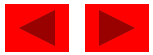
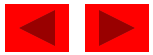
Chapter 4 – C Program Control

Outline



Objectives

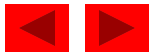
- In this chapter, you will learn:
  - To be able to use the **`for`** and **`do…while`** repetition statements.
  - To understand multiple selection using the **`switch`** selection statement.
  - To be able to use the **`break`** and **`continue`** program control statements
  - To be able to use the logical operators (**`&&`** , **`||`** , **`!`**)



4.1 Introduction

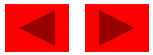
- We have learned
  - Selection structures (選擇): `if, if . . . else`
  - Repetition structures (迴圈): `while`
- This chapter introduces
  - Additional repetition control structures
    - `for`
    - `do...while`
  - `switch` multiple selection statement
  - `break` statement

    Used for exiting immediately and rapidly from certain selection and repetition structures
  - `continue` statement
    - Used for skipping the remainder of the body of a repetition structure and proceeding with the next iteration of the loop
  - logical operators (`&&` , `||` , `!`)



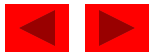
4.2 The Essentials of Repetition

- Loop
  - Group of instructions computer executes repeatedly while some condition remains `true`
- Counter-controlled repetition
  - ***Definite repetition***: know how many times loop will execute
  - Control variable used to count repetitions
- Sentinel-controlled repetition
  - ***Indefinite repetition***
  - Used when number of repetitions not known
  - Sentinel value indicates "end of data"



4.3 Essentials of Counter-Controlled Repetition

- Counter-controlled repetition requires
  - The *name* of a control variable (or loop counter)
  - The *initial value* of the control variable
  - An *increment* (or *decrement*) by which the control variable is modified each time through the loop
  - A *condition* that tests for the final value of the control variable (i.e., whether looping should continue)



4.3 Essentials of Counter-Controlled Repetition

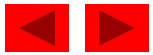
- Example:

```
int counter = 1;           // initialization
while ( counter <= 10 ) { // repetition condition
   printf( "%d\n", counter );
   ++counter;              // increment
}
```

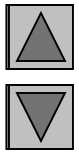
  - The statement

```
int counter = 1;
```

    - Names `counter`
    - Defines it to be an integer
    - Reserves space for it in memory
    - Sets it to an initial value of `1`



Counter-Control Repetition



Outline

```
1  /* Fig. 4.1: fig04_01.c
2     Counter-controlled repetition */
3  #include <stdio.h>
4
5  /* function main begins program execution */
6  int main()
7  {
8     int counter = 1;              /* initialization */
9
10    while ( counter <= 10 ) {      /* repetition condition */
11       printf ( "%d\n", counter ); /* display counter */
12       ++counter;                  /* increment */
13    } /* end while */
14
15    return 0; /* indicate program ended successfully */
16
17 } /* end function main */
```

fig04_01.c

```
1
2
3
4
5
6
7
8
9
10
```

Program Output

4.3 Essentials of Counter-Controlled Repetition

- Condensed code
  - C Programmers would make the program more concise
  - Initialize **`counter`** to **`0`**

```
counter = 0;

while ( ++counter <= 10 )
   printf( "%d\n, counter );
```

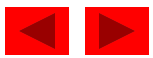
此處 counter 先加 1，再判斷是否 <= 10

請問迴圈會做幾次？

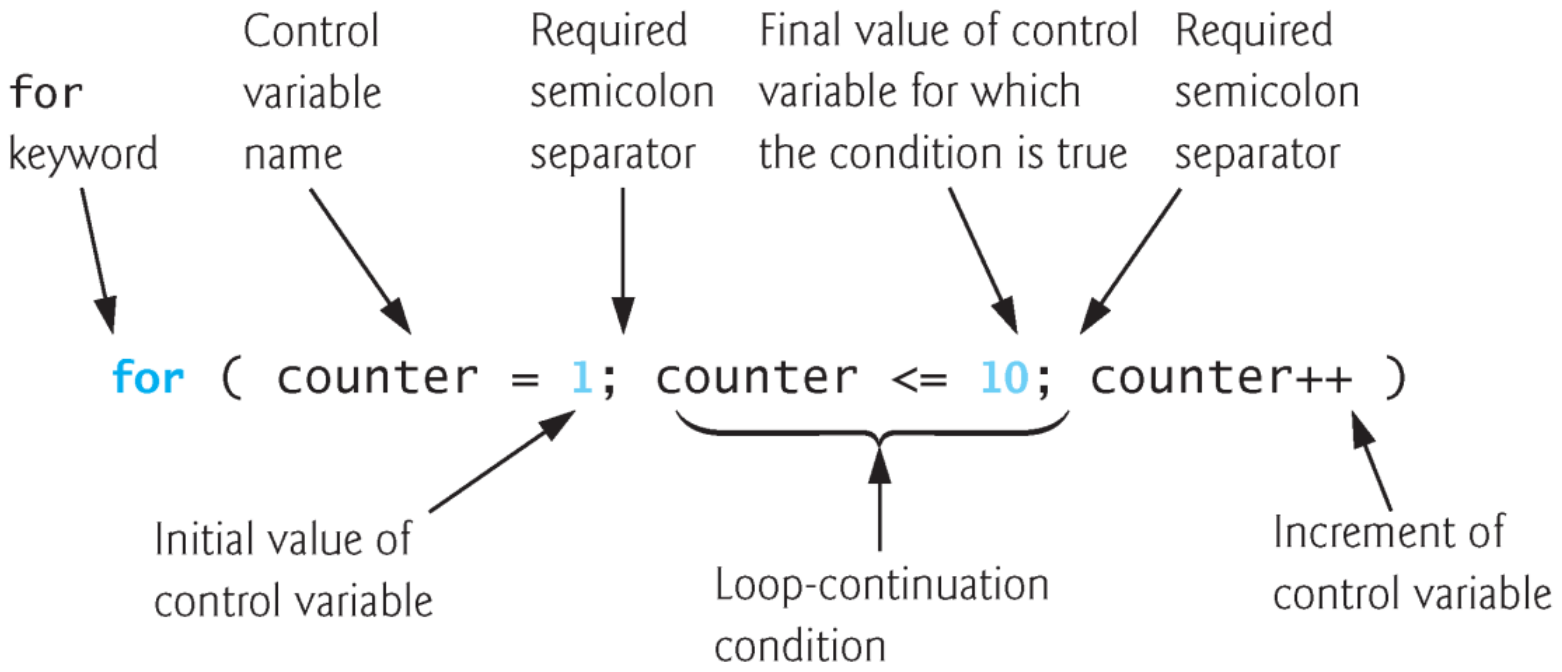
如果改成

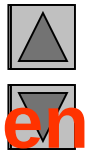
```
while ( counter++ <=  10 )
printf( "%d\n", counter );
```

會做幾次？



4.4 The `for` Repetition Statement



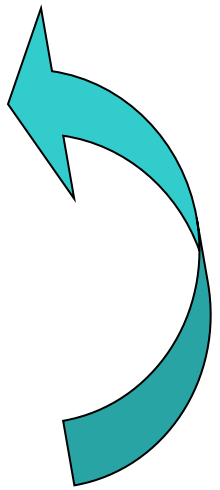


Outline

4.4 The `for` Repetition Statement

Rewrite the program on the lower-right corner with **`for`** repetition statement

```
1  /* Fig. 4.2: fig04_02.c
2     Counter-controlled repetition with the for statement */
3  #include <stdio.h>
4
5  /* function main begins program execution */
6  int main()
7  {
8     int counter; /* define counter */
9
10    /* initialization, repetition condition, and increment
11       are all included in the for statement header. */
12    for ( counter = 1; counter <= 10; counter++ ) {
13       printf( "%d\n", counter );
14    } /* end for */
15
16    return 0; /* indicate program ended successfully */
17
18 } /* end function main */
```



```
8     int counter = 1;                /* initialization */
9
10    while ( counter <= 10 ) {       /* repetition condition */
11       printf ( "%d\n", counter ); /* display counter */
12       ++counter;                  /* increment */
13    } /* end while */
```

4.4 The `for` Repetition Statement

- Format when using `for` loops

  `for` (*initialization*; *loopContinuationTest*; *increment*)
    statement

- **`for`** loops can usually be rewritten as **`while`** loops:

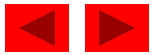
  initialization;
  `while` (*loopContinuationTest*) **`{`**
    statement;
    increment;
  `}`

- Example:

```
for( counter = 1; counter <= 10; counter++ )
   printf( "%d\n", counter );
```

  – Prints the integers from **one** to **ten**

No semicolon (;) after last expression



4.4 The `for` Repetition Statement

- Initialization and increment
  - Can be ***comma-separated lists***
  - Example:

```
for ( i = 0, j = 0;  j + i <= 10; j++, i++ )
   printf( "%d\n", j + i );
```

- Increment Expression（以下四種都可用）

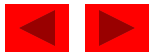
```
counter = counter + 1
counter += 1
++counter
counter++          /* preferred */
```

- Arithmetic expressions
  - Initialization, loop-continuation test, and increment can contain arithmetic expressions. If x = 2 and y = 10

```
for ( j = x; j <= 4 * x * y; j += y / x )
```

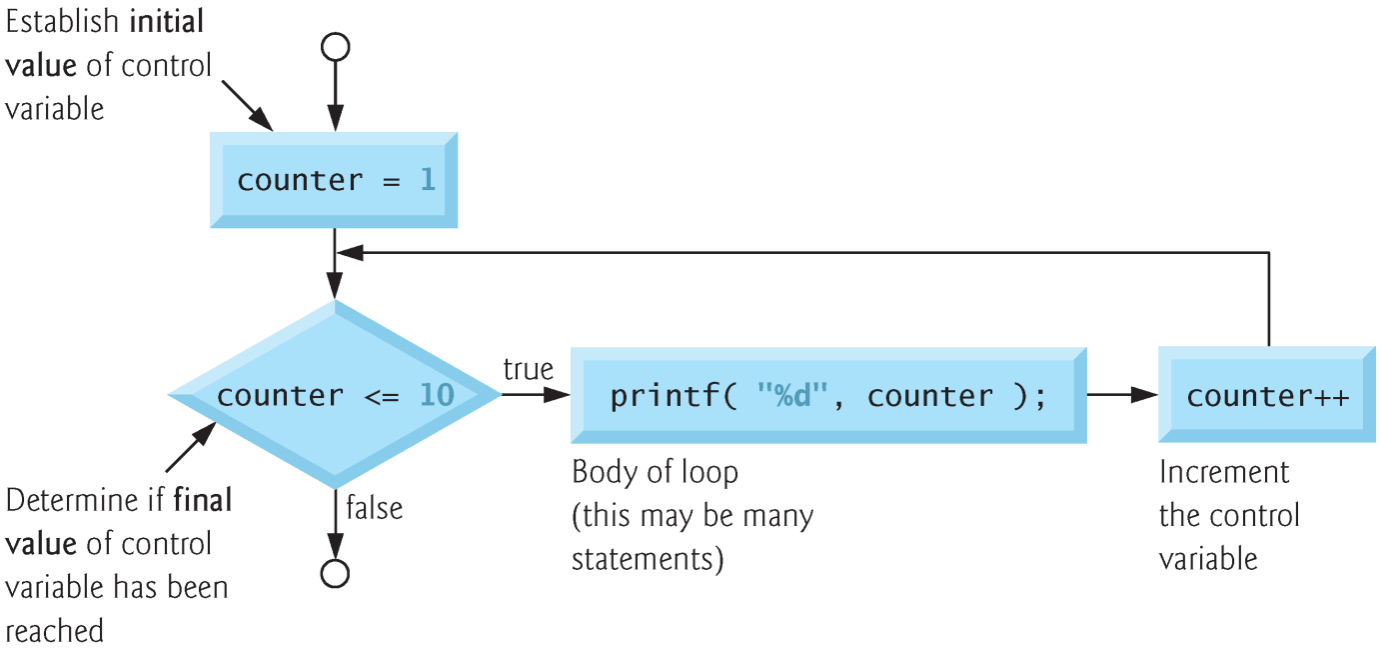
  is equivalent to

```
for ( j = 2; j <= 80; j += 5 )
```

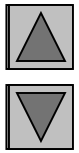



4.5 The `for` Statement : Notes and Observations

- Notes about the `for` statement:
  - "Increment" may be negative (decrement)
  - If the loop continuation condition is initially `false`
    - The body of the `for` statement is not performed
    - Control proceeds with the next statement after the `for` statement
  - Control variable
    - Often printed or used inside for body, but not necessary



Using `for` to Sum Numbers



Outline

fig04_05.c

```
1  /* Fig. 4.5: fig04_05.c
2     Summation with for */
3  #include <stdio.h>
4
5  /* function main begins program execution */
6  int main()
7  {
8     int sum = 0; /* initialize sum */
9     int number;  /* number to be added to sum */
10
11    for ( number = 2; number <= 100; number += 2 ) {
12       sum += number; /* add number to sum */
13    } /* end for */
14
15    printf( "Sum is %d\n", sum ); /* output sum */
16
17    return 0; /* indicate program ended successfully */
18
19 } /* end function main */
```

```
Sum is 2550
```

$$2 + 4 + 6 + 8 + \ldots \quad 100 = 2550$$

4.6 Example: Computing Compound Interest

A person invests $1000.00 in a savings account yielding 5% interest per year. Assuming that all interest is left on deposit in the account, calculate and print the amount of money in the account at the end of each year for 10 years. Use the following formula for determining these amounts:

$$a = p (1 + r)^n$$

where

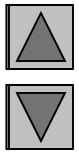
p is the principal (本金)

r is the interest rate (利率)

n is the number of years

a is the 本利和 (deposit)

Calculating Compound Interest with `for`



Outline

fig04_06.c (Part 1 of 2)

```
1  /* Fig. 4.6: fig04_06.c
2     Calculating compound interest */
3  #include <stdio.h>
4  #include <math.h>
5
6  /* function main begins program execution */
7  int main()
8  {
9     double amount;              /* amount on deposit */
10    double principal = 1000.0; /* starting principal */
11    double rate = .05;          /* interest rate */
12    int year;                   /* year counter */
13
14    /* output table column head */
15    printf( "%4s%21s\n", "Year", "Amount on deposit" );
16
17    /* calculate amount on deposit for each of ten years */
18    for ( year = 1; year <= 10; year++ ) {
19
20       /* calculate new amount for specified year */
21       amount = principal * pow( 1.0 + rate, year );
22
23       /* output one table row */
24       printf( "%4d%21.2f\n", year, amount );
25    } /* end for */
26
```

如果程式中用到數學函數時，必須引入 **math.h** 標頭檔

```
%d:  integers
%f:  floating-point values
%s:  strings (字串)
```

`%4s%21s` in the printf, same as `printf("Year    Amount on deposit\n");`

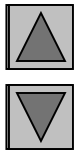
pow(x,y) calculates x^y where x and y are double

Need **#include <math.h>**

%4d%21.2f in the printf

```
27    return 0; /* indicate program ended successfully */
28
29 } /* end function main */
```

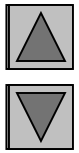
```
Year    Amount on deposit
   1              1050.00
   2              1102.50
   3              1157.63
   4              1215.51
   5              1276.28
   6              1340.10
   7              1407.10
   8              1477.46
   9              1551.33
  10              1628.89
```



Outline

fig04_06.c (Part 2 of 2)

Program Output



Outline

5.3 Math Library Functions

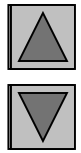
Function	Description	Example
`sqrt( x )`	square root of x	`sqrt( 900.0 )` is `30.0` `sqrt( 9.0 )` is `3.0`
`exp( x )`	exponential function e^x	`exp( 1.0 )` is `2.718282` `exp( 2.0 )` is `7.389056`
`log( x )`	natural logarithm of x (base e)	`log( 2.718282 )` is `1.0` `log( 7.389056 )` is `2.0`

`log10( x )`	logarithm of x (base 10)	`log10( 1.0 )` is `0.0`
		`log10( 10.0 )` is `1.0`
		`log10( 100.0 )` is `2.0`

`fabs( x )`	absolute value of x	`fabs( 13.5 )` is `13.5`
		`fabs( 0.0 )` is `0.0`
		`fabs( -13.5 )` is `13.5`

`ceil( x )`	rounds x to the smallest integer not less than x	`ceil( 9.2 )` is `10.0` `ceil( -9.8 )` is `-9.0`
`floor( x )`	rounds x to the largest integer not greater than x	`floor( 9.2 )` is `9.0` `floor( -9.8 )` is `-10.0`

Fig. 5.2 | Commonly used math library functions. (Part 1 of 2.)



Outline

5.3 Math Library Functions

Function	Description	Example
`pow( x, y )`	x raised to power y (x^y)	`pow( 2, 7 )` is `128.0` `pow( 9, .5 )` is `3.0`
`fmod( x, y )`	remainder of x/y as a floating-point number	`fmod( 13.657, 2.333 )` is `1.992`
`sin( x )`	trigonometric sine of x (x in radians)	`sin( 0.0 )` is `0.0`
`cos( x )`	trigonometric cosine of x (x in radians)	`cos( 0.0 )` is `1.0`
`tan( x )`	trigonometric tangent of x (x in radians)	`tan( 0.0 )` is `0.0`

Fig. 5.2 | Commonly used math library functions. (Part 2 of 2.)

九九乘法表 – Nested for Loops

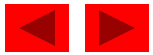
```
1×1= 1  1×2= 2  1×3= 3  1×4= 4  1×5= 5  1×6= 6  1×7= 7  1×8= 8  1×9= 9
2×1= 2  2×2= 4  2×3= 6  2×4= 8  2×5=10  2×6=12  2×7=14  2×8=16  2×9=18
3×1= 3  3×2= 6  3×3= 9  3×4=12  3×5=15  3×6=18  3×7=21  3×8=24  3×9=27
4×1= 4  4×2= 8  4×3=12  4×4=16  4×5=20  4×6=24  4×7=28  4×8=32  4×9=36
5×1= 5  5×2=10  5×3=15  5×4=20  5×5=25  5×6=30  5×7=35  5×8=40  5×9=45
6×1= 6  6×2=12  6×3=18  6×4=24  6×5=30  6×6=36  6×7=42  6×8=48  6×9=54
7×1= 7  7×2=14  7×3=21  7×4=28  7×5=35  7×6=42  7×7=49  7×8=56  7×9=63
8×1= 8  8×2=16  8×3=24  8×4=32  8×5=40  8×6=48  8×7=56  8×8=64  8×9=72
9×1= 9  9×2=18  9×3=27  9×4=36  9×5=45  9×6=54  9×7=63  9×8=72  9×9=81
Press any key to continue
```

```
/* Example Table99.c, nested for loops 印出九九乘法表 */

#include <stdio.h>

int main()
{
   int i,j;

   for ( i=1 ; i<=9 ; i++ )
   {
      for ( j=1 ; j<=9 ; j++ )
         printf("%d*%d=%2d  ",i,j,i*j);

   printf("\n");
   }

   return 0;
}
```

迴圈在哪裡？

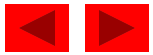
/* 外層迴圈 */

/* 內層迴圈 */



九九乘法表 – Nested while Loops

```
/* Example Table99, nested while loops 求9*9乘法表 */
#include <stdio.h>

int main()
{
   int i=1, j=1;                              /* 設定迴圈控制變數的初值 */

   while (i<=9)                               /* 外層迴圈 */
   {

      while (j<=9)                  /* 內層迴圈 */
      {
         printf("%d*%d=%2d  ",i,j,i*j);
         j++;
      }

      printf("\n");
      i++;
      j=1;
   }

   return 0;
}
```

九九乘法表 – Nested for Loops

Question: How to modify the source code to produce

```
1×1= 1
2×1= 2  2×2= 4
3×1= 3  3×2= 6  3×3= 9
4×1= 4  4×2= 8  4×3=12  4×4=16
5×1= 5  5×2=10  5×3=15  5×4=20  5×5=25
6×1= 6  6×2=12  6×3=18  6×4=24  6×5=30  6×6=36
7×1= 7  7×2=14  7×3=21  7×4=28  7×5=35  7×6=42  7×7=49
8×1= 8  8×2=16  8×3=24  8×4=32  8×5=40  8×6=48  8×7=56  8×8=64
9×1= 9  9×2=18  9×3=27  9×4=36  9×5=45  9×6=54  9×7=63  9×8=72  9×9=81
```

```
1×1= 1  1×2= 2  1×3= 3  1×4= 4  1×5= 5  1×6= 6  1×7= 7  1×8= 8  1×9= 9
2×1= 2  2×2= 4  2×3= 6  2×4= 8  2×5=10  2×6=12  2×7=14  2×8=16
3×1= 3  3×2= 6  3×3= 9  3×4=12  3×5=15  3×6=18  3×7=21
4×1= 4  4×2= 8  4×3=12  4×4=16  4×5=20  4×6=24
5×1= 5  5×2=10  5×3=15  5×4=20  5×5=25
6×1= 6  6×2=12  6×3=18  6×4=24
7×1= 7  7×2=14  7×3=21
8×1= 8  8×2=16
9×1= 9
```

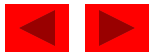

4.7 The switch Multiple-Selection Statement

- switch
  - Useful when a variable or expression is tested for all the values it can assume and different actions are taken
- Format
  - Series of **case** labels and an optional **default** case

```
switch ( value ){
    case 1:
        actions;
        break;          //如果不加 break ，會繼續執行下面的 actions
    case 2:
        actions;
        break;
    default:
        actions;
        break;          //可加可不加
    }
```

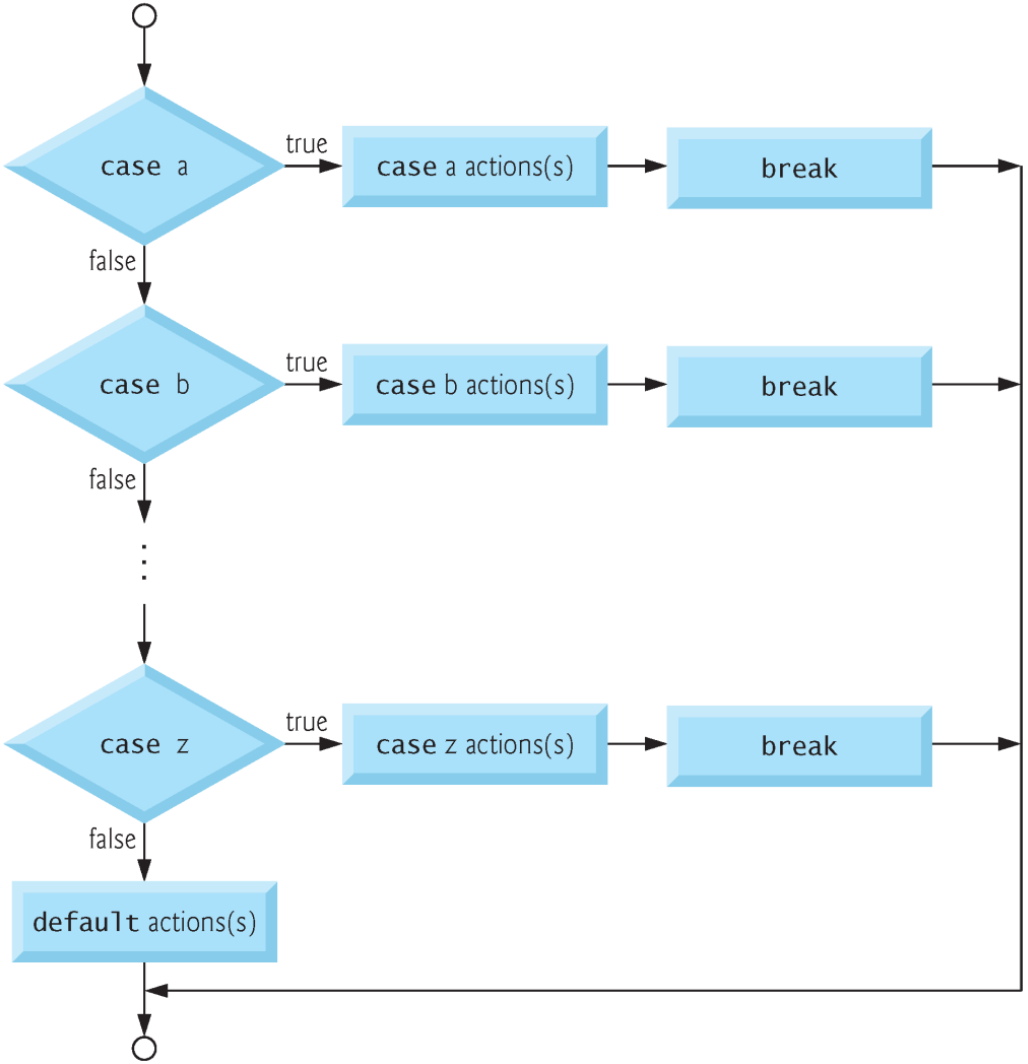
如果變數名稱 value 是數值的話，此處 case 1 其中的 1 為 value 的數值，但是如果 value 是字元的話，必須用 case 'A'，其中的 A 為 value 的值。

  - **break;** exits from statement

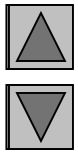


4.7 The `switch` Multiple-Selection Statement

- Flowchart of the `switch` statement



Counting Letter Grades with `switch`



Outline

fig04_07.c (Part 1 of 3)

```
1  /* Fig. 4.7: fig04_07.c
2     Counting letter grades */
3  #include <stdio.h>
4
5  /* function main begins program execution */
6  int main()
7  {
8     char grade;       /* one grade */
9     int aCount = 0; /* number of As */
10    int bCount = 0; /* number of Bs */
11    int cCount = 0; /* number of Cs */
12    int dCount = 0; /* number of Ds */
13    int fCount = 0; /* number of Fs */
14
15    printf(  "Enter the letter grades.\n"  );
16    printf(  "Enter the EOF character to end input.\n"  );
17
18    /* loop until user types end-of-file key sequence */
19    while ( ( grade = getchar() ) != EOF ) {
20
21       /* determine which grade was input */
22       switch ( grade ) { /* switch nested in while */
23
24          case 'A':     /* gr
25          case 'a':     /* or lowercase a */
26             ++aCount; /* increment aCount
27             break;    /* necessary to exit switch */
28
```

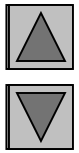
宣告 **grade** 為字元

此處 aCount, bCount 等分別是出現 A，B，...等字元的次數。

The **getchar( )** function reads one character from the keyboard and stores that character in variable **grade**

EOF (end-of-file) is system dependent. In MS Windows, EOF is <crtl-z>

此處 value 是字元，所以用 case 'A'，其中的 A 為 value 的值。

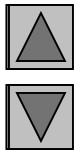


Outline

fig04_07.c (Part 2 of 3)

```
29          case 'B':   /* grade was uppercase B */
30          case 'b':   /* or lowercase b */
31             ++bCount; /* increment bCount */
32             break;    /* exit switch */
33
34          case 'C':   /* grade was uppercase C */
35          case 'c':   /* or lowercase c */
36             ++cCount; /* increment cCount */
37             break;    /* exit switch */
38
39          case 'D':   /* grade was uppercase D */
40          case 'd':   /* or lowercase d */
41             ++dCount; /* increment dCount */
42             break;    /* exit switch */
43
44          case 'F':   /* grade was uppercase F */
45          case 'f':   /* or lowercase f */
46             ++fCount; /* increment fCount */
47             break;    /* exit switch */
48
49          case '\n':  /* ignore newlines, */
50          case '\t':  /* tabs, */
51          case ' ':   /* and spaces in input */
52             break;    /* exit switch */
53
```

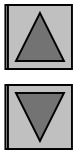
注意：每個 case 最後必須加上 break ，跳出 switch 區塊，否則會繼續執行下一個 case 。



Outline

fig04_07.c (Part 3 of 3)

```
54          default:     /* catch all other characters */
55             printf( "Incorrect letter grade entered." );
56             printf( " Enter a new grade.\n" );
57             break;    /* optional; will exit switch anyway */
58       } /* end switch */
59
60    } /* end while */
61
62    /* output summary of results */
63    printf( "\nTotals for each letter grade are:\n" );
64    printf( "A: %d\n", aCount ); /* display number of A grades */
65    printf( "B: %d\n", bCount ); /* display number of B grades */
66    printf( "C: %d\n", cCount ); /* display number of C grades */
67    printf( "D: %d\n", dCount ); /* display number of D grades */
68    printf( "F: %d\n", fCount ); /* display number of F grades */
69
70    return 0; /* indicate program ended successfully */
71
72 } /* end function main */
```



Outline

Program Output

```
Enter the letter grades.
Enter the EOF character to end input.
a
b
c
C
A
d
f
C
E
Incorrect letter grade entered. Enter a new grade.
D
A
b
^Z

Totals for each letter grade are:
A: 3
B: 2
C: 3
D: 2
F: 1
```

4.8 The do...while Repetition Statement

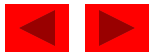
- The do...while repetition statement
  - Similar to the while structure
  - Condition for repetition tested after the body of the loop is performed
    - ***Implication***: All actions are performed at least once
  - Format:

```
do {
   statement;
} while ( condition );
```

- Example (initially, counter = 1):

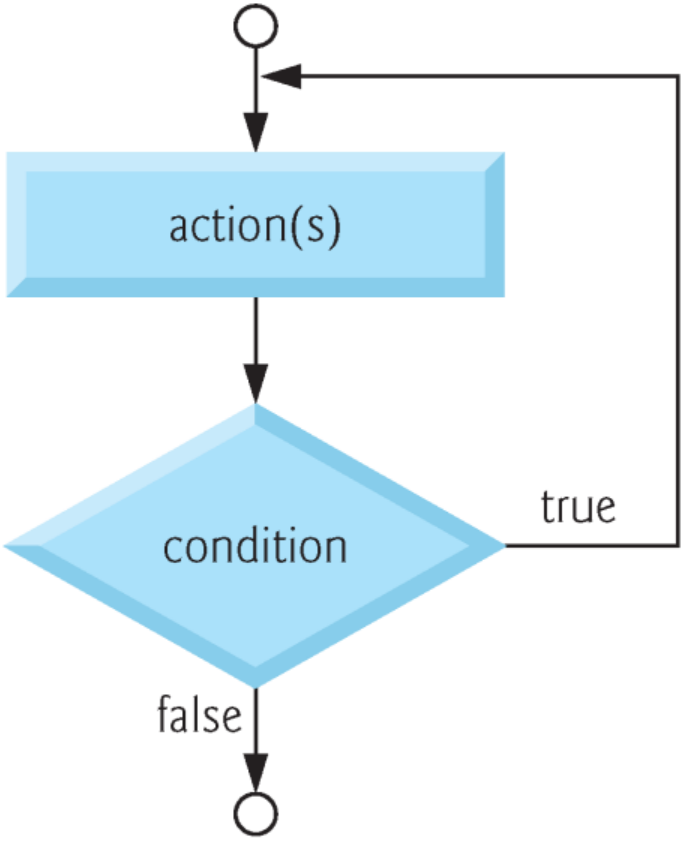
```
do {
   printf( "%d  ", counter );
} while (++counter <= 10);
```

  - Prints the integers from 1 to 10



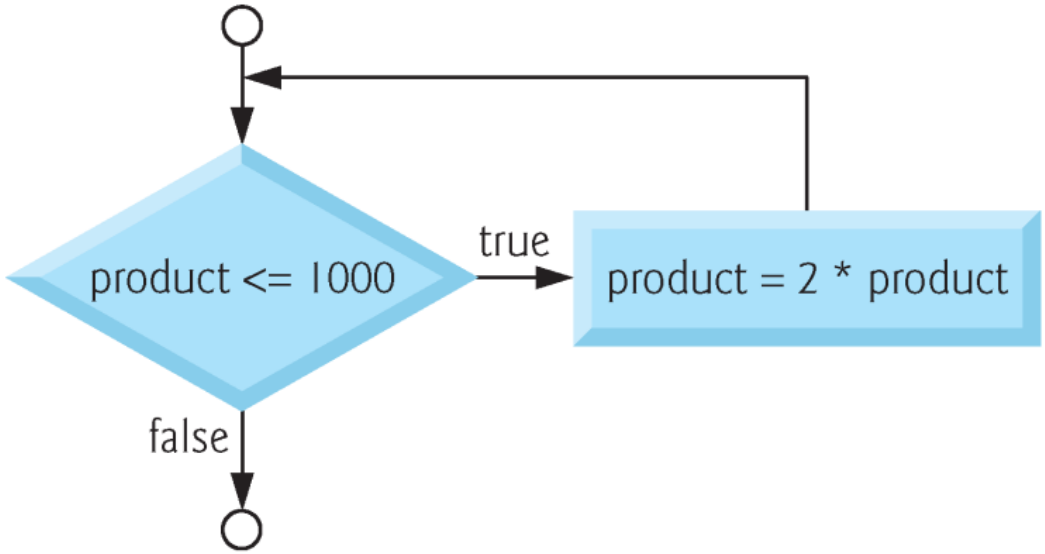
4.8 The do…while Repetition Statement

- Flowchart of the do…while repetition statement



The `while` Repetition Statement

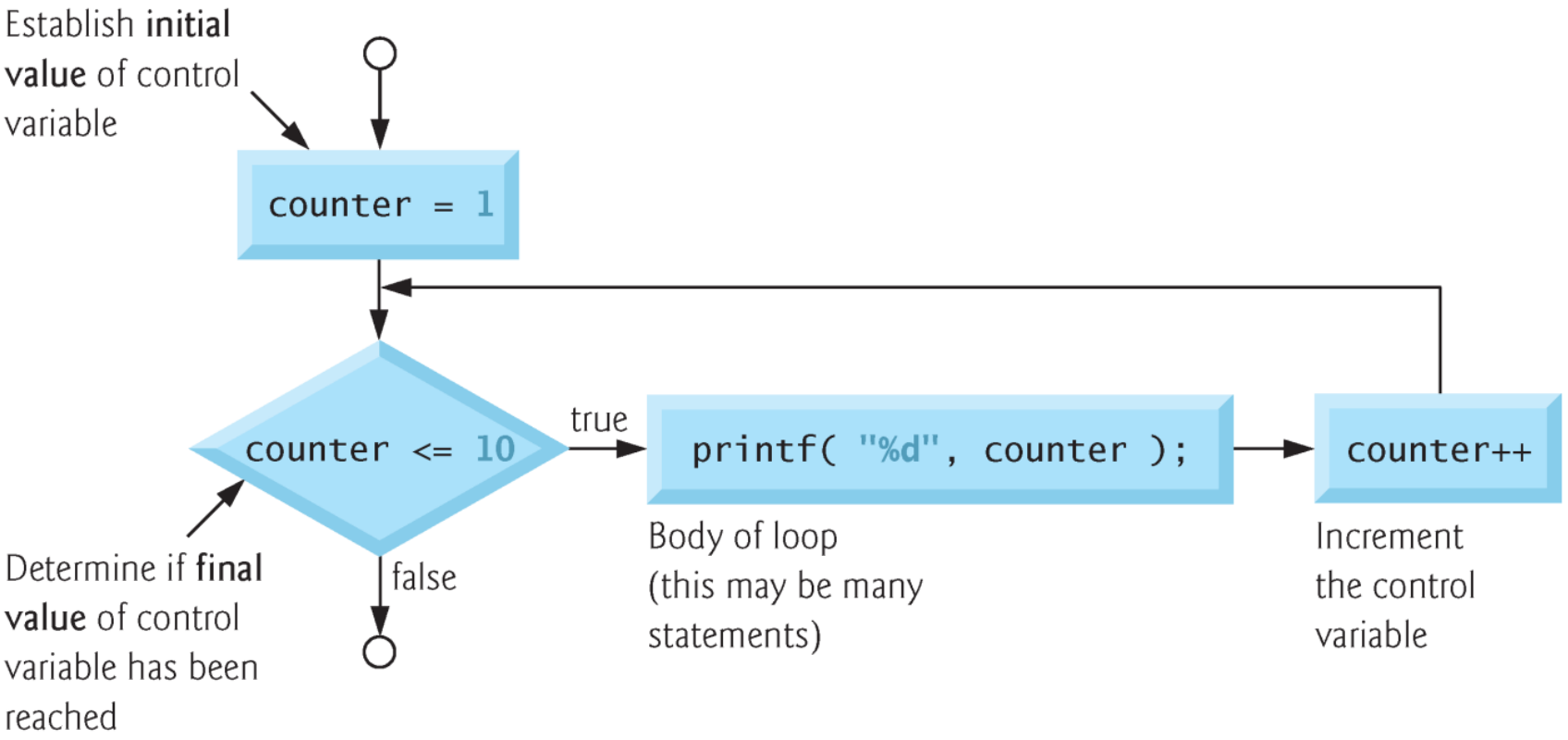
```
int product = 2;
while ( product <= 1000 )
      product = 2 * product;
```



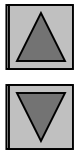
The final value of product will be 1024.

The for Repetition Statement

```
for( counter = 1; counter <= 10; counter++ )
   printf( "%d\n", counter );
```



Example of `do ... while` Statement



Outline

```
1  /* Fig. 4.9: fig04_09.c
2     Using the do/while repetition statement */
3  #include <stdio.h>
4
5  /* function main begins program execution */
6  int main()
7  {
8     int counter = 1; /* initialize counter */
9
10    do {
11       printf( "%d  ", counter ); /* display counter */
12    } while ( ++counter <= 10 ); /* end do...while */
13
14    return 0; /* indicate program ended successfully */
15
16 } /* end function main */
```

fig04_09.c

```
1  2  3  4  5  6  7  8  9  10
```

Program Output

Question: What if we set `while ( counter++ <= 10 );` ?

`1 2 3 4 5 6 7 8 9 10 11`

while, for, do . . . while 之比較

語法：

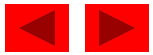
```
for ( initialization; loopContinuationTest; increment )
{
 statement;
}
```

```
initialization;
while ( loopContinuationTest ) {
   statement;
   increment;
}
```

```
initialization;
do {
      statement;
     increment;
    } while (loopContinuationTest );
```

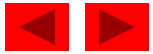
for、while 與 do while 迴圈的比較

迴圈特性	迴圈種類		
	for	while	do while
前端測試判斷條件	是	是	否
後端測試判斷條件	否	否	是
於迴圈主體中需要更改控制變數的值	否	是	是
迴圈控制變數會自動增加	是	否	否
迴圈重複的次數	已知	皆可	皆可
至少執行迴圈主體的次數	0 次	0 次	1 次
何時重複執行迴圈	條件成立	條件成立	條件成立

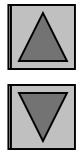


4.9 The `break` and `continue` Statements

- `break`
  - Causes *immediate exit* from a **repetition** (i.e., `while`, `for`, `do…while`) or a **selection** (i.e., `switch`) structure.
  - Program execution continues with the first statement after the structure
  - Common uses of the `break` statement
    - Escape early from a loop
    - Skip the remainder of a `switch` statement



Using the `break` Statement in a `for` Statement



Outline

fig04_11.c

```
1  /* Fig. 4.11: fig04_11.c
2     Using the break statement in a for statement */
3  #include <stdio.h>
4
5  /* function main begins program execution */
6  int main()
7  {
8     int x; /* counter */
9
10    /* loop 10 times */
11    for ( x = 1; x <= 10; x++ ) {
12
13       /* if x is 5, terminate loop */
14       if ( x == 5 ) {
15          break; /* break loop only if x is 5 */
16       } /* end if */
17
18       printf( "%d ", x ); /* display value of x */
19    } /* end for */
20
21    printf( "\nBroke out of loop at x == %d\n", x );
22
23    return 0; /* indicate program ended successfully */
24
25 } /* end function main */
```

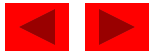
Use `break` to break out of the loop at `x == 5` (當 `x == 5` 時，跳出 `for` 迴圈)

```
1 2 3 4

Broke out of loop at x == 5
```

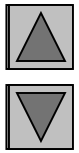
The `continue` Statement

`continue`

- Skips the remaining statements in the body of a repetition (`while`, `for` or `do…while`) structure and proceeds with the next iteration of the loop (不會跳出迴圈)
- `while` and `do…while`
  - *Loop-continuation test* is evaluated immediately after the `continue` statement is executed
- `for`
  1. *Increment expression* is executed, then
  2. *loop-continuation test* is evaluated



Using a `continue` Statement in a `for` Statement



Outline

fig04_12.

```
1  /* Fig. 4.12: fig04_12.c
2     Using the continue statement in a for statement */
3  #include <stdio.h>
4
5  /* function main begins program execution */
6  int main()
7  {
8     int x; /* counter */
9
10    /* loop 10 times */
11    for ( x = 1; x <= 10; x++ ) {
12
13       /* if x is 5, continue with next iteration of loop */
14       if ( x == 5 ) {
15          continue; /* skip remaining code in loop body */
16       } /* end if */
17
18       printf( "%d ", x ); /* display value of x */
19    } /* end for */
20
21    printf( "\nUsed continue to skip printing the value 5\n" );
22
23    return 0; /* indicate program ended successfully */
24
25 } /* end function main */
```

```
1 2 3 4 6 7 8 9 10
```

Use `continue` to skip printing the value 5

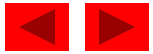
x 值繼續加一，沒有跳出 `for` 迴圈，與 `break` 不同！！

如何將 `for` 迴圈改成 `while` 迴圈？需要注意哪些地方？

4.10 Logical Operators

- && (logical AND)
  - Returns `true` if both conditions are `true`
- || (logical OR)
  - Returns `true` if either of its conditions are `true`
- ! (logical NOT, logical negation)
  - Reverses the truth/falsity of its condition
  - Unary operator, has one operand
- Useful for testing the conditions in a repetition or selection structure

Expression	Result
`true && false`	`false`
`true || false`	`true`
`!false`	`true`



4.10 Logical Operators

expression1	expression2	expression1 && expression2
0	0	0
0	nonzero	0
nonzero	0	0
nonzero	nonzero	1

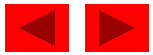
Fig. 4.13 | Truth table for the logical AND (&&) operator.

expression1	expression2	expression1 || expression2
0	0	0
0	nonzero	1
nonzero	0	1
nonzero	nonzero	1

Fig. 4.14 | Truth table for the logical OR (||) operator.

expression	!expression
0	1
nonzero	0

Fig. 4.15 | Truth table for operator ! (logical negation).



4.10 Logical Operators

- The Code

```
if ( a > b > c )  /* 錯誤!! */
```

should be

```
if ( a > b && b > c )
```

```
int a = 5, b = 4, c = 3;
if( a > b > c )
   printf( " a > b > c is true \n");
```

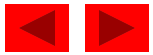
會列印嗎？

- The Code

```
if ( semesterAverage >= 90 || finalExam >= 90 )
   printf( "Student grade is A\n");
```

- The Codes (with x = 10, y = 1, a = 3, b = 3, g = 5, i = 2, j = 9)

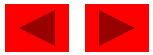
```
!( x < 5 ) && !( y >= 7 )
!( a == b ) || !( g != 5 )
!( ( x <= 8 ) && ( y > 4 ) )
!( ( i > 4 ) || ( j <= 6 ) )
```

4.10 Logical Operators

Assume i = 1, j = 2, k = 3 and m = 2. What does each of the following statements print?

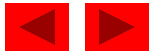
```
printf( "%d", i == 1 );                    ANS: 1
printf( "%d", j == 3 );                    ANS: 0
printf( "%d", i >= 1 && j < 4 );           ANS: 1
printf( "%d", m < = 99 && k < m );         ANS: 0
printf( "%d", j >= i || k == m );          ANS: 1
printf( "%d", k + m < j || 3 - j >= k );
                                           ANS: 0
printf( "%d", !m );                        ANS: 0
printf( "%d", !( j - m ) );                ANS: 1
printf( "%d", !( k > m ) );                ANS: 0
printf( "%d", !( j > k ) );                ANS: 1
```

4.10 Logical Operators

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

Fig. 4.16 | Operator precedence and associativity,

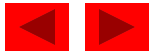


4.11 Confusing Equality (==) and Assignment (=) Operators

- Dangerous error
  - Does not ordinarily cause syntax errors
  - *Any expression that produces a value can be used in control structures*
  - Nonzero values are `true`, zero values are `false`
  - Example using ==:

```
if ( payCode == 4 )
   printf( "You get a bonus!\n" );
```

    - Checks `payCode`, if it is `4` then a bonus is awarded



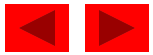
4.11 Confusing Equality (==) and Assignment (=) Operators

– Example, replacing == with =:

```
if ( payCode = 4 )
   printf( "You get a bonus!\n" );
```

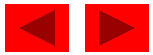
- This sets `payCode` to `4`
- `4` is nonzero, so expression is `true`, and bonus awarded no matter what the `payCode` was

– Logic error, not a syntax error

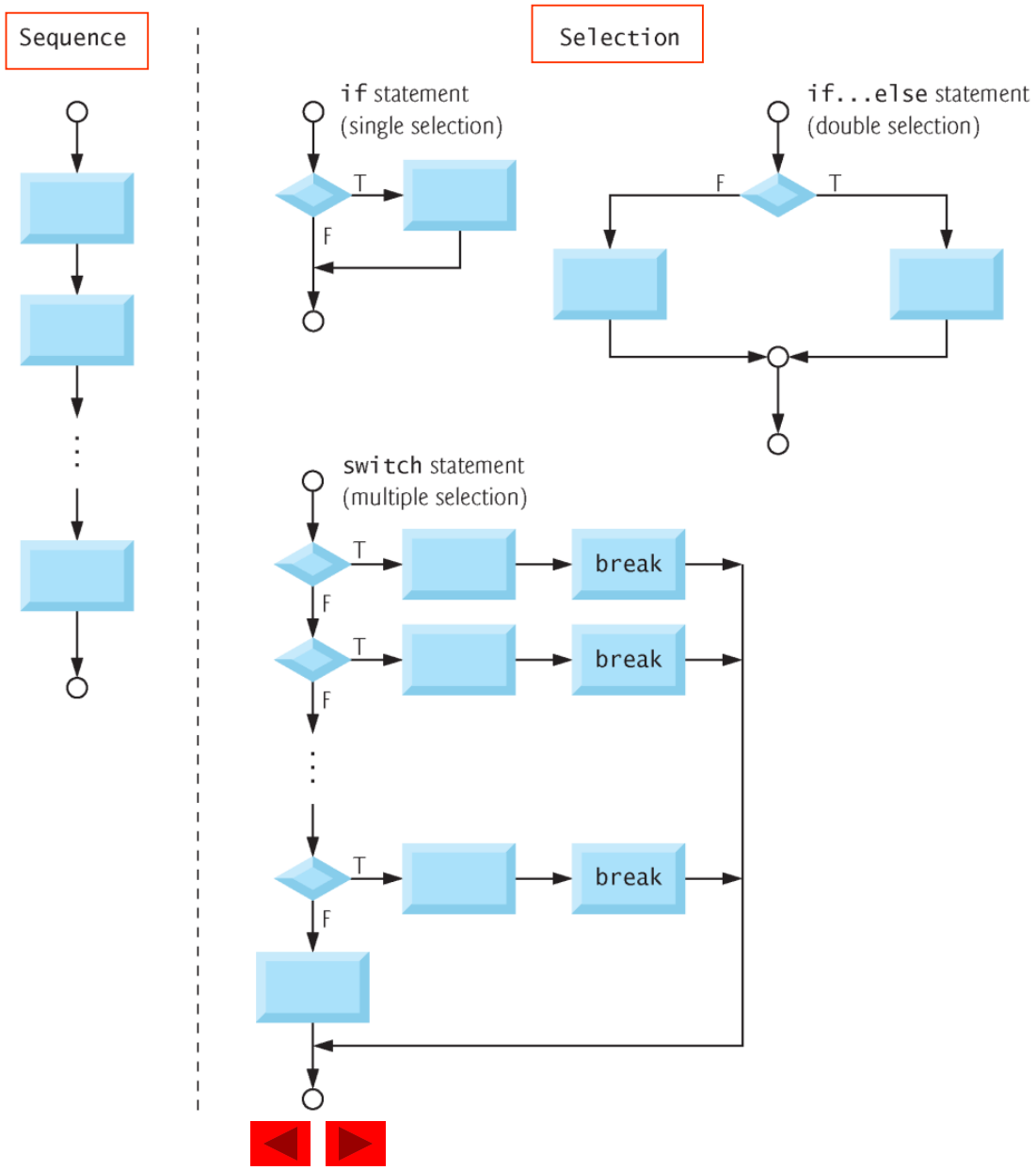


Assignment (=) Operators

- lvalues
  - Expressions that can appear on the *left* side of an assignment operator
  - Their values can be changed, such as variable names
    - `x = 4;`
- rvalues
  - Expressions that can only appear on the *right* side of an assignment operator
  - Constants, such as numbers
    - Cannot write `4 = x;`
    - Must write `x = 4;`
  - lvalues can be used as rvalues, but not vice versa
    - `y = x;`



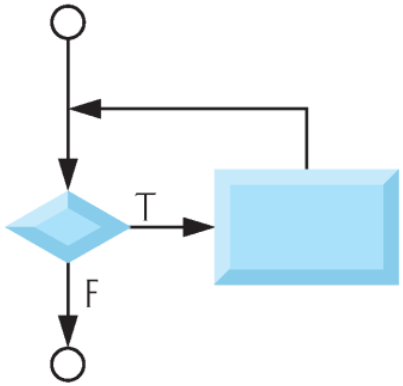
4.12 Structured-Programming Summary



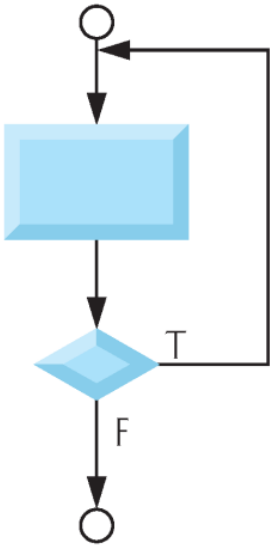
4.12 Structured-Programming Summary

Repetition

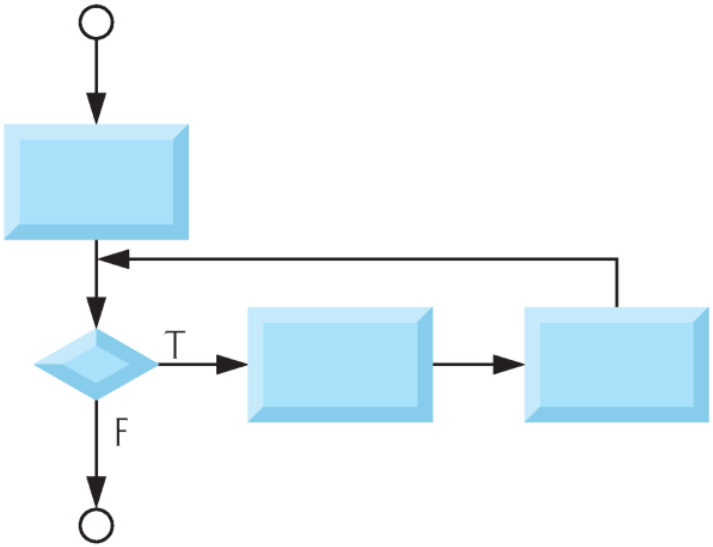
`while` statement



`do...while` statement



`for` statement



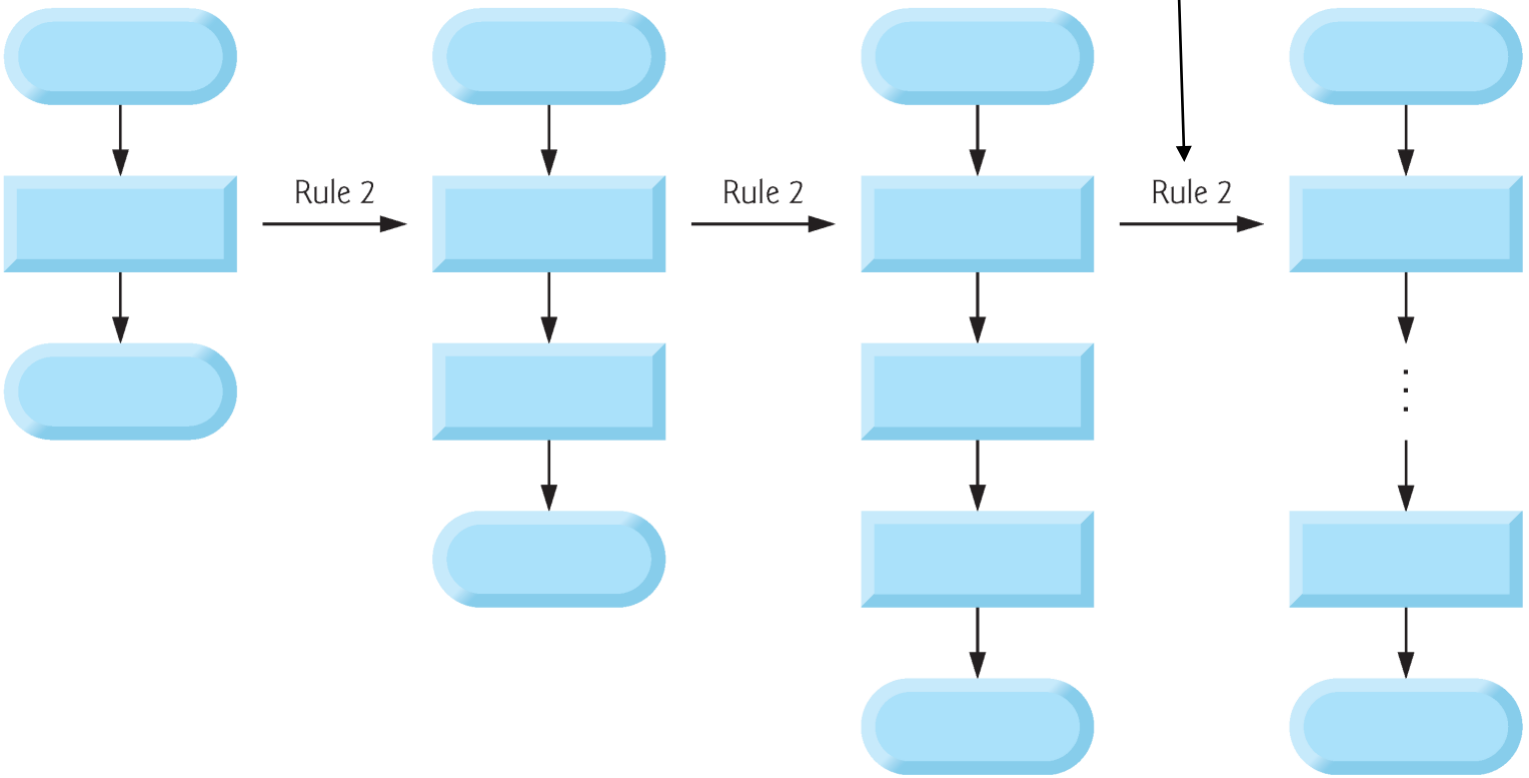
4.12 Structured-Programming Summary

- Structured Programming
  - Easier than unstructured programs to understand, test, debug and, modify programs
- Rules for Forming Structured Programming
  - Rules developed by programming community
  - Only single-entry/single-exit control structures are used
  - Rules:
    1. Begin with the "simplest flowchart"
    2. Stacking (堆疊) rule: Any rectangle (action) can be replaced by two rectangles (actions) in sequence
    3. Nesting (層狀) rule: Any rectangle (action) can be replaced by any control structure (sequence, `if`, `if...else`, `switch`, `while`, `do...while` or `for`)
    4. Rules 2 and 3 can be applied in any order and multiple times

4.12 Structured-Programming Summary

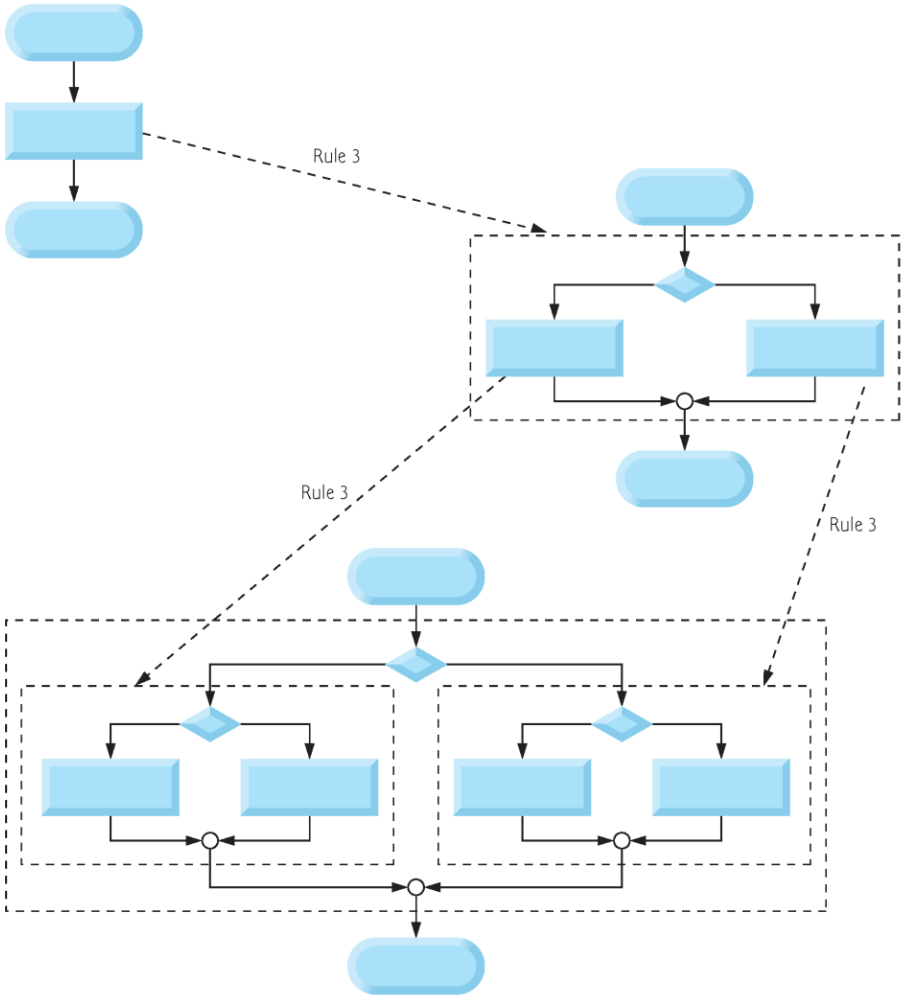
Rule 1 - Begin with the simplest flowchart

Rule 2 - Any rectangle can be replaced by two rectangles in sequence



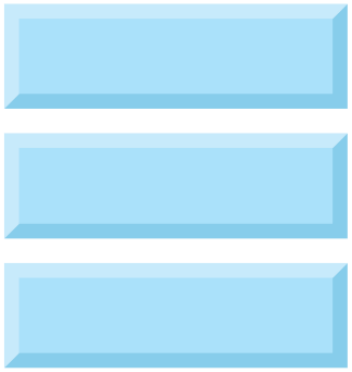
4.12 Structured-Programming Summary

Rule 3 - Replace any rectangle with a control structure

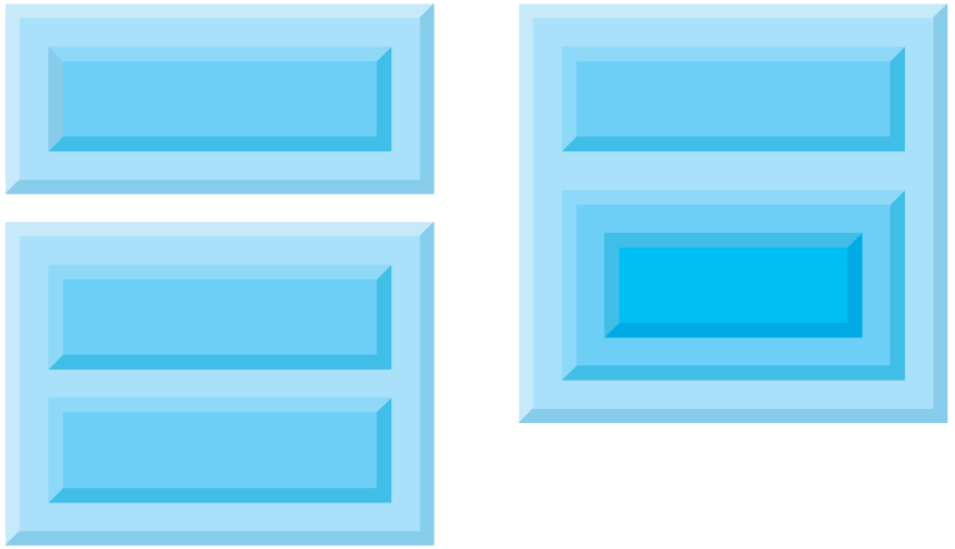


4.12 Structured-Programming Summary

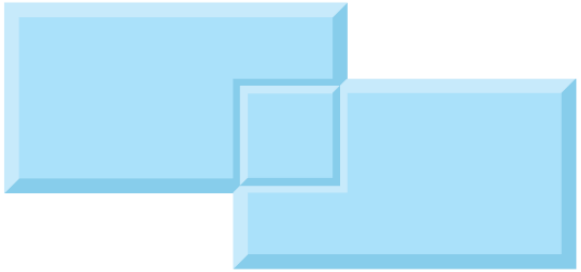
Stacked building blocks



Nested building blocks

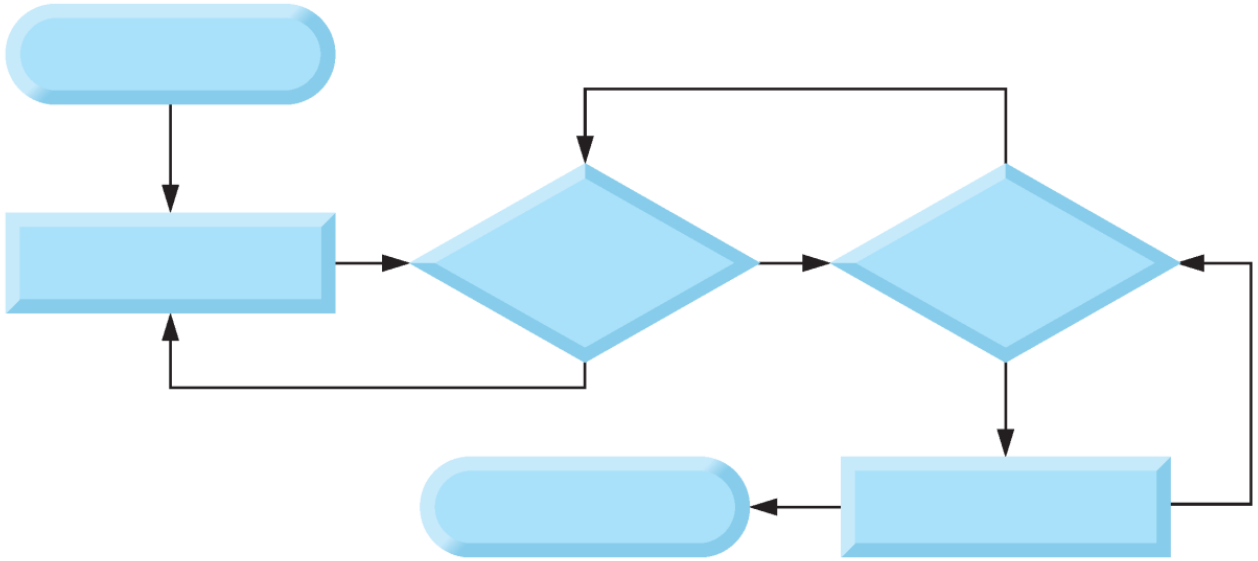


Overlapping building blocks
(Illegal in structured programs)



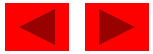
4.12 Structured-Programming Summary

Figure 4.23 An unstructured flowchart.



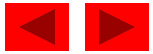
4.12 Structured-Programming Summary

- All programs can be broken down into 3 controls
  - **Sequence** – handled automatically by compiler
  - **Selection** – `if`, `if...else` or `switch`
  - **Repetition** – `while`, `do...while` or `for`
    - Can only be combined in two ways
      - Nesting (rule 3)
      - Stacking (rule 2)
  - Any *selection* can be rewritten as an `if` statement, and any *repetition* can be rewritten as a `while` statement



Review

- In this chapter, we have learned:
  - To be able to use the **`for`** and **`do...while`** repetition statements.
  - To understand multiple selection using the **`switch`** selection statement.
  - To be able to use the **`break`** and **`continue`** program control statements
  - To be able to use the logical operators (**`&&`** , **`||`** , **`!`**)



Exercises