Recursion in C++

```
#include <iostream.h>
#include <iomanip.h>

int factorial (int n) {
    if (n <= 1) return 1;                  // base case
    else return n * factorial(n-1);        // recursive case
}

main() {
    for (i=0; i<=10; i++)
        cout << setw(2) << i << "! = " << factorial(i) << endl;
}
```

Function Overloading

- Different versions must have different argument types.

- The return value is not considered when determining which function to call, only the arguments are taken into account.

Function Overloading (2)

double sqrt(double i);

// called with *sqrt(25.0);*

int sqrt(int i); // called with *sqrt(16);*

double sqrt(int i); // illegal

int f(int x = 0);

int f(void);

// what if the call *f()*?

Function Overloading (3)

```
void g(int x);                    // case a
void g(double x, int y = 0);      // case b

g(2.0);      // case b
g(0);        // case a
g(0, 0);     // case b
g('c');      // ambiguous
```

Function Overloading (4)

h(double x, int y);

h(int x, double y);

// what if the call *h(10, 10)*?

Function Template

```
int mul(int a, int b)                    { return a*b; }
double mul(double a, double b)  { return a*b; }

template <class Type>
Type mul(Type a, Type b} { return a*b; }

int a = mul(2, 3);
double b = mul(5.0, 10.0);
```

Array Size

- The size must be a constant.

  a. must be known at compile time.

  b. certainly not changed later.

  c. cannot free up once not needed.

- Does not know its own size, needs to carry around ***additional variable*** with its size.

Array Initialization

- Zero out (or initialized to default value).
- Prototype to initialize with "normal" array:

int n[3] = {1, 2, 3};

int n[3] = {1, 2};

int grades [] = {15, 23, 44, 78, 92};

int num_students = sizeof(grades) / sizeof(int);

- Cannot be assigned as a whole, for example, *array1 = array2;*

Character Array

- Define string literal.
- *char s[] = “test”;*

Array Access

- Index (or subscript) starts with 0, ends with (size - 1).
- No range checking, will be a run-time error.

Array Parameter

- ***int arr[20];***
  void f(int a[]);
  // the call *f(arr)* is implemented as
  // call-by-reference.
- ***f (int val, int &ref) { val++; ref++; }***
  g() {
  int i = 1,
  j = 1;
  f(i, j);
  cout << i << j << endl; // 1 2
  }

Multidimensional Array

int ia[2][3] = { {1, 2, 3}, {4, 5, 6} };

int a[5][10]; // *&a[1]* - *&a[0]* = 40 (10 integers)

int a1[][10], **a2;

typedef int A10[10];

A10 *b = a; b++; // b = &a[1]

Pointer Type

int *p;

p = &x; // the address of object *x*

p = 0;

// assignment of the special value 0

p = (int *) 2203

// an absolute address in memory

Addressing and Dereferencing

```
int a = 2, b;
int *p = &a;
   // pointer initialization to the address of a
b = p;
// illegal, pointer is not convertible to integer
b = *p + 1;        // okay
p = &b;            // p points to b
```

Simulating Call-by-Reference

- Declare a function parameter to be a pointer.
- Use the dereferenced pointer in the function body.
- Pass an address as an argument when the function is called.

Simulating Call-by-Reference (cont)

```
swap (int *p, int *q)
{
    int temp;

    if (*p > *q) {
        temp = *p;
        *p = *q;
        *q = temp;
    }
}

int i, j;
swap(&i, &j);
```

Reference Declarations

int i = 5;

// *i* is located in memory with value 5

int *p = &i;

// *p* is **located in memory** with value *&i*

int &r = i; // *r* an *i* are the same object

int *&s = p;

// *s* and *p* are the same object

Passing a Reference

```
swap (int &p, int &q)
{
    int temp;

    if (p > q) {
        temp = p;
        p = q;
        q = temp;
    }
}

int i, j;
swap(i, j);
```

Arrays vs Pointers

int a[100], *p;

// *p = a;* and *p = &a[0];* are equivalent

a = p; // illegal

++*a;* // illegal

a += 2; // illegal

Passing Arrays to Functions

```
int sum(int a[], int size) {
   int i, s = 0;
   for (i = 0; i < size; i++) s += a[i];
   return s;
}

int v[100];
sum(v, 100);
```

Arrays in Java

- ***int [] data;*** // array declaration

- The variable declaration does not create the array, this must be done using the keyword *new*, and at this point the size of the array is set.

  data = new int[100];

  // a 100 element array

Arrays in Java (cont)

- Both steps can be done at the same time if the array size is known at that point in the program.

```
int [] data = new int[100];
```

Java Collections Framework

- Collection:
  - Object that groups multiple elements into one unit.
  - Also called container.

- Collection framework consists of:
  - Interfaces
    - Abstract data type
  - Implementations
    - Reusable data structures
  - Algorithms
    - Reusable functionality

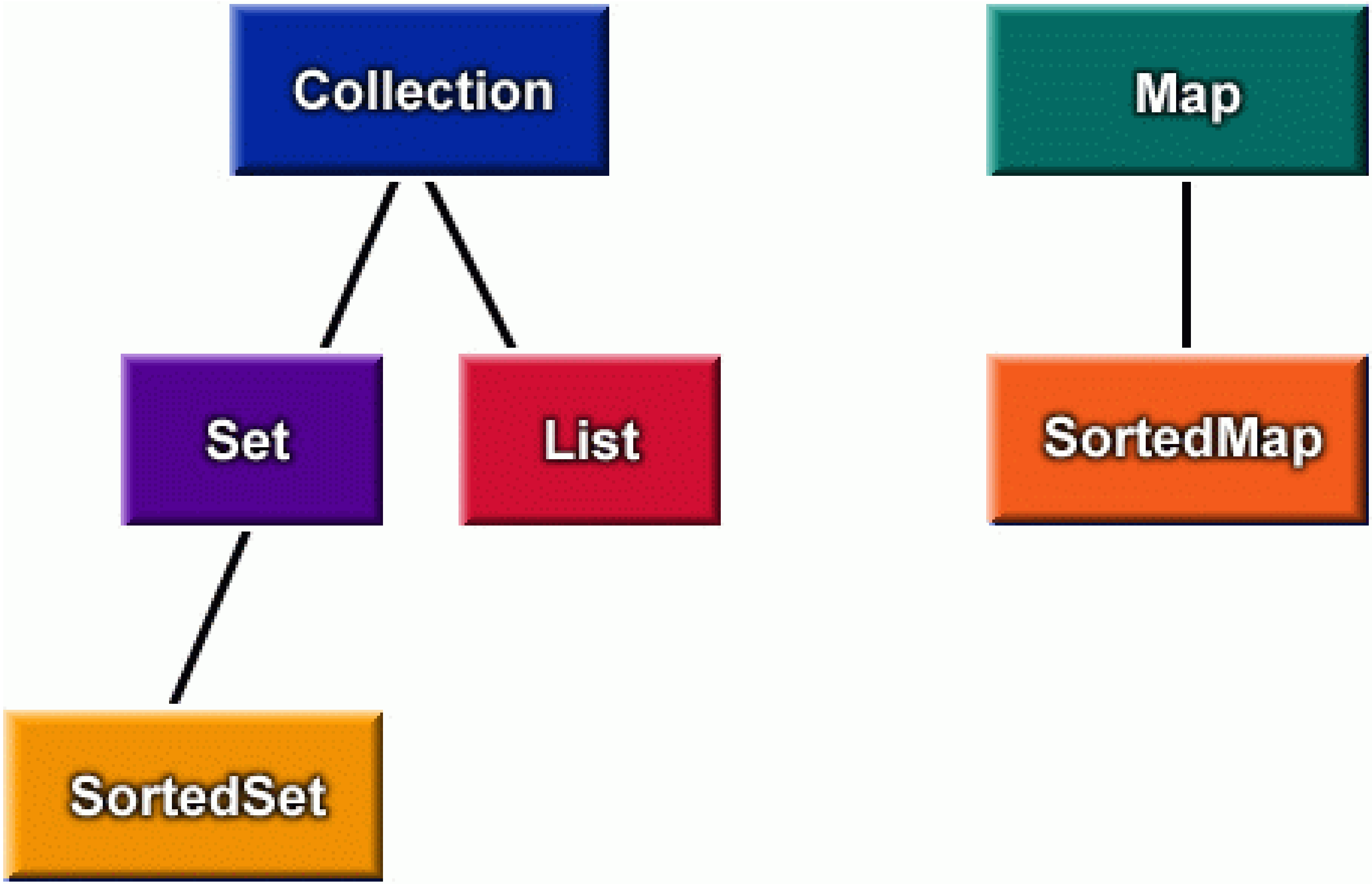
Collections Framework (cont)

- Goals:
  - Reduce programming effort
  - Make APIs easier to learn
  - Make APIs easier to design and implement
  - Reuse software
  - Increase performance

Core Collection Interfaces

- **Collection**
  - Group of elements
- **Set**
  - No duplicate elements
- **List**
  - Ordered collection
- **Map**
  - Maps keys to elements
- **SortedSet**, **SortedMap**
  - Sorted ordering of elements

Core Collection Hierarchy



Collections Interface Implementations

- General implementations:
  - Primary public implementation
  - Example
    - List – ArrayList, LinkedList
    - Set – TreeSet, HashSet
    - Map – TreeMap, HashMap
- Wrapper implementations:
  - Combined with other interfaces
  - Example
    - synchronizedArrayList, unmodifiableHashMap

Collections Interface Methods

- boolean add(Object o)
  – Add specified element
- boolean contains(Object o)
  – True if collection contains specified element
- boolean remove(Object o)
  – Removes specified element from collection
- Boolean equals(Object o)
  – Compares object with collection for equality
- Iterator iterator()
  – Returns an iterator over the elements in collection

Interface Methods (2)

- boolean addAll(Collection c)
  - Adds all elements in specified collection
- boolean containsAll(Collection c)
  - True if collection contains all elements in collection
- boolean removeAll(Collection c)
  - Removes all elements in specified collection
- boolean retainAll(Collection c)
  - Retains only elements contained in specified collection

Interface Methods (3)

- void clear()
  - Removes all elements from collection
- boolean isEmpty()
  - True if collection contains no elements
- int size()
  - Returns number of elements in collection
- Object[] toArray()
  - Returns array containing all elements in collection

Interface Methods (4)

- void shuffle(List list, Random rnd)
  - Randomly permute list using rnd

- void sort(List list, Comparator c)
  - Sorts list into ascending order
  - According Comparator ordering of elements

Iterator Interface

- Iterator
  - Common interface for all Collection classes
  - Used to examine all elements in collection

- Properties
  - Order of elements is unspecified (may change)
  - Can remove current element during iteration
  - Works for any collection

Iterator Interface (cont)

- **Interface**

```
public interface Iterator {
    boolean hasNext();
    Object next();
    void remove();          // optional, called once per next()
}
```

- **Example usage**

```
Iterator i = myCollection.iterator();
while (i.hasNext()) {
     myCollectionElem x = (myCollectionElem) i.next();
}
```

Collection Classes in Java

- In addition to ***Arrays***, Java has Vectors and Hashtables.
- A ***Vector*** is a dynamically expandable/contractable collection of objects – these are referencable in a similar way to the elements of an array.

Collection Classes (2)

- A ***Hashtable*** is a dynamically expandable collection of key/value pairs. Both key and value are objects.

- This allows **random access** to values by supplying the key (implemented by a hashing algorithm defined in the class object, but overridable).

Collection Classes (3)

- As both collection classes accommodate only objects, int’s, short’s, double’s etc must first be wrapped using a wrapper class.
- Vectors can easily be processed sequentially, but to do this with Hashtables it is necessary to employ an Enumeration object.

Vectors

```
public class Garage {

  private Vector fleet = new Vector();

  public int addVehicle(Vehicle v) {
      fleet.addElement(v);
      return fleet.size() - 1;
  }   // end addVehicle
```

Vectors (2)

```
public Vehicle getVehicle(int num) {
    Vehicle v = (Vehicle)fleet.elementAt(num);
    return v;
}   // end getVehicle

public void serviceFleet() {
    for(int i = 0; i < fleet.size(); i++)
        fleet.elementAt(i).service();
}   // end serviceFleet

} // end class Garage
```

Vectors (3)

- To add items to vector use the method addElement().
- To access items, use the method elementAt() – Vectors are indexed like arrays.
- The item returned from a Vector is assumed to be of class object and has to be cast to the correct type – called DownCasting.

Vectors (4)

- The number of elements in a Vector is given by the method size().

- Processing is similar to arrays although Enumerations can be used (by calling elements() method).

Wrapper Classes

```
public class Grades {

   private Vector marks = new Vector();

   public void addScore(int grade) {
   marks.addElement(new Integer(grade));
} // end addScore
```

Wrapper Classes (2)

```
public int getScoreAt(int pos) {
   Integer val;
   val = (Integer)marks.elementAt(pos);
   return val.intValue();
}  // end getScoreAt

}  // end class Grades
```

Wrapper Classes (3)

- As Vectors and Hashtables can only contain objects, to store simple data types, such as int, long, double etc wrapper classes are needed.
- There are separate wrapper classes for all basic data types e.g. Byte, Short, Long, Float, Character, Boolean.

Wrapper Classes (4)

- Each instance of a wrapper class contains a single attribute of the corresponding simple type.

Hashtables

```
public class Garage {

    private Hashtable fleet =
        new Hashtable();

    public void addVehicle(Vehicle v) {
        fleet.put(v.getReg(), v);
    }   // end addVehicle
```

Hashtables (2)

```
public Vehicle getVehicle(String reg) {
        return (Vehicle)fleet.get(reg);
} // end getVehicle
```

Hashtables (3)

```
public void serviceFleet() {
    Vehicle v;
    Enumeration e = fleet.elements();
    while (e.hasMoreElements()) {
        v = (Vehicle)e.nextElement();
        v.service();
    }   // end while
} // end serviceFleet
} // end class Garage
```

Hashtables (4)

- The collection is keyed on registration number.
- Traversing all items in a Hashtable requires the use of an Enumeration instance.

Hashtables (5)

- Enumerations operate like a file, starting at the ‘first’ item and working sequentially through until ***end-of-file***.
- Must obtain a new enumeration to repeat the process.

- An ***Enumeration*** makes no guarantees about the order in which the values are returned.

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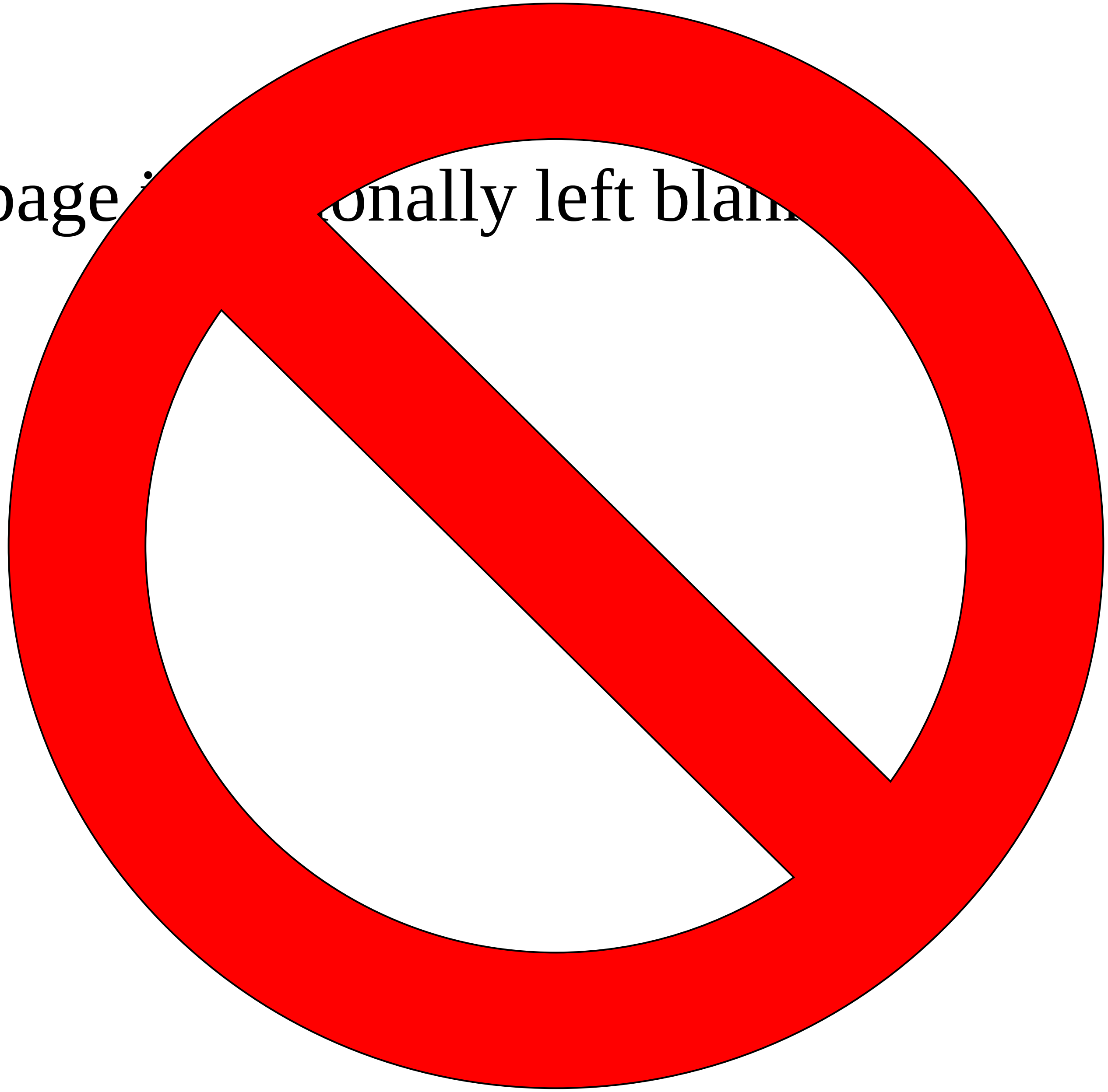

Chapter 3 - Functions

Outline

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3.2 Program Components in C++
3.3 Math Library Functions
3.4 Functions
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Chapter 3 - Functions

Outline

3.16 Inline Functions
3.17 References and Reference Parameters
3.18 Default Arguments
3.19 Unary Scope Resolution Operator
3.20 Function Overloading
3.21 Function Templates

3.3 Math Library Functions

- Perform common mathematical calculations
  - Include the header file **<cmath>**
- Example

```
cout << sqrt( 900.0 );
```

  - All functions in math library return a **double**

Method	Description	Example
`ceil( x )`	rounds *x* to the smallest integer not less than *x*	`ceil( 9.2 )` is `10.0` `ceil( -9.8 )` is `-9.0`
`cos( x )`	trigonometric cosine of *x* (*x* in radians)	`cos( 0.0 )` is `1.0`
`exp( x )`	exponential function *ex*	`exp( 1.0 )` is `2.71828` `exp( 2.0 )` is `7.38906`

`fabs( x )`	absolute value of *x*	`fabs( 5.1 )` is `5.1`
		`fabs( 0.0 )` is `0.0`
		`fabs( -8.76 )` is `8.76`

`floor( x )`	rounds *x* to the largest integer not greater than *x*	`floor( 9.2 )` is `9.0` `floor( -9.8 )` is `-10.0`
`fmod( x, y )`	remainder of *x/y* as a floating-point number	`fmod( 13.657, 2.333 )` is `1.992`
`log( x )`	natural logarithm of *x* (base *e*)	`log( 2.718282 )` is `1.0` `log( 7.389056 )` is `2.0`
`log10( x )`	logarithm of *x* (base 10)	`log10( 10.0 )` is `1.0` `log10( 100.0 )` is `2.0`
`pow( x, y )`	*x* raised to power *y* (*xy*)	`pow( 2, 7 )` is `128` `pow( 9, .5 )` is `3`
`sin( x )`	trigonometric sine of *x* (*x* in radians)	`sin( 0.0 )` is `0`
`sqrt( x )`	square root of *x*	`sqrt( 900.0 )` is `30.0` `sqrt( 9.0 )` is `3.0`
`tan( x )`	trigonometric tangent of *x* (*x* in radians)	`tan( 0.0 )` is `0`

Fig. 3.2 Math library functions.

3.4 Functions

- Functions
  - Modularize a program
  - Software reusability
    - Call function multiple times
- Local variables
  - Known only in the function in which they are defined
  - All variables declared in function definitions are local variables
- Parameters
  - Local variables passed to function when called
  - Provide outside information

3.5 Function Definitions

- Format for function definition

  return-value-type function-name`(` *parameter-list* `)`
  `{`
  declarations and statements
  `}`

  – Parameter list
    - If no arguments, use **`void`** or leave blank

  – Return-value-type
    - Data type of result returned (use **`void`** if nothing returned)

3.5 Function Definitions

- Example function

```
int square( int y )
{
  return y * y;
}
```

- **`return`** keyword
  - Returns data, and control goes to function's caller
    - If no data to return, use **`return;`**
  - Function ends when reaches right brace
    - Control goes to caller

3.6 Function Prototypes

- Function prototype
  - Only needed if function definition after function call
- Prototype must match function definition
  - Function prototype

```
double maximum( double, double, double );
```

  - Definition

```
double maximum( double x, double y, double z )
{
 …
}
```

3.8 Random Number Generation

- **`rand`** function (**`<cstdlib>`**)
  - **`i = rand();`**
  - Generates unsigned integer between 0 and RAND_MAX (usually 32767)
- Scaling and shifting
  - Modulus (remainder) operator: **`%`**
    - **`10 % 3`** is **`1`**
    - **`x % y`** is between **`0`** and **`y - 1`**
  - Example

```
i = rand() % 6 + 1;
```

    - **`"Rand() % 6"`** generates a number between **`0`** and **`5`** (scaling)
    - **`"+ 1"`** makes the range 1 to 6 (shift)

3.8 Random Number Generation

- Calling rand() repeatedly
  - Gives the same sequence of numbers
- Pseudorandom numbers
  - Preset sequence of "random" numbers
  - Same sequence generated whenever program run
- To get different random sequences
  - Provide a seed value
    - Like a random starting point in the sequence
    - The same seed will give the same sequence
  - **`srand(seed);`**
    - **`<cstdlib>`**
    - Used before **`rand()`** to set the seed

3.8 Random Number Generation

- Can use the current time to set the seed
  - No need to explicitly set seed every time
  - **`srand( time( 0 ) );`**
  - **`time( 0 );`**
    - **`<ctime>`**
    - Returns current time in seconds
- General shifting and scaling
  - *Number* **`=`** *shiftingValue* **`+ rand() %`** *scalingFactor*
  - shiftingValue = first number in desired range
  - scalingFactor = width of desired range

3.9 Example: Game of Chance and Introducing enum

- Enumeration
  - Set of integers with identifiers

  `enum` *typeName* **`{`***constant1*, *constant2*…**`};`**

  - Constants start at 0 (default), incremented by 1
  - Constants need unique names
  - Cannot assign integer to enumeration variable
    - Must use a previously defined enumeration type
- Example

```
enum Status {CONTINUE, WON, LOST};
Status enumVar;
enumVar = WON; // cannot do enumVar = 1
```

3.9 Example: Game of Chance and Introducing enum

- Enumeration constants can have preset values

```
enum Months { JAN = 1, FEB, MAR, APR, MAY,
  JUN, JUL, AUG, SEP, OCT, NOV, DEC};
```

  - Starts at 1, increments by 1

3.10 Storage Classes

- Variables have attributes
  - Have seen name, type, size, value
  - Storage class
    - How long variable exists in memory
  - Scope
    - Where variable can be referenced in program
  - Linkage
    - For multiple-file program, which files can use it

3.13 Example Using Recursion: Fibonacci Series

- Order of operations
  - `return fibonacci( n - 1 ) + fibonacci( n - 2 );`
- Do not know which one executed first
  - C++ does not specify
  - Only **`&&`**, **`||`** and **`?:`** guaranteed left-to-right evaluation
- Recursive function calls
  - Each level of recursion doubles the number of function calls
    - 30^{th} number = 2^30 ~ 4 billion function calls
  - Exponential complexity

3.14 Recursion vs. Iteration

- Repetition
  - Iteration: explicit loop
  - Recursion: repeated function calls
- Termination
  - Iteration: loop condition fails
  - Recursion: base case recognized
- Both can have infinite loops
- Balance between performance (iteration) and good software engineering (recursion)

3.15 Functions with Empty Parameter Lists

- Empty parameter lists
  - **`void`** or leave parameter list empty
  - Indicates function takes no arguments
  - Function **`print`** takes no arguments and returns no value
    - **`void print();`**
    - **`void print( void );`**

3.16 Inline Functions

- Inline functions
  - Keyword **`inline`** before function
  - Asks the compiler to copy code into program instead of making function call
    - Reduce function-call overhead
    - Compiler can ignore **`inline`**
  - Good for small, often-used functions
- Example

```
inline double cube( const double s )
   { return s * s * s; }
```

  - **`const`** tells compiler that function does not modify **`s`**

3.17 References and Reference Parameters

- Call by value
  - Copy of data passed to function
  - Changes to copy do not change original
  - Prevent unwanted side effects
- Call by reference
  - Function can directly access data
  - Changes affect original

3.17 References and Reference Parameters

- Pointers
  - Another way to pass-by-refernce
- References as aliases to other variables
  - Refer to same variable
  - Can be used within a function

```
int count = 1; // declare integer variable count
Int &cRef = count; // create cRef as an alias for count
++cRef; // increment count (using its alias)
```

- References must be initialized when declared
  - Otherwise, compiler error
  - Dangling reference
    - Reference to undefined variable

```
1  // Fig. 3.22: fig03_22.cpp
2  // References must be initialized.
3  #include <iostream>
4
5  using std::cout;
6  using std::endl;
7
8  int main()
9  {
10    int x = 3;
11    int &y;      // Error: y must be initialized
12
13    cout << "x = " << x << endl << "y = " << y << endl;
14    y = 7;
15    cout << "x = " << x << endl << "y = " << y << endl;
16
17    return 0;  // indicates successful termination
18
19 } // end main
```

Uninitialized reference – compiler error.

Borland C++ command-line compiler error message:

```
Error E2304 Fig03_22.cpp 11: Reference variable 'y' must be
  initialized- in function main()
```

Microsoft Visual C++ compiler error message:

```
D:\cpphtp4_examples\ch03\Fig03_22.cpp(11) : error C2530: 'y' :
  references must be initialized
```

fig03_22.cpp (1 of 1)

fig03_22.cpp output (1 of 1)

3.18 Default Arguments

- Function call with omitted parameters
  - If not enough parameters, rightmost go to their defaults
  - Default values
    - Can be constants, global variables, or function calls
- Set defaults in function prototype

```
int myFunction( int x = 1, int y = 2, int z = 3 );
```

  - **`myFunction(3)`**
    - **`x = 3`**, **`y`** and **`z`** get defaults (rightmost)
  - **`myFunction(3, 5)`**
    - **`x = 3`**, **`y = 5`** and **`z`** gets default

Outline

fig03_24.cpp
(1 of 2)

```
// Fig. 3.24: fig03_24.cpp
// Using the unary scope resolution operator.
#include <iostream>

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

#include <iomanip>

using std::setprecision;

// define global constant PI
const double PI = 3.14159265358979;

int main()
{
   // define local constant PI
   const float PI = static_cast< float >( ::PI );

   // display values of local and global PI constants
   cout << setprecision( 20 )
        << "  Local float value of PI = " << PI
        << "\nGlobal double value of PI = " << ::PI << endl;

   return 0;  // indicates successful termination
```

Access the global `PI` with `::PI`.

Cast the global `PI` to a `float` for the local `PI`. This example will show the difference between `float` and `double`.

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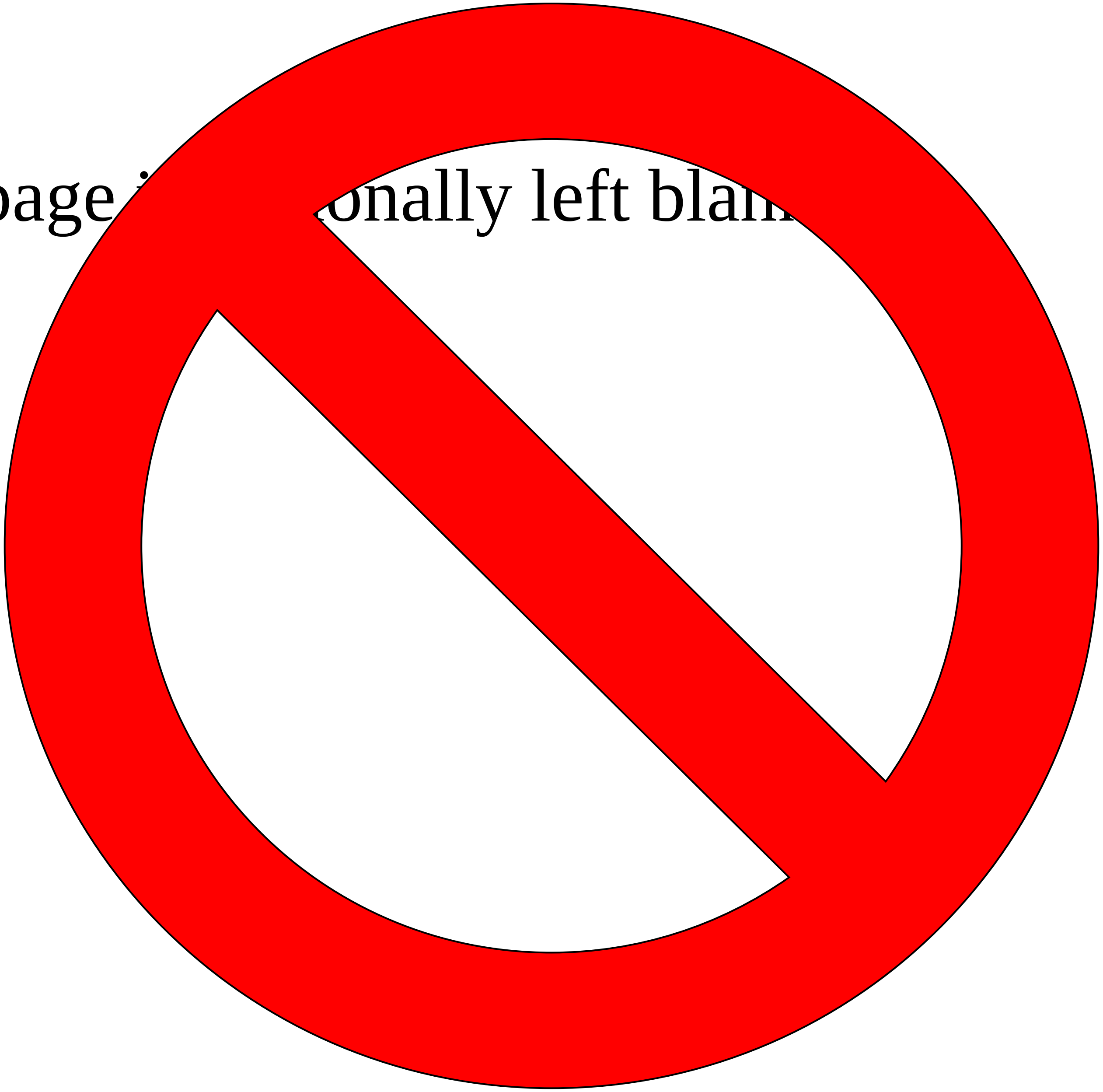

Chapter 4 - Arrays

Outline

4.1 Introduction
4.2 Arrays
4.3 Declaring Arrays
4.4 Examples Using Arrays
4.5 Passing Arrays to Functions
4.6 Sorting Arrays
4.7 Case Study: Computing Mean, Median and Mode Using Arrays
4.8 Searching Arrays: Linear Search and Binary Search
4.9 Multiple-Subscripted Arrays

4.1 Introduction

- Arrays
  - Structures of related data items
  - Static entity (same size throughout program)
- A few types
  - Pointer-based arrays (C-like)
  - Arrays as objects (C++)

4.4 Examples Using Arrays

- Initializing arrays
  - For loop
    - Set each element
  - Initializer list
    - Specify each element when array declared

```
int n[ 5 ] = { 1, 2, 3, 4, 5 };
```

    - If not enough initializers, rightmost elements 0
    - If too many syntax error
  - To set every element to same value

```
int n[ 5 ] = { 0 };
```

  - If array size omitted, initializers determine size

```
int n[] = { 1, 2, 3, 4, 5 };
```

    - 5 initializers, therefore 5 element array

Outline

fig04_07.cpp
(1 of 1)

fig04_07.cpp
output (1 of 1)

```
// Fig. 4.7: fig04_07.cpp
// A const object must be initi

int main()
{
   const int x;  // Error: x mu

   x = 7;        // Error: cannot modify a const variable

   return 0;     // indicates successful termination

} // end main
```

Uninitialized **const** results in a syntax error. Attempting to modify the **const** is another error.

```
d:\cpphtp4_examples\ch04\Fig04_07.cpp(6) : error C2734: 'x' :
   const object must be initialized if not extern
d:\cpphtp4_examples\ch04\Fig04_07.cpp(8) : error C2166:
   l-value specifies const object
```

4.4 Examples Using Arrays

- Strings
  - Arrays of characters
  - All strings end with **`null`** (**`'\0'`**)
  - Examples
    - **`char string1[] = "hello";`**
      - **`Null`** character implicitly added
      - **`string1`** has 6 elements
    - **`char string1[] = { 'h', 'e', 'l', 'l', 'o', '\0’ };`**

fig04_12.cpp
(1 of 2)

```
// Fig. 4_12: fig04_12.cpp
// Treating character arrays as strings.
#include <iostream>

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

int main()
{
   char string1[ 20 ],                // 
   char string2[] = "string literal"; // 

   // read string from user into a
   cout << "Enter the string \"hel
   cin >> string1;   // reads "hello" [space terminates input]

   // output strings
   cout << "string1 is: " << string1
        << "\nstring2 is: " << string2;

   cout << "\nstring1 with spaces between characters is:\n";

```

Two different ways to declare strings. **`string2`** is initialized, and its size determined automatically .

Examples of reading strings from the keyboard and printing them out.

4.9 Multiple-Subscripted Arrays

- To initialize
  - Default of **`0`**
  - Initializers grouped by row in braces

```
int b[ 2 ][ 2 ] = { { 1, 2 }, { 3, 4 } };
```

Row 0 **Row 1**

1	2
3	4

```
int b[ 2 ][ 2 ] = { { 1 }, { 3, 4 } };
```

1	0
3	4

4.4 Examples Using Arrays

- Recall static storage
  - If **`static`**, local variables save values between function calls
  - Visible only in function body
  - Can declare local arrays to be static
    - Initialized to zero on first function call

```
static int array[3];
```

4.5 Passing Arrays to Functions

- Arrays passed-by-reference
  - Functions can modify original array data
  - Value of name of array is address of first element
    - Function knows where the array is stored
    - Can change original memory locations
- Individual array elements passed-by-value
  - Like regular variables
  - `square( myArray[3] );`

4.5 Passing Arrays to Functions

- Functions taking arrays
  - Function prototype
    - **`void modifyArray( int b[], int arraySize );`**
    - **`void modifyArray( int [], int );`**
      - Names optional in prototype
    - Both take an integer array and a single integer
  - No need for array size between brackets
    - Ignored by compiler
  - If declare array parameter as **`const`**
    - Cannot be modified (compiler error)
    - **`void doNotModify( const int [] );`**

4.9 Multiple-Subscripted Arrays

- Function prototypes
  - Must specify sizes of subscripts
    - First subscript not necessary, as with single-scripted arrays
  - `void printArray( int [][ 3 ] );`

```
// Fig. 4.22: fig04_22.cpp
// Initializing multidimensional arrays.
#include <iostream>

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

void printArray( int [][ 3 ] );

int main()
{
   int array1[ 2 ][ 3 ] = { { 1, 2, 3 }, { 4, 5, 6 } };
   int array2[ 2 ][ 3 ] = { 1, 2, 3, 4, 5 };
   int array3[ 2 ][ 3 ] = { { 1, 2 }, { 4 } };

   cout << "Values in array1 by row are:" << endl;
   printArray( array1 );

   cout << "Values in array2 by row are:" << endl;
   printArray( array2 );

   cout << "Values in array3 by row are:" << endl;
   printArray( array3 );

   return 0;  // indicates successful termination

} // end main
```

Note the format of the prototype.

Note the various initialization styles. The elements in **`array2`** are assigned to the first row and then the second.