Chapter 6: Classes and Data Abstraction

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6.1 Introduction

- Object-oriented programming (OOP)
  - Encapsulates data (attributes) and functions (behavior) into packages called classes
- Information hiding
  - Implementation details are hidden within the classes themselves
- Classes
  - Classes are the standard unit of programming
  - A class is like a blueprint – reusable
  - Objects are instantiated (created) from the class
  - For example, a house is an instance of a "blueprint class"

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

  - Members of the same structure must have unique names
  - Two different structures may contain members of the same name
  - Each structure definition must end with a semicolon

6.2 Structure Definitions

- Self-referential structure
  - Contains a member that is a pointer to the same structure type
  - Used for linked lists, queues, stacks and trees
- **`struct`**
  - Creates a new data type that is used to declare variables
  - Structure variables are declared like variables of other types
  - Example:

```
Time timeObject, timeArray[ 10 ],
     *timePtr, &timeRef = timeObject;
```

6.3 Accessing Members of Structures

- Member access operators:
  - Dot operator (`.`) for structures and objects
  - Arrow operator (`->`) for pointers
  - Print member **`hour`** of **`timeObject`**:

```
cout << timeObject.hour;
```

OR

```
timePtr = &timeObject;
cout << timePtr->hour;
```

  - **`timePtr->hour`** is the same as **`( *timePtr ).hour`**
  - Parentheses required: `*` has lower precedence than `.`

```
// Fig. 6.1: fig06_01.cpp
// Create a structure, set its members, and print it.
#include <iostream>

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

struct Time {    // structure definition
   int hour;     // 0-23
   int minute;   // 0-59
   int second;   // 0-59
};

void printMilitary( const Time & );  // prototype
void printStandard( const Time & );  // prototype

int main()
{
   Time dinnerTime;    // variable of new type Time

   // set members to valid values
   dinnerTime.hour = 18;
   dinnerTime.minute = 30;
   dinnerTime.second = 0;

   cout << "Dinner will be held at ";
   printMilitary( dinnerTime );
   cout << " military time,\nwhich is ";
   printStandard( dinnerTime );
   cout << " standard time.\n";

```

Creates the user-defined structure type **`Time`** with three integer members: **`hour`**, **`minute`** and **`second`**.

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

Outline

- Define the **`struct`**

1.1 Define prototypes for the functions

Create a **`struct`** ata type

2.1 Set and print the time

```
   // set members to invalid values
   dinnerTime.hour = 29;
   dinnerTime.minute = 73;

   cout << "\nTime with invalid values: ";
   printMilitary( dinnerTime );
   cout << endl;
   return 0;
}

// Print the time in military format
void printMilitary( const Time &t )
{
   cout << ( t.hour < 10 ? "0" : "" ) << t.hour << ":"
        << ( t.minute < 10 ? "0" : "" ) << t.minute;
}

// Print the time in standard format
void printStandard( const Time &t )
{
   cout << ( ( t.hour == 0 || t.hour == 12 ) ?
             12 : t.hour % 12 )
        << ":" << ( t.minute < 10 ? "0" : "" ) << t.minute
        << ":" << ( t.second < 10 ? "0" : "" ) << t.second
        << ( t.hour < 12 ? " AM" : " PM" );
}
```

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

Outline

2.2 Set the time to an invalid hour, then print it

3. Define the functions `printMilitary` and `printStandard`

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

Time with invalid values: 29:73
```

Outline

Program Output

6.5 Implementing a Time Abstract Data Type with a Class

- Classes
  - Model objects that have attributes (data members) and behaviors (member functions)
  - Defined using keyword **`class`**
  - Have a body delineated with braces (**{** and **}**)
  - Class definitions terminate with a semicolon
  - Example:

```
class Time {
public:
   Time();
   void setTime( int, int, int );
   void printMilitary();
   void printStandard();
private:
   int hour;     // 0 - 23
   int minute;   // 0 - 59
   int second;   // 0 - 59
};
```

`Public:` and **`Private:`** are member-access specifiers.

`setTime`, **`printMilitary`**, and **`printStandard`** are **member functions**.

`Time` is the constructor.

`hour`, **`minute`**, and **`second`** are **data members**.

6.5 Implementing a Time Abstract Data Type with a Class

- Member access specifiers
  - Classes can limit the access to their member functions and data
  - The three types of access a class can grant are:
    - **`Public`** — Accessible wherever the program has access to an object of the class
    - **`private`** — Accessible only to member functions of the class
    - **`Protected`** — Similar to private and discussed later
- Constructor
  - Special member function that initializes the data members of a class object
  - Cannot return values
  - Have the same name as the class

6.5 Implementing a Time Abstract Data Type with a Class

- Class definition and declaration
  - Once a class has been defined, it can be used as a type in object, array and pointer declarations
  - Example:

```
Time sunset,                 // object of type Time
     arrayOfTimes[ 5 ],      // array of Time objects
     *pointerToTime,         // pointer to a Time object
     &dinnerTime = sunset;   // reference to a Time object
```

Note: The class name becomes the new type specifier.

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

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

// Time abstract data type (ADT) definition
class Time {
public:
   Time();                        // constructor
   void setTime( int, int, int ); // set hour, minute, second
   void printMilitary();          // print military time format
   void printStandard();          // print standard time format
private:
   int hour;     // 0 – 23
   int minute;   // 0 – 59
   int second;   // 0 – 59
};

// Time constructor initializes each data member to zero.
// Ensures all Time objects start in a consistent state.
Time::Time() { hour = minute = second = 0; }

// Set a new Time value using military time. Perform validity
// checks on the data values. 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;
}
```

Outline

1. Define a `Time` class

1.1 Define default values for the time

Note the **`::`** preceding the function names.

```
// Print Time in military format
void Time::printMilitary()
{
   cout << ( hour < 10 ? "0" : "" ) << hour << ":"
        << ( minute < 10 ? "0" : "" ) << minute;
}

// Print Time in standard format
void Time::printStandard()
{
   cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 )
        << ":" << ( minute < 10 ? "0" : "" ) << minute
        << ":" << ( second < 10 ? "0" : "" ) << second
        << ( hour < 12 ? " AM" : " PM" );
}

// Driver to test simple class Time
int main()
{
   Time t;  // instantiate object t of class

   cout << "The initial military time is ";
   t.printMilitary();
   cout << "\nThe initial standard time is ";
   t.printStandard();

```

```
The initial military time is 00:00
The initial standard time is 12:00:00 AM
```

Notice how functions are called using the dot (`.`) operator.

Outline

1.2 Define the two functions `printMilitary` and `printstandard`

2. In `main`, create an object of class `Time`

2.1Print the initial (default) time

```
   t.setTime( 13, 27, 6 );
   cout << "\n\nMilitary time after setTime is ";
   t.printMilitary();
   cout << "\nStandard time after setTime is ";
   t.printStandard();

   t.setTime( 99, 99, 99 );  // attempt invalid settings
   cout << "\n\nAfter attempting invalid settings:"
        << "\nMilitary time: ";
   t.printMilitary();
   cout << "\nStandard time: ";
   t.printStandard();
   cout << endl;
   return 0;
}
```

```
Military time after setTime is 13:27
Standard time after setTime is 1:27:06 PM
```

```
After attempting invalid settings:
Military time: 00:00
Standard time: 12:00:00 AM
```

Outline

2.2 Set and print the

2.3 Set the time to an invalid hour

2.4 Print the time

```
The initial military time is 00:00
The initial standard time is 12:00:00 AM

Military time after setTime is 13:27
Standard time after setTime is 1:27:06 PM

After attempting invalid settings:
Military time: 00:00
Standard time: 12:00:00 AM
```

Program Output

6.5 Implementing a Time Abstract Data Type with a Class

- Destructors
  - Functions with the same name as the class but preceded with a tilde character (**~**)
  - Cannot take arguments and cannot be overloaded
  - Performs "termination housekeeping"
- Binary scope resolution operator (**`::`**)
  - Combines the class name with the member function name
  - Different classes can have member functions with the same name
- Format for defining member functions

  ReturnType ClassName::MemberFunctionName( ){
  …
  }

6.5 Implementing a Time Abstract Data Type with a Class

- If a member function is defined inside the class
  - Scope resolution operator and class name are not needed
  - Defining a function outside a class does not change it being **`public`** or **`private`**
- Classes encourage software reuse
  - Inheritance allows new classes to be derived from old ones

6.6 Class Scope and Accessing Class Members

- Class scope
  - Data members and member functions
- File scope
  - Non member functions
- Inside a scope
  - Members accessible by all member functions
    - Referenced by name
- Outside a scope
  - Members are referenced through handles
    - An object name, a reference to an object or a pointer to an object

6.6 Class Scope and Accessing Class Members

- Function scope
  - Variables only known to function they are defined in
  - Variables are destroyed after function completion
- Accessing class members
  - Same as structs
  - Dot (**`.`**) for objects and arrow (**`->`**) for pointers
  - Example:
    - **`t.hour`** is the **`hour`** element of **`t`**
    - **`TimePtr->hour`** is the **`hour`** element

```
// Fig. 6.4: fig06_04.cpp
// Demonstrating the class member access operators . and ->
//
// CAUTION: IN FUTURE EXAMPLES WE AVOID PUBLIC DATA!
#include <iostream>

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

// Simple class Count
class Count {
public:
   int x;
   void print() { cout << x << endl; }
};

int main()
{
   Count counter,                // create counter object
         *counterPtr = &counter, // pointer to counter
         &counterRef = counter;  // reference to counter

   cout << "Assign 7 to x and print using the object's name: ";
   counter.x = 7;       // assign 7 to data member x
  counter.print();     // call member function print

   cout << "Assign 8 to x and print using a reference: ";
   counterRef.x = 8;    // assign 8 to data member x
   counterRef.print();  // call member function print

```

It is rare to have **`public`** member variables. Usually only member functions are **`public`**; this keeps as much information hidden as possible.

Outline

1. Class definition

2. Create an object of the class

2.1 Assign a value to the object. Print the value using the dot operator

2.2 Set a new value and print it using a reference

```
   cout << "Assign 10 to x and print using a pointer: ";
   counterPtr->x = 10;  // assign 10 to data member x
   counterPtr->print(); // call member function print

   return 0;
}
```

Outline

2.3 Set a new value and print it using a pointer

```
Assign 7 to x and print using the object's name: 7
Assign 8 to x and print using a reference: 8
Assign 10 to x and print using a pointer: 10
```

Program Output

6.7 Separating Interface from Implementation

- Separating interface from implementation
  - Makes it easier to modify programs
  - Header files
    - Contains class definitions and function prototypes
  - Source-code files
    - Contains member function definitions

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

// prevent multiple inclusions of header file
#ifndef TIME1_H
#define TIME1_H

// Time abstract data type definition
class Time {
public:
   Time();                         // constructor
   void setTime( int, int, int ); // set hour, minute, second
   void printMilitary();           // print military time format
   void printStandard();           // print standard time format
private:
   int hour;     // 0 - 23
   int minute;   // 0 - 59
   int second;   // 0 - 59
};

#endif
```

Dot (**.**) replaced with underscore (**_**) in file name.

If **`time1.h`** (**`TIME1_H`**) is not defined (**`#ifndef`**) then it is loaded (**`#define TIME1_H`**). If **`TIME1_H`** *is* already defined, then everything up to **`#endif`** is ignored.

This prevents loading a header file multiple times.

Outline

1. Using the same Time class as before

```
// Fig. 6.5: time1.cpp
// Member function definitions for Time class.
#include <iostream>

using std::cout;

#include "time1.h"

// Time constructor initializes each data member to zero.
// Ensures all Time objects start in a consistent state.
Time::Time() { hour = minute = second = 0; }

// Set a new Time value using military time. Perform validity
// checks on the data values. 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;
}

// Print Time in military format
void Time::printMilitary()
{
   cout << ( hour < 10 ? "0" : "" ) << hour << ":"
        << ( minute < 10 ? "0" : "" ) << minute;
}

// Print time in standard format
void Time::printStandard()
{
   cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 )
        << ":" << ( minute < 10 ? "0" : "" ) << minute
        << ":" << ( second < 10 ? "0" : "" ) << second
        << ( hour < 12 ? " AM" : " PM" );
}
```

Source file uses **`#include`** to load the header file

Source file contains function definitions

Outline

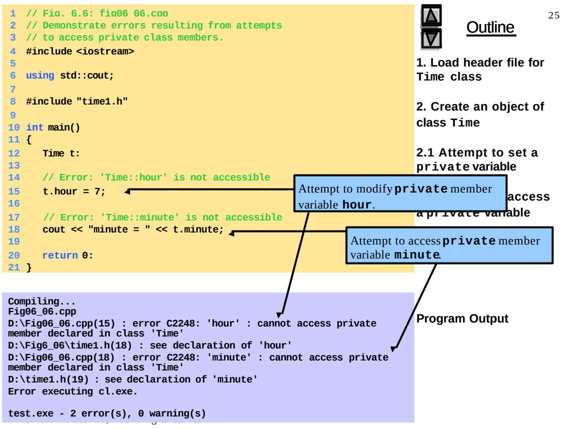
2. Create a source code file

2.1 Load the header file to get the class definitions

2.2. Define the member functions of the class

6.8 Controlling Access to Members

- **`public`**
  - Presents clients with a view of the services the class provides (interface)
  - Data and member functions are accessible
- **`private`**
  - Default access mode
  - Data only accessible to member functions and **`friend`**s
  - **`private`** members only accessible through the **`public`** class interface using **`public`** member functions



```
// Fig. 6.6: fig06_06.cpp
// Demonstrate errors resulting from attempts
// to access private class members.
#include <iostream>

using std::cout;

#include "time1.h"

int main()
{
   Time t;

   // Error: 'Time::hour' is not accessible
   t.hour = 7;

   // Error: 'Time::minute' is not accessible
   cout << "minute = " << t.minute;

   return 0;
}
```

Attempt to modify **private** member variable **hour**.

Attempt to access **private** member variable **minute**.

```
Compiling...
Fig06_06.cpp
D:\Fig06_06.cpp(15) : error C2248: 'hour' : cannot access private
member declared in class 'Time'
D:\Fig6_06\time1.h(18) : see declaration of 'hour'
D:\Fig06_06.cpp(18) : error C2248: 'minute' : cannot access private
member declared in class 'Time'
D:\time1.h(19) : see declaration of 'minute'
Error executing cl.exe.

test.exe - 2 error(s), 0 warning(s)
```

Outline

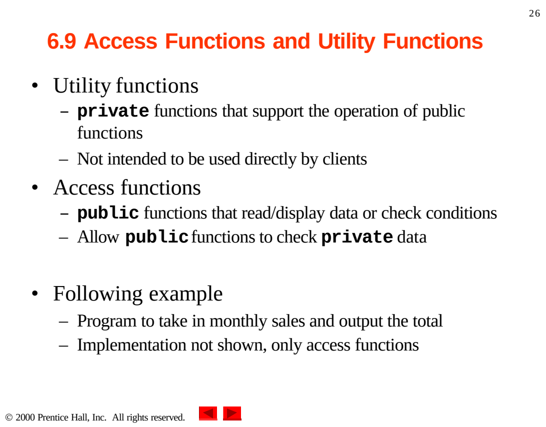
1. Load header file for `Time` class

2. Create an object of class `Time`

2.1 Attempt to set a `private` variable

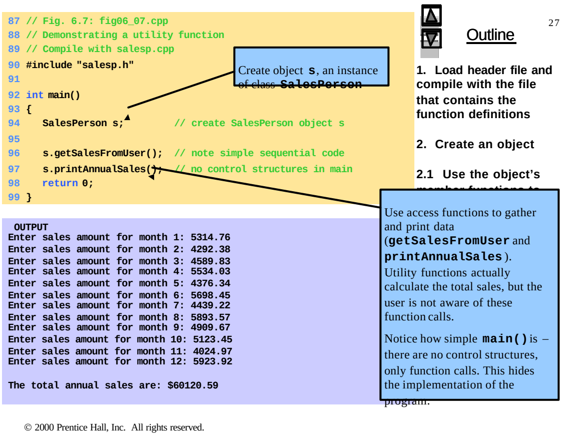
access a private variable

Program Output



6.9 Access Functions and Utility Functions

- Utility functions
  - **`private`** functions that support the operation of public functions
  - Not intended to be used directly by clients
- Access functions
  - **`public`** functions that read/display data or check conditions
  - Allow **`public`** functions to check **`private`** data
- Following example
  - Program to take in monthly sales and output the total
  - Implementation not shown, only access functions



```
// Fig. 6.7: fig06_07.cpp
// Demonstrating a utility function
// Compile with salesp.cpp
#include "salesp.h"

int main()
{
   SalesPerson s;         // create SalesPerson object s

   s.getSalesFromUser();  // note simple sequential code
   s.printAnnualSales();  // no control structures in main
   return 0;
}
```

Create object **`s`**, an instance of class **`SalesPerson`**

```
 OUTPUT
Enter sales amount for month 1: 5314.76
Enter sales amount for month 2: 4292.38
Enter sales amount for month 3: 4589.83
Enter sales amount for month 4: 5534.03
Enter sales amount for month 5: 4376.34
Enter sales amount for month 6: 5698.45
Enter sales amount for month 7: 4439.22
Enter sales amount for month 8: 5893.57
Enter sales amount for month 9: 4909.67
Enter sales amount for month 10: 5123.45
Enter sales amount for month 11: 4024.97
Enter sales amount for month 12: 5923.92

The total annual sales are: $60120.59
```

Outline

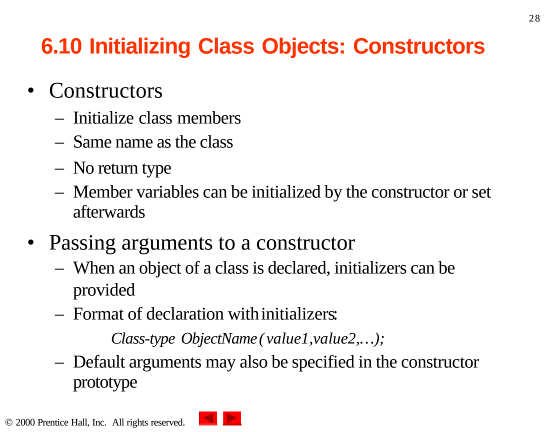
1. Load header file and compile with the file that contains the function definitions

2. Create an object

2.1 Use the object's member functions to

Use access functions to gather and print data (**`getSalesFromUser`** and **`printAnnualSales`**). Utility functions actually calculate the total sales, but the user is not aware of these function calls.

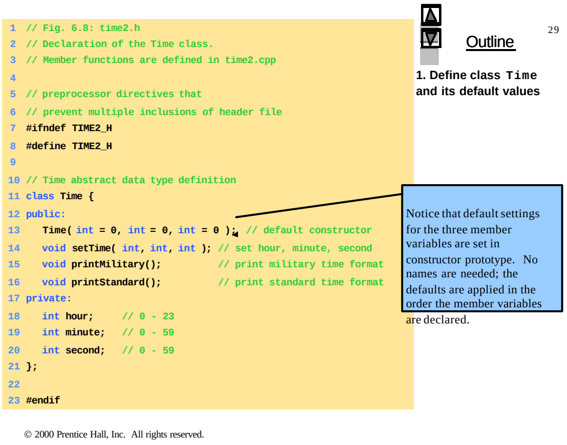
Notice how simple **`main()`** is – there are no control structures, only function calls. This hides the implementation of the program.



6.10 Initializing Class Objects: Constructors

- Constructors
  - Initialize class members
  - Same name as the class
  - No return type
  - Member variables can be initialized by the constructor or set afterwards
- Passing arguments to a constructor
  - When an object of a class is declared, initializers can be provided
  - Format of declaration with initializers:

    Class-type ObjectName(value1,value2,…);
  - Default arguments may also be specified in the constructor prototype

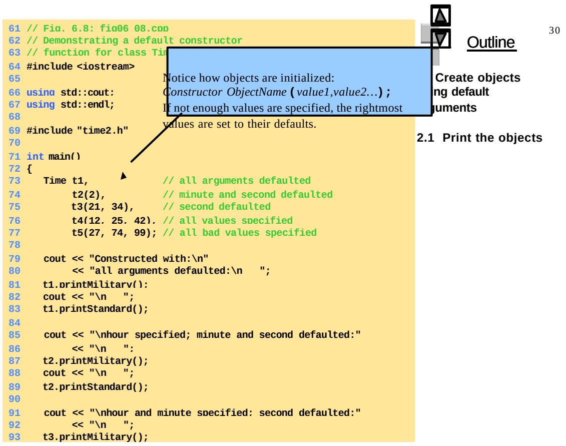


```
// Fig. 6.8: time2.h
// Declaration of the Time class.
// Member functions are defined in time2.cpp

// preprocessor directives that
// prevent multiple inclusions of header file
#ifndef TIME2_H
#define TIME2_H

// Time abstract data type definition
class Time {
public:
   Time( int = 0, int = 0, int = 0 );  // default constructor
   void setTime( int, int, int ); // set hour, minute, second
   void printMilitary();          // print military time format
   void printStandard();          // print standard time format
private:
   int hour;     // 0 - 23
   int minute;   // 0 - 59
   int second;   // 0 - 59
};

#endif
```

Outline

1. Define class `Time` and its default values

Notice that default settings for the three member variables are set in constructor prototype. No names are needed; the defaults are applied in the order the member variables are declared.



```
// Fig. 6.8: fig06_08.cpp
// Demonstrating a default constructor
// function for class Time
#include <iostream>

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

#include "time2.h"

int main()
{
   Time t1,             // all arguments defaulted
        t2(2),          // minute and second defaulted
        t3(21, 34),     // second defaulted
        t4(12, 25, 42), // all values specified
        t5(27, 74, 99); // all bad values specified

   cout << "Constructed with:\n"
        << "all arguments defaulted:\n   ";
   t1.printMilitary();
   cout << "\n   ";
   t1.printStandard();

   cout << "\nhour specified; minute and second defaulted:"
        << "\n   ";
   t2.printMilitary();
   cout << "\n   ";
   t2.printStandard();

   cout << "\nhour and minute specified; second defaulted:"
        << "\n   ";
   t3.printMilitary();
```

Notice how objects are initialized:
Constructor ObjectName **(** *value1,value2…* **) ;**
If not enough values are specified, the rightmost values are set to their defaults.

Outline

Create objects ng default uments

2.1 Print the objects

```
    cout << "\n   ":
    t3.printStandard();

    cout << "\nhour, minute, and second specified:"
         << "\n   ":
    t4.printMilitary();
    cout << "\n   ";
    t4.printStandard();

    cout << "\nall invalid values specified:"
         << "\n   ";
    t5.printMilitary();
    cout << "\n   ":
    t5.printStandard();
    cout << endl;

    return 0:
}
```

```
 OUTPUT
Constructed with:
all arguments defaulted:
   00:00
   12:00:00 AM
hour specified; minute and second defaulted:
   02:00
   2:00:00 AM
hour and minute specified; second defaulted:
   21:34
   9:34:00 PM
hour, minute, and second specified:
   12:25
   12:25:42 PM
all invalid values specified:
   00:00
   12:00:00 AM
```

When only **hour** is specified, **minute** and **second** are set to their default values of **0**.

Outline

2.1 (continued) Print the objects.

Output

6.12 Using Destructors

- Destructors
  - Are member function of class
  - Perform termination housekeeping before the system reclaims the object's memory
  - Complement of the constructor
  - Name is tilde (**~**) followed by the class name (i.e., **~Time**)
    - Recall that the constructor's name is the class name
  - Receives no parameters, returns no value
  - One destructor per class
    - No overloading allowed

6.13 When Constructors and Destructors Are Called

- Constructors and destructors called automatically
  - Order depends on scope of objects
- Global scope objects
  - Constructors called before any other function (including **main**)
  - Destructors called when **main** terminates (or **exit** function called)
  - Destructors not called if program terminates with **abort**
- Automatic local objects
  - Constructors called when objects are defined
  - Destructors called when objects leave scope
    - i.e., when the block in which they are defined is exited
  - Destructors not called if the program ends with **exit** or **abort**

6.13 When Constructors and Destructors Are Called

- Static local objects
  - Constructors called when execution reaches the point where the objects are defined
  - Destructors called when **main** terminates or the **exit** function is called
  - Destructors not called if the program ends with **abort**

```
// Fig. 6.9: create.h
// Definition of class CreateAndDestroy.
// Member functions defined in create.cpp.
#ifndef CREATE_H
#define CREATE_H

class CreateAndDestroy {
public:
   CreateAndDestroy( int );  // constructor
   ~CreateAndDestroy();      // destructor
private:
   int data;
};

#endif
```

Outline

1. Create a header file

1.1 Include function prototypes for the destructor and constructor

```
// Fig. 6.9: create.cpp
// Member function definitions for class CreateAndDestroy
#include <iostream>

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

#include "create.h"

CreateAndDestroy::CreateAndDestroy( int value )
{
   data = value;
   cout << "Object " << data << "   constructor";
}

CreateAndDestroy::~CreateAndDestroy()
   { cout << "Object " << data << "   destructor " << endl; }
```

Constructor and Destructor changed to print when they are called.

Outline

2. Load the header file

2.1 Modify the constructor and destructor

```
// Fig. 6.9: fig06_09.cpp
// Demonstrating the order in which constructors and
// destructors are called.
#include <iostream>

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

#include "create.h"

void create( void );   // prototype

CreateAndDestroy first( 1 );  // global object

int main()
{
   cout << "   (global created before main)" << endl;

   CreateAndDestroy second( 2 );        // local object
   cout << "   (local automatic in main)" << endl;

   static CreateAndDestroy third( 3 );  // local object
   cout << "   (local static in main)" << endl;

   create();  // call function to create objects

   CreateAndDestroy fourth( 4 );        // local object
   cout << "   (local automatic in main)" << endl;
   return 0;
}
```

Outline

3. Create multiple objects of varying types

```

// Function to create objects
void create( void )
{
   CreateAndDestroy fifth( 5 );
   cout << "   (local automatic in create)" << endl;

   static CreateAndDestroy sixth( 6 );
   cout << "   (local static in create)" << endl;

   CreateAndDestroy seventh( 7 );
   cout << "   (local automatic in create)" << endl;
}
```

Outline

```
OUTPUT
Object 1   constructor   (global created before main)
Object 2   constructor   (local automatic in main)
Object 3   constructor   (local static in main)
Object 5   constructor   (local automatic in create)
Object 6   constructor   (local static in create)
Object 7   constructor   (local automatic in create)
Object 7   destructor
Object 5   destructor
Object 4   constructor   (local automatic in main)
Object 4   destructor
Object 2   destructor
Object 6   destructor
Object 3   destructor
Object 1   destructor
```

Program Output

Notice how the order of the constructor and destructor call depends on the types of variables (automatic, global and **`static`**) they are associated with.

6.14 Using Data Members and Member Functions

- Member functions
  - Allow clients of the class to *set* (i.e., write) or *get* (i.e., read) the values of private data members
  - Example:

    Adjusting a customer's bank balance

    - **`private`** data member **`balance`** of a class **`BankAccount`** could be modified through the use of member function **`computeInterest`**
    - A member function that sets data member **`interestRate`** could be called **`setInterestRate`**, and a member function that returns the **`interestRate`** could be called **`getInterestRate`**
  - Providing *set* and *get* functions does not make **`private`** variables **`public`**
  - A set function should ensure that the new value is valid

6.15 A Subtle Trap: Returning a Reference to a Private Data Member

- Reference to an object
  - Alias for the name of the object
  - May be used on the left side of an assignment statement
  - Reference can receive a value, which changes the original object as well
- Returning references
  - **`public`** member functions can return non-**`const`** references to **`private`** data members
    - Should be avoided, breaks encapsulation

```
// Fig. 6.11: time4.h
// Declaration of the Time class.
// Member functions defined in time4.cpp

// preprocessor directives that
// 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;
};

#endif
```

Notice how member function **`badSetHour`** returns a reference (**`int &`** is the return type).

Outline

1. Define class

1.1 Function prototypes

1.2 Member variables

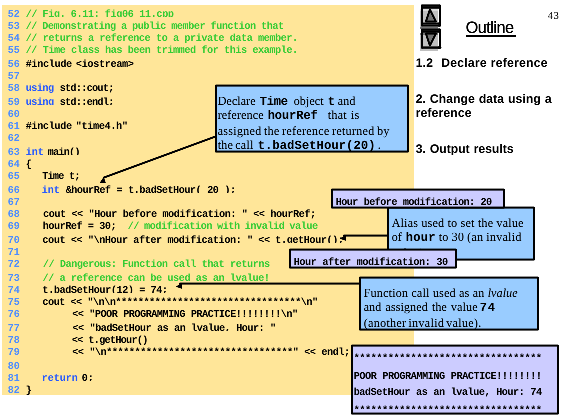
```
// Fig. 6.11: time4.cpp
// Member function definitions for Time class.
#include "time4.h"

// Constructor function to initialize private data.
// Calls member function setTime to set variables.
// Default values are 0 (see class definition).
Time::Time( int hr, int min, int sec )
   { setTime( hr, min, sec ); }

// Set the values of hour, minute, and second.
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;
}

// Get the hour value
int Time::getHour() { return hour; }

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

   return hour;  // DANGEROUS reference return
}
```

`badSetHour` returns a reference to the **`private`** member variable **`hour`**. Changing this reference will alter **`hour`** as well.

Outline

1. Load header

1.1 Function definitions



```
// Fig. 6.11: fig06_11.cpp
// Demonstrating a public member function that
// returns a reference to a private data member.
// Time class has been trimmed for this example.
#include <iostream>

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

#include "time4.h"

int main()
{
   Time t;
   int &hourRef = t.badSetHour( 20 );

   cout << "Hour before modification: " << hourRef;
   hourRef = 30;  // modification with invalid value
   cout << "\nHour after modification: " << t.getHour();

   // Dangerous: Function call that returns
   // a reference can be used as an lvalue!
   t.badSetHour(12) = 74;
   cout << "\n\n**********************************\n"
        << "POOR PROGRAMMING PRACTICE!!!!!!!!\n"
        << "badSetHour as an lvalue, Hour: "
        << t.getHour()
        << "\n**********************************" << endl;

   return 0;
}
```

Declare **Time** object **t** and reference **hourRef** that is assigned the reference returned by the call **t.badSetHour(20)**.

```
Hour before modification: 20
```

Alias used to set the value of **hour** to 30 (an invalid

```
Hour after modification: 30
```

Function call used as an *lvalue* and assigned the value **74** (another invalid value).

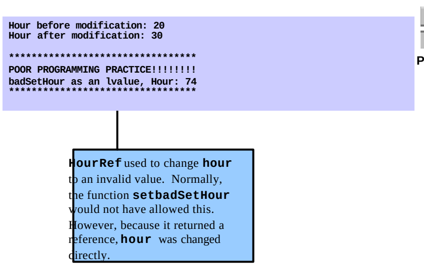
```
**********************************
POOR PROGRAMMING PRACTICE!!!!!!!!
badSetHour as an lvalue, Hour: 74
**********************************
```

Outline

1.2 Declare reference

2. Change data using a reference

3. Output results



```
Hour before modification: 20
Hour after modification: 30

**********************************
POOR PROGRAMMING PRACTICE!!!!!!!!
badSetHour as an lvalue, Hour: 74
**********************************
```

hourRef used to change **hour** to an invalid value. Normally, the function **setbadSetHour** would not have allowed this. However, because it returned a reference, **hour** was changed directly.

Outline

Program Output

6.16 Assignment by Default Memberwise Copy

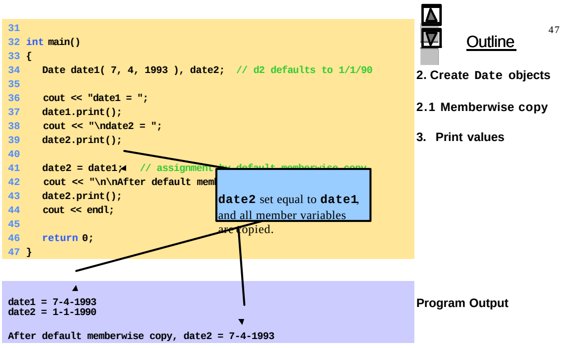
- Assigning objects
  - An object can be assigned to another object of the same type using the assignment operator (**=**)
  - Member by member copy
- Objects may be
  - Passed as function arguments
  - Returned from functions (call-by-value default)

```
// Fig. 6.12: fig06_12.cpp
// Demonstrating that class objects can be assigned
// to each other using default memberwise copy
#include <iostream>

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

// Simple Date class
class Date {
public:
   Date( int = 1, int = 1, int = 1990 ); // default constructor
   void print();
private:
   int month;
   int day;
   int year;
};

// Simple Date constructor with no range checking
Date::Date( int m, int d, int y )
{
   month = m;
   day = d;
   year = y;
}

// Print the Date in the form mm-dd-yyyy
void Date::print()
   { cout << month << '-' << day << '-' << year; }
```

Outline

1. Define class

1.1 Define member functions



```

int main()
{
   Date date1( 7, 4, 1993 ), date2;  // d2 defaults to 1/1/90

   cout << "date1 = ";
   date1.print();
   cout << "\ndate2 = ";
   date2.print();

   date2 = date1;   // assignment by default memberwise copy
   cout << "\n\nAfter default memb
   date2.print();
   cout << endl;

   return 0;
}
```

date2 set equal to **date1**, and all member variables are copied.

```
date1 = 7-4-1993
date2 = 1-1-1990

After default memberwise copy, date2 = 7-4-1993
```

Outline

2. Create **Date** objects

2.1 Memberwise copy

3. Print values

Program Output

6.17 Software Reusability

- Software resusability
  - Implementation of useful classes
  - Class libraries exist to promote reusability
    - Allows for construction of programs from existing, well-defined, carefully tested, well-documented, portable, widely available components
  - Speeds development of powerful, high-quality software