Introduction to C++ Programming

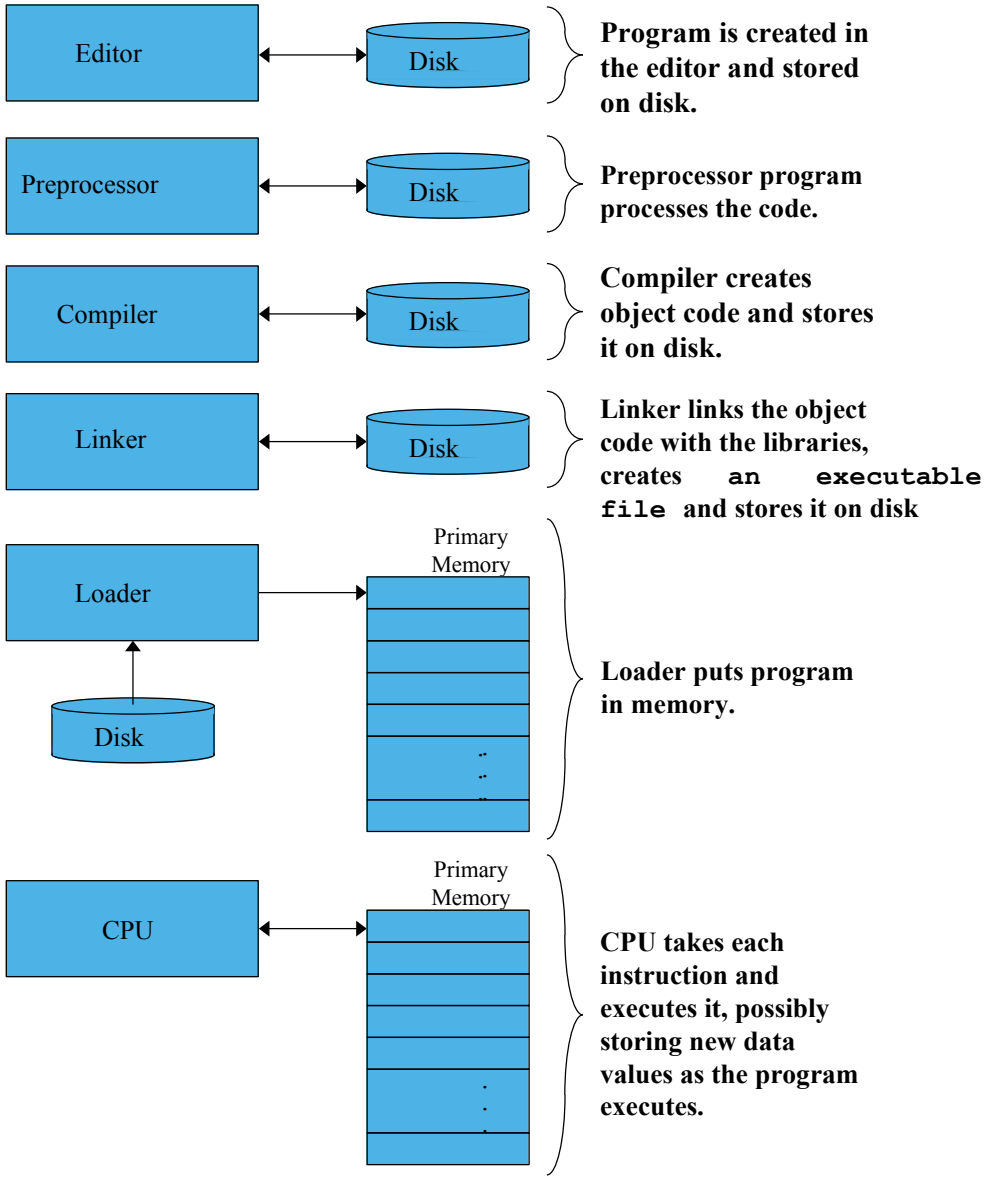
Lecture 2

Oct 7, 2020,

Basics of a Typical C++ Environment

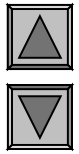
Phases of C++ Programs:

1. Edit
2. Preprocess
3. Compile
4. Link
5. Load
6. Execute



A Simple Program: Printing a Line of Text

- Before writing the programs
  - Comments
    - Document programs
    - Improve program readability
    - Ignored by compiler
    - Single-line comment
      - Use C's comment /* .. */ OR Begin with **`// or`**
  - Preprocessor directives
    - Processed by preprocessor before compiling
    - Begin with **#**



Outline

```
// Fig. 1.2: fig01_02.cpp
// A first program
#include <iostream

// function main b
int main()
{
   std::cout << "

   return 0;   //

} // end function main
```

```
Welcome to C++!
```

Single-line comments.

Function **main** returns an

r directive to

Left brace **{** begins function body.

ars

exactly once in every C++ program..

Statements end with a semicolon **;**.

Corresponding right brace **}** ends function

Name

Stream insertion operator.

namespace **std**.

Keyword **return** is one of several means to exit function; value **0** indicates program terminated successfully.

cpp

fig01_02.cpp output (1 of 1)

A Simple Program: Printing a Line of Text

- Standard output stream object
  - `std::cout`
  - "Connected" to screen
  - `<<`
    - Stream insertion operator
    - Value to right (right operand) inserted into output stream
- Namespace
  - `std::` specifies using name that belongs to "namespace" `std`
  - `std::` removed through use of `using` statements
- Escape characters
  - \
  - Indicates "special" character output

A Simple Program: Printing a Line of Text

Escape Sequence	Description
`\n`	Newline. Position the screen cursor to the beginning of the next line.
`\t`	Horizontal tab. Move the screen cursor to the next tab stop.
`\r`	Carriage return. Position the screen cursor to the beginning of the current line; do not advance to the next line.
`\a`	Alert. Sound the system bell.
`\\`	Backslash. Used to print a backslash character.
`\"`	Double quote. Used to print a double quote character.

Another Simple Program: Adding Two Integers

- Variables
  - Location in memory where value can be stored
  - Common data types
    - `int` - integer numbers
    - `char` - characters
    - `double` - floating point numbers
  - Declare variables with name and data type before use

```
int integer1;
int integer2;
int sum;
```

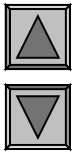
  - Can declare several variables of same type in one declaration
    - Comma-separated list

```
int integer1, integer2, sum;
```

Another Simple Program: Adding Two Integers

- Input stream object
  - **>>** (stream extraction operator)
    - Used with `std::cin`
    - Waits for user to input value, then press *Enter* (Return) key
    - Stores value in variable to right of operator
      - Converts value to variable data type
- **=** (assignment operator)
  - Assigns value to variable
  - Binary operator (two operands)
  - Example:

```
sum = variable1 + variable2;
```



Outline

fig01_06.cpp
(1 of 1)

```
1  // Fig. 1.6: fig01_06.cpp
2  // Addition program.
3  #include <iostream>
4
5  // function main begins program execution
6  int main()
7  {
8     int integer1;  // first number to be input by user
9     int integer2;  // second nu
10    int sum;       // variable
11
12    std::cout << "Enter first i
13    std::cin >> integer1;                    // read an integer
14
15    std::cout << "Enter second
16    std::cin >> integer2;
17
18    sum = integer1 + integer2;
19
20    std::cout << "Sum is " << sum << std::endl; // print sum
21
22    return 0;   // indicate that program ended successfully
23
24 } // end function main
```

Declare integer variables.

Use stream extraction operator with standard input stream to obtain user input.

Calculations can be performed in output statements: alternative for lines 18 and 20:

```
std::cout << "Sum is " << integer1 + integer2 << std::endl;
```

buffer."

Concatenating, chaining or cascading stream insertion operations.

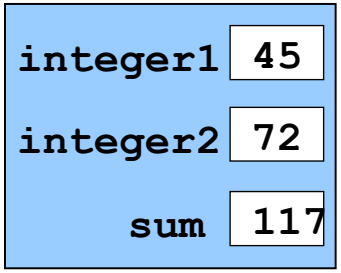
Memory Concepts

- Variable names
  - Correspond to actual locations in computer's memory
  - Every variable has name, type, size and value
  - When new value placed into variable, overwrites previous value

  - std::cin >> integer1;
  - Assume user entered 45

  - std::cin >> integer2;
  - Assume user entered 72

  - sum = integer1 + integer2;



Arithmetic

- Arithmetic calculations
  - `*` : Multiplication
  - `/` : Division
    - Integer division truncates remainder
      - `7 / 5` evaluates to 1
  - `%` : Modulus operator returns remainder
      - `7 % 5` evaluates to 2

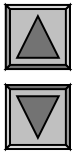
Operator(s)	Operation(s)	Order of evaluation (precedence)
`()`	Parentheses	Evaluated first. If the parentheses are nested, the expression in the innermost pair is evaluated first. If there are several pairs of parentheses "on the same level" (i.e., not nested), they are evaluated left to right.
`*`, `/`, or `%`	Multiplication Division Modulus	Evaluated second. If there are several, they re evaluated left to right.
`+` or `-`	Addition Subtraction	Evaluated last. If there are several, they are evaluated left to right.

Decision Making: Equality and Relational Operators

- `if` structure
  - Make decision based on truth or falsity of condition
    - If condition met, body executed
    - Else, body not executed
- Equality and relational operators
  - Equality operators
    - Same level of precedence
  - Relational operators
    - Same level of precedence
  - Associate left to right
- `using` statements
  - Eliminate use of `std::` prefix
  - Write `cout` instead of `std::cout`

Decision Making: Equality and Relational Operators

Standard algebraic equality operator or relational operator	C++ equality or relational operator	Example of C++ condition	Meaning of C++ condition
Relational operators			
>	`>`	`x > y`	`x` is greater than `y`
<	`<`	`x < y`	`x` is less than `y`
≥	`>=`	`x >= y`	`x` is greater than or equal to `y`
≤	`<=`	`x <= y`	`x` is less than or equal to `y`
Equality operators			
=	`==`	`x == y`	`x` is equal to `y`
≠	`!=`	`x != y`	`x` is not equal to `y`



Outline

fig01_14.cpp
(1 of 2)

```
// Fig. 1.14: fig01_14.cpp
// Using if statements, relational
// operators, and equality operators.
#include <iostream>

using std::cout; // program uses cout
using std::cin;  // program uses cin
using std::endl; // program uses endl

// function main begins progra
int main()
{
   int num1;  // first nu
   int num2;  // second n

   cout << "Enter two integers
        << "the relationships
   cin >> num1 >> num2;   // r

   if ( num1 == num2 )
      cout << num1 << " is equ

   if ( num1 != num2 )
      cout << num1 << " is not equal to " << num2 << endl;
```

using statements eliminate need for **std::** prefix.

Declare variables.

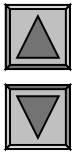
Can write **cout** and **cin** without **std::** prefix.

if structure compares values of **num1** and
equality

If condition is true (i.e., values are equal), execute this

if structure compares values of **num1** and
inequality.

If condition is true (i.e., values are not equal), execute this statement.



Outline

```
26    if ( num1 < num2 )
27       cout << num1 << " is less than " << num2 << endl;
28
29    if ( num1 > num2 )
30       cout << num1 << " is greater than " << num2 << endl;
31
32    if ( num1 <= num2 )
33       cout << num1 << " is less than or equal to "
34            << num2 << endl;
35
36    if ( num1 >= num2 )
37       cout << num1 << " is greater than or equal to "
38            << num2 << endl;
39
40    return 0;   // indicate that program ended successfully
41
42 } // end function main
```

```
Enter two integers, and I will tell you
the relationships they satisfy: 22 12
22 is not equal to 12
22 is greater than 12
22 is greater than or equal to 12
```

fig01_14.cpp

Statements may be split over several lines.

fig01_14.cpp
output (1 of 2)

Algorithms

- Computing problems
  - Solved by executing a series of actions in a specific order
- Algorithm a procedure determining
  - Actions to be executed
  - Order to be executed
  - Example: recipe
- Program control
  - Specifies the order in which statements are executed

Pseudocode

- Pseudocode
  - Artificial, informal language used to develop algorithms
  - Similar to everyday English
- Not executed on computers
  - Used to think out program before coding
    - Easy to convert into C++ program
  - Only executable statements
    - No need to declare variables

Control Structures

- Sequential execution
  - Statements executed in order
- Transfer of control
  - Next statement executed *not* next one in sequence
  - Structured programming – “goto”-less programming
- 3 control structures to build any program
  - Sequence structure
    - Programs executed sequentially by default
  - Selection structures
    - `if`, `if/else`, `switch`
  - Repetition structures
    - `while`, `do/while`, `for`

Keywords

- C++ keywords
  - Cannot be used as identifiers or variable names

C++ Keywords				
Keywords common to the C and C++ programming languages				
`auto`	`break`	`case`	`char`	`const`
`continue`	`default`	`do`	`double`	`else`
`enum`	`extern`	`float`	`for`	`goto`
`if`	`int`	`long`	`register`	`return`
`short`	`signed`	`sizeof`	`static`	`struct`
`switch`	`typedef`	`union`	`unsigned`	`void`
`volatile`	`while`			
C++ only keywords				
`asm`	`bool`	`catch`	`class`	`const_cast`
`delete`	`dynamic_cast`	`explicit`	`false`	`friend`
`inline`	`mutable`	`namespace`	`new`	`operator`
`private`	`protected`	`public`	`reinterpret_cast`	
`static_cast`	`template`	`this`	`throw`	`true`
`try`	`typeid`	`typename`	`using`	`virtual`
`wchar_t`				

Control Structures

- Flowchart
  - Graphical representation of an algorithm
  - Special-purpose symbols connected by arrows (flowlines)
  - Rectangle symbol (action symbol)
    - Any type of action
  - Oval symbol
    - Beginning or end of a program, or a section of code (circles)
- Single-entry/single-exit control structures
  - Connect exit point of one to entry point of the next
  - Control structure stacking

if Selection Structure

- Selection structure
  - Choose among alternative courses of action
  - Pseudocode example:

    If student's grade is greater than or equal to 60

    Print "Passed"
  - If the condition is `true`
    - Print statement executed, program continues to next statement
  - If the condition is `false`
    - Print statement ignored, program continues
  - Indenting makes programs easier to read
    - C++ ignores whitespace characters (tabs, spaces, etc.)

if Selection Structure

- Translation into C++

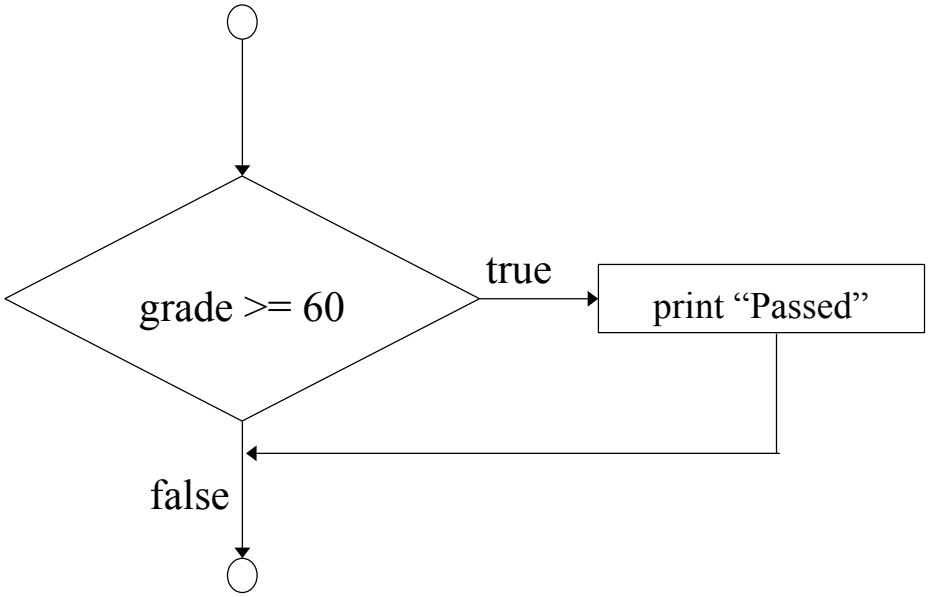
  If student's grade is greater than or equal to 60
  Print "Passed"

```
if ( grade >= 60 )
   cout << "Passed";
```

- Diamond symbol (decision symbol)
  - Indicates decision is to be made
  - Contains an expression that can be true or false
    - Test condition, follow path
- `if` structure
  - Single-entry/single-exit

if Selection Structure

- Flowchart of pseudocode statement



A decision can be made on any expression.

zero - **`false`**

nonzero - **`true`**

Example:

`3 - 4` is **`true`**

`if/else` Selection Structure

- `if`
  - Performs action if condition true
- `if/else`
  - Different actions if conditions true or false
- Pseudocode

  if student's grade is greater than or equal to 60
  print "Passed"
  else
  print "Failed"

- C++ code

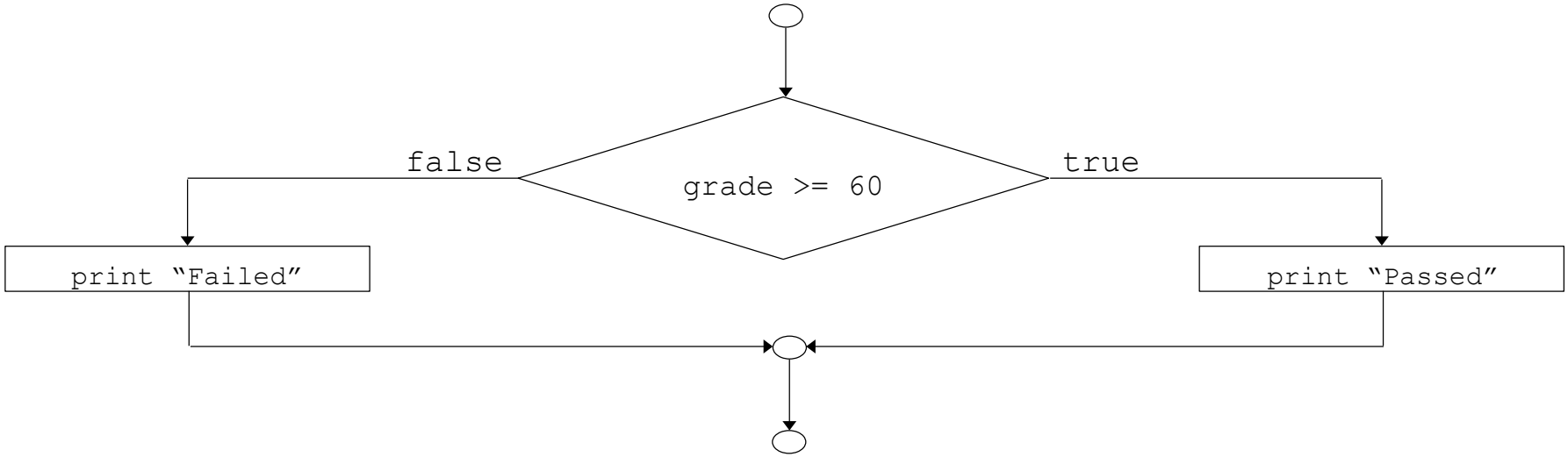
```
if ( grade >= 60 )
   cout << "Passed";
else
   cout << "Failed";
```

`if/else` Selection Structure

- Ternary conditional operator (`?:`)
  - Three arguments (condition, value if **`true`**, value if **`false`**)
- Code could be written:

```
cout << ( grade >= 60 ? "Passed" : "Failed" );
```

Condition **Value if true** **Value if false**



`if/else` Selection Structure

- Nested **`if/else`** structures
  - One inside another, test for multiple cases
  - Once condition met, other statements skipped

```
if student's grade is greater than or equal to 90
      Print "A"
else
      if student's grade is greater than or equal to 80
                Print "B"
            else
        if student's grade is greater than or equal to 70
                  Print "C"
                else
                  if student's grade is greater than or equal to 60
                    Print "D"
          else
                Print "F"
```

`if/else` Selection Structure

- Example

```
if ( grade >= 90 )          // 90 and above
   cout << "A";
else if ( grade >= 80 )     // 80-89
   cout << "B";
else if ( grade >= 70 )     // 70-79
   cout << "C";
else if ( grade >= 60 )     // 60-69
   cout << "D";
else                        // less than 60
   cout << "F";
```

`if/else` Selection Structure

- Compound statement
  - Set of statements within a pair of braces

```
if ( grade >= 60 )
   cout << "Passed.\n";
else {
   cout << "Failed.\n";
   cout << "You must take this course again.\n";
}
```

  - Without braces,

```
cout << "You must take this course again.\n";
```

always executed

- Block
  - Set of statements within braces

while Repetition Structure

- Repetition structure
  - Action repeated while some condition remains true
  - Psuedocode

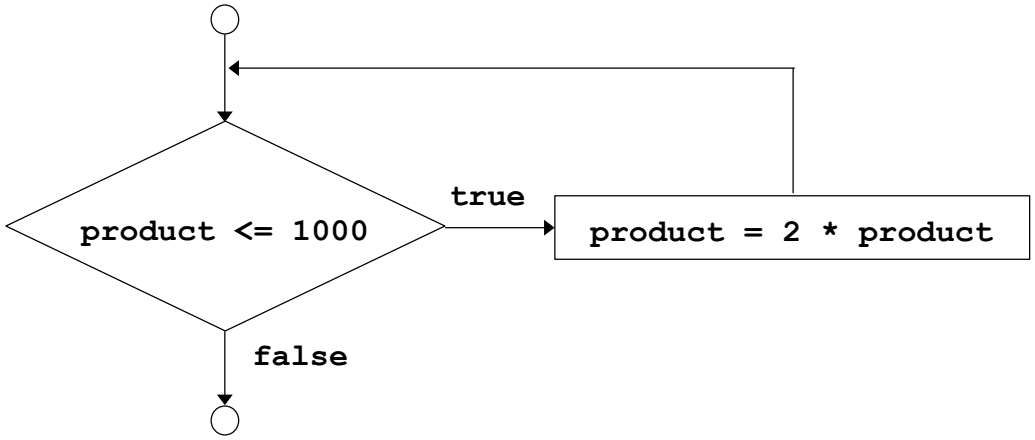
    while there are more items on my shopping list

    Purchase next item and cross it off my list
  - `while` loop repeated until condition becomes false
- Example

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

while Repetition Structure

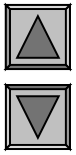
- Flowchart of `while` loop



Counter-Controlled Repetition

- Counter-controlled repetition
  - Loop repeated until counter reaches certain value
- Definite repetition
  - Number of repetitions known
- Example

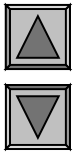
  A class of ten students took a quiz. The grades (integers in the range 0 to 100) for this quiz are available to you. Determine the class average on the quiz.



Outline

fig02_07.cpp
(1 of 2)

```
// Fig. 2.7: fig02_07.cpp
// Class average program with counter-controlled repetition.
#include <iostream>

using std::cout;
using std::cin;
using std::endl;

// function main begins program execution
int main()
{
   int total;        // sum of grades input by user
   int gradeCounter; // number of grade to be entered next
   int grade;        // grade value
   int average;      // average of grades

   // initialization phase
   total = 0;          // initialize total
   gradeCounter = 1;   // initialize loop counter

```



Outline

fig02_07.cpp
(2 of 2)

fig02_07.cpp
output (1 of 1)

```
   // processing phase
   while ( gradeCounter <= 10 ) {        // loop 10 times
      cout << "Enter grade: ";           // prompt for input
      cin >> grade;                      // read grade from user
      total = total + grade;             // add grade to total
      gradeCounter = gradeCounter + 1;   // increment counter
   }

   // termination phase
   average = total / 10;                 // integer division

   // display result
   cout << "Class average is

   return 0;   // indicate p

} // end function main
```

The counter gets incremented each time the loop executes. Eventually, the counter causes the loop to end.

```
Enter grade: 98
Enter grade: 76
Enter grade: 71
Enter grade: 87
Enter grade: 83
Enter grade: 90
Enter grade: 57
Enter grade: 79
Enter grade: 82
Enter grade: 94
Class average is 81
```

Sentinel-Controlled Repetition

- Suppose problem becomes:

  Develop a class-averaging program that will process an arbitrary number of grades each time the program is run

  – Unknown number of students

  – How will program know when to end?

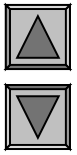
- Sentinel value

  – Indicates "end of data entry"

  – Loop ends when sentinel input

  – Sentinel chosen so it cannot be confused with regular input

    - -1 in this case



Outline

fig02_09.cpp
(1 of 3)

```
// Fig. 2.9: fig02_09.cpp
// Class average program with sentinel-controlled repetition.
#include <iostream>

using std::cout;
using std::cin;
using std::endl;
using std::fixed;

#include <iomanip>        // parameterized stream manipulators

using std::setprecision;  // sets numeric output precision

// function main begins program execution
int main()
{
   int total;          // sum of grades
   int gradeCounter;   // number of grades entered
   int grade;          // grade value

   double average;     // number with decimal point for average

   // initialization phase
   total = 0;          // initialize total
   gradeCounter = 0;   // initialize loop counter
```

Data type **double** used to represent decimal numbers.

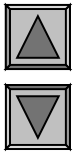
fig02_09.cpp
(2 of 3)

```
26
27    // processing phase
28    // get first grade from user
29    cout << "Enter grade, -1 to end: ";  // prompt for input
30    cin >> grade;                        // read grade from user
31
32    // loop until sentin
33    while ( grade != -1
34       total = total + g
35       gradeCounter = gr
36
37       cout << "Enter gr
38       cin >> grade;
39
40    } // end while
41
42    // termination phase
43    // if user entered at least one grade ...
44    if ( gradeCounter != 0 ) {
45
46       // calculate average of all grades entered
47       average = static_cast< double >( total ) / gradeCounter;
48
```

`static_cast<double>()` treats **`total`** as a **`double`** temporarily (casting).

Required because dividing two integers truncates the remainder.

`gradeCounter` is an **`int`**, but it gets *promoted* to **`double`**.



Outline

fig02_09.cpp
(3 of 3)

fig02_09.cpp
output (1 of 1)

```
      // display average with two digits of precision
      cout << "Class average is " << setprecision( 2 )
           << fixed << average << endl;

   } // end if part of if/else

   else // if no grades were entered, output appropriate message
      cout << "No grades were entered" << endl;

   return 0;   // indicate program ended successfully

} // end function main
```

```
Enter grade, -1 to end: 75
Enter grade, -1 to end: 94
Enter grade, -1 to end: 97
Enter grade, -1 to end: 88
Enter grade, -1 to end: 70
Enter grade, -1 to end: 64
Enter grade, -1 to end: 83
Enter grade, -1 to end: 89
Enter grade, -1 to end: -1
Class average is 82.50
```

`setprecision(2)` prints two digits past decimal point (rounded to fit precision).

Programs that use this must include **`<iomanip>`**

`fixed` forces output to print in fixed point format (not scientific notation). Also, forces trailing zeros and decimal point to print.

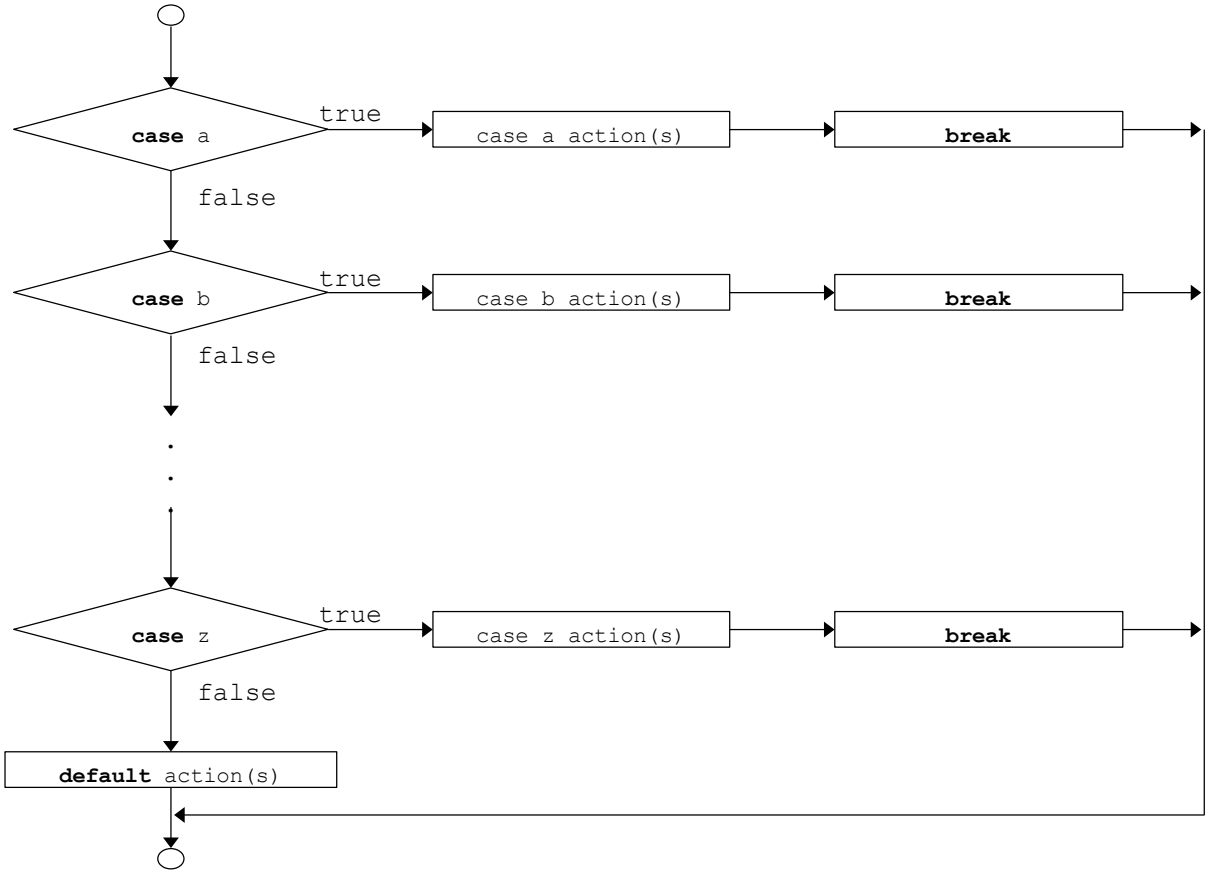
Include **`<iostream>`**

switch Multiple-Selection Structure

- **switch**
  - Test variable for multiple values
  - Series of **case** labels and optional **default** case

```
switch ( variable ) {
        case value1:        //  taken if variable == value1
                statements
                break;       //  necessary to exit switch

        case value2:
        case value3:        //  taken if variable == value2 or == value3
                statements
                break;

        default:            //  taken if none matches
                statements
                break;
}
```

switch Multiple-Selection Structure



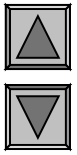
switch Multiple-Selection Structure

- Example upcoming
  - Program to read grades (A-F)
  - Display number of each grade entered
- Details about characters
  - Single characters typically stored in a **`char`** data type
    - **`char`** a 1-byte integer, so **`char`**s can be stored as **`int`**s
  - Can treat character as **`int`** or **`char`**
    - 97 is the numerical representation of lowercase ‘a’ (ASCII)
    - Use *single quotes* to get numerical representation of character

```
cout << "The character (" << 'a' << ") has the value "

      << static_cast< int > ( 'a' ) << endl;
```

Prints

```
The character (a) has the value 97
```



Outline

fig02_22.cpp
(1 of 4)

```
// Fig. 2.22: fig02_22.cpp
// Counting letter grades.
#include <iostream>

using std::cout;
using std::cin;
using std::endl;

// function main begins program execution
int main()
{
   int grade;        // one grade
   int aCount = 0;   // number of As
   int bCount = 0;   // number of Bs
   int cCount = 0;   // number of Cs
   int dCount = 0;   // number of Ds
   int fCount = 0;   // number of Fs

   cout << "Enter the letter grades." << endl
        << "Enter the EOF character to end input." << endl;

```

```
22    // loop until user types end-of-file key sequence
23    while ( ( grade = cin.get() ) != EOF ) {
24
25       // determine which grade was input
26       switch ( grade ) {  // switch structure nested in while
27
28          case 'A':        // grade was uppercase A
29          case 'a':        // or lowercase a
30             ++aCount;     // increment aCount
31             break;        //
32
33          case 'B':        //
34          case 'b':        //
35             ++bCount;     //
36                           //
37
38                           //
39                           //
40             ++cCount;     //
41             break;        //
42
```

break causes **switch** to end and the program continues with the first statement after the **switch** structure.

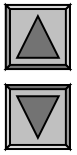
Compares **grade** (an **int**) to the numerical representations of **A** and **a**.

Assignment statements have a value, which is the same as the variable on the left of the **=**. The value of this statement is the same as the value returned by **cin.get()**.

This can also be used to initialize multiple variables:
a = b = c = 0;

cin.get() uses dot notation (explained chapter 6). This function gets 1 character from the keyboard (after *Enter* pressed), and it is assigned to **grade**.

cin.get() returns EOF (end-of-file) after the EOF character is input, to indicate the end of data. EOF may be ctrl-d or ctrl-z, depending on your OS.



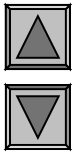
Outline

fig02_22.cpp
(3 of 4)

```
43          case 'D':         // grade was uppercase D
44          case 'd':         // or lowercase d
45             ++dCount;      // increment dCount
46             break;         // exit switch
47
48          case 'F':         // grade was
49          case 'f':         // or lowerc
50             ++fCount;      // increment
51             break;         // exit swit
52
53          case '\n':        // ignore ne
54          case '\t':        // tabs,
55          case ' ':         // and spac
56             break;         // exit swi
57
58          default:          // catch all other characters
59             cout << "Incorrect letter grade entered."
60                  << " Enter a new grade." << endl;
61             break;         // optional; will exit switch anyway
62
63       } // end switch
64
65    } // end while
66
```

This test is necessary because *Enter* is pressed after each letter grade is input. This adds a newline character that must be removed. Likewise, we want to ignore any whitespace.

Notice the **`default`** statement, which catches all other cases.



Outline

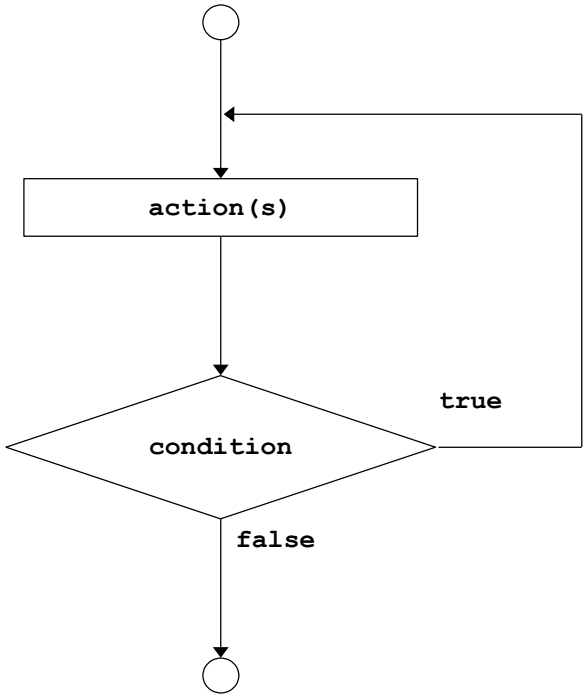
fig02_22.cpp
(4 of 4)

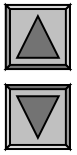
```
   // output summary of results
   cout << "\n\nTotals for each letter grade are:"
        << "\nA: " << aCount   // display number of A grades
        << "\nB: " << bCount   // display number of B grades
        << "\nC: " << cCount   // display number of C grades
        << "\nD: " << dCount   // display number of D grades
        << "\nF: " << fCount   // display number of F grades
        << endl;

   return 0;  // indicate successful termination

} // end function main
```

do/while Repetition Structure

- Similar to **`while`** structure
  - Makes loop continuation test at end, not beginning
  - Loop body executes at least once
- Format

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





Outline

fig02_24.cpp
(1 of 1)

fig02_24.cpp
output (1 of 1)

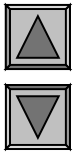
```
// Fig. 2.24: fig02_24.cpp
// Using the do/while repetition structure.
#include <iostream>

using std::cout;
using std::endl;

// function main begins program execution
int main()
{
   int counter = 1;

   do {
      cout << counter << "  ";   // display counter
   } while ( ++counter <= 10 );  // end do/while

   cout << endl;

   return 0;   // indicate successful termination

} // end function main
```

Notice the preincrement in loop-continuation test.

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

break and **continue** Statements

- **`break`** statement
  - Immediate exit from **`while`**, **`for`**, **`do/while`**, **`switch`**
  - Program continues with first statement after structure
- Common uses
  - Escape early from a loop
  - Skip the remainder of **`switch`**



Outline

fig02_26.cpp
(1 of 2)

```
// Fig. 2.26: fig02_26.cpp
// Using the break statement in a for structure.
#include <iostream>

using std::cout;
using std::endl;

// function main begins program execution
int main()
{

   int x;  // x declared here so it can be used after the loop

   // loop 10 times
   for ( x = 1; x <= 10; x++ ) {

      // if x is 5, terminate loop
      if ( x == 5 )
         break;           // break loop only if x is 5

      cout << x << " ";   // display value of x

   } // end for

   cout << "\nBroke out of loop when x became " << x << endl;
```

Exits **for** structure when **break** executed.

Logical Operators

- Used as conditions in loops, **if** statements
- **&&** (logical **AND**)
  - **true** if both conditions are **true**

```
if ( gender == 1 && age >= 65 )
   ++seniorFemales;
```

- **||** (logical **OR**)
  - **true** if either of condition is **true**

```
if ( semesterAverage >= 90 || finalExam >= 90 )
   cout << "Student grade is A" << endl;
```

Logical Operators

- **!** (logical **NOT**, logical negation)
  - Returns **true** when its condition is **false**, & vice versa

```
if ( !( grade == sentinelValue ) )
   cout << "The next grade is " << grade << endl;
```

Alternative:

```
if ( grade != sentinelValue )
   cout << "The next grade is " << grade << endl;
```

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

- Common error
  - Does not typically cause syntax errors
- Aspects of problem
  - Expressions that have a value can be used for decision
    - Zero = false, nonzero = true
  - Assignment statements produce a value (the value to be assigned)

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

- Example

```
if ( payCode == 4 )
   cout << "You get a bonus!" << endl;
```

  - If paycode is 4, bonus given

- If **==** was replaced with **=**

```
if ( payCode = 4 )
   cout << "You get a bonus!" << endl;
```

  - Paycode set to 4 (no matter what it was before)
  - Statement is true (since 4 is non-zero)
  - Bonus given in every case

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

- Lvalues
  - Expressions that can appear on left side of equation
  - Can be changed (I.e., variables)

```
x = 4;
```

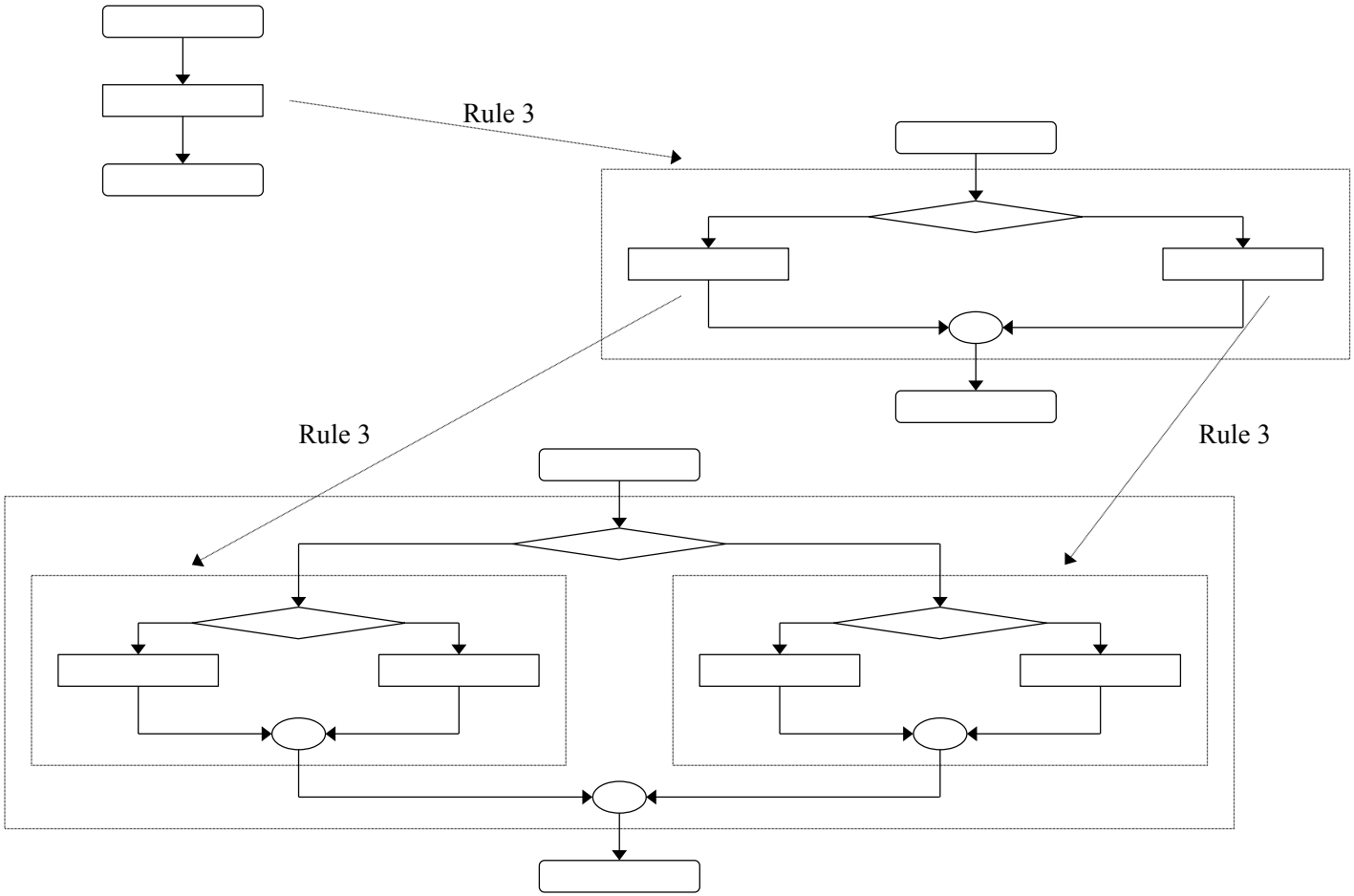
- Rvalues
  - Only appear on right side of equation
  - Constants, such as numbers (i.e. cannot write `4 = x;`)
- Lvalues can be used as rvalues, but not vice versa

Structured-Programming Summary

- Structured programming
  - Programs easier to understand, test, debug and modify
- Rules for structured programming
  - Only use single-entry/single-exit control structures
  - Rules
    1) Begin with the "simplest flowchart"
    2) Any rectangle (action) can be replaced by two rectangles (actions) in sequence
    3) 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

Structured-Programming Summary

Representation of Rule 3 (replacing any rectangle with a control structure)



Structured-Programming Summary

- All programs broken down into
  - Sequence
  - Selection
    - **`if`**, **`if/else`**, or **`switch`**
    - Any selection can be rewritten as an **`if`** statement
  - Repetition
    - **`while`**, **`do/while`** or **`for`**
    - Any repetition structure can be rewritten as a **`while`** statement