Structures and Classes

- In C++, the definition of a structure has been expanded so that it can also include member functions, including constructors and destructor functions, in just the same way that a class can.
- The only difference between a structure and a class is that, by default, the members of a class are private but the members of a structure are public.

Constructors & Destructors

- A constructor is called each time an object of that class is created.
- Any initializations that need to be performed on an object can be done automatically by the constructor function.
- A constructor function has the same name as the class of which it is a part and has no return type.

Constructors & Destructors (cont)

- Data member of a class cannot be initialized in the class definition.

- A destructor function is declared as preceding the class name with a ~.

Example

```
class Time {
        // Time abstract data type (ADT) definition.
public:
   Time()   { hour = minute = second = 0; }
                        // constructor
  ~Time();              // destructor

private:
  int hour, minute, second;
};
```

Constructor Taking Parameters

- ***Time(int = 0 , int = 0, int = 0);***

  // default arguments

- Destructor functions may not have parameters.

Inheritance

- All public elements of the base class will also public elements of the derived class.

- All private elements of the base elements remain private to it and are not directly accessible by the derived class.

Example

```
// Define base class
class Base {
      int i;

public:
      void set_i(int n);
      int get_i();
};

// Define derived class
class Derived : public Base {
      int j;

public:
      void set_j(int n);
      int mul()          { return j * get_i(); }
}
```

Example (cont)

```
Derived ob;

ob.set_i(10);          // load i in Base
ob.set_j(4);           // load j in Derived
cout << ob.mul();      // display 40
```

"const" Member Functions & Data Members

- A member function can be declared to be able to read but not write the object for which it is called.

  E.g., ***int getHour () const {};*** // return hour

- A non-const member function cannot be called for a const object.

  E.g.,

  ```
  void setHour (int);             // set hour
  const Time noon (12, 0, 0);     // constant object
  noon.setHour (10);              // illegal
  ```

"const" Member Functions & Data Members (2)

- It is better to declare "const" all member functions that do not need to modify the current object so that you can use them on a const object if you need to.

- The const declaration is not allowed for constructors and destructors.

"const" Member Functions & Data Members (3)

- **const** data members must be initialized using member initializer.

  E.g.,

```
class Increment {
        const int count;
        const int dummy;
};
Increment (int c, int d) : count(c),
                           dummy(d) {};
```

Objects as Members of Classes

- Objects are constructed from the inside out and destructed in the reverse order from the outside in.
- Better to initialize member objects explicitly through member initializers.

```
Employee (char fname, int bmonth, int hyear)
            : birthDate(bmonth),
              hireDate(hyear) {};
```

This eliminates the overhead of "doubly initializing" member objects, i.e., once when the member object's default **constructor** is called and again when **set** functions are used to initialize the member object.

"friend" Functions

- Not a member of a class but still has access to its private members.

- It is not possible to call a friend function by using an object name and a class member access operator (a dot or arrow). Instead, friends are called just like ***regular functions***.

"friend" Functions (cont)

- Will typically be passed one or more objects of the class for which they are defined to operate upon. E.g.,

```
class Count {
        // friend declaration
        friend void setX(Count &c, int val)      { c.x = val; }
private:
        int x;                    // private data member
};

Count cnt;
setX(cnt, 8);                // set x with a friend
```

“friend” Classes

```
class class_one {
   friend class class_two;
```

- Friendship is granted, not taken.
- Friendship is neither symmetric nor transitive.

The "this" Pointer

- "this" is a pointer that is automatically passed to any member function when it is called.
- Only member functions are passed a pointer, therefore, a friend does not have "this" pointer.
- (*this).data-member, where parentheses are needed because the dot operator has higher precedence than the * operator.

Static Class Members

- Only one copy of the static member variable exists – no matter how many objects of that class are created.
- Static member variable exists before any object of its class is created.
- Must be called by prefixing its name with the class name and binary scope resolution operator.
- Within a static member function, there is no "this" pointer.

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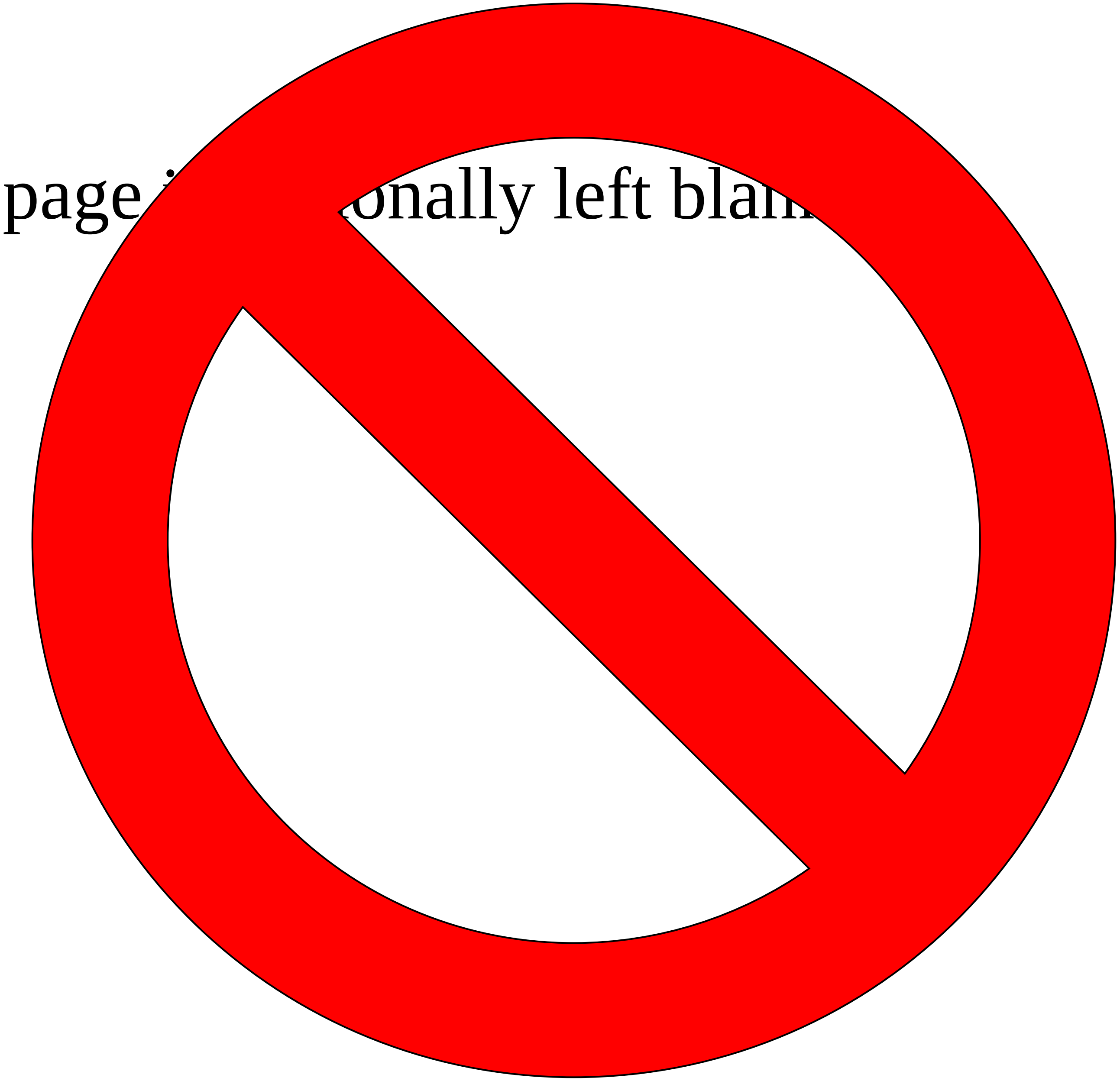


Chapter 6: Classes and Data Abstraction

Outline

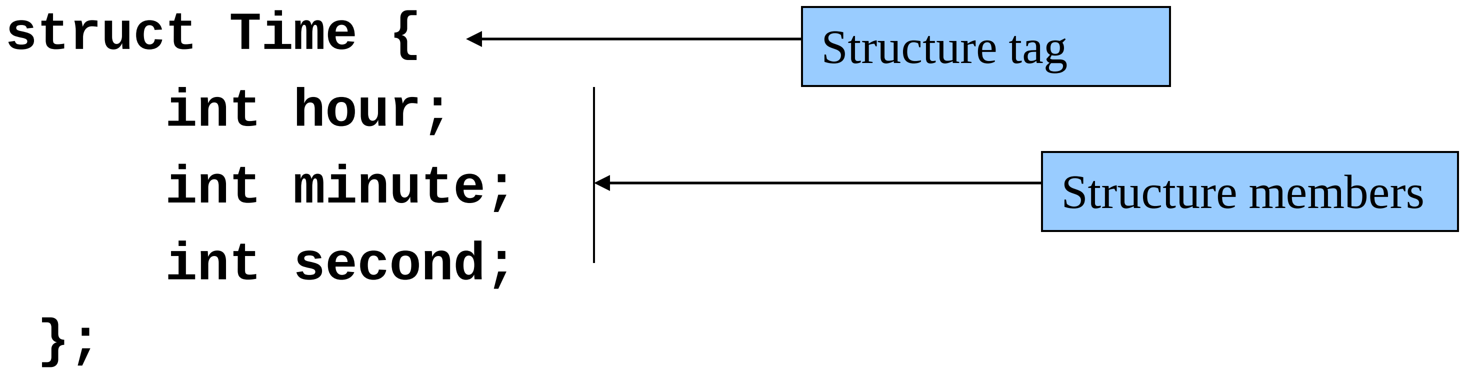
6.1 Introduction
6.2 Structure Definitions
6.3 Accessing Structure Members
6.4 Implementing a User-Defined Type `Time` with a `struct`
6.5 Implementing a `Time` Abstract Data Type with a `class`
6.6 Class Scope and Accessing Class Members
6.7 Separating Interface from Implementation
6.8 Controlling Access to Members
6.9 Access Functions and Utility Functions
6.10 Initializing Class Objects: Constructors
6.11 Using Default Arguments with Constructors
6.12 Destructors
6.13 When Constructors and Destructors Are Called
6.14 Using *Set* and *Get* Functions
6.15 Subtle Trap: Returning a Reference to a `private` Data Member
6.16 Default Memberwise Assignment
6.17 Software Reusability

6.1 Introduction

- Object-oriented programming (OOP)
  - Encapsulates data (attributes) and functions (behavior) into packages called classes
- Information hiding
  - Class objects communicate across well-defined interfaces
  - Implementation details hidden within classes themselves
- User-defined (programmer-defined) types: classes
  - Data (data members)
  - Functions (member functions or methods)
  - Class instance: object

6.2 Structure Definitions

- Structures
  - Aggregate data types built using elements of other types



```
struct Time {
        int hour;
        int minute;
        int second;
 };
```

Structure tag

Structure members

- Structure member naming
  - In same **`struct`**: must have unique names
  - In different **`struct`**s: can share name
- **`struct`** definition must end with semicolon

6.4 Implementing a User-Defined Type `Time` with a `struct`

- Default: structures passed by value
  - Pass structure by reference
    - Avoid overhead of copying structure
- C-style structures
  - No “interface”
    - If implementation changes, all programs using that **`struct`** must change accordingly
  - Cannot print as unit
    - Must print/format member by member
  - Cannot compare in entirety
    - Must compare member by member

fig06_01.cpp
(3 of 3)

```cpp
// print time in universal-time format
void printUniversal( const Time &t )
{
   cout << setfill( '0' ) << setw( 2 ) << t.hour << ":"
        << setw( 2 ) << t.minute << ":"
        << setw( 2 ) << t.second;

} // end function printUniversal

// print time in standard-time format
void printStandard( const Time &t )
{
   cout << ( ( t.hour == 0 || t.hour == 12 ) ?
              12 : t.hour % 12 ) << ":" << setfill( '0' )
        << setw( 2 ) << t.minute << ":"
        << setw( 2 ) << t.second
        << ( t.hour < 12 ? " AM" : " PM" );

} // end function printStandard
```

Use parameterized stream manipulator **setfill**.

Use dot operator to access data members.

```
Dinner will be held at 18:30:00 universal time,
which is 6:30:00 PM standard time.

Time with invalid values: 29:73:00
```

6.5 Implementing a `Time` Abstract Data Type with a `class`

- Constructor function
  - Special member function
    - Initializes data members
    - Same name as class
  - Called when object instantiated
  - Several constructors
    - Function overloading
  - No return type

6.5 Implementing a `Time` Abstract Data Type with a `class`

- Member functions defined outside class
  - Binary scope resolution operator (**`::`**)
    - “Ties” member name to class name
    - Uniquely identify functions of particular class
    - Different classes can have member functions with same name
- Member functions defined inside class
  - Do not need scope resolution operator, class name
  - Compiler attempts **`inline`**
    - Outside class, inline explicitly with keyword **`inline`**

Outline

```
// Fig. 6.3: fig06_03.cpp
// Time class.
#include <iostream>

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

#include <iomanip>

using std::setfill;
using std::setw;

// Time abstract data type (ADT) definition
class Time {

public:
   Time();                        // constructor
   void setTime( int, int, int ); // set hour, minute, second
   void printUniversal();         // print universal-time format
   void printStandard();          // print standard-time format

```

Define class **`Time`**.

fig06_03.cpp
(1 of 5)

fig06_03.cpp
(2 of 5)

```
private:
   int hour;        // 0 - 23 (24-hour clock format)
   int minute;      // 0 - 59
   int second;      // 0 - 59

}; // end class Time

// Time constructor initializes each data me
// ensures all Time objects start in a consi
Time::Time()
{
   hour = minute = second = 0;

} // end Time constructor

// set new Time value using universal time, perform validity
// checks on the data values and set invalid values to zero
void Time::setTime( int h, int m, int s )
{
   hour = ( h >= 0 && h < 24 ) ? h : 0;
   minute = ( m >= 0 && m < 60 ) ? m : 0;
   second = ( s >= 0 && s < 60 ) ? s : 0;

} // end function setTime

```

Constructor initializes **`private`** data members to **`0`**.

`public` member function checks parameter values for validity before setting **`private`** data members.

fig06_03.cpp
(3 of 5)

```cpp
// print Time in universal format
void Time::printUniversal()
{
   cout << setfill( '0' ) << setw( 2 ) << hour << ":"
        << setw( 2 ) << minute << ":"
        << setw( 2 ) << second;

} // end function printUniversal

// print Time in standard format
void Time::printStandard()
{
   cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 )
        << ":" << setfill( '0' ) << setw( 2 ) << minute
        << ":" << setw( 2 ) << second
        << ( hour < 12 ? " AM" : " PM" );

} // end function printStandard

int main()
{
   Time t;  // instantiate object t of class Time

```

No arguments (implicitly "know" purpose is to print data members); member function calls more concise.

Declare variable `t` to be object of class `Time`.

6.5 Implementing a `Time` Abstract Data Type with a `class`

- Destructors
  - Same name as class
    - Preceded with tilde (**~**)
  - No arguments
  - Cannot be overloaded
  - Performs “termination housekeeping”

6.6 Class Scope and Accessing Class Members

- Class scope
  - Data members, member functions
  - Within class scope
    - Class members
      - Immediately accessible by all member functions
      - Referenced by name
  - Outside class scope
    - Referenced through handles
      - Object name, reference to object, pointer to object

time1.h (1 of 1)

```
// Fig. 6.5: time1.h
// Declaration of class Time.
// Member functions are defined in t

// prevent multiple inclusions
#ifndef TIME1_H
#define TIME1_H

// Time abstract d                  n
class Time {

public:
   Time();                        // constructor
   void setTime( int, int,                              econd
   void printUniversal();                               e format
   void printStandard();                                 format

private:
   int hour;     // 0 - 23 (24-hour clock format)
   int minute;   // 0 - 59
   int second;   // 0 - 59

}; // end class Time

#endif
```

Preprocessor code to prevent multiple inclusions.

Code between these directives not included if name **TIME1_H** already defined.

"If not defined"

Preprocessor directive defines name **TIME1_H**.

Naming convention: header file name with underscore replacing period.

time1.cpp (1 of 3)

```
// Fig. 6.6: time1.cpp
// Member-function definitions for class Time.
#include <iostream>

using std::cout;

#include <iomanip>

using std::setfill;
using std::setw;

// include definition of class Time from time1.h
#include "time1.h"

// Time constructor initializes each data member to zero.
// Ensures all Time objects
Time::Time()
{
   hour = minute = second =

} // end Time constructor

```

Include header file **time1.h**.

Name of header file enclosed in quotes; angle brackets cause preprocessor to assume header part of C++ Standard Library.

6.8 Controlling Access to Members

- Class member access
  - Default **private**
  - Explicitly set to **private**, **public**, **protected**
- **struct** member access
  - Default **public**
  - Explicitly set to **private**, **public**, **protected**
- Access to class’s **private** data
  - Controlled with access functions (accessor methods)
    - Get function
      - Read **private** data
    - Set function
      - Modify **private** data

6.9 Access Functions and Utility Functions

- Access functions
  - **`public`**
  - Read/display data
  - Predicate functions
    - Check conditions
- Utility functions (helper functions)
  - **`private`**
  - Support operation of **`public`** member functions
  - Not intended for direct client use

6.11 Using Default Arguments with Constructors

- Constructors
  - Can specify default arguments
  - Default constructors
    - Defaults all arguments

      OR
    - Explicitly requires no arguments
    - Can be invoked with no arguments
    - Only one per class

6.12 Destructors

- Destructors
  - Special member function
  - Same name as class
    - Preceded with tilde (**~**)
  - No arguments
  - No return value
  - Cannot be overloaded
  - Performs “termination housekeeping”
    - Before system reclaims object’s memory
      - Reuse memory for new objects
  - No explicit destructor
    - Compiler creates “empty” destructor”

6.13 When Constructors and Destructors Are Called

- Order of constructor, destructor function calls
  - Global scope objects
    - Constructors
      - Before any other function (including **`main`**)
    - Destructors
      - When **`main`** terminates (or **`exit`** function called)
      - Not called if program terminates with **`abort`**
  - Automatic local objects
    - Constructors
      - When objects defined
        - Each time execution enters scope
    - Destructors
      - When objects leave scope
        - Execution exits block in which object defined
      - Not called if program ends with **`exit`** or **`abort`**

6.13 When Constructors and Destructors Are Called

- Order of constructor, destructor function calls
  - **`static`** local objects
    - Constructors
      - Exactly once
      - When execution reaches point where object defined
    - Destructors
      - When **`main`** terminates or **`exit`** function called
      - Not called if program ends with **`abort`**

6.15 Subtle Trap: Returning a Reference to a `private` Data Member

- Returning references
  - `public` member functions can return non-`const` references to `private` data members
    - Client able to modify `private` data members

time4.h (1 of 1)

```
// Fig. 6.21: time4.h
// Declaration of class Time.
// Member functions defined in time4.cpp

// prevent multiple inclusions of header file
#ifndef TIME4_H
#define TIME4_H

class Time {

public:
   Time( int = 0, int = 0, int = 0 );
   void setTime( int, int, int );
   int getHour();

   int &badSetHour( int );  // DANGEROUS reference return

private:
   int hour;
   int minute;
   int second;

}; // end class Time

#endif
```

Function to demonstrate effects of returning reference to **`private`** data member.

time4.cpp (2 of 2)

```
// return hour value
int Time::getHour()
{
   return hour;

} // end function getHour

// POOR PROGRAMMING PRACTICE:
// Returning a reference to a private data member.
int &Time::badSetHour( int hh )
{
   hour = ( hh >= 0 && hh < 24 )

   return hour;  // DANGEROUS reference return

} // end function badSetHour
```

Return reference to **`private`** data member **`hour`**.

6.16 Default Memberwise Assignment

- Assigning objects
  - Assignment operator (**=**)
    - Can assign one object to another of same type
    - Default: memberwise assignment
      - Each right member assigned individually to left member

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Chapter 7: Classes Part II

Outline

7.1 Introduction
7.2 `const` (Constant) Objects and `const` Member Functions
7.3 Composition: Objects as Members of Classes
7.4 friend Functions and friend Classes
7.5 Using the `this` Pointer
7.6 Dynamic Memory Allocation with Operators new and delete
7.7 `static` Class Members
7.8 Data Abstraction and Information Hiding
7.8.1 Example: Array Abstract Data Type
7.8.2 Example: String Abstract Data Type
7.8.3 Example: Queue Abstract Data Type
7.9 Container Classes and Iterators
7.10 Proxy Classes

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7.2 const (Constant) Objects and const Member Functions

- Principle of least privilege
  - Only give objects permissions they need, no more
- Keyword **`const`**
  - Specify that an object is not modifiable
  - Any attempt to modify the object is a syntax error
  - Example

```
const Time noon( 12, 0, 0 );
```

- Declares a **`const`** object **`noon`** of class **`Time`** and initializes it to 12

7.2 const (Constant) Objects and const Member Functions

- **`const`** objects require **`const`** functions
  - Member functions declared **`const`** cannot modify their object
  - **`const`** must be specified in function prototype and definition
  - Prototype:

    ReturnType FunctionName(param1,param2…) const;
  - Definition:

    ReturnType FunctionName(param1,param2…) const { …}
  - Example:

    ```
    int A::getValue() const { return
       privateDataMember };
    ```
    - Returns the value of a data member but doesn't modify anything so is declared **`const`**
- Constructors / Destructors cannot be **`const`**
  - They need to initialize variables, therefore modifying them

7.2 const (Constant) Objects and const Member Functions

- Member initializer syntax
  - Data member increment in class `Increment`
  - constructor for `Increment` is modified as follows:

```
Increment::Increment( int c, int i )
     : increment( i )
   { count = c; }
```

  - `: increment( i )` initializes increment to `i`
  - All data members can be initialized using member initializer syntax
  - `const`s and references must be initialized using member initializer syntax
  - Multiple member initializers
    - Use comma-separated list after the colon

7.3 Composition: Objects as Members of Classes

- Composition
  - Class has objects of other classes as members
- Construction of objects
  - Member objects constructed in order declared
    - Not in order of constructor’s member initializer list
  - Constructed before their enclosing class objects (host objects)

7.4 friend Functions and friend Classes

- **friend** function and **friend** classes
  - Can access **private** and **protected** members of another class
  - **friend** functions are not member functions of class
    - Defined outside of class scope
- Properties of friendship
  - Friendship is granted, not taken
  - Not symmetric (if **B** a **friend** of **A**, **A** not necessarily a **friend** of **B**)
  - Not transitive (if **A** a **friend** of **B**, **B** a **friend** of **C**, **A** not necessarily a **friend** of **C**)

7.4 friend Functions and friend Classes

- **`friend`** declarations
  - To declare a **`friend`** function
    - Type **`friend`** before the function prototype in the class that is giving friendship

```
friend int myFunction( int x );
```

    should appear in the class giving friendship

  - To declare a **`friend`** class
  - Type **`friend class Classname`** in the class that is giving friendship
  - if **`ClassOne`** is granting friendship to **`ClassTwo`**,

```
friend class ClassTwo;
```

  - should appear in **`ClassOne`**'s definition

```
// Fig. 7.5: fig07_05.cpp
// Friends can access private members of a class.
#include <iostream>

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

// Modified Count class
class Count {
   friend void setX( Count &, int ); // friend declaration
public:
   Count() { x = 0; }                // constructor
   void print() const { cout << x << endl; }  // output
private:
   int x;  // data member
};

// Can modify private data of Count because
// setX is declared as a friend function of
void setX( Count &c, int val )
{
   c.x = val;  // legal: setX is a friend of Count
}

int main()
{
   Count counter;

   cout << "counter.x after instantiation: ";
   counter.print();
```

setX a **friend** of class **Count** (can access **private** data).

setX is defined normally and is not a member function of **Count**.

Changing **private** variables allowed.

Outline

1. Class definition

1.1 Declare function a friend

1.2 Function definition

1.3 Initialize Count object

7.5 Using the this Pointer

- **`this`** pointer
  - Allows objects to access their own address
  - Not part of the object itself
  - Implicit first argument on non-static member function call to the object
  - Implicitly reference member data and functions
  - The type of the **`this`** pointer depends upon the type of the object and whether the member function using **`this`** is **`const`**
  - In a non-**`const`** member function of **`Employee`**, **`this`** has type

    ```
    Employee * const
    ```

    - Constant pointer to an **`Employee`** object
  - In a **`const`** member function of **`Employee`**, this has type

    ```
    const Employee * const
    ```

    - Constant pointer to a constant **`Employee`** object

7.5 Using the this Pointer

- Examples using **`this`**
  - For a member function print data member **`x`**, either

```
this->x
```

or

```
( *this ).x
```

- Cascaded member function calls
  - Function returns a reference pointer to the same object

```
{ return *this; }
```

  - Other functions can operate on that pointer
  - Functions that do not return references must be called last

7.5 Using the this Pointer

- Example of cascaded member function calls
  - Member functions **`setHour`**, **`setMinute`**, and **`setSecond`** all return **`*this`** (reference to an object)
  - For object **`t`**, consider

```
t.setHour(1).setMinute(2).setSecond(3);
```

  - Executes **`t.setHour(1)`**, returns **`*this`** (reference to object) and the expression becomes

```
t.setMinute(2).setSecond(3);
```

  - Executes **`t.setMinute(2)`**, returns reference and becomes

```
t.setSecond(3);
```

  - Executes **`t.setSecond(3)`**, returns reference and becomes

```
t;
```

  - Has no effect

7.7 static Class Members

- **static** class members
  - Shared by all objects of a class
    - Normally, each object gets its own copy of each variable
  - Efficient when a single copy of data is enough
    - Only the **static** variable has to be updated
  - May seem like global variables, but have class scope
    - only accessible to objects of same class
  - Initialized at file scope
  - Exist even if no instances (objects) of the class exist
  - Both variables and functions can be **static**

7.7 `static` Class Members

- **`static`** variables
  - Static variables are accessible through any object of the class
  - **`public static`** variables
    - Can also be accessed using scope resolution operator(**`::`**)

```
Employee::count
```

  - **`private static`** variables
    - When no class member objects exist, can only be accessed via a **`public static`** member function
      - To call a **`public static`** member function combine the class name, the **`::`** operator and the function name

```
Employee::getCount()
```

7.7 static Class Members

- **Static** functions
  - **static** member functions cannot access non-**static** data or functions
  - There is no **this** pointer for **static** functions, they exist independent of objects