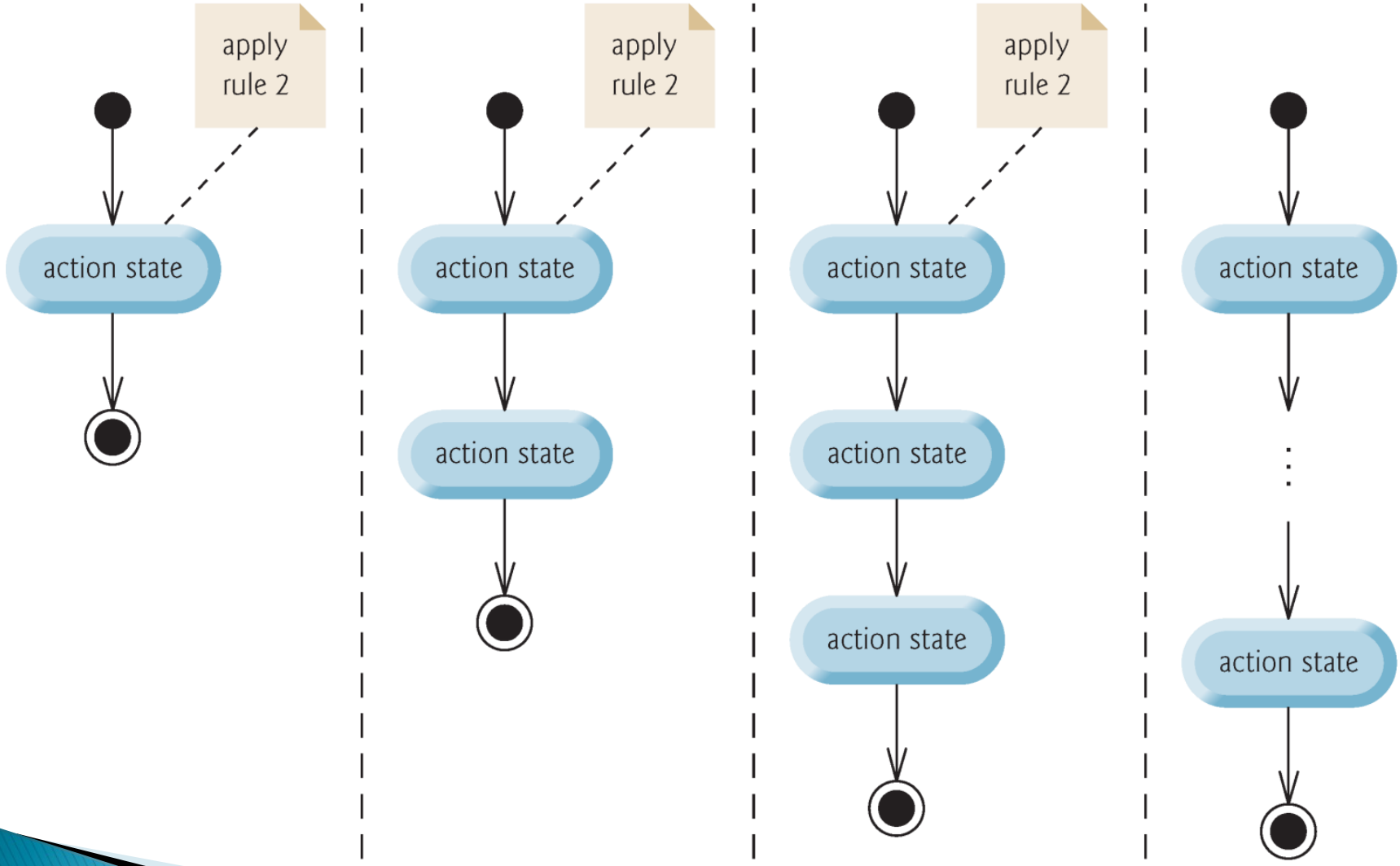
Rules for Forming Structured Programs

- Begin with the simplest activity diagram.
- **Stacking Rule (堆叠规则):** Any action state can be replaced by two action states in sequence.
- **Nesting Rule (嵌套规则):** Any action state can be replaced by any control statement (sequence of action states, `if`, `if…else`, `switch`, `while`, `do…while` or `for`).
- Stacking rule and nesting rule can be applied as often as you like and in any order.

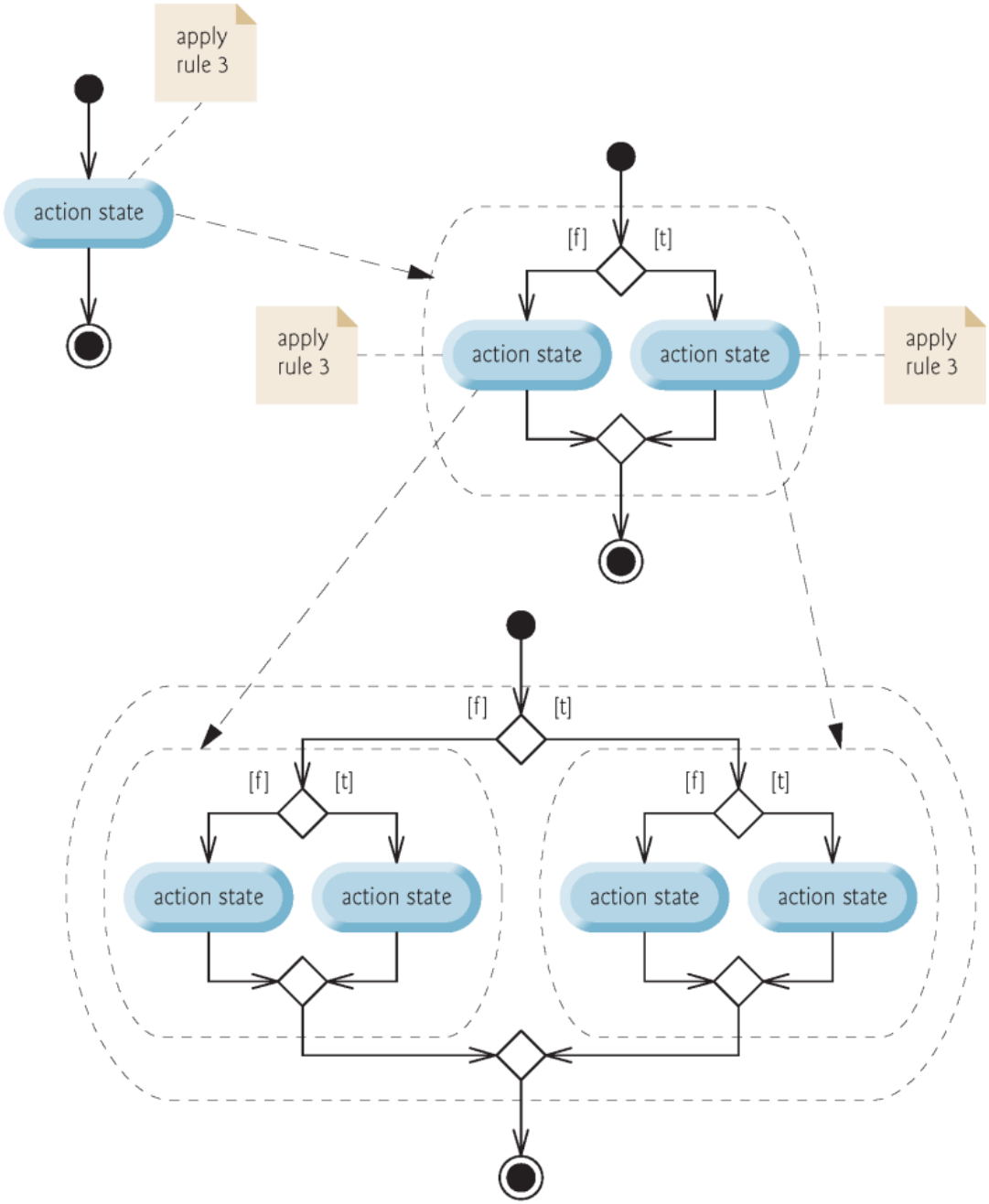


Begin with the simplest activity diagram.

Apply stacking rule



Apply nesting rule



Structured Programming Summary

- Selection is implemented in one of three ways:
  - `if` statement (single selection)
  - `if…else` statement (double selections)
  - `switch` statement (multiple selections)
- The simple `if` statement is sufficient to provide any form of selection—everything that can be done with the `if…else` and `switch` can be implemented by combining `if` statements.

Structured Programming Summary

- Repetition is implemented in one of three ways:
  - `while` statement
  - `do…while` statement
  - `for` statement
- The `while` statement is sufficient to provide any form of repetition. Everything that can be done with `do…while` and `for` can be done with the `while` statement.

Structured Programming Summary

- In essence, any form of control ever needed in a Java program can be expressed in terms of
  - sequence
  - `if` statement (selection)
  - `while` statement (repetition)

  and that these can be combined in only two ways—stacking and nesting.

A Simple Case Study: Nested Loops

- Design a Java program to find all prime numbers (质数) within a user-specified range [a, b]

Algorithm formulation:

```
Get inputs a and b from users
For each integer c in [a, b]
    if c is a prime number
        print c
```

How to check?

Prime numbers can only be divided evenly by 1 and itself

A Simple Case Study: Nested Loops

- Design a Java program to find all prime numbers (质数) within a user-specified range [a, b]

Algorithm formulation:

```
Get inputs a and b from users
For each integer c in [a, b]
    if c is a prime number
        print c
```

```
set isPrime to true
For each integer d in [2, c-1]
    if c % d is equal to 0
        set isPrime to false
        break
```

Java Code – Part 1

```
// in main method
Scanner sc = new Scanner(System.in);
System.out.print("Enter a number for a: ");
int a = sc.nextInt();
System.out.print("Enter a number for b: ");
int b= sc.nextInt();
if(a <= 1 || b < a) {
    System.out.println("Invalid range!");
    sc.close();
    return;
}
```


Java Code – Part 2

```
// a nested loop
for(int i = a; i <= b; i++) {
    boolean isPrime = true;
    for(int j = 2; j <= i - 1; j++) {
        if(i % j == 0) {
            isPrime = false;
            break;
        }
    }
    if(isPrime) {
        System.out.println(i);
    }
}
sc.close();
```

Inner loop

Outer loop

