



Chapter 4

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**

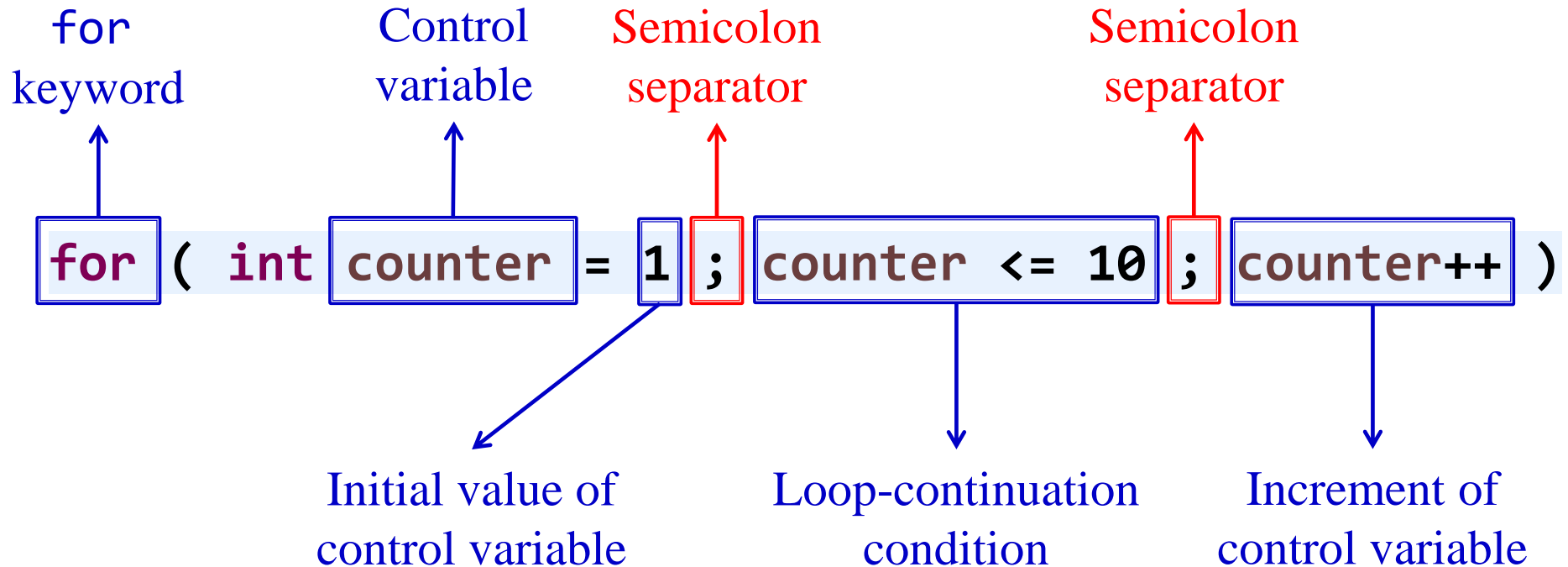
```
public class WhileCounter {  
    public static void main(String[] args) {  
        int counter = 1; → Control variable (loop counter)  
        while ( counter <= 10 ) { → Loop continuation condition  
            System.out.printf("%d", counter);  
            ++counter; → Counter increment (or decrement)  
in each iteration  
        }  
        System.out.println();  
    }  
}
```

The **for** Repetition Statement

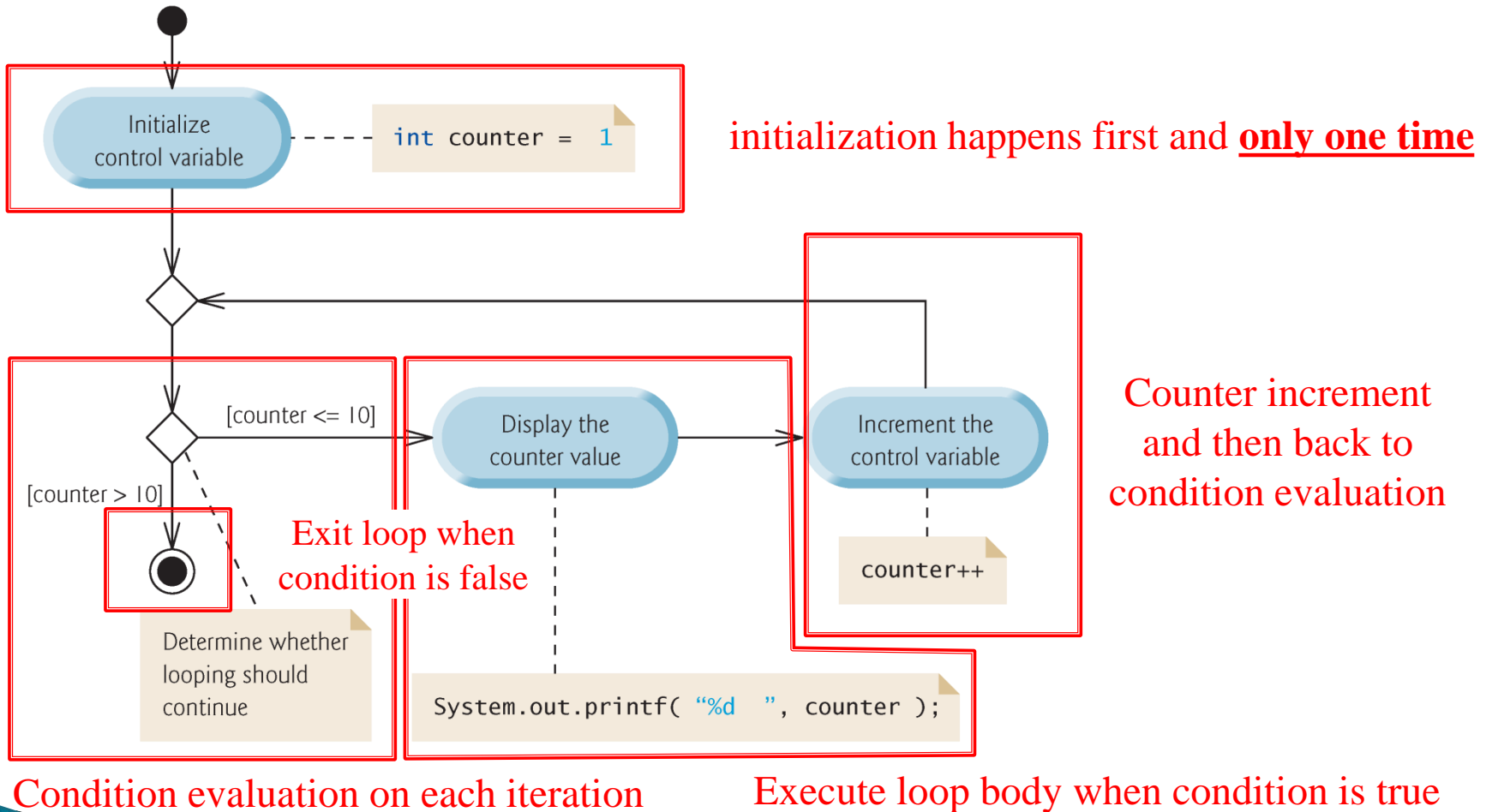
- ▶ Specifies the counter-controlled-repetition details in a single line of code

```
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



Execution Flow of for Loop



Common logic error: Off-by-one

```
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?  
}
```



Boundary Values

```
int sum = 0;
for(int i=1; i<=100; i++) {
    sum += i;
}
System.out.println(sum);
```

Example 1: Compute the sum of 1 to 100

```
char[] arr = {'a','b','c','d'};
for(int i=0; i<arr.length; i++) {
    System.out.println(arr[i]);
}
```

Example 2: Print all the elements in the array


Be careful on the boundary values!

- What if `i<100` is tested in ex. 1?
- What if `i<=arr.length` is tested in ex.2?

Boundary Values

```
char[] arr = {'a', 'b', 'c', 'd'};  
for(int i=0; i<arr.length; i++) {  
    System.out.println(arr[i]);  
}
```

Example 2: Print all the elements in the array



```
char[] arr = {'a', 'b', 'c', 'd'};  
for(char element: arr) {  
    System.out.println(element);  
}
```

Works on the basis of element instead of the index

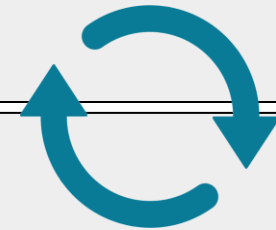
Easier way to iterate a collection

The **for** and **while** loops

- ▶ In most cases, a **for** statement can be easily represented with an equivalent **while** statement

```
for(initialization; loop-continuation condition; increment/decrement exp) {  
    statement(s);  
}
```

```
initialization;  
while(loop-continuation condition) {  
    statement(s);  
    increment/decrement exp;  
}
```



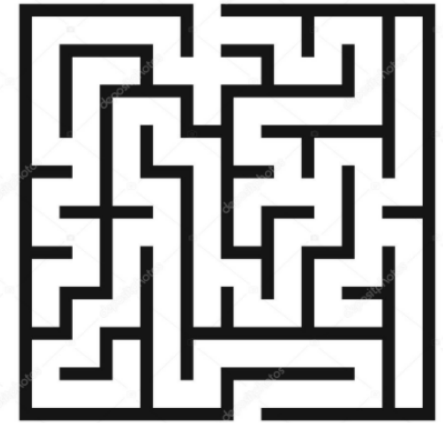


The **for** and **while** loops

- ▶ 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 : *
```



Control variable scope in **for**

- ▶ If the *initialization* expression in the for header **declares** the control variable, the control variable can be used only in that for statement.

```
int i;
```

Declaration: stating the type and name of a variable

```
i = 3;
```

Assignment (definition): storing a value in a variable.

Initialization is the first assignment.

```
for(int i = 1; i <= 10; i++) {  
    // i can only be used  
    // in the loop body  
}
```

```
int i;  
for(i = 1; i <= 10; i++) {  
    // i can be used here  
}  
// i can also be used  
// after the loop until  
// the end of the enclosing block
```

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 *increment* if the program calculates it with statements in the loop's body or no increment 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 increment 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 *increment/decrement* expressions can contain multiple expressions separated by commas.

```
for (int i = 2; i <= 20; total += i, i += 2) {  
    System.out.println(total);  
}
```

=

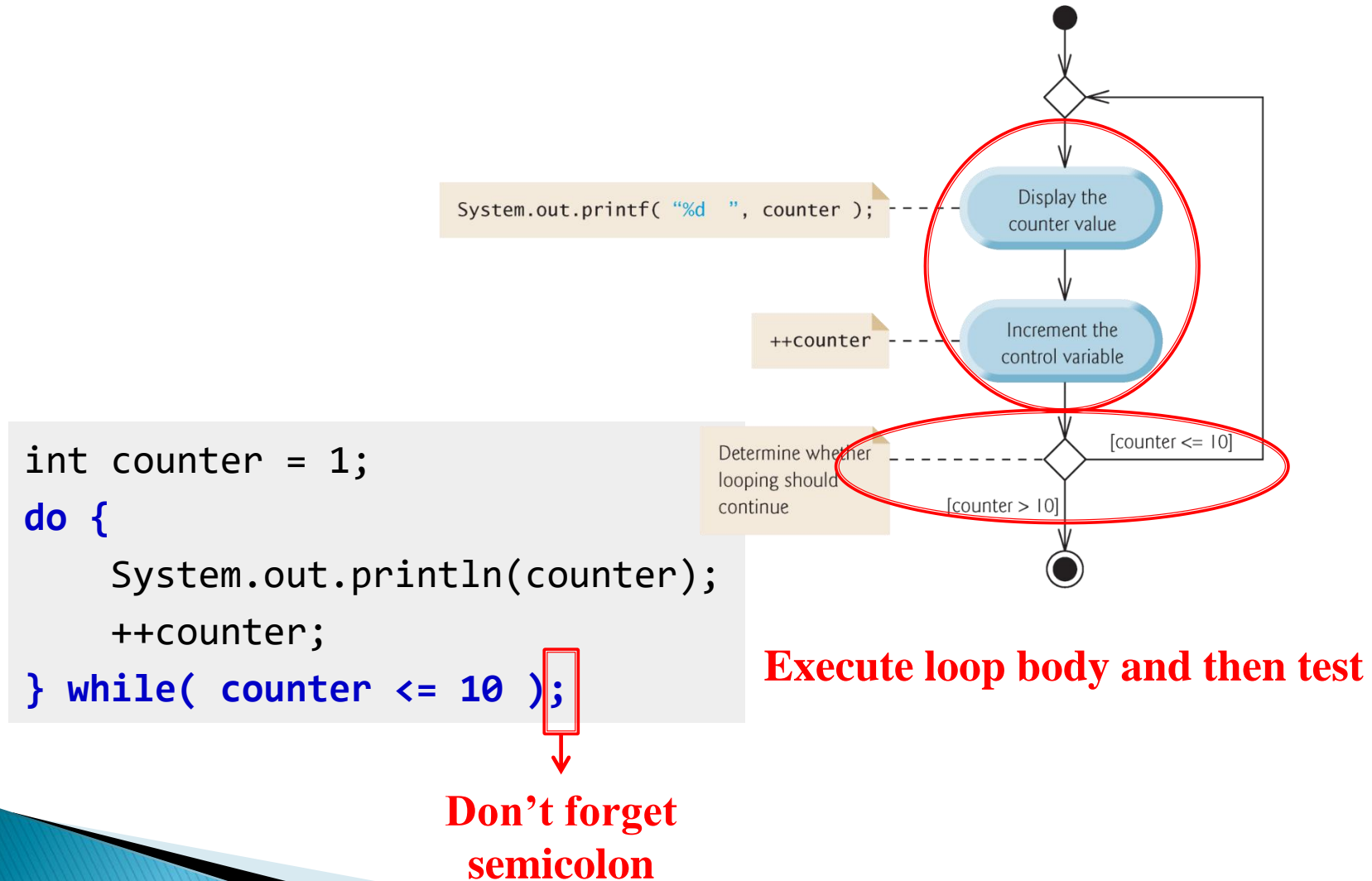
```
int total = 0;  
for (int i = 2; i <= 20; i += 2) {  
    System.out.println(total);  
    total += i; // why last line?  
}
```




The **do...while** repetition statement

- ▶ **do...while** is similar to **while**
- ▶ In **while**, the program tests the loop-continuation condition **before executing the loop body**; if the condition is false, the loop body never executes.
- ▶ **do...while** tests the loop-continuation condition **after executing the loop body**. **The loop body always executes at least once.**

Execution flow of do..while





do...while vs while

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

No output

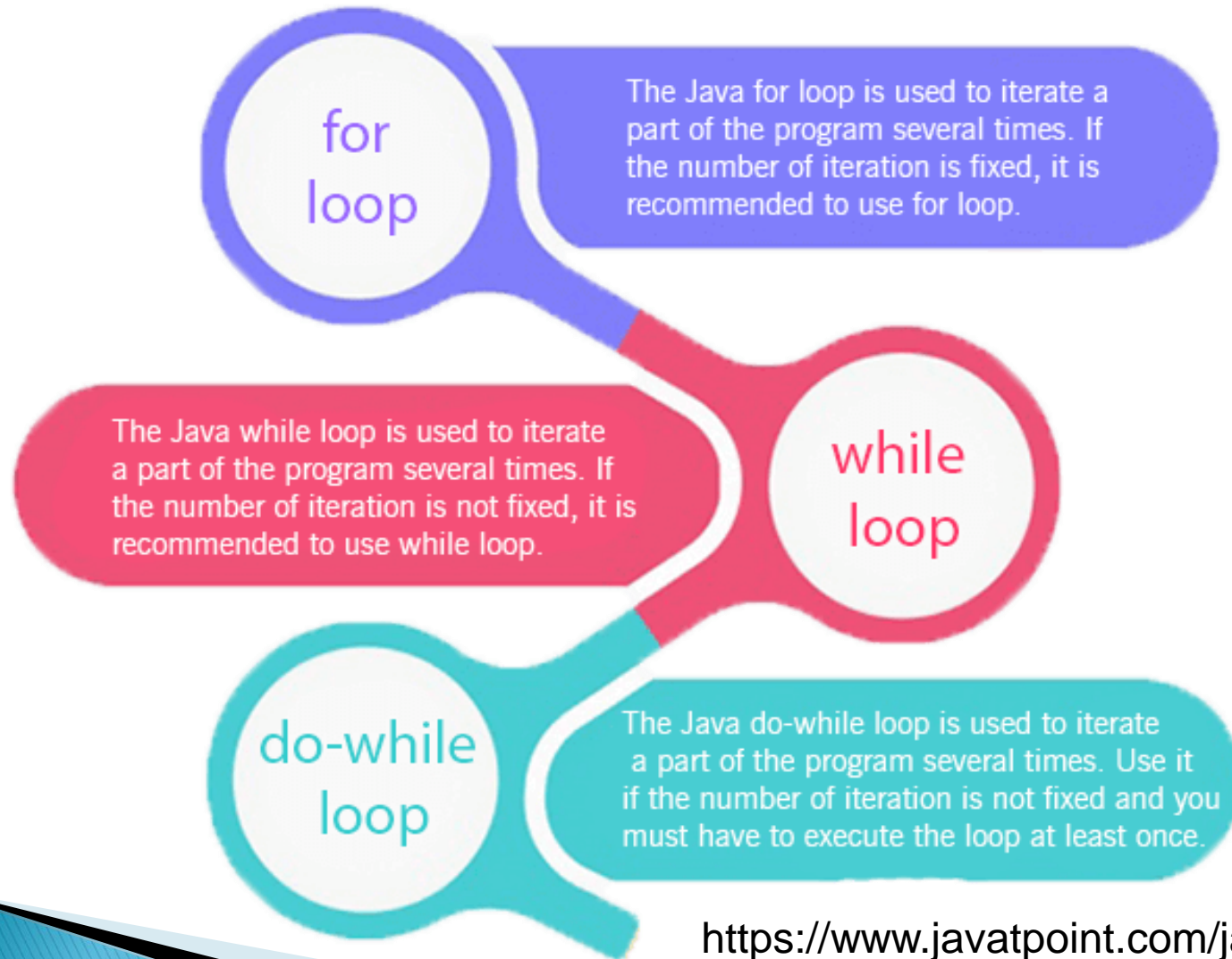
while: Condition is tested at the beginning of the loop

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

Output: num>5

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

Summary of Loops



<https://www.javatpoint.com/java-for-loop>



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");  
}
```

Letter grade



Score range

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* statement performs different actions based on the values of an **integral expression** of type byte, short, int or char etc.*
- ▶ It consists of a block that contains a sequence of **case labels** and an **optional default case**.

* Starting from Java 7, strings are also supported

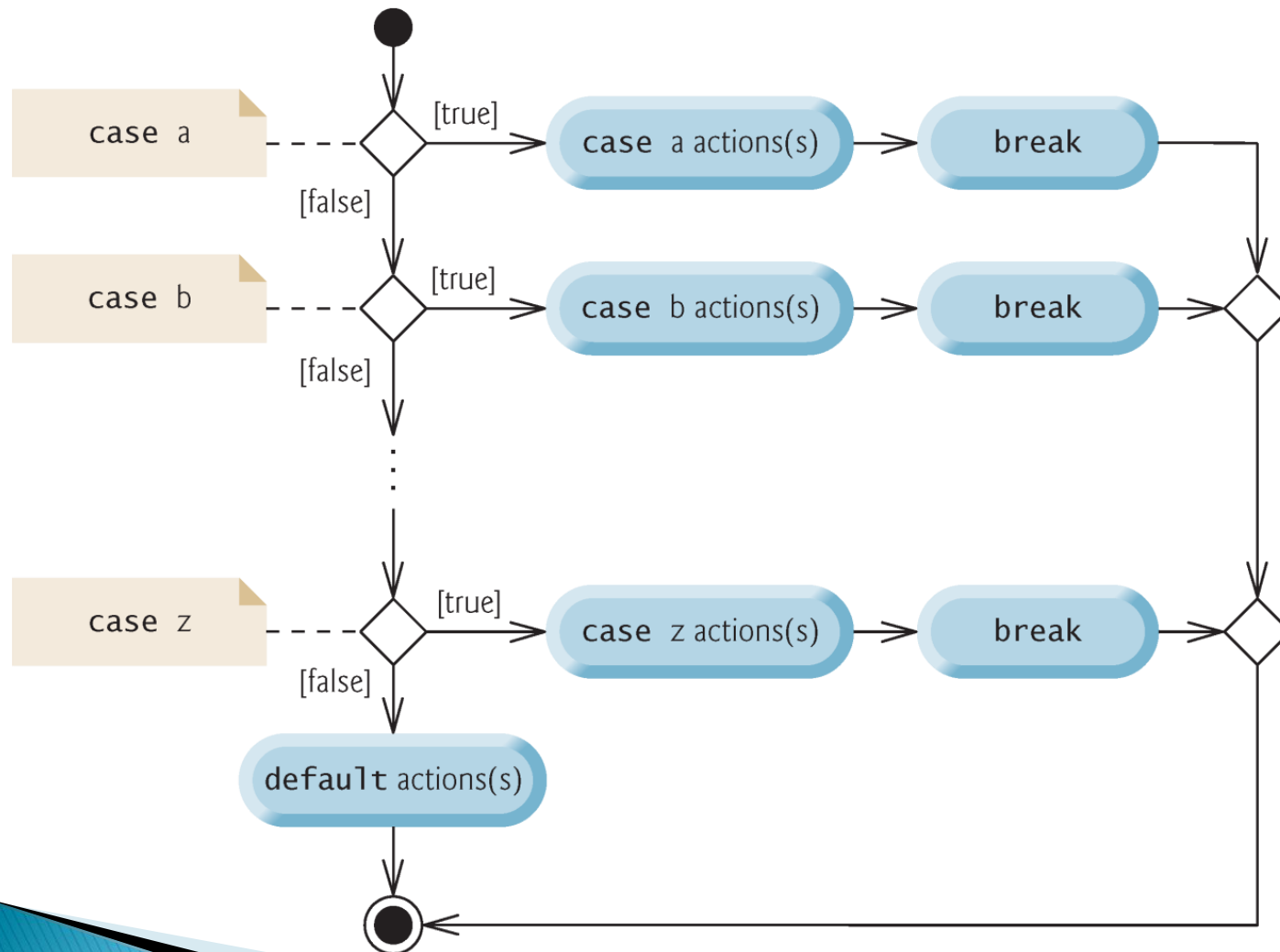
The switch Multiple-Selection Statement

controlling expression

```
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 program compares the **controlling expression**'s value with each case label.
- ▶ If a match occurs, the program executes that case's statements.
- ▶ If no match occurs, the default case executes.
- ▶ If no match occurs and there is no default case, program simply continues with the first statement after switch.

Execution flow of switch



The switch Multiple-Selection Statement

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



ERROR

- ▶ switch does not provide a mechanism for **testing ranges of values**—every value must be listed in a separate case label (`grade` is char, case label should also be char)

```
switch (grade) {  
    case 'A' : {  
        System.out.println("90 - 100");  
        break;  
    }  
    case ...:..  
}
```

- ▶ Each case can have multiple statements (braces are optional)

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");  
}
```

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");  
}
```

- **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

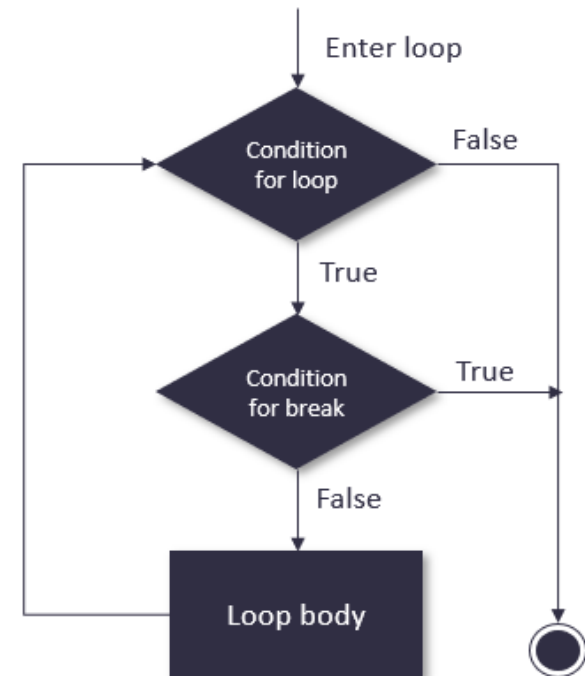


Objectives

- ▶ 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

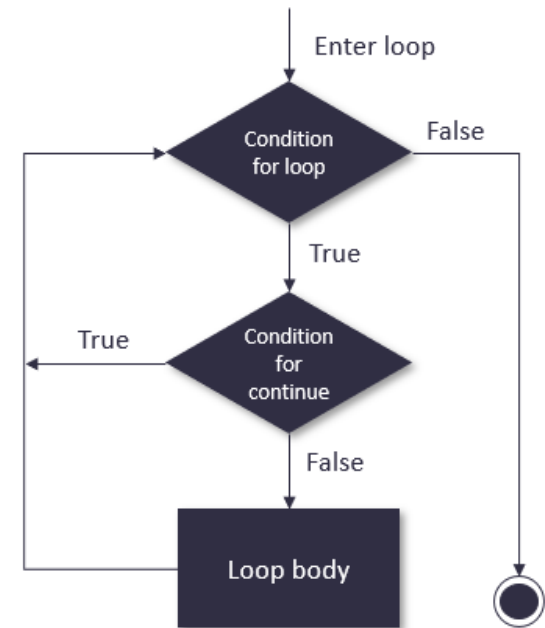
```
public class BreakTest {  
    public static void main(String[] args) {  
        int count;  
        for(count = 1; count <= 10; count++) { // loop 10 times  
            if(count == 5) {  
                break; // terminate loop if count == 5  
            }  
            System.out.printf("%d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



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

- ▶ Help form complex conditions by combining simple ones; return a boolean
 - `&&` (conditional AND)
 - `||` (conditional OR)
 - `!` (logical NOT)
 - `&` (boolean logical AND)
 - `|` (boolean logical inclusive OR)
 - `^` (boolean logical exclusive OR)
- ▶ `&`, `|` and `^` are also **bitwise operators** when applied to integral operands.

<https://www.runoob.com/java/java-operators.html>

The && (Conditional AND) Operator

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

expression1	expression2	expression1 && expression2
false	false	false
false	true	false
true	false	false
true	true	true

The `||` (Conditional OR) Operator

- ▶ `||` ensures that *either or both* of two conditions are true before choosing a certain path of execution
- ▶ Operator `&&` has a higher precedence than operator `||`
- ▶ Both operators associate from left to right

expression1	expression2	expression1 expression2
false	false	false
false	true	true
true	false	true
true	true	true

`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 == FEMALE) && (age >= 65)`

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

- ▶ `(gender == FEMALE) || (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**
- ▶ This operator evaluates both of its operands

expression1	expression2	expression1 ^ expression2
false	false	false
false	true	true
true	false	true
true	true	false

The ! (Logical Not) Operator

- ▶ ! (also known as **logical negation** or **logical complement**)

unary operator “**reverses**” the value of a condition.

expression	! expression
false	true
true	false

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

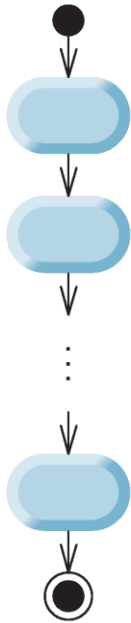


Objectives

- ▶ 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

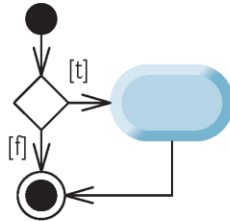
Sequence



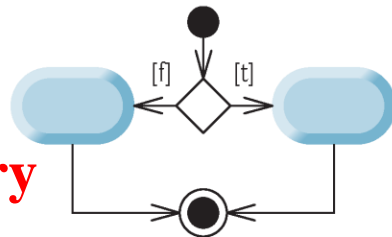
**Always single-entry
and single-exit**

Selection

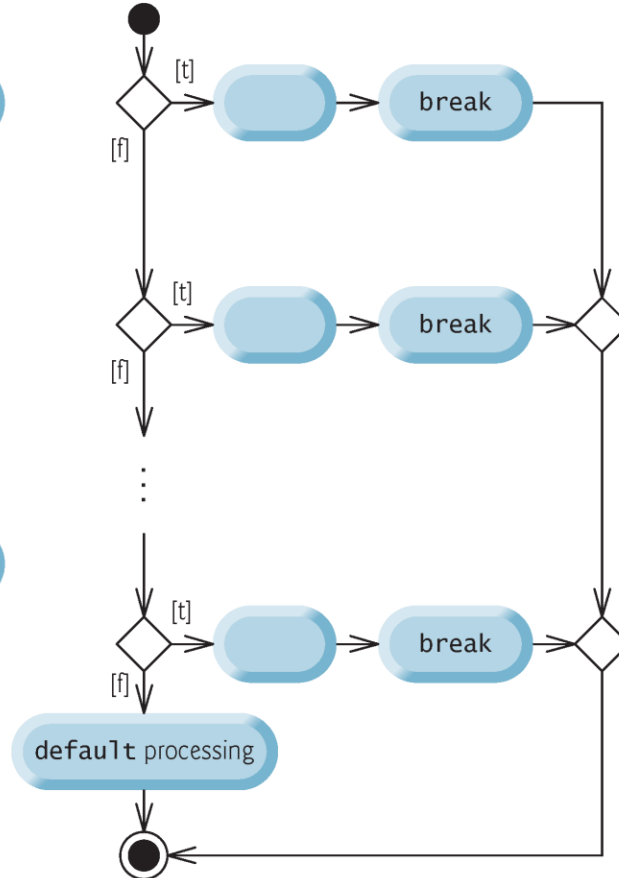
if statement
(single selection)



if...else statement
(double selection)



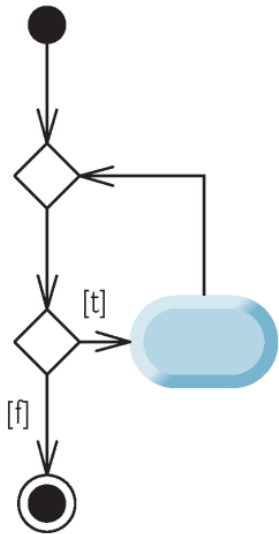
switch statement with breaks
(multiple selection)



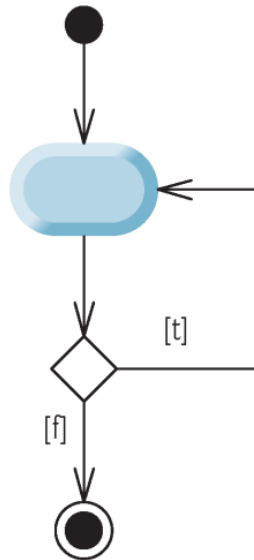
Control Structures Summary

Repetition

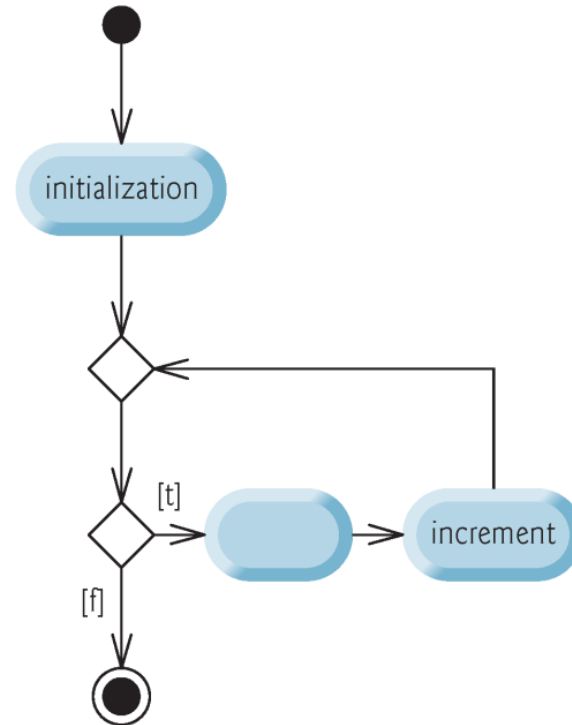
while statement



do...while statement



for statement



Structured Programming

(结构化编程)

- ▶ Make use of controls structures to produce programs with **high quality and clarity**
- ▶ In contrast to using simple jumps such as the **goto** statement

```
public static void Main()  
{
```

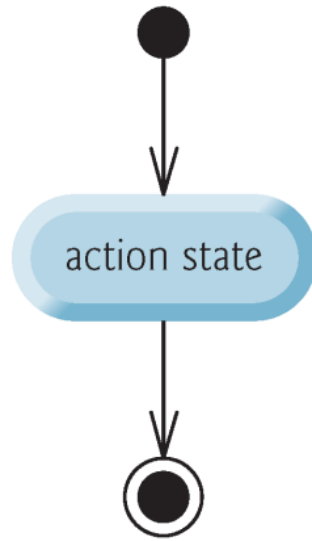
```
    labelA; ←  
    if ( ... )  
        goto labelC;  
    if ( ... )  
        goto labelB;  
  
    labelD; ←  
    if ( ... )  
        goto labelE;  
    labelC ←  
  
    labelE; ←  
  
    if ( ... )  
        goto labelA;  
    if ( ... )  
        goto labelD;  
    labelB; ←
```

```
}
```



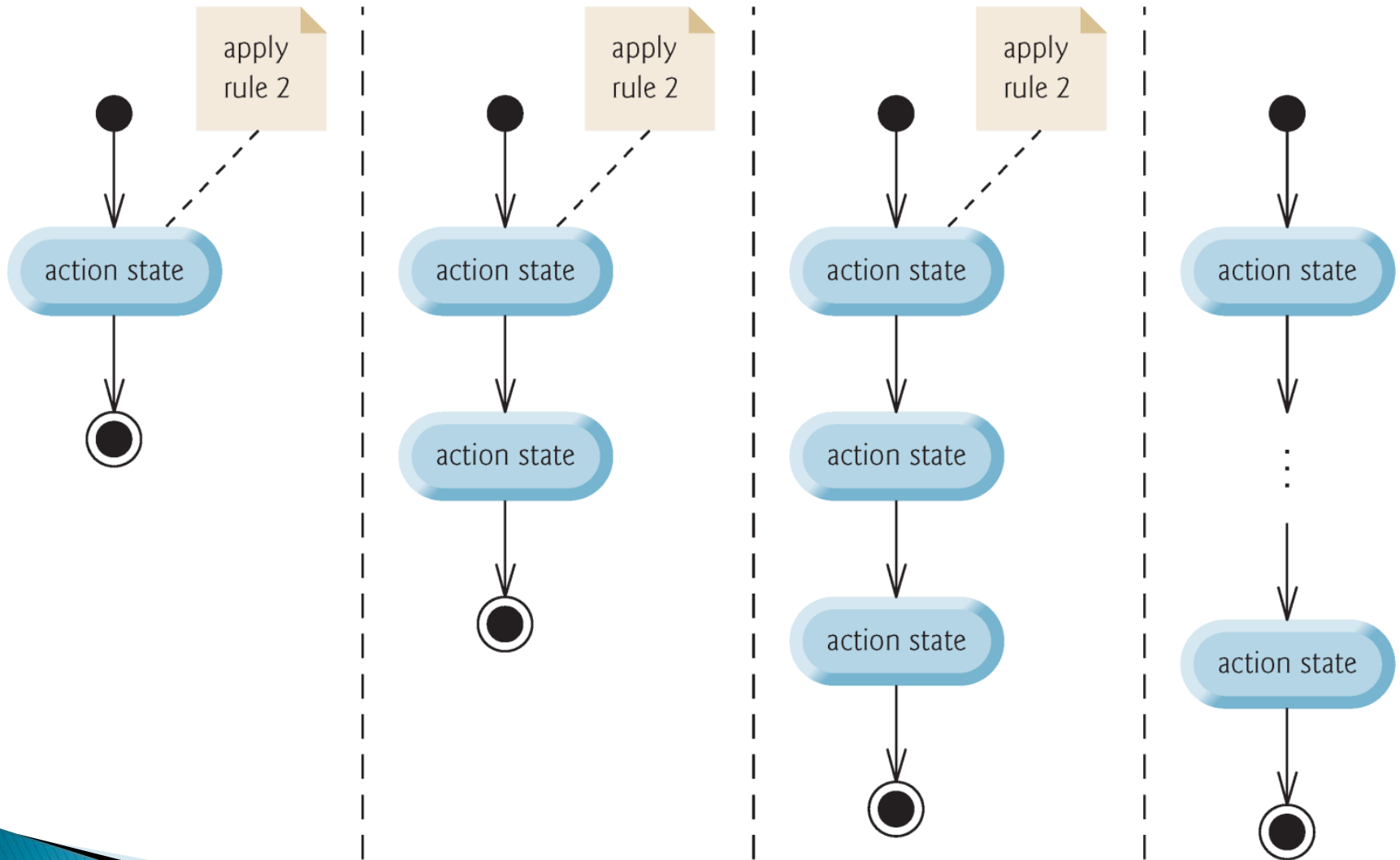
Rules for Forming Structured Programs

- ▶ 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**.

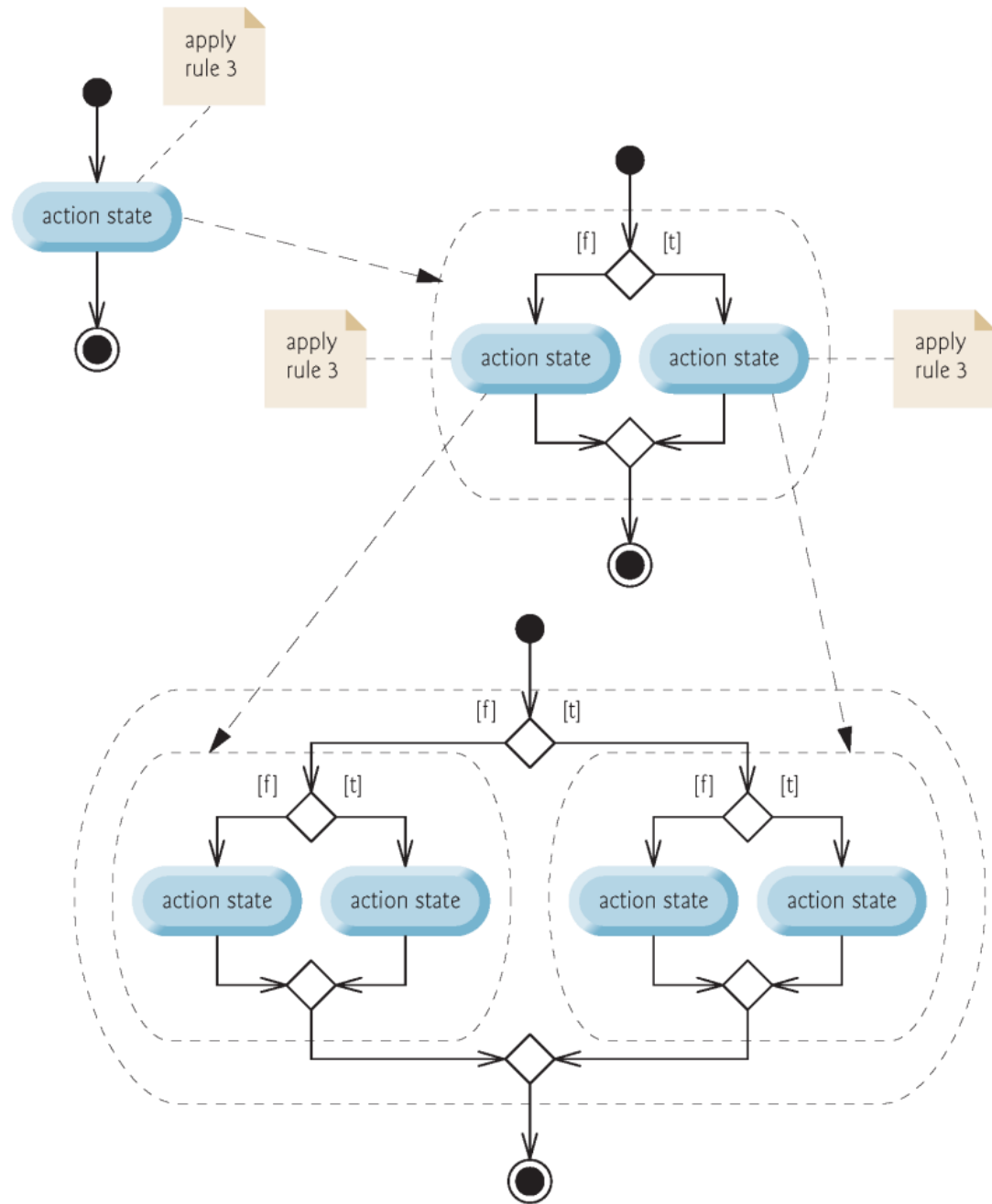


Begin with the simplest activity diagram.

Apply stacking rule



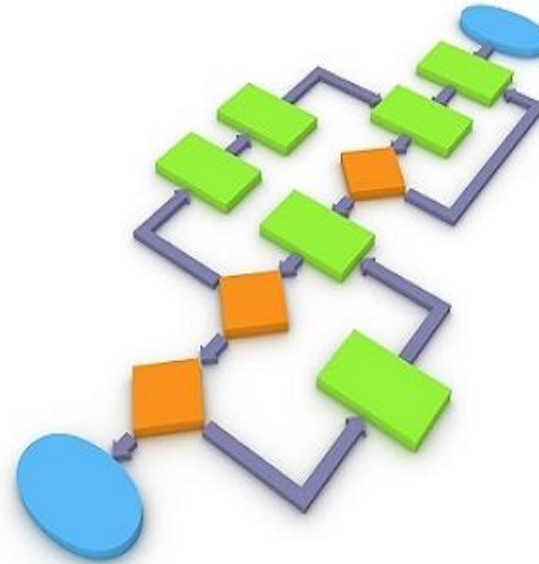
Apply nesting rule



Structured Programming Summary

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

- Sequence
- Selection
- Repetition





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