

UCLA Stat 130D Statistical Computing and Visualization in C++

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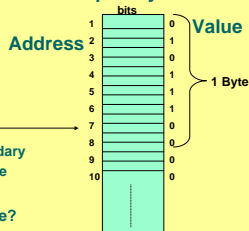
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http://www.stat.ucla.edu/~dinov/courses_students.html

Introduction to Computers and C++ Programming

- Computer Systems, Writing, compiling, making, packaging, distributing and running programs/software
- - Variables and assignments, Input/Output, Data types and expressions
 - Procedural (structured) vs. OOP
 - Classes, methods, abstract data types
 - Overloading (functions & classes)
 - Call-by-value vs. call-by-reference
 - I/O Streams
 - Multidimensional Arrays
 - Strings
 - Pointers, dynamic arrays
 - Recursion

Computer Systems

- **Hardware** -- Parts of a computer you can touch
 - » PC
 - » Workstation
 - » Mainframe
 - » Network
 - » input/output
 - » memory
 - primary, secondary
 - fixed, removable
 - » CPU
 - » Why 8Bits = 1Byte?

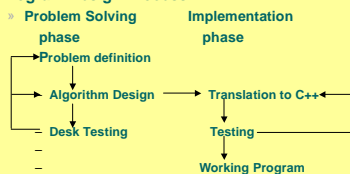


Computer Systems

- **Software** -- Parts of a computer you *cannot* touch
 - » Operating Systems
 - Macintosh
 - Windows
 - Linux
 - » High-Level Languages
 - Ada, C++, Java, BASIC, Lisp, Scheme
 - » Compilers
 - Source program, object program, Linking
 - » Editor: Integrated Development Environments (IDE)
 - IDEs combine editor, compiler and the execution environment (usually including a debugger)

Programming and Problem Solving

- **Algorithms**
 - » Idea is more general than 'program'
 - » Hard part of solving a problem is finding the algorithm
- **Program Design Process**



Software Life Cycle

- Analysis and specification of task (problem definition).
- Design of the software (algorithm design)
- Implementation (coding).
- Testing
- Maintenance and evolution of the system
- Obsolescence

1.3 Introduction to C++

- Origins of the C++ Language
 - Bjarne Stroustrup designed C++ for modeling.
 - C++ is an OOP extension of the C language.
 - C was developed as a systems programming language from the B language in the Unix environment. It grew into a general purpose programming language as its libraries were developed.

A Sample C++ Program

```
#include <iostream>
using namespace std;
int main()
{
    int number_of_pods, peas_per_pod, total_peas;
    cout << "Press return after entering a number.\n";
    cout << "Enter the number of pods:\n";
    cin >> number_of_pods;
    cout << "Enter the number of peas in a pod:\n";
    cin >> peas_per_pod;

    total_peas = number_of_pods * peas_per_pod;
    cout << "If you have ";
    cout << number_of_pods;
    cout << " pea pods\n";
    cout << "and ";
    cout << peas_per_pod;
    cout << " peas in each pod, then\n";
    cout << "you have ";
    cout << total_peas;
    cout << " peas in all the pods.\n";

    return 0;
}
```

Some details of a C++ Program

```
#include <iostream>
using namespace std;
int main()
{
```

- These lines are a complicated way to say "the program starts here"

```
    return 0;
```

```
}
```

- The last two lines say "the program ends here."

Some Details of a C++ Program

```
int number_of_pods, peas_per_pod, total_peas;
```

- This is a variable declaration.
- Variable must be declared before they can be used.
- Variables are used to store values.
- The *int* in the declaration says the variables can hold *integer* values.
- Other lines are (*executable*) *statements* that tell the computer to do some task.

Some Details of a C++ Program

- **cout** [*see-out*] is the output stream. It is attached to the monitor screen. **<<** is the insertion operator
- **cin** [*see-in*] is the input stream and is attached to the keyboard. **>>** is the extraction operator.
- "Press return after entering a number.\n" is called a *cstring* literal. It is a message for the user.
- `cout << "Press return ... \n"` sends the message to `cout`
- `cin >> number_of_pods;`

Some Details of a C++ Program

```
cout << "Enter the number of peas in a pod.\n";
cin >> peas_per_pod;
```

- The first of these lines sends a request to the user.
- The second extracts an integer value (the type of `peas_per_pod`) into `peas_per_pod`.

Some Details of a C++ Program

```
total_peas = number_of_pods * peas_per_pod;
```

- The asterisk, *, is used for multiplication.
- This line multiplies the already entered values of number_of_pods and peas_per_pod to give a value which is stored (assigned to) total_peas.

Display 1.9 Layout of a Simple C++ Program

```
#include <iostream>
using namespace std;
int main()
{
    variable_declarations
    Statement1;
    Statement2;
    ...
    Statement_last;
    return 0;
}
(Other functions may follow)
```

An include directive
More later, for now "do it"
Declares main function
Start of main's block

Says "end program here"
End of main's block

Compiling and Running a C++ Program

- You write a C++ program using a text editor exactly as you would [write a letter](#), [create a home-page](#) or [compose an e-mail](#).
- Compiling depends on the environment.
- You may be using an Integrated Development Environment or IDE. Each IDE has its own way to do things.
- Read your manuals *and* consult a local expert.
- You may be using a command line compiler. In that event, you may some thing like write:
`cc myProgram.cpp`
- Your compiler may require .cxx., .cc, .cpp or perhaps .C
- Linking is usually automatic. Again, read your manuals and ask a local expert.

1.4 Testing and Debugging

- An error in a program, whether due to design errors or coding errors, are known as bugs.
- Program Errors are classified as
 - **design errors** -- if you solved the wrong problem, you have design errors.
 - **syntax errors** -- violation of language's grammar rules, usually caught by the compiler, and reported by **compiler error messages**.
 - **run-time errors** -- a program that compiles may die while running with a run-time error message that may or may not be useful.
 - **logic error** -- a program that compiles and runs to normal completion may not do what you want. May be a design error.

Kinds of Errors

- **Design errors occur when specifications are do not match the problem being solved.**
- **The compiler detects errors in syntax**
- **Run-time errors result from incorrect assumptions, incomplete understanding of the programming language, or unanticipated user errors.**

Summary

- **Hardware** physical computing machines.
- **Software** programs that run on hardware.
- Five computer components: input and output devices, CPU, main memory, secondary memory.
- There are two kinds of memory: main and secondary. Main memory is used when program is running. Secondary memory is usually nonvolatile.
- Main memory is divided into bytes, usually individually addressable.
- Byte: 8 bits. A bit is 0 or 1.
- **KiloByte**: 1KB = 2^{10} ~1,000 Bytes.
(MegaByte) 1MB = 2^{10} KB ~1,000,000B.
(GigaByte) 1GB = 2^{10} MB; **(Tera)** 1TB = 2^{10} GB; **(Peta)** 1PB = 2^{10} TB
- **Note**: In reality, 1Byte = 9Bits, 9-th bit is for parity check

Summary(continued)

- A compiler translates high level language to machine language.
- Algorithm is a sequence of precise instructions that lead to a solution to a problem.
- A solution to a problem begins with algorithm design.
- Errors are of several kinds: syntax, run-time, and logic errors.
- A variable is used to name a number.
- `cout <<` is an output statement
- `cin >>` is an input statement

Pitfall: Uninitialized Variables

- A variable that has not been set by your program will have the value left there by the last program to use the memory associated with that variable. This is an UNINITIALIZED variable. It contains garbage in the root sense of the word.
- This is illegal and incorrect but few compilers will catch this error.

```
int x = 3;           double pi = 3.14159;
int x(3);           double pi(3.14159);
int x;
x = 3;
```

20

Include Directories and Namespaces

- `#include <iostream>`
`using namespace std;`
- These lines provide declarations necessary to make `iostream` library available.
- C++ divides collections of names into namespaces. To access names in a namespace, the second line above, the `using directive`, is sufficient. It means that your program can use any name in the namespace `std`.
- A C++ namespace usually contains more than just names. They usually contain code as well.
- Older compilers will require the older style, `<iostream.h>`, and such compilers may not like the `using directive`. If your compiler doesn't like the `using directive`, just omit it.

21

Escape sequences

- The `\` (backslash) preceding a character tells the compiler that the next character does not have the same meaning as the character by itself.
 - An escape sequence is typed as two characters with no space between them.
 - `\\` is a real backslash character, not the escape character, a backslash that does not have the property of changing the meaning of the next character.
- ```
\n newline
\t tab character (same as control-h)
\a alert, or bell
\" double quote (that does not end a string literal).
```

22

## Formatting for Numbers with a Decimal Point

- The following statements will cause your floating point output to be displayed with 2 places of decimals and will always show the decimal point even when the output has a zero fractional part.

```
cout.setf(ios::fixed);
cout.setf(ios::showpoint);
cout.precision(2);
//Output format:
78.50
```

23

## Input using cin

- When a program reaches a `cin >>` statement, it waits for input. You are responsible for prompting the user of your program for proper input.
- Syntax:  
`cin >> number >> size;`  
`cin >> time_to_go`  
`>> points_needed;`

24

## Designing input and output

- Echoing your input is frequently requested by problem statements. Even when not requested, it is usually better to echo your input.

- Example:

```
....
cout << "Enter ... \n";
cin >> user_entry_variable;
cout << "You Entered: " << user_entry_variable;
....
```

- Scientific vs. floating point notation:  
3.14159; 0.00314159 x 10<sup>3</sup>; 0.00314159e3

25

## Other Number types

| Type                        | Memory used | Range                                                      | Precision - meaningful digits |
|-----------------------------|-------------|------------------------------------------------------------|-------------------------------|
| (unsigned) char             | 1 byte      | [0 ; 255]                                                  | NA                            |
| short<br>(a.k.a. short int) | 2 bytes     | -32,767<br>to 32,767                                       | NA                            |
| int                         | 4 bytes     | -2,147,483,647<br>to 2,147,483,647                         | NA                            |
| long                        | 4 bytes     | same as int                                                | NA                            |
| float                       | 4 bytes     | approximately<br>10 <sup>-38</sup> to 10 <sup>38</sup>     | 7 digits                      |
| double                      | 8 bytes     | approximately<br>10 <sup>-308</sup> to 10 <sup>308</sup>   | 15 digits                     |
| long double                 | 10 bytes    | approximately<br>10 <sup>-4932</sup> to 10 <sup>4932</sup> | 15 digits                     |

26

## Two Additional Variable Types char and bool

- **char** is a special type that is designed to hold single members of the ASCII character set.
  - ▶ Some vendors have extended ASCII character encoding to include more characters than upper and lower case letters, digits and punctuation. (Notably: IBM, on the PC, which has been adopted in nearly all Microsoft software.)
  - ▶ **cstring** (from C) and **string** (from the Standard Library) are for more than one char value.
  - ▶ **bool** is a type that was added to C++ in the 1995 Draft ANSI Standard. There are only two values: **true** and **false**. Almost all compilers support the **bool** type.
- Why do we need additional (**bool/char**) variable types?

27

## Arithmetic Operators and Expressions division /, and modulus %, for integer values

Division /, and modulus % are complementary operations. Mod, or modulus, %, works ONLY for integer types.

```
4 ← 12 / 3 is the quotient
3 | 12
 12
 --
 0 ← 12 % 3 = 12 mod 3 is the remainder
```

**Euclidean Algorithm**

```
4 ← 14 / 3 quotient = 3 THIS IS NOT 4.66
3 | 14
 12
 --
 2 ← 14 % 3 remainder after division
```

Dividend == divisor \* quotient + remainder.

28

## Arithmetic Operators and Expressions Precedence

When two operators appear in an arithmetic expression, there are **PRECEDENCE** rules that tell us what happens.

Evaluate the expression,

**X + Y \* Z**

by multiplying Y and Z first then the result is added to X.

**Rule:** Do inside most parentheses first, then multiplication and division next, additions and subtractions next, and break all ties left to right.

29

## Simple Flow of Control A simple branching mechanism

- Making decision in computer programs requires changing the execution from next instruction next to some other instruction next. This is called **flow of control**.

- There are two types of flow of control: **selection** and **looping**.
- **Looping** repeats an action, and will be discussed later.
- **Selection** chooses between alternative actions.

- **Selection:**

```
if (expression) ← Control Expression returns a bool value
 action1; ← Affirmative clause. Executed if Expression is true
else
 action2; ← Negative clause. Executed if Expression is false
```

30

## Comparison Operators

C++ provides comparison operators for making decisions in computer programs. These operators return a value of type *bool*: *true* or *false*.

| Math Symbol | English                  | C++ Notation | C++ Sample     | Math Equivalent |
|-------------|--------------------------|--------------|----------------|-----------------|
| =           | equal to                 | ==           | x + 7 == 2 * y | x + 7 = 2y?     |
| ≠           | not equal to             | !=           | ans != 'n'     | ans ≠ 'n'?      |
| <           | less than                | <            | count < m + 3  | count < m + 3?  |
| ≤           | less than or equal to    | <=           | time <= limit  | time ≤ limit?   |
| >           | greater than             | >            | time > limit   | time > limit?   |
| ≥           | greater than or equal to | >=           | age >= 21      | age ≥ 21?       |

31

## Logical (Boolean) Operators

- The 'and' operator **&&**  
Syntax: (Comparison\_1) && (Comparison\_2)  
Example, in an assignment to a bool variable:  
bool in\_range;  
in\_range = (0 < score) && (10 < score);
- The 'or' operator **||**. Example -- in an if-else statement  
if ( (x == 1) || (x == y) )  
cout << "x is 1 or x equals y. \n";  
else cout < "x is neither 1 nor equal to y.\n";

Not operator (!, ^, ~): E.g., ~x is true ↔ x is false

32

## PITFALL: strings of inequalities

Suppose x, y and z are integer values.

```
if (x < y < z) // Unfortunately, this is WRONG BUT IT COMPILES.
cout << "z is between x and y";
```

Here is why the expression is WRONG.

- In mathematics  $x < y < z$  is short hand for  $x < y$  &&  $y < z$ .
- In C++, this is not true. It is still valid C++, but *isn't what you expect from the mathematics*. In C++ the *precedence rules* require  $x < y < z$  be evaluated like this:  
 $(x < y) < z$
- The parenthesized expression returns a bool value. The < requires the same type on both sides. The bool value gets converted to the *int* value 0 (for *false*) or 1 (for *true*). Then  $0 < z$  or  $1 < z$  compiles. And gives (most of the time) a *wrong* answer!

33

## PITFALL: using = instead of ==

```
if (x = 12) // The = should have been ==
cout << "x is equal to 12";
else
cout << "x is not equal to 12";
```

- The second expression is NEVER executed, regardless of the value of x before this statement is encountered.
- WORSE*, after this if statement executes, the expression  $x = 12$  HAS ASSIGNED the value 12 to x.
- Why? The expression  $x = 12$  returns the value 12, which is converted to the *bool* value *true*, which is used by the *if*.
- Always write:

```
if (12 == x) // Compiler will say: 12 = x "non-lvalue on left"
cout << "x is equal to 12";
else
cout << "x is not equal to 12";
```

34

## Simple Loop Mechanisms

Most programs include a mechanism to repeat a block of code multiple times. 30 Students, 30 grades on each test, 100 workers, pay check generator block runs 100 times.

C++ provides loops named

**while**  
**for**  
**do while**

The piece of code the loop executes is called the **body**.  
Each loop execution of the body is called an **iteration**.

35

## Display 2.10 A while loop

```
while (count_down > 0)
{
 cout << "Hello ";
 count_down = count_down - 1;
}
```

```
while(bool expression)
{
 several statements
}
```

**Do not put a semicolon here**  
**This usually causes an infinite loop.**

```
do {
 cout << "Hello\n";
 cout << "Do you want another greeting?\n";
 << "Press y for yes, n for no,\n";
 cin >> ans;
} while (ans == 'y' || ans == 'Y'); // Don't forget the semicolon
```

36

## Increment and decrement operators

C++ provides the ++ and -- operators, each in each of two forms, prefix and postfix.

The text, for good teaching reasons, leaves the use of expressions using ++ and -- to provide a value until later.

For now, we use `n++`; as a synonym for `n = n + 1`; and `n--` for a synonym `n = n - 1`;

37

## Programming Style Comments

- The most difficult part of any programming language to learn to use *properly* comments.
- A comment should *always* tie the code to the problem being solved. In some circumstances, a comment could explain 'tricky' code. (It is better to write clear code and omit the comment.)
- /\* comment in this style \*/ may span more than one line.
- // these comments run from the // to the end of the line.

38

## Indenting

- Indenting: elements considered a group should be indented to look like a group (E.g., C++ Builder vs. Notepad).
- if-else, while, and do-while should be indented as in the sample code.
- The affirmative clause and negative clause of if-else statements should be indented more than surrounding code.
- The body of loops should be indented more than surrounding code.
- CONSISTENCY of style is more important than any particular style standard.

39

## Program header comments

Comments should be placed at the start of the program that describes the essential information about the program:

```
/**The file name (part of what package)
 * The author
 * The address or other means to contact the author
 * The purpose of the program
 * What/How the program does
 * The date written or version number
 */
```

40

## Predefined Functions Libraries

```
#include <cmath> // include declarations of math
 // library functions
#include <iostream> // include definitions of
 // iostream objects
using namespace std; // make names available
int main()
{
 cout << sqrt(3.0) << endl; // call math library function
 // sqrt with argument 3.0, send
 // the returned value to cout
}
```

3

41

## A Function call

```
//Computes the size of a dog house that can be purchased
//given the user's budget.
#include <iostream>
#include <cmath>
using namespace std;

int main()
{
 const double COST_PER_SQ_FT = 10.50;
 double budget, area, length_side;

 cout << "Enter the amount budgeted for your dog house $";
 cin >> budget;

 area = budget/COST_PER_SQ_FT;
 length_side = sqrt(area); // the function call
}
```

42

## A Function call

```
cout.setf(ios::fixed);
cout.setf(ios::showpoint);
cout.precision(2);
cout << "For a price of $" << budget << endl
 << "I can build you a luxurious square dog house!\n"
 << "that is " << length_side
 << " feet on each side.\n";

return 0;
}
```

NOTE: "makefiles"

43

## PITFALL: Problems with Library functions

- Some compilers do not comply with the ISO Standard.
- If your compiler does not work with `#include <iostream>` use `#include <iostream.h>`
- Similarly, for headers like `cstdlib`: use `stdlib.h`, and for `cmath`, use `math.h`
- Most compilers at least coexist with the headers without the `.h`, but some are hostile to these headers.

44

## Predefined Functions Type changing functions

Question: 9/2 is an int, but we want the 4.5 floating point result. We want the integer part of some floating point number. How do we manage?

Answer: Type casting, or "type changing functions".

C++ provides a function named `double` that takes a value of some other type and converts it to double.

Example:

```
int total, number;
double ratio;
// input total, number
winnings = double(total) / number;
```

45

## Programmer Defined Functions function prototypes

- A function prototype tells you all the information you need to call the function. A prototype of a function (or its definition) must appear in your code prior to any call to the function.
- Syntax: *Don't forget the semicolon!*
  - `Type_of_returned_value Function_Name(Parameter_list);`
  - Place prototype comment here.
  - `Parameter_list` is a comma separated list of parameter definitions:  
`type_1 param_1, type_2 param_2, ..., type_N param_N`
- Example:  
`double total_weight(int number, double weight_of_one);`  
*// Returns total weight of number of items that // each weigh weight\_of\_one*

46

## Programmer Defined Functions A function Definition

```
#include <iostream>
using namespace std;

double total_cost(int number_par, double price_par);
//Computes total cost, including 5% sales tax, on number_par items at a cost of price_par each.

int main()
{ double price, bill;
 int number;
 cout << "Enter the number of items purchased: ";
 cin >> number;
 cout << "Enter the price per item $";
 cin >> price;

 bill = total_cost(number, price); ← The function call
 cout.setf(ios::fixed); cout.setf(ios::showpoint); cout.precision(2);
 cout << number << " items at " << "$" << price << " each.\n"
 << "Final bill, including tax, is $" << bill << endl;
 return 0;
}
```

47

## 3.3 Programmer Defined Functions Display 3.3 A function Definition (Slide 2 of 2)

```
double total_cost(int number_par, double price_par) ← The function heading
{
 heading
 const double TAX_RATE = 0.05; //5% sales tax
 double subtotal;

 subtotal = price_par * number_par;
 return (subtotal + subtotal*TAX_RATE);
} ← The function definition
```

The function body

48

### 3.3 Programmer Defined Functions Call-by-value Parameters

Consider the function call:

```
bill = total_cost(number, price);
```

- The *values* of the arguments number and price are “plugged” in for the *formal parameters*.
- A function of the kind discussed in this chapter does not send any output to the screen, but does send a kind of “output” back to the program. The function returns a return-statement instead of cout-statement for “output.”

49

### Programmer Defined Functions Alternate form for Function Prototypes

- The **parameter names are not required:**  

```
double total_cost(int number, double price);
```
- It is permissible to write:  

```
double total_cost(int, double);
```

50

### PITFALL

#### → Arguments in the wrong order ←

- When a function is called, C++ substitutes the first argument given in the call for the first parameter in the definition, the second argument for the second parameter, and so on.
- *There is no check for reasonableness. The only things checked are:*
  - i) that there is agreement of argument type with parameter type and
  - ii) that the number of arguments agrees with the number of parameters.
- If you do not put correct arguments in call in the correct order, C++ will happily assign the “wrong” arguments to the “right” parameters.
- Function-overloading

51

### Procedural Abstraction Principle of Information Hiding

- David Parnas, in 1972 stated the principle of information hiding.
  - A function’s author (service provider programmer) should know everything about how the function does its job, but nothing but specifications about how the function will be used.
  - The client programmer – the programmer who will call the function in her code – should know only the function specifications, but nothing about how the function is implemented.

52

### Local Variables Namespaces

All our use of namespaces has amounted to

```
#include <iostream>
using namespace std;
```

While this is correct, we are sidestepping the reason namespaces were introduced into C++, though we have done this for good teaching reasons.

In short, we have been “polluting the global namespace.” So long as our programs are small, so this is not a problem.

This won’t always be the case, so you should learn to put the using directive in the proper place.

53

### 3.5 Local Variables Namespaces Revisited (2 of 2)

Placing a using directive anywhere is analogous to putting all the definitions from the namespace there. This is why we have been polluting the global namespace. We have been putting all the namespace std names from our header file in the global namespace.

The rule, then is:

Place the namespace directive,  
using namespace std;

inside the block where the names will be used. The next slide is Display 3.13 with the namespace directive place correctly.

54

## Local Variables Using Namespaces

```
//Computes the area of a circle and the volume of a sphere.
//Uses the same radius for both calculations.
#include <iostream>
#include <cmath>//Some compilers may use math.h instead of cmath.
const double PI = 3.14159;
double area(double radius);
//Returns the area of a circle with the specified radius.
double volume(double radius);
//Returns the volume of a sphere with the specified radius.
int main()
{
 using namespace std;
 double radius_of_both, area_of_circle, volume_of_sphere;
 cout << "Enter a radius to use for both a circle\n"
 << "and a sphere (in inches): ";
 cin >> radius_of_both;
```

55

## Local Variables Using Namespaces

```
area_of_circle = area(radius_of_both);
volume_of_sphere = volume(radius_of_both);
cout << "Radius = " << radius_of_both << " inches\n"
 << "Area of circle = " << area_of_circle
 << " square inches\n"
 << "Volume of sphere = " << volume_of_sphere
 << " cubic inches\n";
 return 0;
}
double area(double radius)
{
 using namespace std;
 return (PI * pow(radius, 2));
}
double volume(double radius)
{
 using namespace std;
 return ((4.0/3.0) * PI * pow(radius, 3));
}
```

56

## Overloading Function Names

- C++ distinguishes two functions by examining the **function name** and the **argument list** for **number** and **type** of arguments.
- The function that is chosen is the function with the same number of parameters as the number of arguments and that matches the types of the parameter list sufficiently well.
- This means you do not have to generate names for functions that have very much the same task, but have different types.

57

## Overloading Function Names Overloading a Function Name

```
//Illustrates overloading the function name ave.
#include <iostream>
double ave(double n1, double n2);
//Returns the average of the two numbers n1 and n2.
double ave(double n1, double n2, double n3);
//Returns the average of the three numbers n1, n2, and n3.
int main()
{
 using namespace std;
 cout << "The average of 2.0, 2.5, and 3.0 is "
 << ave(2.0, 2.5, 3.0) << endl;
 cout << "The average of 4.5 and 5.5 is "
 << ave(4.5, 5.5) << endl;
 return 0;
}
```

58

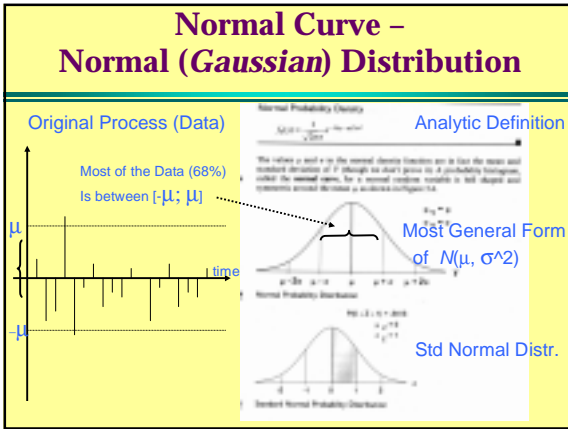
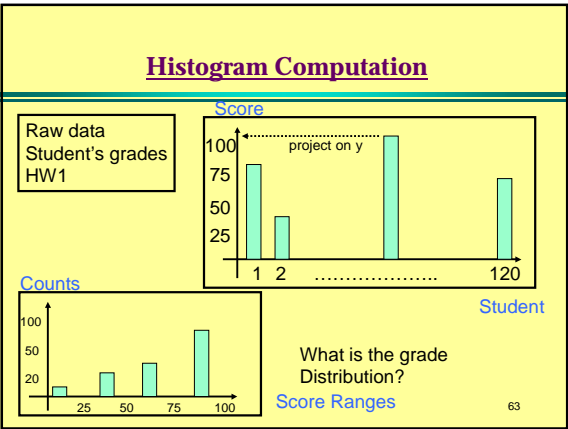
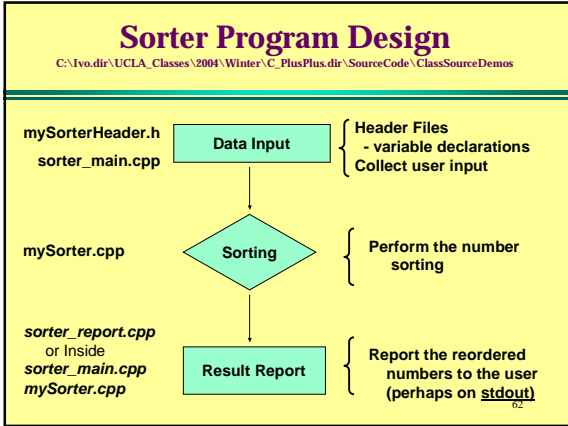
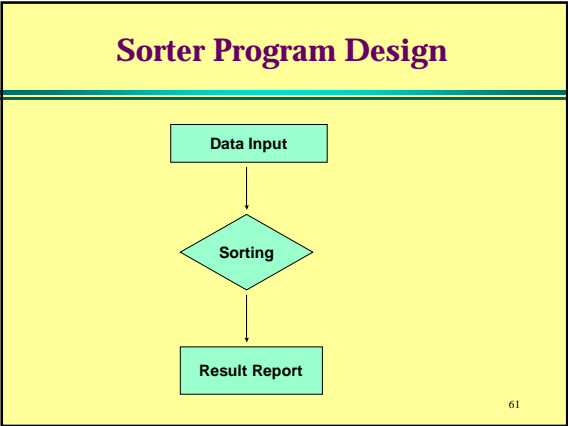
## Overloading Function Names Automatic Type Conversion

- We pointed out that when overloading function names, the C++ compiler compares the number and sequence of types of the arguments to the number and sequence of types for candidate functions.
- In choosing which of several candidates to use when overloading function names, the compiler will choose an *exact* match if one is available.
- An integral type will be *promoted* to a larger integral type if necessary to find a match. An integral type will be promoted to a floating point type if necessary to get a match.

59

## Sorter Program Design

60



```

// Example
// Simple Histogram Computation
#include <iostream>

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

void getUserInput();
void computeHistogram();
int reportHistogram();
int n0, n1, n2, n3, n4, n5, n6, n7, n8, n9;

int main()
{
 getUserInput();
 computeHistogram();
 cout << "Output of the Histogram Report is " <<
 reportHistogram() << " 0 indicates ok!";
 return (0);
}

```

65

```

void getUserInput()
{ // get user input
}

void computeHistogram()
{ // integers in [0;11], histogram bins [0;3], [4;7], [8;11]
 int bin1, bin2, bin3;
}

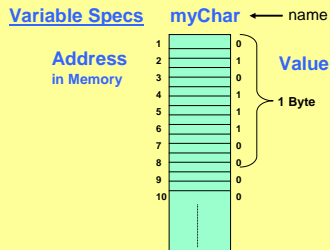
int reportHistogram()
{ // report number of integers inside each bin
}

```

66

## Call-by-Reference Parameters

### A first view of Call-by-reference



67

## Call-by-Reference Parameters

### A first view of Call-by-reference

- The call-by-value mechanism we have used until now is not adequate to certain tasks.
- Input subtasks should be carried out with a function call. This is not adequate for more than one return value. We need another mechanism.
- With a Call-by-Value parameter, the corresponding argument is only read for its value. The argument can be variable, but this is not necessary. The parameter is initialized with the value of the value-parameter.
- With Call-by-Reference, the corresponding argument must be variable, and the behavior of the function is *as if the variable were substituted for the parameter*.

68

### A first view of Call-by-reference

- To make a parameter a call-by-reference, parameter, an **ampersand (&)** is placed between the type name and the variable name in the function header and in any prototypes that are to declare this function in other places. **a call-by-reference parameter**

Example: void Get\_Input( double & f\_variable)

```
{
 using namespace std;
 cout << "Enter a Fahrenheit, I will return Celsius\n";
 cin >> f_variable;
}
```

69

Call by Reference parameters (1 of 2)  
 //Program to demonstrate call-by-reference parameters.  
 #include <iostream>

```
void get_numbers(int& input1, int& input2);
//Reads two integers from the keyboard.
```

```
void swap_values(int& variable1, int& variable2);
//Interchanges the values of variable1 and variable2.
```

```
void show_results(int output1, int output2);
//Shows the values of variable1 and variable2, in that order.
```

```
int main()
{
 int first_num, second_num;

 get_numbers(first_num, second_num);
 swap_values(first_num, second_num);
 show_results(first_num, second_num);
 return 0;
}
```

70

Call by Reference parameters (2 of 2)

```
//Uses iostream:
void get_numbers(int& input1, int& input2)
{
 using namespace std;
 cout << "Enter two integers: ";
 cin >> input1
 >> input2;
}

void swap_values(int& variable1, int& variable2)
{
 int temp;
 temp = variable1;
 variable1 = variable2;
 variable2 = temp;
}

//Uses iostream:
void show_results(int output1, int output2)
{
 using namespace std;
 cout << "In reverse order the numbers are: "
 << output1 << " " << output2 << endl;
}
```

```
get_numbers(first_num, second_num);
swap_values(first_num, second_num);
show_results(first_num, second_num);
```

71

### Call-by-Reference in Detail

- The whole truth is - it is the **address** of the argument is used in place of the parameter, and the address is used to **fetch values** from the argument as well as to **write to the argument**.

72

## Parameters and Arguments

If you keep these points in mind, you can handle all the parameter passing language.

1. The **formal parameters** for a function are listed in the function prototype and function definition header. A formal parameter is a **place holder** and a **local variable** that is filled at the time the function is called.
2. **Arguments** appear in a comma separated list in the call to **any** function, and are used to fill in the corresponding formal parameters. When the function is called, the arguments are **plugged in** for the formal parameters.
3. The terms **call-by-value** and **call-by-reference** refer to the mechanism that is used in the "plugging in" process.

73

## Parameters and Arguments

In the **call-by-value** method, the arguments are read, and the parameters are initialized using a **copy of the value** of the argument.

In the **call-by-reference** method, the argument **must be a variable**. The behavior is exactly as if the argument were substituted for the parameter. Then if the code assigns the parameter, it is the argument that is changed. The mechanism is to **pass the address of the argument** and then the parameter mechanism knows where the argument is so when the parameter is written, the argument is where the writing is done.

74

## Mixed Parameter Lists

It is entirely feasible to have **value parameters** (call-by-value parameter) mixed in with **reference parameters** (call-by-reference parameters).

Function prototype definition:

```
void example(int& par1, int par2, double& par3, int &n);
```

Function Call:

```
example(arg1, 17, arg3, local_n);
```

Here 17 is permissible because par2 is a value parameter. This code may (*but by no means must*) change the values of **arg1** and **arg3**.

75

## PITFALL: Inadvertent Local Variables

Omitting an ampersand (&) when you intend a reference parameter is a mistake that bites twice.

(1) It makes you code run incorrectly, the compiler probably won't catch it!

(2) The Bug is very difficult to find because *it looks right*. See the following

76

### Inadvertent local variables

```
//Inadvertent local variables. Shows what happens when you omit &
//Program to demonstrate call-by-reference parameters.
```

```
#include <iostream>
```

```
void get_numbers(int& input1, int& input2);
```

```
//Reads two integers from the keyboard.
```

```
void swap_values(int variable1, int variable2);
//Interchanges the values of variable1 and variable2.
```

```
void show_results(int output1, int output2);
//Shows the values of variable1 and variable2, in that order.
```

```
int main()
```

```
{
 using namespace std;
 int first_num, second_num;
 get_numbers(first_num, second_num);
 swap_values(first_num, second_num);
 show_results(first_num, second_num);
 return 0;
}
```

77

### Inadvertent local variables (2 of 2)

```
void swap_values(int variable1, int variable2)
{ int temp;
 temp = variable1;
 variable1 = variable2;
 variable2 = temp;
}
```

Forgot the & here, which  
Makes these inadvertent local variables  
Variable swap stays local to swap\_values

```
//Uses iostream:
```

```
void get_numbers(int& input1, int& input2)
```

```
{ using namespace std;
 cout << "Enter two integers: ";
 cin >> input1
 >> input2;
}
```

What happens if there's  
a discrepancy between  
function prototype and  
header definitions?

```
//Uses iostream:
void show_results(int output1, int output2)
{ using namespace std;
 cout << "In reverse order the numbers are: "
 << output1 << " " << output2 << endl;
}
```

78

## Using Procedural Abstraction

### Functions calling functions

- A function may call another function, or *itself*, and the second function could call back the first.
- The situation is exactly the same as if the first call had been in the main function.
- swaps the values of two variables if the values are out of order.

```
// Function Calling Another Function (1 of 2)
// Program to demonstrate a function calling another function.
#include <iostream>

void get_input(int& input1, int& input2);
// Reads two integers from the keyboard.

void swap_values(int& variable1, int& variable2);
// Interchanges the values of variable1 and variable2.

void myOrder(int& n1, int& n2);
// Orders the numbers in the variables n1 and n2
// so that after the function call n1 <= n2.

void report_results(int output1, int output2);
// Outputs the values in output1 and output2.
// Assumes that output1 <= output2

int main()
{ int first_num, second_num;

 get_input(first_num, second_num);
 myOrder(first_num, second_num);
 report_results(first_num, second_num);
 return 0;
}
```

80

```
// Function Calling Another Function (2 of 2)
void get_input(int& input1, int& input2)
{ using namespace std;
 cout << "Enter two integers: ";
 cin >> input1 >> input2;
}

void swap_values(int& variable1, int& variable2)
{ int temp;
 temp = variable1;
 variable1 = variable2;
 variable2 = temp;
}

void myOrder(int& n1, int& n2)
{ if (n1 > n2) swap_values(n1, n2); }

void report_results(int output1, int output2)
{ using namespace std;
 cout << "In increasing order the numbers are: "
 << output1 << " " << output2 << endl;
}
```

81

## Preconditions and Postconditions

- The **Prototype** comment should be broken into a **precondition** and a **postcondition**.
- The **precondition** is what is required to be true when the function is called.
- The **postcondition** describes the effect of calling the function, including any returned value and any effect on reference parameters.

## Preconditions and Postconditions

Example Pre - and Post-conditions.

```
// square root function, sqrt
// Prototype:
double sqrt(double arg);
// Pre: arg >= 0;
// Post: returns value, where value^2 == arg
```

If the Precondition is satisfied the function promises to put the Postcondition true.

If the precondition is not satisfied, the function's behavior is not constrained (not guaranteed) in any way.

## Testing and Debugging Functions

### Stubs and Drivers

- Every function should be designed, coded and tested as a separate unit from the rest of the program.
- Every function should be tested in a program in which every other function in that program has already been completely tested and debugged.
- This is catch 22. You need a framework to develop and test, but the framework must be debugged as well. How to get around?

## Stubs and Drivers

- Every function should be designed, coded and tested as a separate unit from the rest of the program.
- This is the essence of the top-down design strategy.
- How do you test a function? By writing a simple, short program called a **driver** that calls the function. The driver should be simple enough that we can confirm its correctness by inspection.

## Stubs and Drivers

- How do you test a program that needs a function, before you have written the function?
- By writing a simple, short program called a **stub** that provides the program with the same prototype, and provides enough data to the caller so the caller can be tested.
- The stub should be simple enough that we can confirm its correctness by inspection.

## Stubs and Drivers

- How do you test a program using stubs when the program needs several functions?
- We write stubs for all the functions, then write the real functions, putting them into the program **one at a time**. This way the complete program and already written code continues to be tested, while the new functions are written and tested until the final program is produced.
- Imagine how impossible it may be to debug a program which has errors in two, or more functions?!?

```

Driver Program (1 of 3)
// Driver program for the function get_input.
#include <iostream>

void get_input(double& cost, int& turnover);
// Precondition: User is ready to enter values correctly.
// Postcondition: The value of cost has been set to the
// wholesale cost of one item. The value of turnover has been
// set to the expected number of days until the item is sold.

int main()
{
 using namespace std;
 double wholesale_cost;
 int shelf_time;
 char ans;

 get_input(wholesale_cost, shelf_time);
 return 0;
}

```

```

void get_input(double& cost, int& turnover)
{
 using namespace std;
 cout << "Enter the wholesale cost of item $";
 cin >> cost;
 cout << "Enter the expected number of days until sold: ";
 cin >> turnover;
}

```

88

```

// Driver Program (2 of 3)
// Or for a more complex testing the main driver may be:

do
{
 get_input(wholesale_cost, shelf_time);

 cout.setf(ios::fixed);
 cout.setf(ios::showpoint);
 cout.precision(2);
 cout << "Wholesale cost is now $" << wholesale_cost << endl;
 cout << "Days until sold is now " << shelf_time << endl;

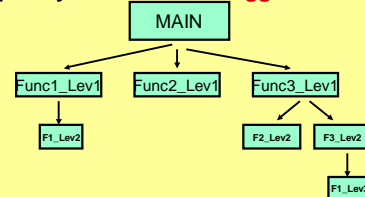
 cout << "Test again?"
 << " (Type y for yes or n for no): ";
 cin >> ans;
 cout << endl;
} while (ans == 'y' || ans == 'Y');

```

89

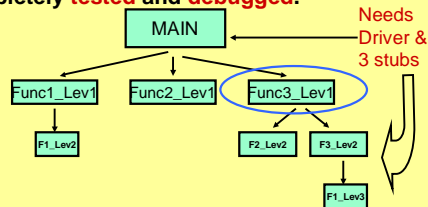
## Fundamental Rule for Testing Functions

- Every function should be tested in a program where every other function in that program is **functional**, has already been completely **tested and debugged**.



## Fundamental Rule for Testing Functions

- Every function should be tested in a program where every other function in that program is **functional**, has already been completely **tested and debugged**.



```
// Program that uses a Stub (part 1 of 4)
// Determines the retail price of an item according to
// the pricing policies of the Quick-Shop supermarket chain.
#include <iostream>

void introduction();
// Postcondition: Description of program is written on the screen.

void get_input(double& cost, int& turnover);
// Precondition: User is ready to enter values correctly.
// Postcondition: The value of cost has been set to the
// wholesale cost of one item. The value of turnover has been
// set to the expected number of days until the item is sold.

double price(double cost, int turnover);
// Precondition: cost is the wholesale cost of one item.
// turnover is the expected number of days until sale of the item.
// Returns the retail price of the item.
```

92

```
// Program that uses a Stub (part 2 of 4)
void report_output(double cost, int turnover, double price);
// Precondition: cost is the wholesale cost of one item; turnover is the
// expected time until sale of the item; price is the retail price of the item.
// Postcondition: The values of cost, turnover, and price have been
// written to the screen.

int main()
{
 double wholesale_cost, retail_price;
 int shelf_time;

 introduction();
 get_input(wholesale_cost, shelf_time);
 retail_price = price(wholesale_cost, shelf_time);
 report_output(wholesale_cost, shelf_time, retail_price);
 return 0;
}
```

93

```
// Program that uses a Stub (part 3 of 4)
// Uses iostream:
void introduction()
{
 using namespace std;
 cout << "This program determines the retail price for\n"
 << "an item at a Quick-Shop supermarket store.\n";
}

// Uses iostream:
void get_input(double& cost, int& turnover)
{
 using namespace std;
 cout << "Enter the wholesale cost of item $";
 cin >> cost;
 cout << "Enter the expected number of days until sold: ";
 cin >> turnover;
}
```

94

```
// Program that uses a Stub (part 4 of 4)
// Uses iostream:
void give_output(double cost, int turnover, double price)
{
 using namespace std;
 cout.setf(ios::fixed);
 cout.setf(ios::showpoint);
 cout.precision(2);
 cout << "Wholesale cost = $" << cost << endl
 << "Expected time until sold = "
 << turnover << " days" << endl
 << "Retail price= $" << price << endl;
}

// This is only a stub:
double price(double cost, int turnover)
{
 return 9.99; // Not correct, but good enough for some testing.
}
```

95

## Streams and Basic File I/O

- A **stream** is a flow of characters (or other kind of data).
- Data flowing **INTO** your program is an **input stream**.
- Data flowing **OUT OF** your program is an **output stream**.
- We have dealt with two of the three standard streams already: **cin** and **cout**.
- If **in\_stream** and **out\_stream** are input and output streams, we could write:

```
int the_number;
in_stream >> the_number;
out_stream << "the_number is " << the_number << endl;
```

96

## File I/O

The two code lines need to be embedded in the block of a function. The `#include` goes in the normal position at the top of the file.

Example:

```
#include <fstream>
...
ifstream in_stream;
ofstream out_stream;
```

- These variables are not yet attached to a file, so are not usable.
- The `fstream` library provides a member function named `open` that ties the stream to a file the outside world knows about. (More later on members of an object.)

Example:

```
in_stream.open("infile.dat"); // infile.dat must exist on your system
out_stream.open("outfile.dat"); // outfile.dat will be created.
```

97

## File I/O

In the example:

```
in_stream.open("infile.dat"); // infile.dat must exist on your system
out_stream.open("outfile.dat"); // outfile.dat will be created.
```

The file stream `in_stream` is said to be **open for reading**, and the file stream `out_stream` is said to be **open for writing**.

98

## File I/O

WORDS OF WARNING:

- In the example:  
`in_stream.open("infile.dat"); // infile.dat must exist on your system`  
`out_stream.open("outfile.dat"); // outfile.dat will be created.`
- For Windows, this is at worst "8+3" i.e. 8 characters for the name and 3 characters for the extension. Many recent systems allow long file names. Read your manuals and ask a local expert.
- The file name arguments for `open` is known as the **external name** for the file. This name must be legitimate file names on the system you are using. The stream name is the name of the file to your program.
- If you have a file named `outfile.dat` on your system, and open a file named the same, `outfile.dat`. In a program, the program will delete the old `outfile.dat` and replace it with data from your program.

99

## File I/O

- Once we have **declared the file variables**, `in_stream` and `out_stream`, and **connected them to files** on our system, we can then **take input** from `in_stream` and **send output** to `out_stream` in exactly the same manner as we have for `cin` and `cout`.

Examples:

```
#include <fstream>
...
// appropriate declarations and open statements
int one_number, another_number;
in_stream >> one_number >> another_number;
...
out_stream << "one_number: " << one_number
 << "another_number: " << another_number;
```

100

## File I/O

- Every file should be **closed** when your program is through fetching input or sending output to the file.
- This is done with the `close()` function.

Example:

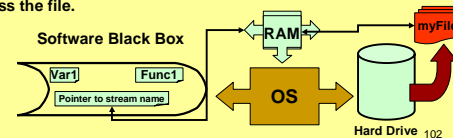
```
in_stream.close();
out_stream.close();
```

- Note that the `close` function takes no arguments.
- If your program terminates normally, the system will close the arguments.
- If the program does not terminate normally, this might not happen.
- File corruption is a real possibility.
- If you want to save output in a file and read it later, then you must close the file before opening it the second time for reading.

101

## A File Has Two Names

- Every input and every output file in a program has two names.
- The **external file name** is the real name of the file, which is the name known to the OS system. It is only used in your program in the call to the open function.
- The **stream name** is the name **declared in the program**, and that is tied to the **external file name** with the open statement.
- After the call to open, the program always uses the stream name to access the file.



102

## Classes and Objects

- Consider the code fragment:

```
#include <fstream>
...
ifstream in_stream;
ofstream out_stream;
in_stream.open("infile.dat");
out_stream.open("outfile.dat");
...
in_stream.close();
out_stream.close();
```
- Here the streams `in_stream` and `out_stream` are **objects**.
- An **object** is a variable that has functions as well as data associated with it.
- The functions `open` and `close` are associated with `in_stream` and `out_stream`, as well as the stream data and file data.

103

## Definition of a hypothetical *Integer* Object

- Variables/Fields: **min-value**; **max-value**
- Functions (operating on Integer objects)  
Suppose  
`Integer int1, int2; // int1 & int2 are objects of type Integer`  
- `int1.compareTo(int2) == 0 ?`

104

## Definition of a hypothetical *Integer* Object

- Variables/Fields: min-value; max-value
- Functions (operating on Integer objects)  
- `int1.compareTo(int2) == 0 ?`  
- `int1.doubleValue()`

105

## Definition of a hypothetical *Integer* Object

- Variables/Fields: min-value; max-value
- Functions (operating on Integer objects)  
- `int1.compareTo(int2) == 0 ?`  
- `int1.doubleValue()`  
- `Integer.parseInt("123") == 123, as an integer`

106

## Definition of a hypothetical *Integer* Object

- Variables/Fields: min-value; max-value
- Functions (operating on Integer objects)  
- `int1.compareTo(int2) == 0 ?`  
- `int1.doubleValue()`  
- `Integer.parseInt("123") == 123, as an integer`  
- `int1.writeAsString()`

107

## Introduction to Classes and Objects (continued)

- Consider the code fragment:

```
#include <fstream>
...
ifstream in_stream;
ofstream out_stream;
in_stream.open("infile.dat");
out_stream.open("outfile.dat");
...
in_stream.close();
out_stream.close();
```
- The functions and data associated with an object are referred to as **members** of the object.
- Functions associated with the object are called **member functions**.
- Data associated with the object are called **data members**.
- Note that data members are not (usually) accessible to functions that aren't members. (More on this later.)


108

## Summary of Classes and Objects

- An **object** is a variable that has functions/data associated with it.
- Functions associated with an object are called **member functions**.
- A **class** is a type whose variables are objects, e.g., `Integer int1`.
- The object's class determines which member functions the object has.

Syntax for calling a **member function** of an **object**:

`Calling_Object.member_function(Argument_List);`

Examples:  `dot operator`

- `in_stream.open("infile.dat");`
- `out_stream.open("outfile.dat");`
- `out_stream.precision(2);`
- The meaning of the Member\_Function\_Name is determined by class (type of) the Calling\_Object.

109

## Programming Tip Checking that a file was opened successfully

- A very common error is attempting to open a file for reading where the **file does not exist or is NOT readable**. The member function `open` fails then.
- Your program must test for this failure, and in the event of failure, manage the error.
- Use the `istream` member function `fail` to test for open failure.  
`in_stream.fail();`  
This function returns a *bool* value that is *true* if the stream is in a fail state, and *false* otherwise.

Example:

```
#include <cstdlib> // for the predefined exit(1); library function
...
in_stream.open("infile.dat");
if(in_stream.fail())
{ cout << "Input file opening failed. \n";
 exit(1); // Predefined function quits the program.
}
```

110

## The exit Statement

- The **exit** statement is written  
`#include <cstdlib> // exit is defined in the header file cstdlib.h`  
`using namespace std; // to gain access to the names`  
`exit(integer_value); // to exit the program`
- When the `exit` statement is executed, the program ends immediately.
- By convention, `1` is used as an argument to `exit` to signal an error.
- By convention, `0` is used to signal a normal successful completion of the program. (Use of other values is implementation defined.)
- The `exit` is defined in the `cstdlib` library header file, so any use requires
  - `#include <cstdlib>`
  - a directive to gain access to the names

### File I/O with Checks on open (1 of 2)

```
// Reads three numbers from the file infile.dat, sums the numbers,
// and writes the sum to the file outfile.dat.
#include <fstream>
#include <iostream>
#include <cstdlib>

int main()
{ using namespace std;
 ifstream in_stream;
 ofstream out_stream;
 in_stream.open("infile.dat");
 if (in_stream.fail())
 { cout << "Input file opening failed.\n";
 exit(1);
 }
 out_stream.open("outfile.dat");
 if (out_stream.fail())
 { cout << "Output file opening failed.\n";
 exit(1);
 }
}
```

112

### // File I/O with Checks on open (2 of 2)

```
int first, second, third;
in_stream >> first >> second >> third;
out_stream << "The sum of the first 3\n"
 << "numbers in infile.dat\n"
 << "is " << (first + second + third)
 << endl;

in_stream.close();
out_stream.close();

return 0;
}
```

113

## File Names as Input (1 of 4)

- So far, we have used only **cstring** literals for stream names for input and output files.
- You can specify your own file names from the keyboard or from file input. Here's how:
- A variable that can hold a file name is a **cstring** variable.
  - A **cstring** is what the textbook calls **string** in this chapter. This is the string type that C++ inherits from its C parentage.
  - A **cstring** is declared as in the following example:  
`char file_name[256];`
- The **cstring** `file_name`, declared here, can hold **at most 255** characters, (**NOT 256**), indices: `0, 1, 2, ..., 255`.
- Why 255 and not 256?

114

## File Names as Input (2 of 4)

Some notes on behavior of the cstring variables.

- "Why 255, not 256?"
- The character position just beyond the last character entered is used to hold a special character (**end-of-string**) that signals that is the last character. If you enter 255 characters, there really are 256 characters in file\_name, just as the definition suggests.
- You can access the cstring variable file\_name for input and output exactly as you access a variable of type int or a double. (The terminating character is automatically inserted by the istream insertion mechanism.)

115

## File Names as Input (3 of 4)

Example:

```
char file_name[256];
cout << "Enter a file name (maximum of 255 characters)\n";
cin >> file_name;
cout << "I will process file: " << file_name << endl;
// Try to open file file_name for input. Test for success.
ifstream in_stream;
ifstream.open(file_name); // Notice the cstring variable
if (instream.fail())
{
 cout << "Failed to open file " << file_name << " for input\n";
 exit(1);
}
```

116

## File Names as Input (4 of 4)

Notes on related ideas:

There are several generalizations of the cstrings notion. Arrays of any type.

- The string class provided in the C++ Standard Library.
- The vector class from the Standard Template Library.
- Linked lists (Chapter 14) are also a generalization of cstring in the sense that a linked list is a container for objects.

117

### Inputting a File Name (1 of 2)

//Reads three numbers from the file specified by the user, sums the numbers, //and writes the sum to another file specified by the user.

```
#include <fstream>
#include <iostream>
#include <cstdlib>

int main()
{
 using namespace std;
 char in_file_name[256], out_file_name[256];
 ifstream in_stream;
 ofstream out_stream;

 cout << "I will sum three numbers taken from an input\n"
 << "file and write the sum to an output file.\n";
 cout << "Enter the input file name (maximum of 255 characters):\n";
 cin >> in_file_name;
 cout << "Enter the output file name (maximum of 255 characters):\n";
 cin >> out_file_name;
 cout << "I will read numbers from the file " << in_file_name << " and\n"
 << "place the sum in the file " << out_file_name << endl;
}
```

118

### Inputting a File Name (2 of 2)

```
in_stream.open(in_file_name);
if (in_stream.fail())
{
 cout << "Input file opening failed.\n";
 exit(1);
}

out_stream.open(out_file_name);
if (out_stream.fail())
{
 cout << "Output file opening failed.\n";
 exit(1);
}

int first, second, third;
in_stream >> first >> second >> third;
out_stream << "The sum of the first 3\n"
 << "numbers in " << in_file_name << endl
 << "is " << (first + second + third) << endl;

in_stream.close();
out_stream.close();

cout << "End of Program.\n";
return 0;
}
```

119

## Formatting Output with Stream Functions

### Setting Stream Flags

cout .setf(ios::showpoint);

- The ostream member function **setf** sets **flags** in the stream. A stream **flag** is a variable that controls how the stream behaves. The output stream has many flags.
- The **ios::showpoint** is a flag-value defined in the class **ios** [2.34 (US) vs. 2.34 (EU) vs 234 (Non std)].
- Sending the value **ios::showpoint** to the **setf** member function causes the decimal point always to be displayed.

### Formatting Flags for setf

| Flag value                     | Effect                                                                    | Default |
|--------------------------------|---------------------------------------------------------------------------|---------|
| • <code>ios::fixed</code>      | floating output not in e-notation. Unsets scientific flag                 | not set |
| • <code>ios::scientific</code> | floating point output, will be e-notation as needed                       | not set |
| • <code>ios::pos</code>        | a plus (+) sign prefixes all positive output, including exponents         | not set |
| • <code>ios::point</code>      | a decimal point and trailing zeros are printed for floating point output. | not set |

### Formatting Flags for setf

| Flag value              | Effect                                                                                                                                  | Default |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|---------|
| <code>ios::right</code> | if a width is set and output fits within, output is right justified within the field<br>This flag is cleared by setting the right flag. | set     |
| <code>ios::left</code>  | if a width is set and output fits within, output is left justified within the field<br>This flag is cleared by setting the right flag.  | not set |

### I/O Manipulators

An **i/o manipulator** is a function that is called in a nonstandard manner. Manipulators are called by insertion into the output stream as if they were data. The stream calls the manipulator function, changing the state of the i/o stream. The manipulator `setw` (set width), with an argument, and the member function `width`, with an argument, do the same thing.

Example: The output statement

```
cout << "Start"
 << setw(4) << 10 // Print 10 in a field of width 4
 << setw(4) << 20 // Print 20 in a field of width 4
 << setw(6) << 30; // Print 30 in a field of width 6
```

generates the following output (columns are numbered below)

```
Start 10 20 30
123456789012345678901
```

### Streams as Arguments to Functions

A stream may be an argument to a function just like any other object type.

Because the effect of any function that uses a stream it to change the stream, it is necessary to pass the stream by reference.

```
Formatting Output (1 of 3)
// Illustrates output formatting instructions.
// Reads all the numbers in the file rawdata.dat and writes the numbers
// to the screen and to the file neat.dat in a neatly formatted way.
#include <iostream>
#include <fstream>
#include <cstdlib>
#include <iomanip>
using namespace std;

void make_neat(ifstream& messy_file, ofstream& neat_file,
 int number_after_decimalpoint, int field_width);
// Precondition: The streams messy_file and neat_file have been connected
// to files using the function open.
// Postcondition: The numbers in the file connected to messy_file have been
// written to the screen and to the file connected to the stream neat_file.
// The numbers are written one per line, in fixed point notation (i.e., not in
// e-notation), with number_after_decimalpoint digits after the decimal point;
// each number is preceded by a plus or minus sign and each number is in a field of
// a field of width field_width. (This function does not close the file.)
```

125

```
Formatting Output (2 of 3)
int main()
{ ifstream fin;
 ofstream fout;

 fin.open("rawdata.dat");
 if (fin.fail())
 { cout << "Input file opening failed.\n";
 exit(1);
 }

 fout.open("neat.dat");
 if (fout.fail())
 { cout << "Output file opening failed.\n";
 exit(1);
 }

 make_neat(fin, fout, 5, 12);
 fin.close();
 fout.close();
 cout << "End of program.\n";
 return 0;
}
```

126

```

Formatting Output (3 of 3)
// Uses ostream, fstream, and iomanip:
void make_neat(ifstream& messy_file, ofstream& neat_file,
 int number_after_decimalpoint, int field_width)
{
 neat_file.setf(ios::fixed);
 neat_file.setf(ios::showpoint);
 neat_file.setf(ios::showpos);
 neat_file.precision(number_after_decimalpoint);
 cout.setf(ios::fixed);
 cout.setf(ios::showpoint);
 cout.setf(ios::showpos);
 cout.precision(number_after_decimalpoint);

 double next;
 while (messy_file >> next)
 {
 cout << setw(field_width) << next << endl;
 neat_file << setw(field_width) << next << endl;
 }
}

```

127

## Character I/O Member Functions `get` and `put`

- C++ provides low level facilities that input and output (raw) character data.
- The `istream` member function `get` allows reading of one character from the input and store it in a variable of type `char`.  
`char next_symbol;`  
`cin.get(next_symbol);`
- Note that a program can read *any* character this way.
- Note further that this will read a blank, a newline, or any other character.

128

## Member Functions `get` and `put`

If the code fragment

```

char c1, c2, c3, c4, c5 ,c6;
cin.get(c1); cin.get(c2);
cin.get(c3); cin.get(c4);
cin.get(c5); cin.get(c6);

```

is given input consisting of AB followed by return then CD followed by return:

```

AB<cr>
CD<cr>

```

then the above code fragment sets `c1` to 'A', `c2` to 'B' and `c3` to '\n', that is, `c3` is set to the newline character, `c4` is set to 'C', `c5` is set to 'D' and `c6` is set to '\n'.

129

## Member Functions `get` and `put`

- Why?
- For one thing, your program can detect end-of-line instead of having the i/o machinery do it for you.
- This loop will let you read a line of input and stop at the end of a line. Example code:

```

cout << "Enter a line of input. I will echo it:\n";
char symbol;
do
{
 cin.get(symbol);
 cout << symbol;
} while (symbol != '\n');
cout << "That all for this demonstration.\n";

```

130

## Member Function `get`

- Every input stream has a member function `get`.

Syntax:  
`Input_Stream.get(char_variable);`

Example:  
`char next_symbol;`  
`cin.get(next_symbol);`

- To read from a file, use a file stream instead of `cin`.

`in_stream.get(next_symbol);`

131

## Member Function `put`

Every output stream has a member function `put`.

Syntax:  
`output_Stream.put(char_variable);`

Example:  
`cout.put(next_symbol);`  
`cout.put('a');`

To write to a file, use a file stream instead of `cout`.

`out_stream.put(next_symbol);`

As with all output, you must declare and connect your stream to an output file.

132

## A Note on compilers

- If you are using **Emacs** editor under Windows 98, or NT you may find that the input functions **get** and **getline** fail to work in peculiar fashion. Perhaps this is true even if we use the Borland command line compiler.
- A work around is to run the programs in a DOS Window.

## '\n' and "\n"

- '\n' and "\n" seem to be the same thing. They are **NOT** the same. Take care to distinguish them.
- They seem to be the same: A **cout** statement such as `cout << "\n"` or `cout << '\n'` will produce the same output: flush the output buffer and write a newline to the output.
- **HOWEVER:**
- '\n' has type **char** and "\n" is a **cstring** literal. "\n" has type **pointer to char**, which we will study in Chapter 11.
- '\n' and "\n" cannot be compared, nor can either be assigned to a variable the other's type.

134

## '\n' and "\n"

- The text says that "\n" is a string having exactly one character. The string "\n" has only one character stored in it, the newline.
- By contrast, recall the **terminating character** we had to leave space for when we were inputting file names.
- There we saw that cstrings had to have space for one character signal the end of string, beyond what we could use. The string literal "\n" also has a terminating character in addition to the newline character stored in the cstring.

135

## The putback Member Function (1 of 2)

- Sometimes you need to **inspect** but **not process** the next character from the input. To do this you can read the character, decide you didn't want it, and push it back on the input stream.
- The member function, **putback**, is a member of **every** input stream. It takes an argument of type **char**, and replaces the character read from the input.

136

## The putback Member Function (2 of 2)

Example:

```
fin.get(next);
while (next != ' ')
{
 fout.put(next);
 fin.get(next);
}
fin.putback(next);
```

This code reads characters until a blank is encountered, then puts the blank *back on the input*.

**Final notes:**

*The character put back need NOT be the one we read! It can be any character.*

*The input file will not be changed, but the program will behave as if it were (only the local, RAM, copy of the stream is effected).*

137

## Programming Example: Checking Input(1 of 2)

If a program does not check input, a single bad character input can ruin the entire run of a program.

This program allows the user to reenter input until input is satisfactory.  
Code:

```
// Program to demonstrate the functions new_line and get_input.
#include <iostream>
```

```
void new_line();
// Discards all the input remaining on the current input line.
// Also discards the '\n' at the end of the line.
// This version only works for input from the keyboard.
```

```
void get_int(int& number);
// Postcondition: The variable number has been
// given a value that the user approves of.
```

138

## Programming Example: Checking Input(2 of 2)

```
int main()
{
 using namespace std;
 int n;

 get_int(n);
 cout << "Final value read in = "
 << n << endl
 << "End of
 demonstration.\n";
 return 0;
}

// Uses istream:
void new_line()
{
 using namespace std;
 char symbol;
 do
 {
 cin.get(symbol);
 while (symbol != '\n');
 }
}

// Uses istream:
void get_int(int& number)
{
 using namespace std;
 char ans;
 do
 {
 cout << "Enter input number: ";
 cin >> number;
 cout << "You entered " <<
 number
 << " Is that correct? (yes/no):
 ";
 cin >> ans;
 new_line();
 } while ((ans != 'Y') && (ans != 'y'));
}
```

139

## Pitfall: Unexpected '\n' in Input (1 of 3)

- Example with a problem:

```
cout << "enter a number: \n";
int number;
cin >> number;
cout << "enter a letter: \n";
char symbol;
cin.get(symbol);
```

- With the input  
enter a number:  
21  
Enter a letter:  
A

Unfortunately, with this code, the variable *number* gets 21, but character *symbol* gets a newline, not 'A'.

140

## Pitfall: Unexpected '\n' in Input (2 of 3)

- With `get`, one must account for *every character on the input, even the new-line characters*.
- A common problem is forgetting to account for the newline at the ends of every line.
- While it is legal to mix `cin >>` style input with `cin.get()` input, the code in the previous slide can cause problems.

You can rewrite this using the `newline()` function from the Preceding Programming Example to dump the characters remaining on the input.

141

## Pitfall: Unexpected '\n' in Input (3 of 3)

Two workable rewrites of the code on slide 1 of 3 above

```
cout << "enter a number \n";
int number;
cin >> number;
cout << "enter a letter: \n";
char symbol;
cin >> symbol; // as opposed to: cin.get(symbol);
```

Or You may write:

```
cout << "enter a number \n";
int number;
cin >> number;
new_line();
cout << "enter a letter: \n";
char symbol;
cin.get(symbol);
```

•With the input  
enter a number:  
21  
Enter a letter:  
A

142

## The eof Member Function(1 of 2)

Every input-file stream has a function to detect end-of-file called `eof`. The letters stand for **end of file**.

This function returns a `bool` value, true if the input file is at end-of-file, false otherwise.

The result of this function can be used to control a while-loop, a for- loop or an if statement.

Typically, what we are really interested in is when we are *not* at end of file. The code usually reads,

```
while(! file_stream.eof())
{
 // do something with the file_stream
}
```

143

## The eof Member Function (2 of 2)

The while loop might look like this:

```
char next;
in_stream.get(next);
while(! in_stream.eof())
{
 cout << next; // This could be cout.put(next);
 in_stream.get(next);
}
```

This loop reads the file attached to `in_stream` into the char variable `next` character by character.

There is an end of file marker that can be read. The `eof` function does not change from false to true until this marker is read. You can read this marker but writing it out produces unpredictable results.

144

### Call by Reference parameters (1 of 3)

```
// Program to create a file called cplusplus.dat which is identical to the file
// cad.dat, except that all occurrences of 'C' are replaced by "C++".
// Assumes that the uppercase letter 'C' does not occur in cad.dat, except
// as the name of the C programming language.
```

```
#include <fstream>
#include <iostream>
#include <cstdlib>
using namespace std;
```

```
void add_plus_plus(ifstream& in_stream, ofstream& out_stream);
// Precondition: in_stream is connected to an input file with open().
// out_stream has been connected to an output file with open().
// Postcondition: The contents of the file connected to in_stream is
// copied into the file connected to out_stream, but with each 'C' replaced
// by "C++". (The files are not closed by this function.)
```

145

### Call by Reference parameters (2 of 3)

```
int main()
{
 ifstream fin;
 ofstream fout;

 cout << "Begin editing files.\n";

 fin.open("cad.dat");
 if (fin.fail())
 {
 cout << "Input file opening failed.\n";
 exit(1);
 }

 fout.open("cplusplus.dat");
 if (fout.fail())
 {
 cout << "Output file opening failed.\n";
 exit(1);
 }

 add_plus_plus(fin, fout);
}
```

146

### Call by Reference parameters (3 of 3)

```
// int main() continued
```

```
 fin.close();
 fout.close();

 cout << "End of editing files.\n";
 return 0;
}
```

```
void add_plus_plus(ifstream& in_stream, ofstream& out_stream)
{
 char next;

 in_stream.get(next);
 while (!in_stream.eof())
 {
 if (next == 'C') // NOTE char comparison!
 out_stream << "C++";
 else
 out_stream << next;

 in_stream.get(next);
 }
}
```

147

### Some predefined character functions(1 of 2)

#### Predefined Character Functions

To access the library functions, our code must contain

```
#include <cctype>
```

Here is an abbreviated table of functions from cctype.

| Function                        | Description                                                                                                                               | Example                                                                                               |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| <code>toupper(char_expr)</code> | if <code>char_expr</code> is lowercase transform <code>char_expr</code> to uppercase return this value else return <code>char_expr</code> | <code>char c = toupper('a');</code><br><code>cout &lt;&lt; c; // writes 'A'</code>                    |
| <code>tolower(char_expr)</code> | lowercase version of <code>toupper</code>                                                                                                 |                                                                                                       |
| <code>isupper(char_expr)</code> | if <code>arg</code> is uppercase return true else return false                                                                            | <code>char c = 'a';</code><br><code>if (isupper(c))</code><br><code>cout &lt;&lt; "Uppercase";</code> |
| <code>islower(char_expr)</code> | Behavior is as in <code>toupper</code> except <code>islower</code> tests for lowercase                                                    |                                                                                                       |

148

### Display 5.8: Some predefined character functions (2 of 2)

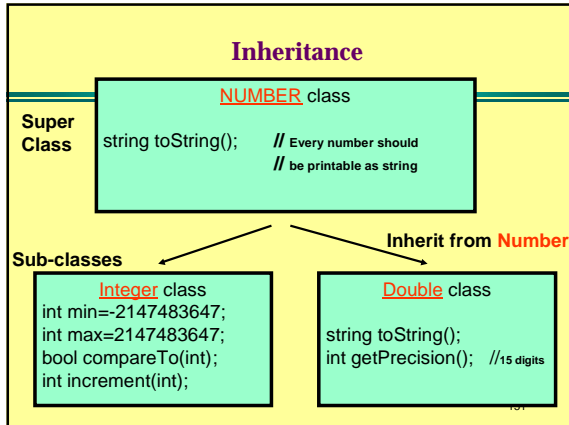
| Function                        | Description                                                                                                                                                                 | Example                                                                                                                                                                                        |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>isalpha(char_expr)</code> | if ( ('a' <= <code>char_expr</code> && <code>char_expr</code> <= 'z')    ('A' <= <code>char_expr</code> && <code>char_expr</code> <= 'Z') ) return true; else return false; | <code>char c = '&amp;';</code><br><code>if (isalpha(c))</code><br><code>cout &lt;&lt; c &lt;&lt; " is a letter.";</code><br>else<br><code>cout &lt;&lt; c &lt;&lt; " is not a letter.";</code> |
| <code>isdigit(char_expr)</code> | if ('0' <= <code>char_expr</code> && <code>char_expr</code> <= '9') return true; else return false;                                                                         | <code>if (isdigit(c))</code><br><code>cout &lt;&lt; c &lt;&lt; " is a digit.";</code><br>else<br><code>cout &lt;&lt; c &lt;&lt; " is not a digit.";</code>                                     |
| <code>isspace(char_expr)</code> | if <code>char_expr</code> is any of whitespace, such as <b>tab</b> , <b>newline</b> or <b>blank</b> , return true; else return false;                                       |                                                                                                                                                                                                |

149

### Inheritance

- One of the most powerful features of C++ is the use of derived classes.
- A class is **derived (subclass)** from another class (**superclass, base-class**) means that the derived class is obtained from the superclass by adding features while **retaining all the features** in the superclass.
- We speak of the derived class **inheriting** from the base-class, and this mechanism as **inheritance**.
- We use the words **Inherit**, **inheriting**, and speak of a derived class **inheriting** from a base class.

150



### Inheritance Among Stream Classes (1 of 3)

- Recall that an **object** has member **data** and **functions**.
- Also a **class** is type whose variables are objects.
- It turns out that ALL file streams are derived from other I/O streams.
- In particular, **ifstream** inherits from **istream**, and **ofstream** inherits from **ostream**.
- Notice that **ifstream** has the **open()** member function but **istream** does not, remember NUMBER – INTEGER class relation. So, sub-class (**ifstream**) not only inherits from the super-class (or base-class) **istream**, but it has extra members.

152

### Inheritance Among Stream Classes(2 of 3)

- We say one class is **derived** from another class if the derived class is obtained from the other super-class by keeping all the features of the super-class and adding additional members: **data/variables** and **functions**.
- Input-file streams are derived from **istream**.
- The class **ofstream** is derived from class **ostream**.
- Any input stream (incl. **ofstream** **outf\_stream**) is an object of type **ostream**, but NOT the other way around. Example:
- void **say\_hello**(**ofstream**& **outf\_stream**)  

```
{ outf_stream << "Hello!" << endl; }
```

 However, the **istream** object **cout** does NOT have a method **close()** as a member!  

```
cout.close(); // illegal
```

**ostream** class  
**cout** object  
No **close()** function

↓

**ofstream** class  
**outf\_stream** object  
**close()** function  
But also **ostream** functionality

### Inheritance Among Stream Classes(3 of 3)

- If class B inherits from class A, then A is said to be the **base** class (superclass), and B is said to be the **derived** class (subclass).
- If class B inherits from class A, then any object of class B is also an object of class A. Wherever a class A object is used, we can substitute it by a class B object.
- If class B inherits from class A, then class A is called the **parent class** and class B is called the **child class**.
- Textbook prefers **base class** and **derived class**.

154

### ofstream objects is an ostream object Making Stream Parameters Versatile

- Suppose you define a function that takes a input stream as an argument and you want the argument to be **cin** in some cases and an **input-file stream** in others. To accomplish this, you can use **istream** as a formal parameter type. Then you can use either an **ifstream** object or an **istream** object as parameter.
- Similarly, you can define a function that uses an **ostream** formal parameter then use either **ostream** arguments or **ofstream** arguments.

Function call with diff streams:  

```
say_hello(cout);
say_hello(outFile_stream);
```

 Possible since, **ofstream** objects ARE also **ostream** objects

```
void say_hello(ostream& o_stream)
{ o_stream << "Hello!" << endl; }
```

155

### Programming Example: Another new\_line function

By using an **istream** formal parameter, we can use this **new\_line** function with either **ifstream** or **istream** arguments.

```
// Uses istream
void new_line(istream& in_stream)
{
 char symbol;
 do
 { in_stream.get(symbol);
 } while (symbol != '\n');
}
```

156

## Default Arguments (1 of 2)

An alternative to writing two versions of `new_line()` we can write one version with a default argument:

```
// Uses iostream
void new_line(istream& in_stream = cin)
{
 char symbol;
 do
 {
 in_stream.get(symbol);
 } while (symbol != '\n');
}
```

157

## Default Arguments (2 of 2)

If we call this as

```
new_line();
```

then the default argument, `cin`, is used.

If we call this as

```
new_line(fin);
```

where `fin` is an `ifstream` object, then the function uses this as the argument.

If several parameters are to have default arguments, but some parameters do not have default arguments, those parameter supplied with default arguments must follow those not supplied with default arguments. If arguments are provided in a call, there must be enough arguments to provide for parameters without defaults. Arguments beyond this number will replace default arguments.

158

## Defining Classes and Abstract Data Types

- Structures
  - Structures for Diverse Data
  - Structures as Function Arguments
  - Initializing Structures
- Classes
  - Defining Classes and Member Functions
  - Public and Private Members
  - Summary of Properties of Classes
  - Constructors for Initialization
- Abstract Data Types
  - Classes to Produce ADTs

159

## Structures

- A **class** is a data type that can be made to behave the same as built-in data types (e.g., `int`). Such data types are called **Abstract Data Types**. A class encapsulates both data and functions.
- A **structure** may be thought of as an object *without* member functions.
- A structure Definition defines a type.

```
struct CDAccount ← structure tag
{
 double balance; ← Member names
 double interest_rate;
 int term; // months until maturity
}; ← DON'T FORGET THE SEMICOLON
```

160

## Structures

- Given the structure definition on the previous slide, **structure variables (of this type)** can be defined by:  
`CDAccount my_account, your_account;`
- This structure variable definition creates member variables *balance*, *interest\_rate*, and *term* associated with the structure, for each structure variable.
- Member variables are **accessed** using the **dot operator**.  
`my_account.balance;` // type is double  
`my_account.interest_rate;` // type is double  
`my_account.term;` // type is int
- Other structure variable's members may also be accessed:  
`your_account.balance;`
- These variables may be used exactly like any other variables.

161

```
// A Structure Definition (1 of 2)
// Program to demonstrate the CDAccount structure type.
#include <iostream>
using namespace std;

// Structure for a bank certificate of deposit:
struct CDAccount
{ double balance;
 double interest_rate;
 int term; // months until maturity
};

void get_data(CDAccount& the_account);
// Postcondition: the_account.balance and the_account.interest_rate
// have been given values that the user entered at the keyboard.

int main()
{
 CDAccount account;
 get_data(account);

 double rate_fraction, interest;
 rate_fraction = account.interest_rate/100.0;
 interest = account.balance*rate_fraction*(account.term/12.0);
 account.balance = account.balance + interest;
}
```

162

```

// A Structure Definition (2 of 2)

cout.setf(ios::fixed);
cout.setf(ios::showpoint);
cout.precision(2);
cout << "When your CD matures in "
 << account.term << " months,\n"
 << "it will have a balance of $"
 << account.balance << endl;
return 0;
}

// Uses iostream:
void get_data(CDAccount& the_account)
{
 cout << "Enter account balance: $";
 cin >> the_account.balance;
 cout << "Enter account interest rate: ";
 cin >> the_account.interest_rate;
 cout << "Enter the number of months until maturity\n"
 << "(must be 12 or fewer months): ";
 cin >> the_account.term;
}

```

163

```

// Member Values
struct CDAccount
{
 double balance;
 double interest_rate;
 int term; // months to run
};

int main()
{
 CDAccount account;
 account.balance = 1000.00;
 account.interest_rate = 4.7;
 account.term = 11;
}

```

164

## The Dot Operator

The **dot operator** is used to specify a **member variable** of a **structure variable**.

Syntax: `Structure_Variable_Name.Member_variable_name`

Example:

```

struct StudentRecord
{
 int student_number;
 char grade;
};

int main()
{
 StudentRecord your_record;
 your_record.student_number = 2001;
 your_record.grade = 'A';
}

```

*The dot operator is also called "structure member access operator".*

165

## Structures as Function Arguments

A function can have

- » call-by-value parameters of structure type and/or
- » call-by-reference parameters of structure type and/or
- » return type that is a structure type

Example, a wrapper that instantiates (constructs) a structure from 3 values:

```

CDAccount shrink_wrap(double the_balance,
 double the_rate, int the_term)
{
 CDAccount temp;
 temp.balance = the_balance;
 temp.interest_rate = the_rate;
 temp.term = the_term;
 return temp;
}

```

166

## Programming Tip(1 of 2) Use Hierarchical Structures

- If a structure has a subset of its members that may be considered an entity, consider nested structures.
- Example: A PersonInfo struct might include a birthday

```

struct Date
{
 int month;
 int day;
 int year;
};

struct PersonInfo
{
 double height; // inches
 int weight; // pounds
 Date birthday;
};

```

## Programming Tip(2 of 2) Use Hierarchical Structures

- Declare a variable of PersonInfo type as usual: `PersonInfo person1;`

```

Person1.birthday
// This is a Date structure, with members accessible
// as in any other structure variable.

```

If the structure variable `person1` has been set, the year a person was born can be obtained by:

```

cout << person1.birthday.year;

```

## Initializing Structures

- A structure may be initialized at the time it is declared.
 

```
struct Date
{ double hour;
 int month;
 int day;
 int year;
};

Date due_date = { 1520.00, 12, 31, 2001};
```
- The sequence of values is used to initialize the successive variables in the struct. The **order is essential**.
- It is an error to have more initializers than variables.
- If there are fewer initializers than variables, the provided initializers are used to initialize the first few data members. The remainder are initialized to 0 for primitive types.

## Classes

### Defining Classes and Member Functions

- A **class** is a data type whose **variables are objects**.
- An **object** is a variable that has member **functions** and member **variables**.
- A class definition specifies the function members and the data members.
- A data members for a class are defined much as we have defined structure members.
- Programmer defined member functions of a class are called exactly as we showed for predefined classes, e.g., **ostream** and **ofstream**.

170

```
// Class with a Member Function (1 of 2)
// Program to demonstrate a very simple example of a class.
// A better version of the class DayOfYear will be given next.

#include <iostream>
using namespace std;

class DayOfYear
{
public:
 void output();
 int month;
 int day;
};

int main()
{
 DayOfYear today, birthday;

 cout << "Enter today's date:\n";
 cout << "Enter month as a number: ";
 cin >> today.month;
 cout << "Enter the day of the month: ";
 cin >> today.day;
 cout << "Enter your birthday:\n";
 cout << "Enter month as a number: ";
 cin >> birthday.month;
 cout << "Enter the day of the month: ";
 cin >> birthday.day;
```

The following members are publicly **accessible**

member function **prototype**

171

```
// Class with a Member Function (1 of 2)

cout << "Today's date is ";
today.output();
cout << "Your birthday is ";
birthday.output();

if (today.month == birthday.month
 && today.day == birthday.day)
 cout << "Happy Birthday!\n";
else
 cout << "@, sorry your B-Day is not today!\n";

return 0;

//Uses iostream:
void DayOfYear::output()
{
 cout << "month = " << month
 << ", day = " << day << endl;
}
```

calls to the member function **Output**

the calling object

scope resolution operator

member function definition

Do we need to define member functions outside the class def?

172

## Encapsulation

Combining several items such as variables, or variables and functions, into a single package, such as an object of some class, is called **encapsulation**

## Member Function Definition

A **member function** is defined as any other function, except that the **Class\_Name** and the **scope resolution operator ::** are given in the function heading.

Syntax:

```
Returned_Type Class_Name::Function_Name(Parameter_List)
{
 // Function Body Statements
}
```

Example:

```
// uses iostream:
void DayOfYear::output()
{
 cout << "month = " << month
 << ", day = " << day << endl;
}
```

The class definition for this example, where month and day are defined as members of class DayOfYear. Note that month and day are not preceded (qualified) by an object name. We will see that the calling object is automatically supplied with the call to **output()**.

## The Dot Operator and the Scope Resolution Operator

Both the dot operator and scope resolution operator are used with member names to specify the thing they are a member of. For example, suppose you have declared a class called *DayOfYear*, and you declare an object called *today* of type *DayOfYear*:

```
DayOfYear today; // today is an object of class DayOfYear
```

You use the **dot operator** `.` to specify a member of this object. For example, `output()` is a member function of class *DayOfYear* (see Display 6.3) and this call will output data stored in the **particular object** *today*: `[today.output();]`

You use the **scope resolution operator** `::` to specify the class name when giving the function definition for a member function. For example, the heading of the function definition for the member function `output()` is: `void DayOfYear::output()`

Remember, the scope resolution operator `::` is used with a class name, while the dot operator is used with an object of that class.

```
// Class with Private Members (1 of 3)
// Program to demonstrate the class DayOfYear.

#include <iostream>
using namespace std;

class DayOfYear
{
public:
 void input();
 void output();

 void set(int new_month, int new_day);
 // Precondition: new_month and new_day form a possible date.
 // Postcondition: The date is reset according to the arguments.

 int get_month();
 // Returns the month, 1 for January, 2 for February, etc.

 int get_day();
 // Returns the day of the month.
private:
 int month;
 int day;
};
```

176

## Class with Private Members (2 of 3)

```
int main()
{
 DayOfYear today, bach_birthday;
 cout << "Enter today's date:\n";
 today.input();
 cout << "Today's date is ";
 today.output();

 bach_birthday.set(3, 21);
 cout << "J. S. Bach's birthday is ";
 bach_birthday.output();

 if (today.get_month() == bach_birthday.get_month() &&
 today.get_day() == bach_birthday.get_day())
 cout << "Happy Birthday Johann Sebastian!\n";
 else
 cout << "Today is NOT Johann Sebastian's B-Day!\n";
 return 0;
}
```

177

## //Class with Private Members (3 of 3)

```
// Uses iostream:
void DayOfYear::input()
{
 cout << "Enter the month as a number: [1;12] ";
 cin >> month;
 cout << "Enter the day of the month: [1;31]";
 cin >> day;
}

void DayOfYear::output()
{
 cout << "month = " << month
 << ", day = " << day << endl;
}

void DayOfYear::set(int new_month, int new_day)
{
 month = new_month;
 day = new_day;
}

int DayOfYear::get_month()
{
 return month;
}

int DayOfYear::get_day()
{
 return day;
}
```

Note we need not provide object name when we're in the scope of the class

178

## Public and Private Members(1 of 2)

With an ideal class definition, the class author should be able to change the details of the class implementation without necessitating changes in any program using the class (code using the class is called "client code").

This requires enough member functions to access the data members whenever necessary. This will allow the representation of the data to be changed as required by changes in implementation without changing client code.

Display 6.4 adds features to satisfy this requirement.

Note the use of the keyword **private** in Display 6.4.

Everything (functions or data members) defined after "private:" line are accessible only in member functions of the class. (See the remark in the next slide.)

The keyword **public** is used to state that the members defined after the "public:" line are accessible in any function that can see the class definition. (Again, see the next slide.)

## Public and Private Members(2 of 2)

Remark:

It is not quite true that everything (functions or data members) defined after "private:" line are accessible only in member functions of the class.

There can be several public and private sections in a class, and there is one other access keyword we will talk about later.

Members defined after "public:" **up to the next "private:"** or **other access specifier keyword** are accessible by all functions. Members defined after "private:" **up to the next public: or other access keyword** are accessible only by all functions defined in the class.

While we won't have several public and private sections in our classes, you may find code that makes use of multiple public and private sections, so we mentioned this for the sake of completeness.

```

The Bank Account Class (1 of 4)
// Program to demonstrate the class BankAccount.
#include <iostream>
using namespace std;
// Class for a bank account:
class BankAccount
{
public:
void set(int dollars, int cents, double rate);
// Postcondition: The account balance has been set to $dollars.cents;
// The interest rate has been set to rate percent.
void set(int dollars, double rate);
// Postcondition: The account balance has been set to $dollars.00.
// The interest rate has been set to rate percent.
void update();
// Postcondition: One year of simple interest has been
// added to the account balance.
double get_balance();
// Returns the current account balance.
double get_rate();
// Returns the current account interest rate as a percent.
void output(ostream& outs);
// Precondition: If outs is a file output stream, then
// outs has already been connected to a file.
// Postcondition: Account balance and interest rate have been written
// to the stream outs.

```

```

The Bank Account Class (2 of 4)
// class BankAccount cont.
private:
double balance;
double interest_rate;
double fraction(double percent);
// Converts a percent to a fraction. For example, fraction(50.3) returns 0.503.
};
int main()
{
BankAccount account1, account2;
cout << "Start of Test:\n";
account1.set(123, 99, 3.0);
cout << "account1 initial statement:\n";
account1.output(cout);
account1.set(100, 5.0);
cout << "account1 with new setup:\n";
account1.output(cout);
account1.update();
cout << "account1 after update (1 yr interest):\n";
account1.output(cout);
account2 = account1;
cout << "account2:\n";
account2.output(cout);
return 0;
}

```

182

```

The Bank Account Class (3 of 4)
void BankAccount::set(int dollars, int cents, double rate)
{
balance = dollars + 0.01*cents;
interest_rate = rate;
}
void BankAccount::set(int dollars, double rate)
{
balance = dollars;
interest_rate = rate;
}
void BankAccount::update()
{
balance = balance + fraction(interest_rate)*balance;
}
double BankAccount::fraction(double percent)
{
return (percent/100.0);
}
double BankAccount::get_balance()
{
return balance;
}
double BankAccount::get_rate()
{
return interest_rate;
}

```

183

```

The Bank Account Class (4 of 4)
// Uses iostream:
void BankAccount::output(ostream& outs)
{
outs.setf(ios::fixed);
outs.setf(ios::showpoint);
outs.precision(2);
outs << "Account balance $" << balance << endl;
outs << "Interest rate " << interest_rate << "%" << endl;
}

```

184

## Programming Tips

- Make Data Members **private**. When defining a class, the normal practice is to make all member variables private. This means these variables can only be accessed or changed using member functions.
- Define **Accessor Functions** (get/set). The operator == does not apply to class objects without additional work. Functions `get_day` and `get_month` are accessors. Consider providing a complete set of accessors to data in useful formats. This will make comparing objects for equality easier.
- Using the Assignment Operator with Objects: The assignment operator = applies to **struct** and **class** objects. In the case where all member variables are primitive (char, short, int, long, float, double, long double, bool) operator = can be used to assign class objects. The members are each assigned.

## Structures versus Classes

- The keyword **struct** was provided in C++ for backward compatibility with C. For this reason many authors treat the struct as a **class** though it does not have function members.
- In fact, a struct can have function and data members exactly like a class. **The only difference is that struct default access is public, whereas class default access is private.**
- We encourage use of the struct without function members and classes as developed in this chapter. This use follows C++ programming custom.

## Constructors for Initialization

- For automatic initialization of class objects at definition, C++ provides a special kind of member function known as a **constructor**.
- A **class constructor** has the same name as the **class**.
- A **constructor does not return a value**, not even void. In a constructor, a return statement is allowed *only without an argument*.
- Class constructors may be overloaded as needed.

## Constructors for Initialization

```
class BankAccount
{
public:
 BankAccount(int dollars, int cents, double rate);
 ...
private:
 double balance;
 ...
};
BankAccount::BankAccount(int d, int c, double r)
{
 dollars = d;
 cents = c;
 rate = r;
}
```

## Constructors for Initialization

// Object Declaration & Initialization:

```
BankAccount account1(10, 50, 2.0);
// sets dollars, cents and rate to values indicated.
```

```
// This is shorthand for
BankAccount account1 = BankAccount(10, 50, 2.0);
```

## Calling a Constructor

A constructor is called automatically when an object is declared, but you must give the arguments for the constructor when you declare the object. A constructor can be called explicitly to create a new object.

**Syntax** (for an object declaration when you have constructors):  
`Class_Name Object_Name(Arguments_for_Constructor);`

Example:  
`BankAccount account1(100, 2.3);`

**Syntax** (for an explicit constructor call):  
`Object_Name = Constructor_Name(Arguments_for_Constructor);`

Example:  
`account1 = BankAccount(200, 3.5);`

A constructor must have the same name as the class of which it is a member. Hence `Class_Name` and `Constructor_Name` are the same identifier.

190

## Programming Tip Always Include a Default Constructor(1 of 3)

```
class SampleClass
{
 // This constructor requires two arguments
public:
 SampleClass(int parameter1, double parameter2);
 void do_stuff();
private:
 int data1;
 double data2;
};

SampleClass my_object(7, 7.77); // OK, supplies required arguments
SampleClass my_object= SampleClass();
// illegal -- no Default constructor
// SampleClass() found.

A constructor with prototype
SampleClass();
is called a default constructor (trivial list of arguments).
```

191

## Programming Tip Always Include a Default Constructor(2 of 3)

```
class SampleClass
{
 // constructor requires two arguments
public:
 SampleClass(int parameter1, double parameter2);
 SampleClass(); ← a default constructor
 void do_stuff();
private:
 int data1;
 double data2;
};

SampleClass my_object(7, 7.77); // OK, supplies required arguments
SampleClass myObject; // Legal -- default constructor
// SampleClass() exists.

The constructor SampleClass() is called a default constructor.
```

192

## Programming Tip

### Always Include a Default Constructor(3 of 3)

If no constructors are provided, the compiler will “implicitly” generate a default constructor that does nothing but be present to be called.

If any constructor is provided at all, no default constructor will be generated. In that case the attempted definition

```
SampleClass myObject;
```

will try to call a default constructor so will fail, as there will be none.

193

## Pitfall:

### Constructors with no arguments

- The declaration  
`BankAccount object_name(100, 2.3);`  
invokes the `BankAccount` constructor that requires two parameters.
- The function call  
`f();`  
invokes a function `f` that takes no parameters
- Conversely,  
`BankAccount object_name();`  
does **NOT** invoke the no-parameter constructor.
- Rather, this line of code defines a **function that returns an object of `BankAccount` type.**

194

## Constructors with No Arguments

When you declare an object and want the constructor with zero arguments to be called, you *do not* include parentheses. For example, to declare an object and pass two arguments, you might do this:

```
BankAccount account(100, 2.3);
```

However, to cause the constructor with NO arguments, to be called, you declare the object:

```
BankAccount account;
```

You do **NOT** declare the object

```
BankAccount account(); //THIS IS NOT WHAT YOU WANT!!
```

(This declares `account` to be a function that has no parameters and returns a `BankAccount` object as its function value.)

196

## Abstract Data Types

### Classes to Produce ADTs

- A data type has a set of values and a set of operations
- For example:  
the `int` type has values `{... , -2, -1, 0, 1, 2, 3, ...}`  
and operations `+, -, *, /, %`.
- A data type is called an **Abstract Data Type (ADT)** if the programmers who use the type do not have access to the details of how the values and operations are implemented.
- Programmer defined types are not automatically ADTs. Care is required in construction of programmer defined types to prevent unintuitive and difficult-to-modify code.

196

## Classes to Produce ADTs

### How to make an ADT:

- Make all the member variables private.
- Make each of the basic operations that the programmer needs a public member function of the class, and fully specify how to use each such function.
- Make any helping functions private member functions.
- The interface consists of the public member functions along with commentary telling how to use the member functions. The interface of an ADT should tell all the programmer need to know to use the ADT.
- The implementation of the ADT tells how the ADT is realized in C++ code. The implementation consists of private members of the class and the definitions of all member functions. This is information the programmer should NOT NEED to use the class.

197

## Programming Example

### Alternative Implementation of a Class

- The client programmer does not need to know how data is stored, nor how the functions are implemented.
- Consequently alternative implementations may store different variables differently.
- Suppose we have `interest_rate` variables, but the different implementations store this value differently (as a percent, say 4.7, vs as a decimal fraction, say 0.047). There are also differences in the implementations `get_balance()` methods. Client user need not be concerned with these differences.
- There may also be other differences between the implementations, e.g., different computational algorithms, totally different program organization which may or may not produce the same output.

198

```

Alternative BankAccount Implementation(1 of 6)
// Demonstrates an alternative implementation of the class BankAccount.
#include <iostream>
#include <cmath>
using namespace std;
// Class for a bank account:
class BankAccount
{
public:
 BankAccount(int dollars, int cents, double rate);
 // Initializes the account balance to $dollars.cents and
 // initializes the interest rate to rate percent.
 BankAccount(int dollars, double rate);
 // Initializes the account balance to $dollars.00 and
 // initializes the interest rate to rate percent.
 BankAccount();
 // Initializes the account balance to $0.00 and the interest rate to 0.0%.
 void update();
 // Postcondition: One year of simple interest has been added to
 // account balance.

```

*Notice that the public members of BankAccount look and behave exactly the same as in Display 6.6*

199

```

Alternative BankAccount Implementation(2 of 6)
double get_balance();
// Returns the current account balance.
double get_rate();
// Returns the current account interest rate as a percent.
void output(ostringstream& outs);
// Precondition: If outs is a file output stream, then
// outs has already been connected to a file.
// Postcondition: Account balance and interest rate have been
// written to the stream outs.
private:
int dollars_part;
int cents_part;
double interest_rate;//expressed as a fraction, e.g., 0.057 for 5.7%
double fraction(double percent);
// Converts a percent to a fraction. For example, fraction(50.3)
// returns 0.503.
double percent(double fraction_value);
// Converts a fraction to a percent. For example, percent(0.503)
// returns 50.3.

```

*New*

200

```

// Alternative BankAccount Implementation(3 of 6)
int main()
{
 BankAccount account1(100, 2.3), account2;
 cout << "account1 initialized as follows:\n";
 account1.output(cout);
 cout << "account2 initialized as follows:\n";
 account2.output(cout);
 account1 = BankAccount(999, 99, 5.5);
 cout << "account1 reset to the following:\n";
 account1.output(cout);
 return 0;
}
BankAccount::BankAccount(int dollars, int cents, double rate)
{
 dollars_part = dollars;
 cents_part = cents;
 interest_rate = fraction(rate);
}

```

201

```

// Alternative BankAccount Implementation(4 of 6)
BankAccount::BankAccount(int dollars, double rate)
{
 dollars_part = dollars;
 cents_part = 0;
 interest_rate = fraction(rate);
}
BankAccount::BankAccount()
{
 dollars_part = 0;
 cents_part = 0;
 interest_rate = 0.0;
}
double BankAccount::fraction(double percent)
{
 return (percent/100.0);
}

```

202

```

// Alternative BankAccount Implementation(5 of 6)
// Uses cmath:
void BankAccount::update()
{
 double balance = get_balance();
 balance = balance + interest_rate*balance;
 dollars_part = floor(balance);
 cents_part = floor((balance - dollars_part)*100);
}
double BankAccount::get_balance()
{
 return (dollars_part + 0.01*cents_part);
}
double BankAccount::percent(double fraction_value)
{
 return (fraction_value*100);
}
double BankAccount::get_rate()
{
 return percent(interest_rate);
}

```

203

```

Alternative BankAccount Implementation(6 of 6)
// Uses iostream:
void BankAccount::output(ostringstream& outs)
{
 outs.setf(ios::fixed);
 outs.setf(ios::showpoint);
 outs.precision(2);
 outs << "Account balance $" << get_balance() << endl;
 outs << "Interest rate " << get_rate() << "% " << endl;
}
//The new definitions of get_balance and get_rate
// ensure that the output will still be in the correct units.
void BankAccount::output(ostringstream& outs)
{
 outs.setf(ios::fixed);
 outs.setf(ios::showpoint);
 outs.precision(2);
 outs << "Account balance $" << balance << endl;
 outs << "Interest rate " << interest_rate << "% " << endl;
}

```

*new definition*

204

### Information Hiding

We discussed information hiding when we introduced functions in Chapter3.

We said that **information hiding**, as applied to functions means that you should write the function so that they can be used with no knowledge of how they were written: as if they were black boxes. We know only the interface and specification.

This principle means that all the programmer needs to know about a function is its prototype and accompanying comment that explains how to use the function.

The use of private member variables and private member functions in the definition of an abstract data type is another way to implement information hiding, where we now apply the principle to data values as well as to functions.

205

### Information Encoding, Transmission and Decoding

- A company wants to **transmit data** over the telephone, but they are concerned that their phones may be tapped. All of their data are transmitted as four-digit integers. They have asked you to write a program that **encrypts their data** so that it can be **transmitted more securely**. Your program should read a four-digit integer and encrypt it as follows: Replace each digit by *(the sum of that digit plus 7) modulus 10*. Then, swap the first digit with the third, swap the second digit with the fourth and print the encrypted integer. Write a separate program that inputs an encrypted four-digit integer and decrypts it to form the original number.

206

### Information Encoding, Transmission and Decoding

- A company wants to **transmit data** over the telephone, but they are concerned that their phones may be tapped. All of their data are transmitted as strings of characters. They have asked you to write a program that **encrypts their data** so that it can be **transmitted more securely**. Your program should read a string from a file and encrypt it as follows: Replace each *char* by *(the sum of its digit plus KEY) modulus 256*. Then, invert every other character. Finally, report the string in reverse order (back-to-front). Ask the user for the integer **KEY** and if **encoding** or **decoding** is to be performed, read the data from a file and write the output message to another file.

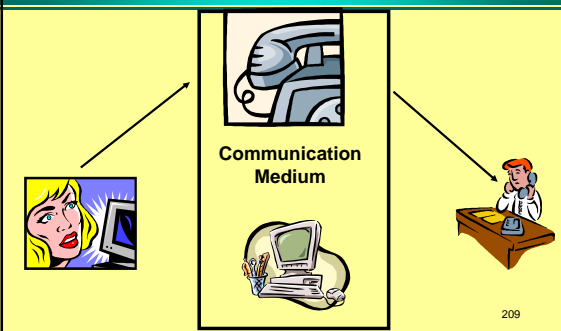
207

### Solution

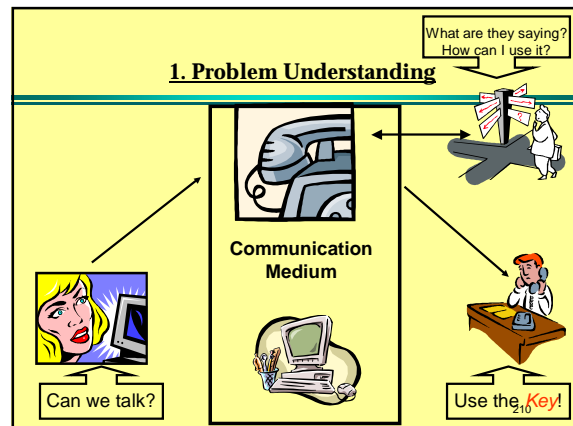
- Problem Understanding
- Top-Down algorithmic design
- Details implementation
- Testing
- Debugging and redesign

208



### 1. Problem Understanding



### 1. Problem Understanding



### 1. Problem Understanding

---

**Encryption:**

- $char \rightarrow (char \text{ plus } KEY) \% 256$
- Then, invert every other character.

$$char \rightarrow \begin{cases} 256-char, & \text{if } char\_index = \text{odd} \\ char, & \text{if } char\_index = \text{even} \end{cases}$$

- Report the string in reverse order


**Decryption:**

- Report the string in reverse order
- Then, invert every other character.

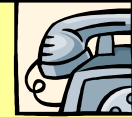
$$char \rightarrow (char \text{ plus } (256-KY)) \% 256$$

211


### 1. Problem Understanding




Can we talk?




**Communication Medium**





Use the Key!



What are they saying?  
How can I use it?