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

Counter increment (or decrement) in each iteration

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

`for` keyword

Control variable

Semicolon separator

Semicolon separator

```
for ( int counter = 1; counter <= 10; counter++ )
```

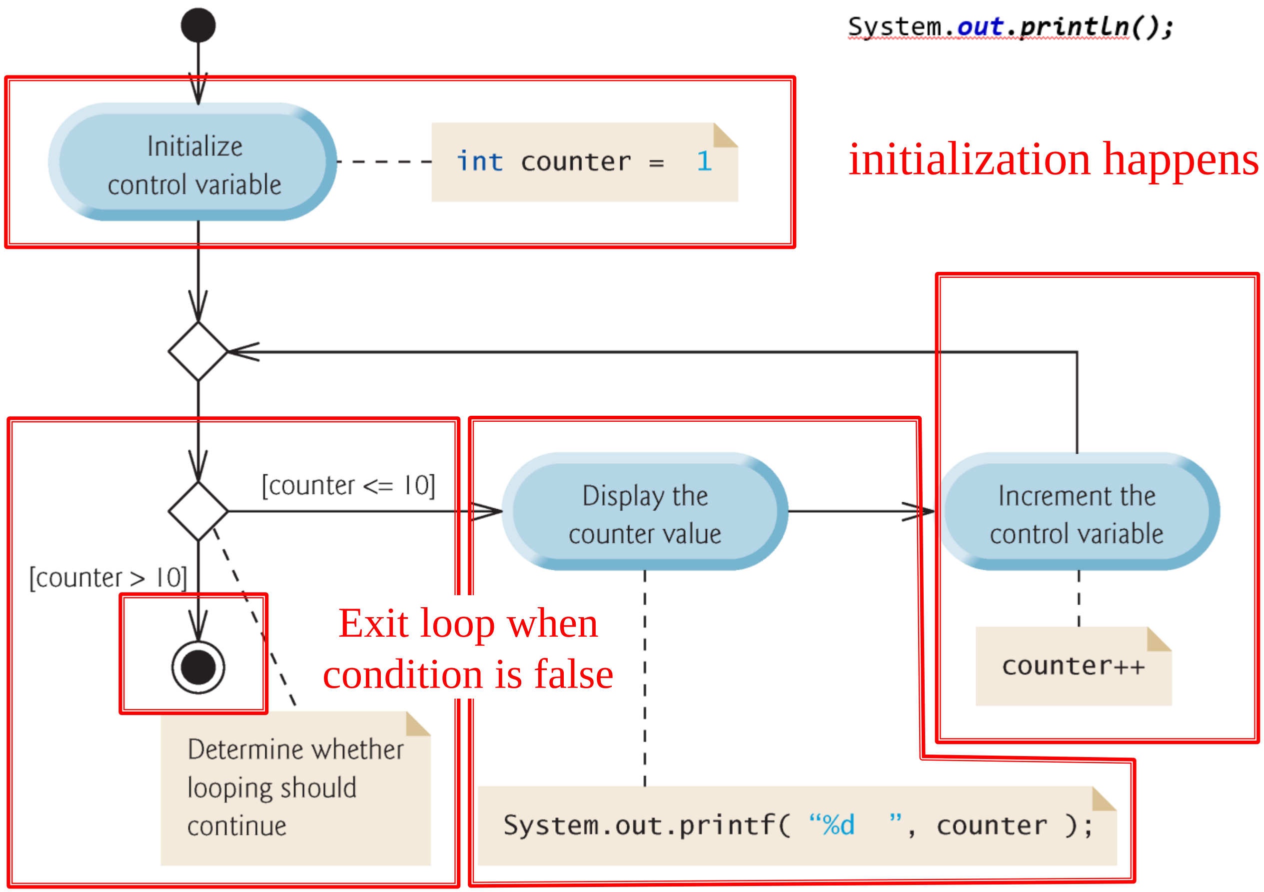
Initial value of control variable

Loop-continuation condition

Increment of control variable

Execution Flow

```
for(int counter = 1; counter <= 10; counter++) {
    System.out.printf("%d", counter);
}
System.out.println();
```



initialization happens first and **only one time**

Counter increment and then back to condition evaluation

Condition evaluation on each iteration

Execute loop body when condition is true

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;
}
```

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?
}
```

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);
}
```

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

- 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.

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

=

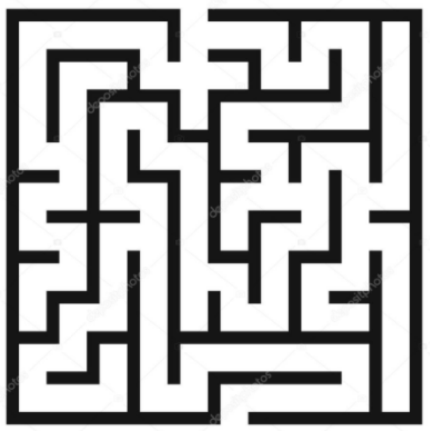
```java
int total = 0, i = 2;
while (i <= 10) {
    System.out.println(total);
    total += i;
    i += 2;
}
```


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 :  *
```



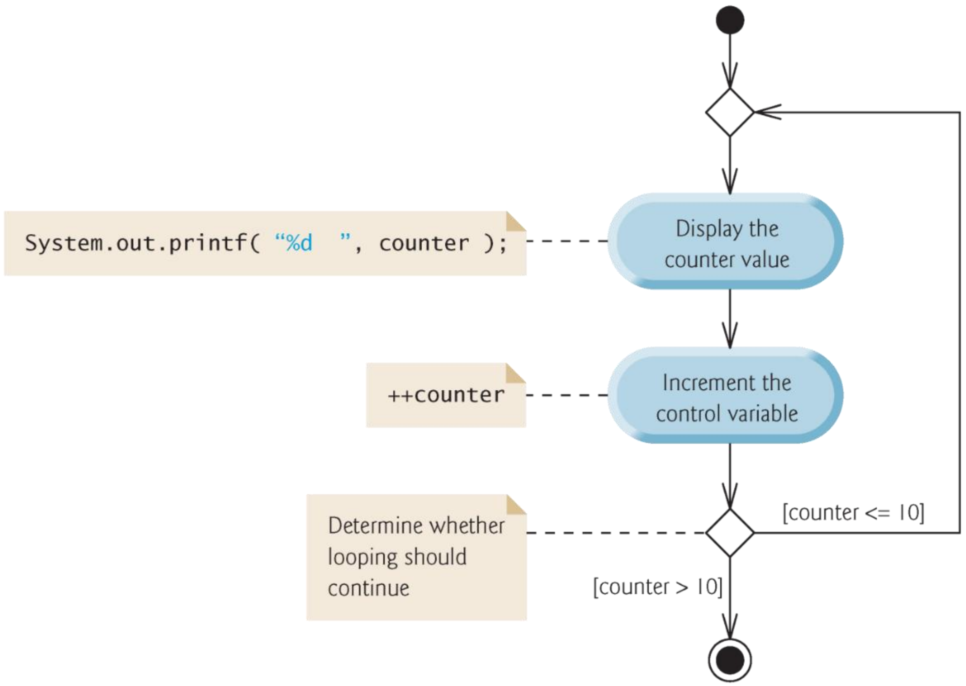
The `do…while` repetition statement

- `do…while` is similar to `while`
- 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

```
int counter = 1;
do {
    System.out.println(counter);
    ++counter;
} while( counter <= 10 );
```

Don't forget semicolon



Execute loop body and then test condition

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

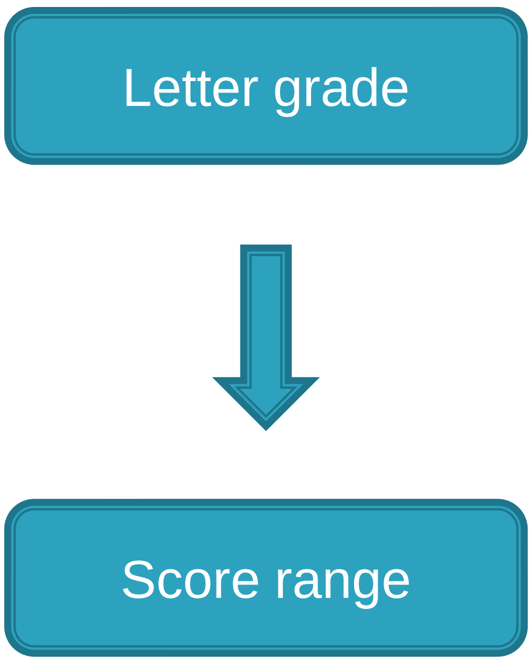
`do…while`: Condition is tested at the end of the loop; body will be executed at least once

Objectives

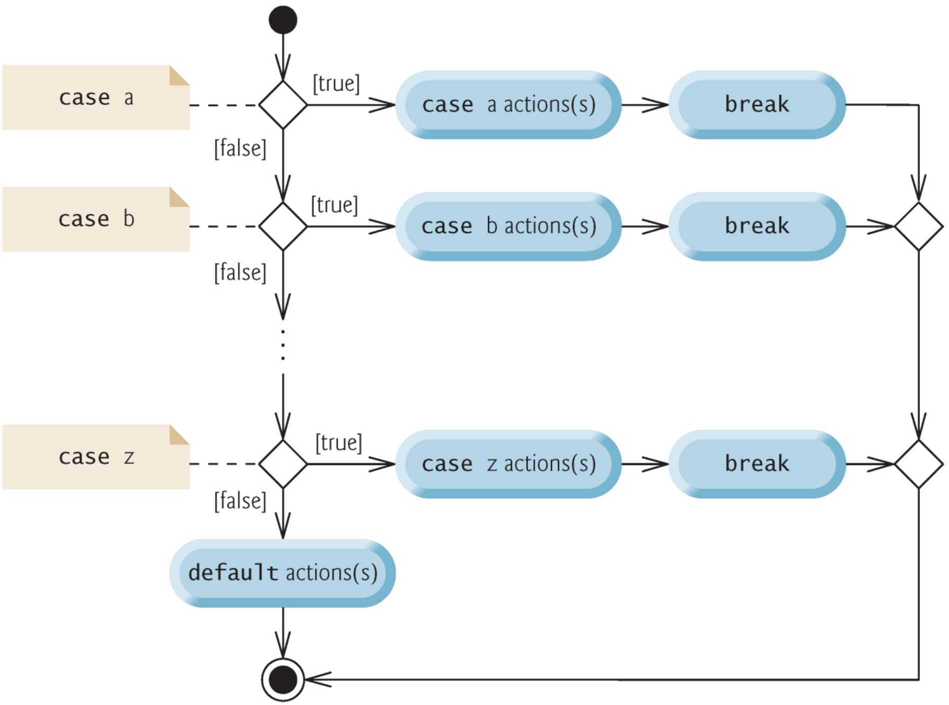
- To use `for` and `do…while` statements
- To use `switch` statement
- To use `continue` and `break` statements
- To use logical operators
- Structured programming

Recall the `if…else` statement

```java
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" );
```

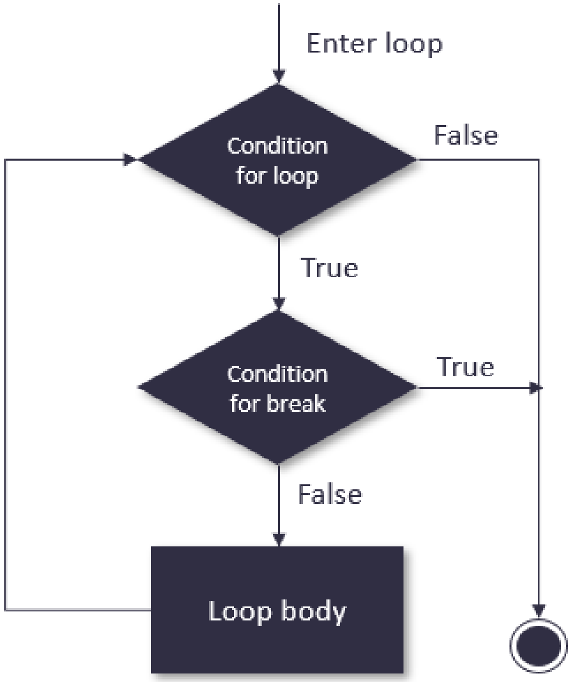
```
switch (studentGrade) {
    case 'A':
        System.out.println("90 - 100");
        break;
    case 'B':
        System.out.println("80 - 89");
        break;
    case 'C':
        System.out.println("70 - 79");
        break;
    case 'D':
        System.out.println("60 - 69");
        break;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

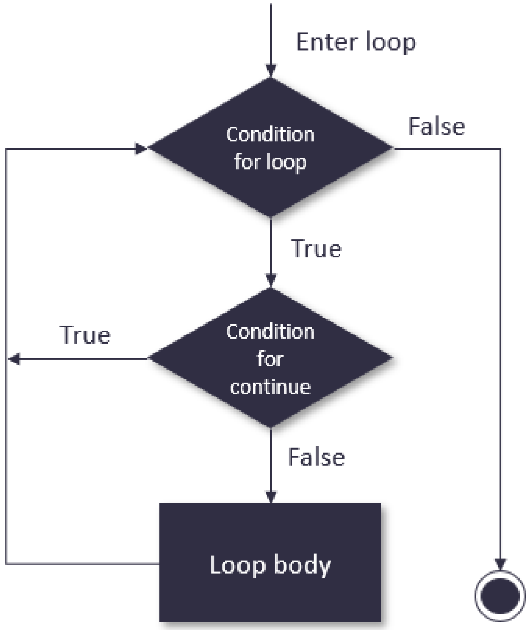
```java
public class BreakTest {
    public static void main(String[] args) {
        int count;
        for(count = 1; count <= 10; count++) { // loop 10 times
            if(count == 5) {
                break; // terminate loop if count == 5
            }
            System.out.printf("%d ", count);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

        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

```java
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

- 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 ||

p1	p2	p1 || p2	*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

$\boxed{\texttt{a \&\& b}}$ `|| c`

Evaluate first (precedence)

$\boxed{\texttt{a || b}}$ `|| 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.

- $\boxed{\texttt{(gender == FEMALE)}}$ `&& ( age >= 65 )`

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

- $\boxed{\texttt{(gender == FEMALE)}}$ `|| ( 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. |

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

Prints 0

```java
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 ^

p1	p2	p1 ^ p2	*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 OR Operation of 5 and 7
  0101
| 0111
 ________
  0111  = 7 (In decimal)
```

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

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

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

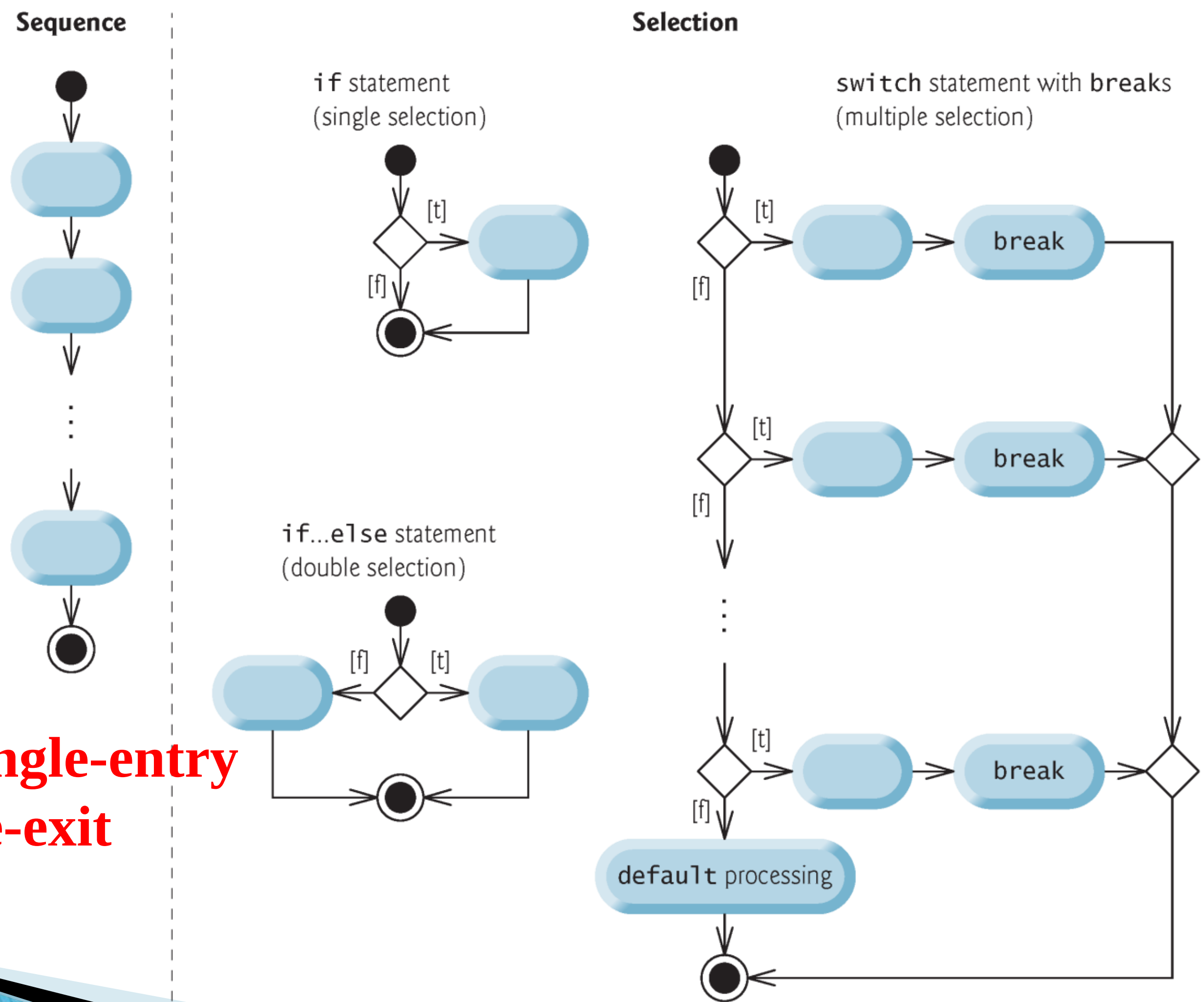
- The operators in expressions are evaluated in the order determined by the rules of parentheses, operator precedence, and operator associativity.
- Parentheses can be used to force the order of evaluation to occur in any sequence.
- Operators with higher precedence are evaluated earlier. For operators 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

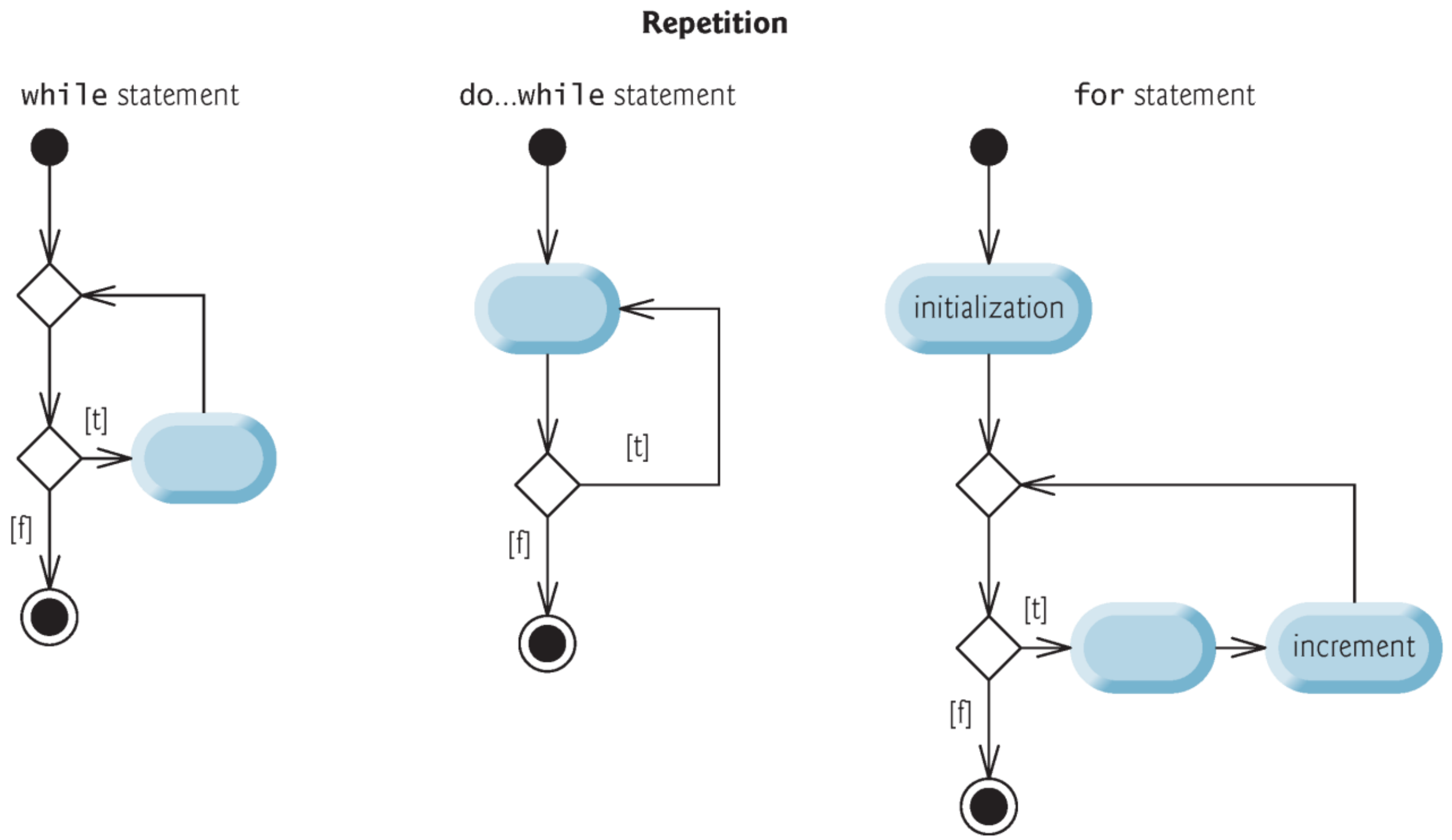
- To use `for` and `do…while` statements
- To use `switch` statement
- To use `continue` and `break` statements
- To use logical operators (逻辑运算符)
- Structured programming

Control Structures Summary



Always single-entry and single-exit

Control Structures Summary

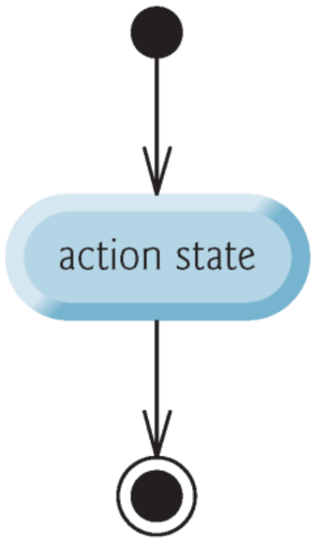


Structured Programming Summary

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

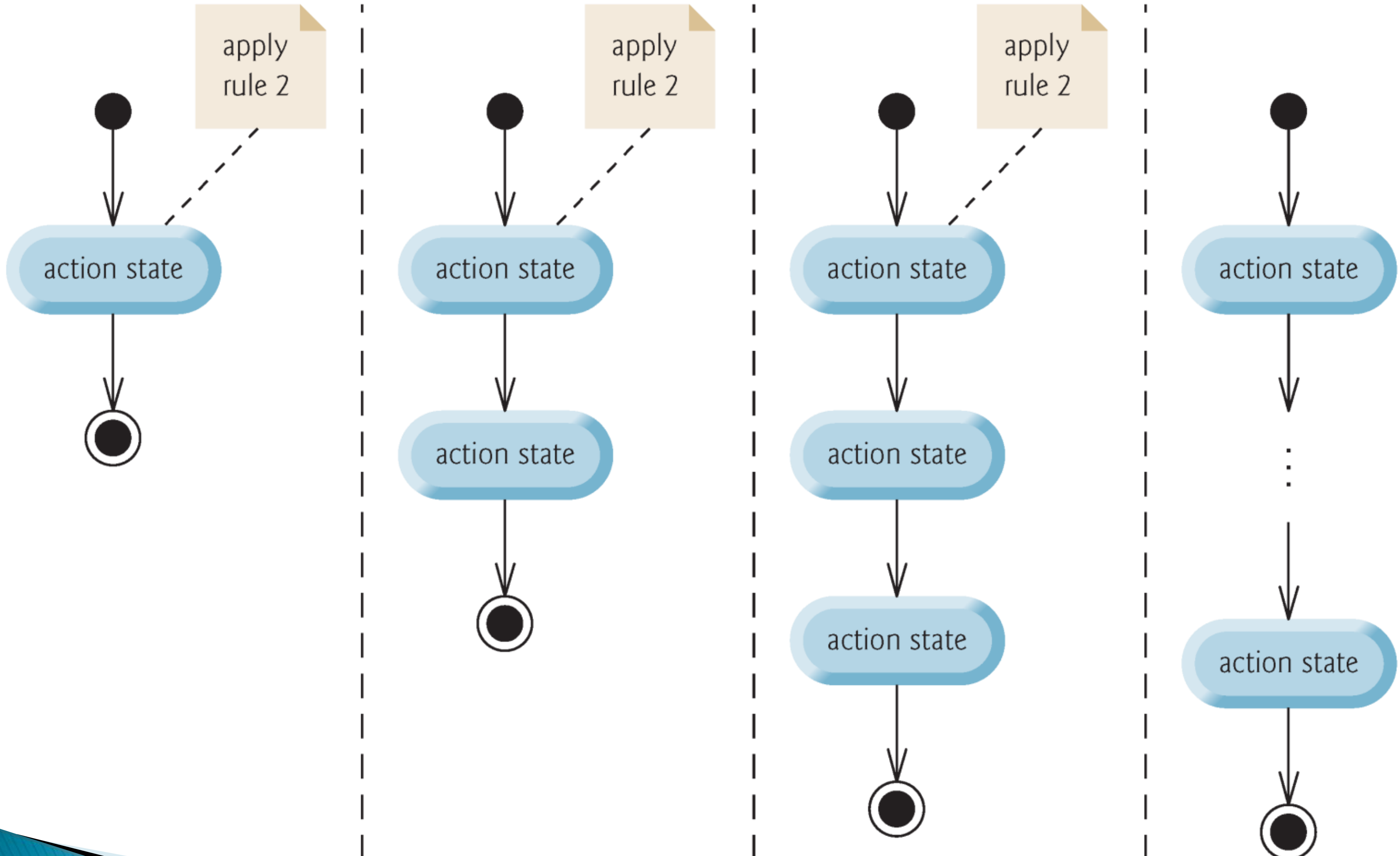
Rules for Forming Structured Programs

- 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.

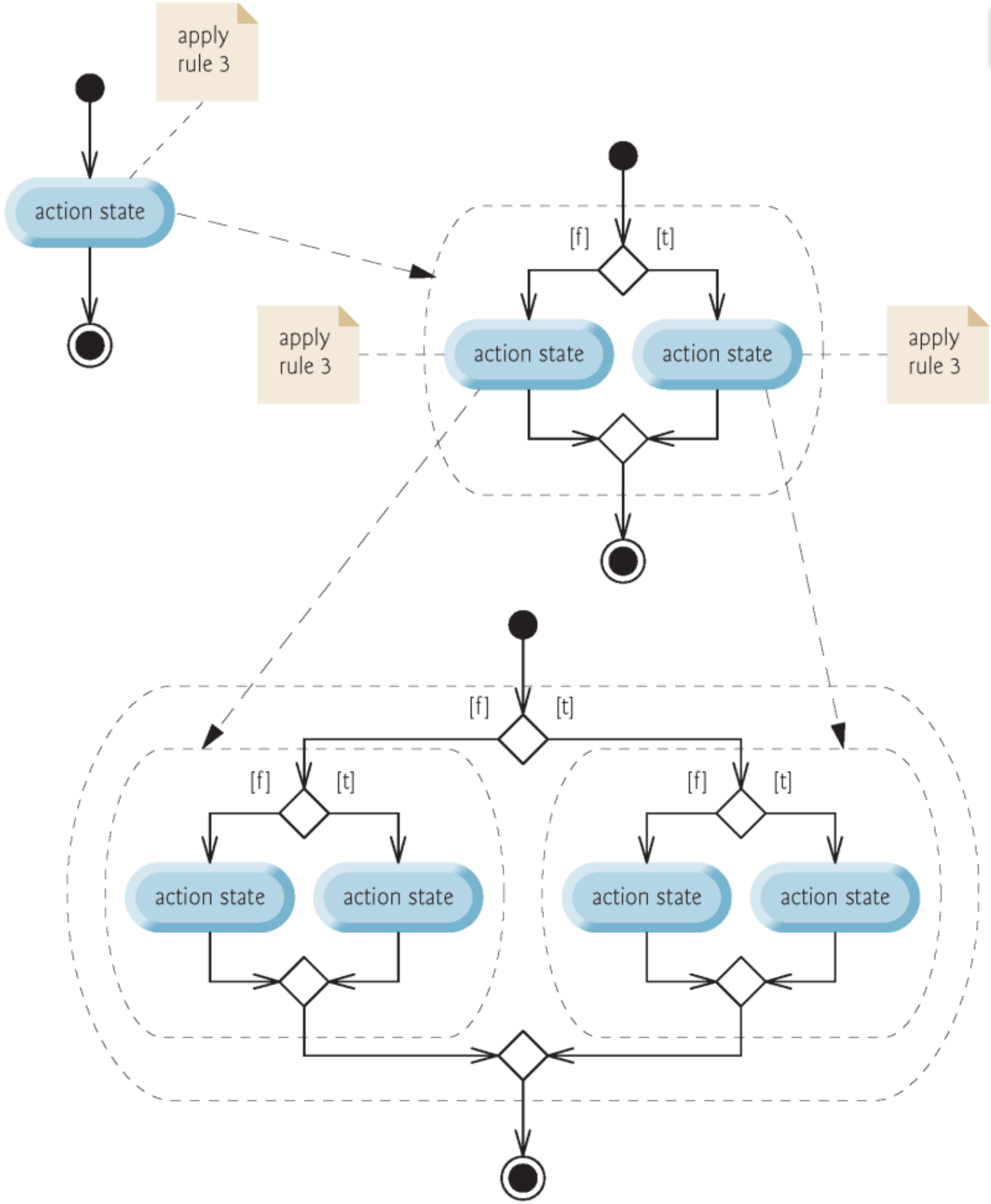


Begin with the simplest activity diagram.

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;
        }
    }                                   Inner loop
    if(isPrime) {
        System.out.println(i);
    }
}                                            Outer loop
sc.close();
```

