COMPREHENSIVE EDITION

PROGRAMMING AND PROBLEM SOLVING WITH C++

SIXTH EDITION

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Chapter 3

Numeric Types, Expressions, and Output

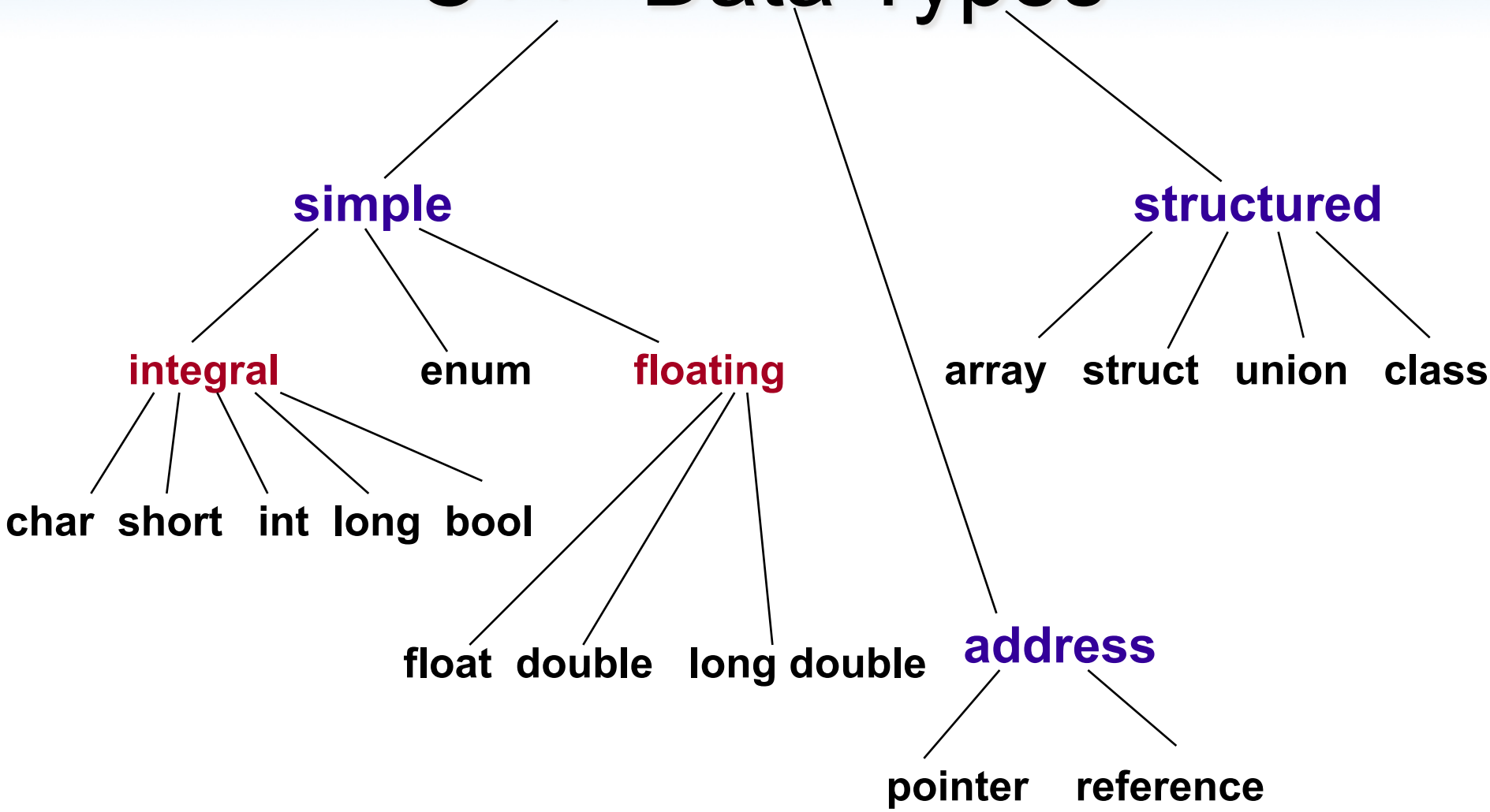
Chapter 3 Topics

- Constants of Type int and float
- Evaluating Arithmetic Expressions
- Implicit Type Coercion and Explicit Type Conversion
- Calling a Value-Returning Function
- Using Function Arguments

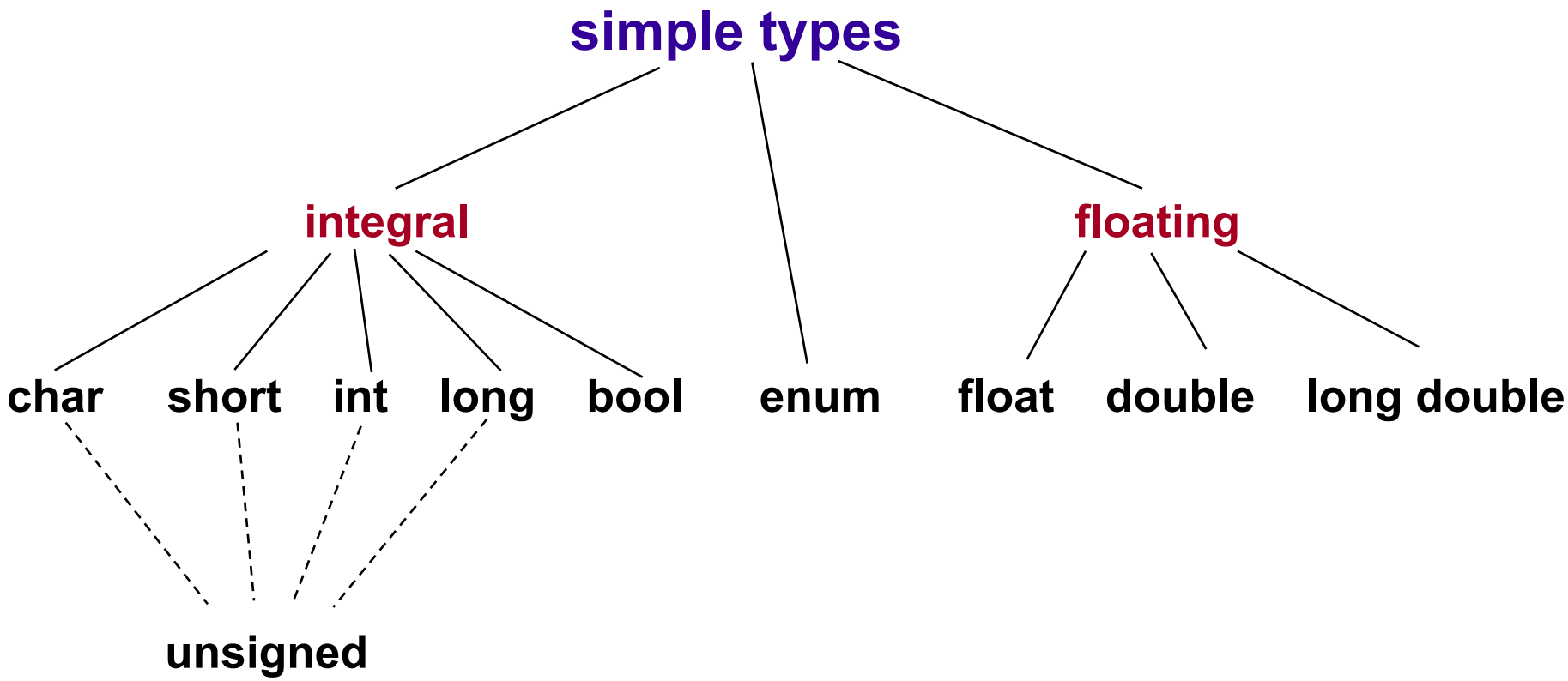
Chapter 3 Topics

- **Using C++ Library Functions in Expressions**
- **Calling a Void Function**
- **C++ Manipulators to Format Output**
- **String Operations length, find, and substr**

C++ Data Types



C++ Simple Data Types



Standard Data Types in C++

- **Integral Types (or Integer Types)**
  - **represent whole numbers and their negatives**
  - **declared as int, short, long, or char**

- **Floating Types**
  - **represent real numbers with a decimal point**
  - **declared as float or double**

Standard Data Types in C++

- Character Type
  - represents single characters such as 'B'
  - declared as char
  - classified as an integral type because C++ allows char to be used for storing integer values with a limited range

Samples of C++ Data Values

int sample values

4578 -4578 0

float sample values

95.274 95. .265

9521E-3 -95E-1 95.213E2

char sample values

'B' 'd' '4' '?' '*'

Scientific Notation

2.7E4 means $2.7 \times 10^{4} =$

2.7000 =

27000.0

2.7E-4 means $2.7 \times 10^{-4} =$

0002.7 =

0.00027

More About Floating Point Values

- **Floating point numbers** have an **integer part** and a **fractional part**, with a decimal point in between.
- Either the integer part or the fractional part, but not both, may be missing

Examples 18.4 500. .8

- 127.358

More About Floating Point Values

- Alternatively, floating point values can have an **exponent**, as in scientific notation
- The number preceding the letter E doesn't need to include a decimal point

Examples 1.84E1 5E2 8E-1

-.127358E3

Division Operator

- The result of the division operator depends on the type of its operands
- If one or both operands has a floating point type, the result is a floating point type.
- Otherwise, the result is an integer type

- Examples

11 / 4	has value	2
11.0 / 4.0	has value	2.75
11 / 4.0	has value	2.75

Main returns an int value to the operating system

```
//*****************************************************
// FreezeBoil  program
// This program computes the midpoint between
// the freezing and boiling points of water
//*****************************************************
#include  < iostream >
using  namespace  std;
const  float FREEZE_PT = 32.0;  // Freezing point of
water
const  float BOIL_PT =  212.0;  // Boiling point of water

int  main()
{
    float avgTemp;      // Holds the result of averaging
                        //  FREEZE_PT and BOIL_PT
```

Function main Continued

```
    cout << "Water freezes at " << FREEZE_PT << endl;
    cout  <<  " and boils at " << BOIL_PT
          << " degrees."  << endl;

    avgTemp  =  FREEZE_PT  +  BOIL_PT;
    avgTemp  =  avgTemp  /  2.0;

    cout  <<  "Halfway between is ";
    cout  <<  avgTemp  <<  " degrees."  <<  endl;

    return  0;
}
```

Modulus Operator

- The **modulus operator** % can only be used with integer type operands and **always has an integer type result**
- Its result is the integer type **remainder** of an integer division
- Example

  11 % 4 has value 3 because

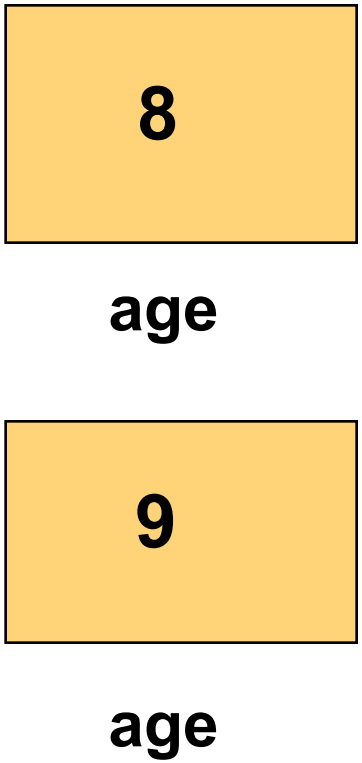
$$\begin{array}{r} R = ? \\ 4 \overline{)\ 11} \end{array}$$

More C++ Operators

```
int  age;

age = 8;

age = age + 1;
```

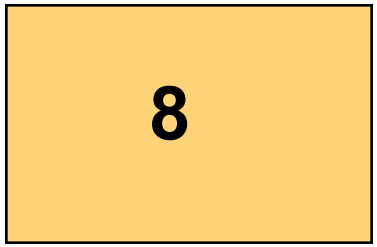


Prefix Form Increment Operator

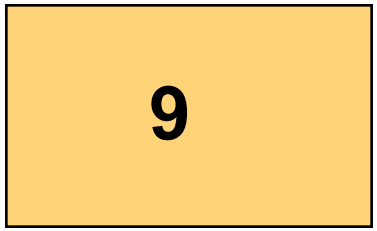
```
int  age;

age = 8;

++age;
```



age



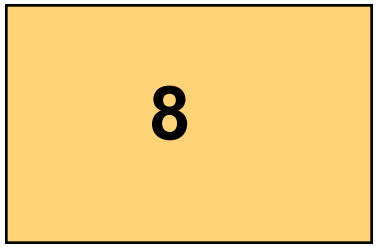
age

Postfix Form Increment Operator

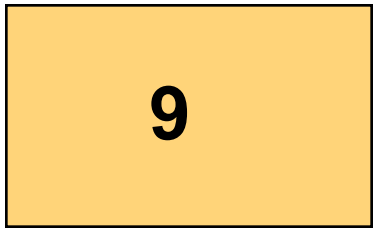
```
int  age;

age = 8;

age++;
```



age



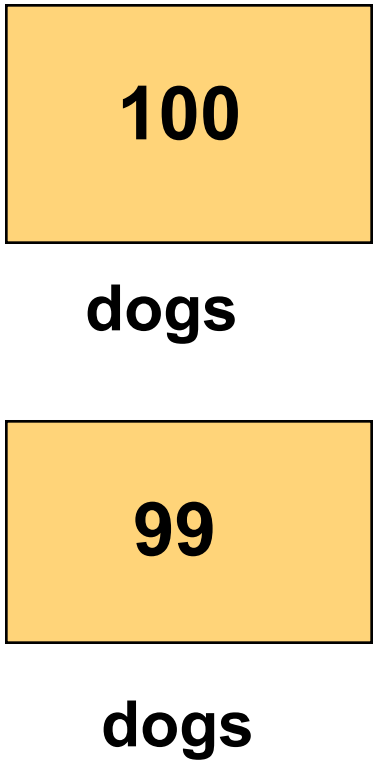
age

Decrement Operator

```
int  dogs;

dogs = 100;

dogs--;
```



Which Form to Use

- When the increment(or decrement) operator is used in a "*stand alone*" statement solely to add one(or subtract one) from a variable's value, it can be used in either prefix or postfix form

USE EITHER

dogs--; --dogs;

BUT...

- **When the increment (or decrement) operator is used in a statement with other operators, the prefix and postfix forms can yield *different* results**

We'll see how later . . .

What is an Expression in C++?

- An **expression** is a valid arrangement of variables, constants, and operators
- In C++ each expression can be evaluated to compute a value of a given type
- The value of the expression

  9.3 * 4.5 is 41.85

Operators can be

binary	**involving 2 operands**	**2 + 3**
unary	**involving 1 operand**	**- 3**
ternary	**involving 3 operands**	***later***

Some C++ Operators

Precedence	Operator	Description
Higher	( )	Function call
	+	Positive
	-	Negative
	*	Multiplication
	/	Division
	%	Modulus(remainder)
	+	Addition
	-	Subtraction
Lower	=	Assignment

Precedence

- Higher Precedence determines which operator is applied first in an expression having several operators

Associativity

- Left to right **associativity**–in an expression having two operators with the same priority, the left operator is applied first

- **Grouping order** –synonmous w/ associativity

- In C++ the binary operators

  *, /, %, +, - are all left associative

- Expression 9 - 5 - 1 means (9 - 5) - 1

  4 - 1

  3

Evaluate the Expression

7 * 10 - 5 % 3 * 4 + 9

(7 * 10) - 5 % 3 * 4 + 9

70 - 5 % 3 * 4 + 9

70 -(5 % 3) * 4 + 9

70 - 2 * 4 + 9

70 -(2 * 4) + 9

70 - 8 + 9

(70 - 8) + 9

62 + 9

71

Parentheses

- Parentheses can be used to change the usual order
- Parts in() are evaluated first
- Evaluate (7 *(10 - 5) % 3) * 4 + 9

```
(7 *(10 - 5) % 3) * 4 + 9
(7 * 5 % 3 ) * 4 + 9
( 35 % 3) * 4 + 9
2 * 4 + 9
8 + 9
17
```

Recall Assignment Operator Syntax

Variable = Expression

- First, expression on right is evaluated
- Then the resulting value is stored in the memory location of variable on left

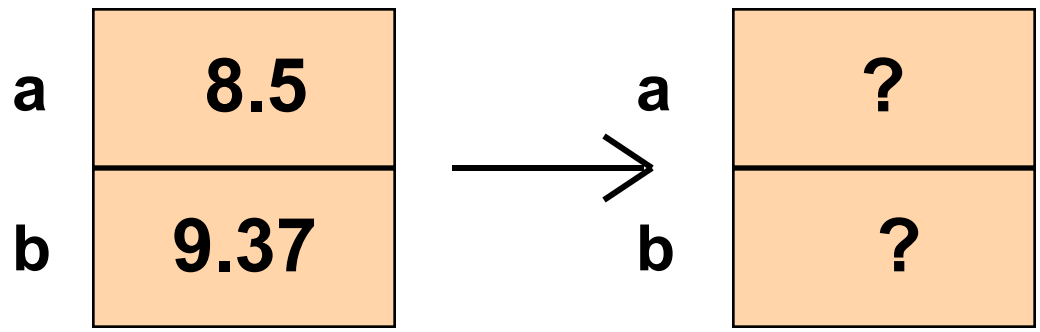
Automatic Type Conversion

- Implict conversion by the compiler of a value from one data type to another is known as automatic type coercion
- An automatic type coercion occurs after evaluation but before the value is stored if the types differ for expression and variable
- See examples on Slides 31, 32, and 33

What value is stored?

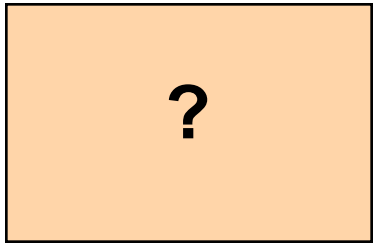
```
float  a;
float  b;

a = 8.5;
b = 9.37;
a = b;
```



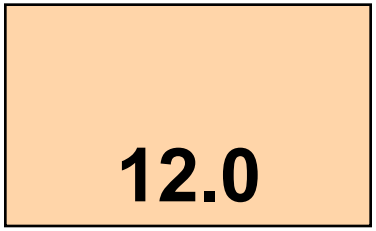
What is stored?

```
float someFloat;
```



someFloat

```
someFloat = 12;    // Causes implicit type conversion
```

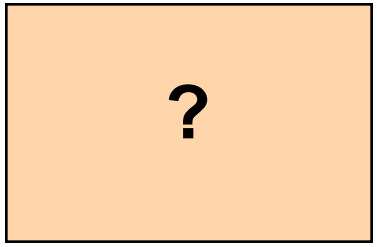


someFloat

What is stored?

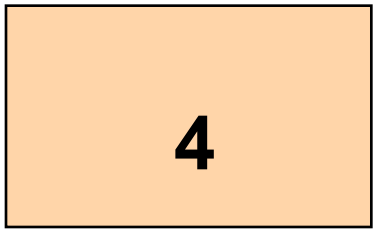
```
int  someInt;

someInt = 4.8;
```



someInt

```
// Causes implicit type conversion
```



someInt

Type Casting is Explicit Conversion of Type

- **Explicit type casting** (or **type conversion**) used to clarify that the mixing of types is intentional, not an oversight
- Explicit type casting helps make programs clear and error free as possible

Examples of Explicit Typecasting

int(4.8)	has value	4
float(5)	has value	5.0
float(7/4)	has value	1.0
float(7) / float(4)	has value	1.75

Some Expressions

int age;

Example	Value
age = 8	8
- age	- 8
5 + 8	13
5 / 8	0
6.0 / 5.0	1.2
float(4 / 8)	0.0
float(4) / 8	0.5
cout << “How old are you?”	cout
cin >> age	cin
cout << age	cout

What values are stored?

```
float  loCost;
float  hiCost;

loCost = 12.342;
hiCost = 12.348;

loCost =
   float(int(loCost * 100.0 + 0.5)) / 100.0;

hiCost  =
   float(int(hiCost * 100.0 + 0.5)) / 100.0;
```

Values were rounded to 2 decimal places

12.34

loCost

12.35

hiCost

Functions

- Every C++ program must have a function called `main`
- Program execution always begins with function `main`
- Any other functions are subprograms and must be called by the `main` function

Function Calls

- One function calls another by using the name of the called function together with() containing an argument list
- A function call temporarily transfers control from the calling function to the called function

More About Functions

- It is not considered good practice for the body block of function main to be long
- Function calls are used to do subtasks
- Every C++ function has a return type
- If the return type is not void, the function returns a value to the calling block

Where are functions?

Functions are subprograms

- **located in libraries, or**
- **written by programmers for their use in a particular program**

HEADER FILE	FUNCTION	EXAMPLE OF CALL	VALUE
<cstdlib>	abs(i)	abs(-6)	6
<cmath>	pow(x,y)	pow(2.0,3.0)	8.0
	fabs(x)	fabs(-6.4)	6.4
<cmath>	sqrt(x)	sqrt(100.0)	10.0
	sqrt(x)	sqrt(2.0)	1.41421
<cmath>	log(x)	log(2.0)	.693147
<iomanip>	setprecision(n)	setprecision(3)	

Write C++ Expressions for

The square root of $b^2 - 4ac$

```
sqrt(b * b - 4.0 * a * c)
```

The square root of the average of myAge and yourAge

```
sqrt((myAge  +  yourAge) / 2)
```

Function Call

- A **function call** temporarily **transfers control** to the called function's code
- When the function's code has finished executing, **control is transferred back** to the calling block

Function Call Syntax

Function Name = (Argument List)

- **The argument list is a way for functions to communicate with each other by passing information**

- **The argument list can contain zero, one, or more arguments, separated by commas, depending on the function**

A void function call stands alone

```
#include <iostream>

void  DisplayMessage(int  n);
// Declares function

int main()
{
    DisplayMessage(15);
    // Function call
    cout  <<  "Good Bye"  <<  endl;
    return 0;
}
```

A void function does NOT return a value

```
// Header and body here

void  DisplayMessage(int  n)
{
    cout  <<  "I have liked math for  "
          <<  n  <<  " years"  << endl;
}
```

Two Kinds of Functions

Value-Returning	Void
Always returns a single value to its caller and is called from within an expression	Never returns a value to its caller and is called as a separate statement

<< is a binary operator

<< is called the output or insertion operator

<< is left associative

Expression	Has value
cout << age	cout

Statement

```
cout << "You are "  << age  <<  " years old\n";
```

<iostream> is header file

- For a library that defines 3 objects

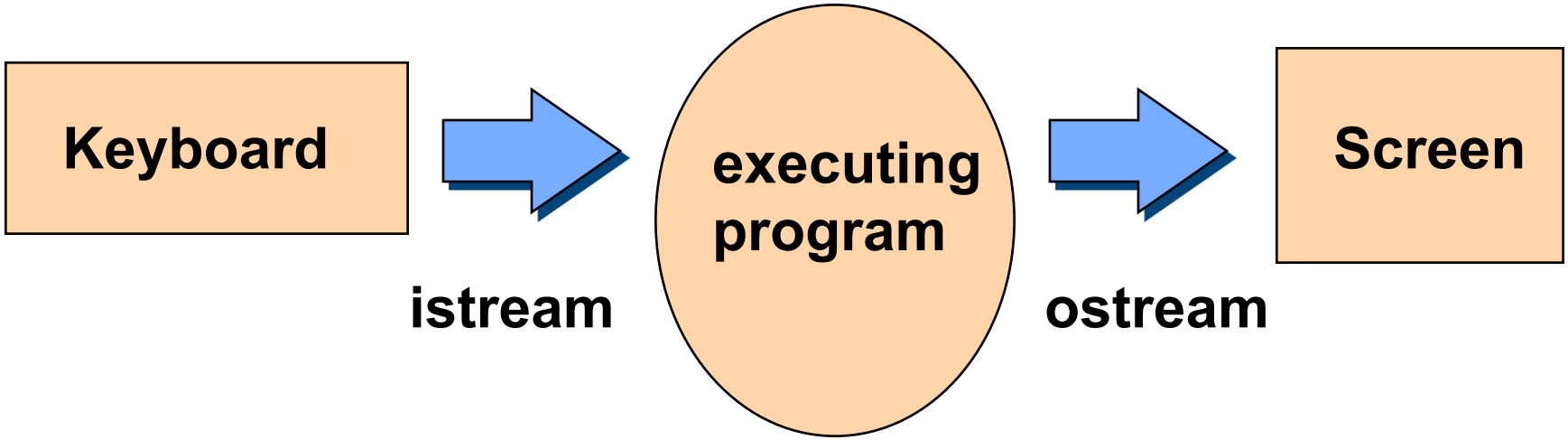
  An **istream** object named **cin** (keyboard)

  An **ostream** object named **cout** (screen)

  An **ostream** object named **cerr** (screen)

No I/O is built into C++

- Instead, a library provides input stream and output stream



Manipulators

- **Manipulators are used only in input and output statements**
- `endl, fixed, showpoint, setw, and setprecision` **are manipulators that can be used to control output format**
- `endl` **is use to terminate the current output line and create blank lines in output**

Insertion Operator(<<)

- The insertion operator `<<` takes 2 operands
- The left operand is a stream expression, such as `cout`
- The right operand is an expression of simple type, a `string`, or a manipulator

Output Statements

SYNTAX(revised)

```
cout << ExpressionOrManipulator
     << ExpressionOrManipulator . . .;
```

Output Statements

SYNTAX

```
cout << Expression << Expression . . .;
```

These examples yield the same output

```
cout << "The answer is ";
cout << 3 * 4;
```

```
cout << "The answer is " << 3 * 4;
```

Using Manipulators `Fixed` and `Showpoint`

- Use the following statement to specify that (for output sent to the cout stream) decimal format (not scientific notation) be used,
- and that a decimal point be included (even for floating values with 0 as fractional part)

```
cout << fixed << showpoint;
```

setprecision(n)

- Requires `#include <iomanip>` and appears in an expression using insertion operator(<<)
- If `fixed` has already been specified, argument `n` determines the number of places displayed after the decimal point for floating point values
- Remains in effect until explicitly changed by another call to `setprecision`

What is exact output?

```
#include  <iomanip> // For setw() and setprecision()
#include  <iostream>

using  namespace  std;

int main()
{
    float   myNumber  =  123.4587;
    cout  <<  fixed  <<   showpoint;
    // Use decimal format
    // Print decimal points
    cout  <<  "Number is "  <<  setprecision(3)
          <<  myNumber     <<  endl;

    return  0;
}
```

OUTPUT

Number is 123.459

Value is rounded if necessary to be displayed with exactly 3 places after the decimal point

Manipulator `setw`

- "Set width" lets us control how many **character positions** the next data item should occupy when it is output

- `setw` is only for formatting numbers and strings, not `char` type data

setw(n)

- Requires `#include <iomanip>` and appears in an expression using insertion operator(<<)
- Argument `n` is called the **fieldwidth specification**
- Argument `n` determines the number of character positions in which to display a right-justified number or string (not char data)

setw(n)

- The number of character positions used is expanded if n is too narrow
- "Set width" affects only the very next item displayed and is useful to align columns of output

A) What is exact output?

```
#include  <iomanip>                    // For setw()
#include  <iostream>
#include  <string>

using  namespace  std;
```

A) What is exact output?, cont...

```
int  main()
{
    int  myNumber    =  123;
    int  yourNumber  =  5;

    cout <<  setw(10)  <<  "Mine"
         <<  setw(10)  <<  "Yours"  << endl
         <<  setw(10)  <<  myNumber
         <<  setw(10)  <<  yourNumber << endl;

    return 0;
}
```

Output

position `12345678901234567890`

```
      Mine      Yours
       123          5
```

Each is displayed right-justified and each is located in a total of 10 positions

B) What is exact output?

```
#include  <iomanip> // For setw() and setprecision()
#include  <iostream>

using  namespace  std;

int  main()
{
    float myNumber    =  123.4;
    float yourNumber  =  3.14159;
```

B) What is exact output, continued?

```
cout  <<  fixed  << showpoint;
    // Use decimal format; print decimal points
    cout  <<  "Numbers are: "  <<  setprecision(4)
          <<  endl  <<  setw(10) <<  myNumber
          <<  endl  <<  setw(10) <<  yourNumber
          <<  endl;
    return 0;
}
```

OUTPUT

```
12345678901234567890
Numbers are:
  123.4000
    3.1416
```

Each is displayed right-justified and rounded if necessary and each is located in a total of 10 positions with 4 places after the decimal point

More Examples

312.0
x

4.827
y

```
    float  x   =  312.0;
    float  y   =  4.827;

OUTPUT
    cout  << fixed << showpoint;

    cout  << setprecision(2)
          << setw(10) << x  << endl
           << setw(10) << y  << endl;

    cout  << setprecision(1)
          << setw(10) << x  << endl
           << setw(10) << y  << endl;

    cout  << setprecision(5)
          << setw(7) << x  << endl
           << setw(7) << y << endl;
```

```
,,,, 312.00
 ,,,,,, 4.83

,,,,, 312.0
 ,,,,,,, 4.8

312.00000
   4.82700
```

HEADER FILE	MANIPULATOR	ARGUMENT TYPE	EFFECT
<iostream>	endl	none	terminates output line
<iostream>	showpoint	none	displays decimal point
<iostream>	fixed	none	activates scientific notation
<iomanip>	setw(n)	int	sets fieldwidth to n positions
<iomanip>	setprecision(n)	int	sets precision to n digits

`length` Function

- Function `length` returns an unsigned integer value that equals the number of characters currently in the string
- Function `size` returns the same value as function length
- You must use dot notation in the call to function `length` or `size`

`find` Function

- Function `find` returns an unsigned integer value that is the beginning position for the first occurrence of a particular substring within the string
- The substring argument can be a `string` constant, a `string` expression, or a `char` value
- If the substring was not found, function `find` returns the special value `string::npos`

`substr` Function

- Function `substr` returns a particular substring of a string
- The first argument is an unsigned integer that specifies a **starting position** within the string
- The second argument is an unsigned integer that specifies the **length** of the desired substring
- **Positions** of characters within a string are **numbered starting from 0, not from 1**

Mortgage Payments

Problem Your parents are thinking about refinancing their mortgage, and have asked you to help them with the calculations. Now that you're learning C++, you realize that you can save yourself a lot of calculator button-pressing by writing a program to do the calculations automatically.

Algorithm

Define Constants

```
Set LOAN_AMOUNT = 50000.00
Set NUMBER_OF_YEARS = 7
Set YEARLY_INTEREST = 0.0524
```

Calculate Values

```
Set monthlyInterest  to YEARLY_INTEREST divided by 12
Set numberOfPayments to NUMBER_OF_YEARS  times 12
Set payment to(LOAN_AMOUNT *
        pow(monthlyInterest+1,numberrOfPayments)
        * monthlyInterest))
         /(pow(monthlyInterest+1, numberOfPayments) - 1)
```

Output Results

```
Print "For a loan amount of " LOAN_AMOUNT "with an interest rate of "
        YEARLY_INTEREST  " and a " NUMBER_OF_YEARS   "
        year mortgage, "
Print "your monthly payments are $"  payment  "."
```

C++ Program

```
//*************************************************
// Mortgage Payment Calculator program
// This program determines the monthly payments on a
// mortgage given the loan amount, the yearly interest,
// and the number of years.
//*************************************************
#include <iostream>        // Access cout
#include <cmath>           // Access power function
#include <iomanip>         // Access manipulators
using namespace std;
const float LOAN_AMOUNT = 50000.00;  // Amount of loan
const float YEARLY_INTEREST = 0.0524;// Yearly interest
const int NUMBER_OF_YEARS = 7;       // Number of years
```

C++ Program

```
int main()
{
    // Local variables
    float monthlyInterest; // Monthly interest rate
    int numberOfPayments;  // Total number of payments
    float payment;         // Monthly payment
    // Calculate values
    monthlyInterest = YEARLY_INTEREST / 12;
    numberOfPayments = NUMBER_OF_YEARS * 12;
    payment =(LOAN_AMOUNT *
        pow(monthlyInterest + 1, numberOfPayments)
        * monthlyInterest)/(pow(monthlyInterest + 1,
        numberOfPayments) - 1);
```

C++ Program

```
    // Output results
    cout << fixed << setprecision(2)
         << "For a loan amount of "
         << LOAN_AMOUNT  << " with an interest rate of "
         << YEARLY_INTEREST << " and a "
         << NUMBER_OF_YEARS
         << " year mortgage, " << endl;
    cout << " your monthly payments are $" << payment
         << "." << endl;
    return 0;
}
```