W6.2 Continuing Classes

- Classes with `const` qualifiers
- Class Composition or Aggregation

7.1 Introduction

- Chapters 6 through 8 discuss object-based programming (OBP)
- Chapters 9 and 10 discuss inheritance and polymorphism

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

Outline

1. Class definition

1.1 Function prototypes

1.2 Member variables

```
// Fig. 7.1: time5.h
// Declaration of the class Time.
// Member functions defined in time5.cpp
#ifndef TIME5_H
#define TIME5_H

class Time {
public:
   Time( int = 0, int = 0, int = 0 );  // default constructor

   // set functions
   void setTime( int, int, int );  // set time
   void setHour( int );     // set hour
   void setMinute( int );   // set minute
   void setSecond( int );   // set second

   // get functions (normally declared const)
   int getHour() const;     // return hour
   int getMinute() const;   // return minute
   int getSecond() const;   // return second

   // print functions (normally declared const)
   void printMilitary() const;  // print m
   void printStandard();        // print s
private:
   int hour;             // 0 - 23
   int minute;           // 0 - 59
   int second;           // 0 - 59
};

#endif
```

const functions

non-**const** functions

Outline

Source Code

1. Load Header

1.1 Function definitions

```
// Fig. 7.1: time5.cpp
// Member function definitions for Time class.
#include <iostream>

using std::cout;

#include "time5.h"

// Constructor function to initialize private data.
// 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 )
{
   setHour( h );
   setMinute( m );
   setSecond( s );
}

// Set the hour value
void Time::setHour( int h )
   { hour = ( h >= 0 && h < 24 ) ? h : 0; }

// Set the minute value
void Time::setMinute( int m )
   { minute = ( m >= 0 && m < 60 ) ? m : 0; }

// Set the second value
void Time::setSecond( int s )
   { second = ( s >= 0 && s < 60 ) ? s : 0; }
```

The constructor is non-**const** but it can be called for **const** objects.

Outline

on definitions

1.2 Purposely leave out const keyword for printStandard

```

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

// Get the minute value
int Time::getMinute() const { return minute; }

// Get the second value
int Time::getSecond() const { return second; }

// Display military format time: HH:MM
void Time::printMilitary() const
{
   cout << ( hour < 10 ? "0" : "" ) << hour <<
        << ( minute < 10 ? "0" : "" ) << minute
}

// Display standard format time: HH:MM:SS AM (or PM)
void Time::printStandard()  // should be const
{
   cout << ( ( hour == 12 ) ? 12 : hour % 12 ) << ":"
        << ( minute < 10 ? "0" : "" ) << minute << ":"
        << ( second < 10 ? "0" : "" ) << second
        << ( hour < 12 ? " AM" : " PM" );
}
```

Keyword **`const`** in function definition and prototype.

Non-**`const`** functions cannot use **`const`** objects, even if they don't modify them (such as **`printStandard`**).

Outline

1. Initialize variables

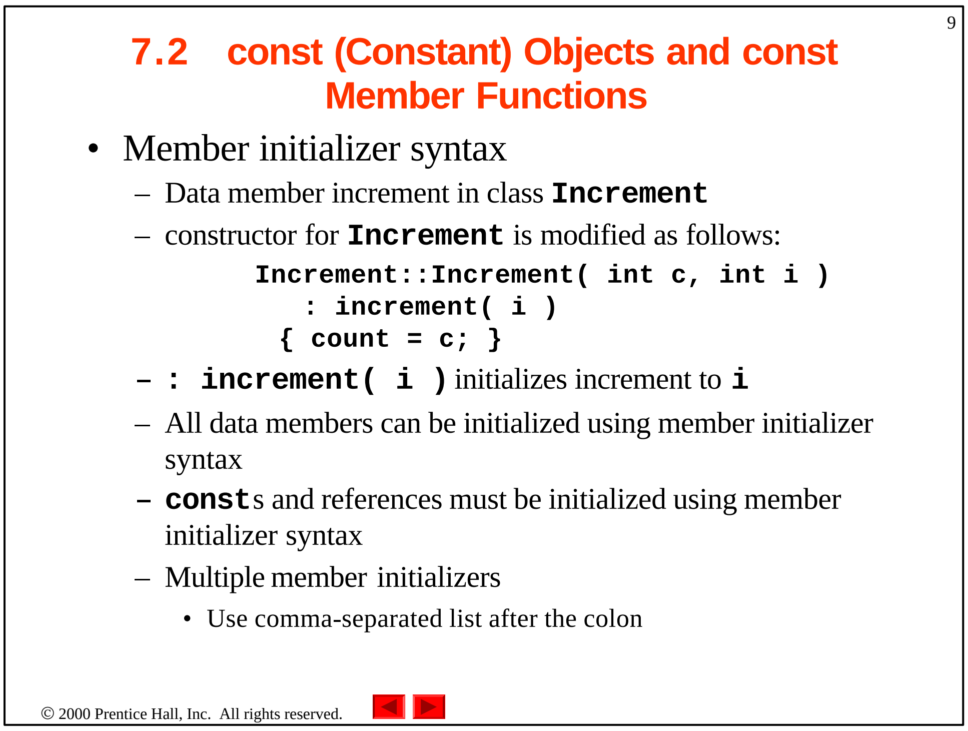
2. Attempt to use non-const functions with const objects

```
// Fig. 7.1: fig07_01.cpp
// Attempting to access a const object with
// non-const member functions.
#include "time5.h"

int main()
{
   Time wakeUp( 6, 45, 0 );       // non-constant object
   const Time noon( 12, 0, 0 );   // constant object

                          // MEMBER FUNCTION   OBJECT
   wakeUp.setHour( 18 );  // non-const         non-const

   noon.setHour( 12 );    // non-const         const

   wakeUp.getHour();      // const             non-const

   noon.getMinute();      // const             const
   noon.printMilitary();  // const             const
   noon.printStandard();  // non-const         const
   return 0;
}
```

Compiler errors generated.

```
Compiling...
Fig07_01.cpp
d:fig07_01.cpp(14) : error C2662: 'setHour' : cannot convert 'this'
pointer from 'const class Time' to 'class Time &'
Conversion loses qualifiers
d:\fig07_01.cpp(20) : error C2662: 'printStandard' : cannot convert
'this' pointer from 'const class Time' to 'class Time &'
Conversion loses qualifiers
Time5.cpp
Error executing cl.exe.

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

Program Output

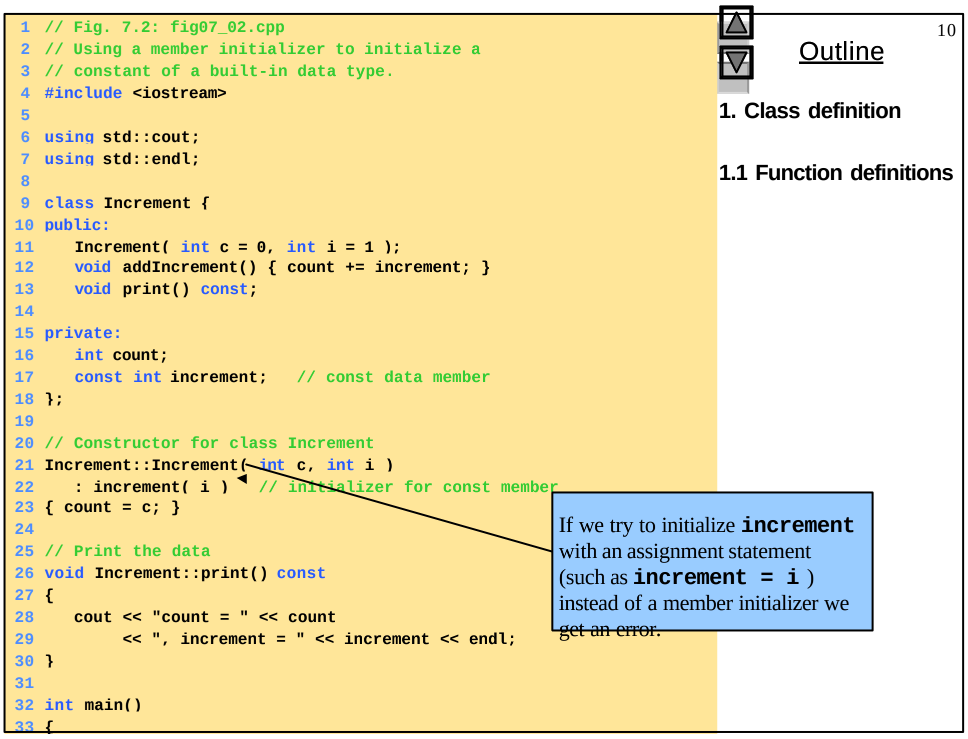


7.2 const (Constant) Objects and const Member Functions

- 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



Outline

1. Class definition

1.1 Function definitions

```
// Fig. 7.2: fig07_02.cpp
// Using a member initializer to initialize a
// constant of a built-in data type.
#include <iostream>

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

class Increment {
public:
   Increment( int c = 0, int i = 1 );
   void addIncrement() { count += increment; }
   void print() const;

private:
   int count;
   const int increment;   // const data member
};

// Constructor for class Increment
Increment::Increment( int c, int i )
   : increment( i )  // initializer for const member
{ count = c; }

// Print the data
void Increment::print() const
{
   cout << "count = " << count
        << ", increment = " << increment << endl;
}

int main()
{
```

If we try to initialize **`increment`** with an assignment statement (such as **`increment = i`**) instead of a member initializer we get an error.

```
   Increment value( 10, 5 );

   cout << "Before incrementing: ";
   value.print();

   for ( int j = 0; j < 3; j++ ) {
      value.addIncrement();
      cout << "After increment " << j + 1 << ": ";
      value.print();
   }

   return 0;
}
```

```
Before incrementing: count = 10, increment = 5
After increment 1: count = 15, increment = 5
After increment 2: count = 20, increment = 5
After increment 3: count = 25, increment = 5
```

Outline

1.2 Initialize variables

2. Function calls

3. Output results

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)

```
// Fig. 7.4: date1.h
// Declaration of the Date class.
// Member functions defined in date1.cpp
#ifndef DATE1_H
#define DATE1_H

class Date {
public:
   Date( int = 1, int = 1, int = 1900 ); // default constructor
   void print() const;  // print date in month/day/year format
   ~Date();  // provided to confirm destruction order
private:
   int month;  // 1-12
   int day;    // 1-31 based on month
   int year;   // any year

   // utility function to test proper day for month and year
   int checkDay( int );
};

#endif
```

Outline

1. Class definition

1.1 Member functions

1.2 Member variables

```
// Fig. 7.4: date1.cpp
// Member function definitions for Date class.
#include <iostream>

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

#include "date1.h"

// Constructor: Confirm proper value for month;
// call utility function checkDay to confirm proper
// value for day.
Date::Date( int mn, int dy, int yr )
{
   if ( mn > 0 && mn <= 12 )       // validate the month
      month = mn;
   else {
      month = 1;
      cout << "Month " << mn << " invalid. Set to month 1.\n";
   }

   year = yr;                      // should validate yr
   day = checkDay( dy );           // validate the day

   cout << "Date object constructor for date ";
   print();         // interesting: a print with no arguments
   cout << endl;
}

```

Constructor will print a line when called.

Outline

1. Load header

1.1 Function definitions

1.2 `Date` constructor

```
// Print Date object in form  month/day/year
void Date::print() const
   { cout << month << '/' << day << '/' << year; }

// Destructor: provided to confirm destru
Date::~Date()
{
   cout << "Date object destructor for date ";
   print();
   cout << endl;
}

// Utility function to confirm proper day value
// based on month and year.
// Is the year 2000 a leap year?
int Date::checkDay( int testDay )
{
   static const int daysPerMonth[ 13 ] =
      {0, 31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31};

   if ( testDay > 0 && testDay <= daysPerMonth[ month ] )
      return testDay;

   if ( month == 2 &&      // February: Check for leap year
        testDay == 29 &&
        ( year % 400 == 0 ||
         ( year % 4 == 0 && year % 100 != 0 ) ) )
      return testDay;

   cout << "Day " << testDay << " invalid. Set to day 1.\n";

   return 1;  // leave object in consistent state if bad value
}
```

Destructor will print a line when called.

Outline

1.3 `print` function

1.4 `Date` destructor

1.5 checkDay function

```
// Fig. 7.4: emply1.h
// Declaration of the Employee class.
// Member functions defined in emply1.cpp
#ifndef EMPLY1_H
#define EMPLY1_H

#include "date1.h"

class Employee {
public:
   Employee( char *, char *, int, int, int, int, int, int );
   void print() const;
   ~Employee();  // provided to confirm destruction order
private:
   char firstName[ 25 ];
   char lastName[ 25 ];
   const Date birthDate;
   const Date hireDate;
};

#endif
```

Composition - including objects of other classes.

Outline

1. Load header

1.1 Class definition

1.2 Member functions

1.3 Member variables

1.3.1 Include `const` variables from `Date` class

```
// Fig. 7.4: emply1.cpp
// Member function definitions for Employee class.
#include <iostream>

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

#include <cstring>
#include "emply1.h"
#include "date1.h"

Employee::Employee( char *fname, char *lname,
                    int bmonth, int bday, int byear,
                    int hmonth, int hday, int hyear )
   : birthDate( bmonth, bday, byear ),
     hireDate( hmonth, hday, hyear )
{
   // copy fname into firstName and be sure that it fits
   int length = strlen( fname );
   length = ( length < 25 ? length : 24 );
   strncpy( firstName, fname, length );
   firstName[ length ] = '\0';

   // copy lname into lastName and be sure that it fits
   length = strlen( lname );
   length = ( length < 25 ? length : 24 );
   strncpy( lastName, lname, length );
   lastName[ length ] = '\0';

   cout << "Employee object constructor: "
        << firstName << ' ' << lastName << endl;
}
```

Constructor will print a line when called.

Outline

1. Load header files

1.1 Function definitions

1.2 `Employee` constructor

1.2.1 Use member-initializer syntax for `const Date` members

```

void Employee::print() const
{
   cout << lastName << ", " << firstName << "\nHired: ";
   hireDate.print();
   cout << "  Birth date: ";
   birthDate.print();
   cout << endl;
}

// Destructor: provided to confirm destruction order
Employee::~Employee()
{
   cout << "Employee object destructor: "
        << lastName << ", " << firstName << endl;
}
```

The **`print`** function is **`const`** and will print whenever a **`Date`** object is created or destroyed. It can print **`const`** objects because it is a **`const`** function.

`Print` requires no arguments, it is linked implicitly to the object that calls it.

Destructor will print a line when called.

Outline

1.3 `print` definition

1.4 `Employee` destructor

```
// Fig. 7.4: fig07_04.cpp
// Demonstrating composition: an object with member objects.
#include <iostream>

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

#include "emply1.h"

int main()
{
   Employee e( "Bob", "Jones", 7, 24, 1949, 3, 12, 1988 );

   cout << '\n';
   e.print();

   cout << "\nTest Date constructor with invalid values:\n";
   Date d( 14, 35, 1994 );  // invalid Date values
   cout << endl;
   return 0;
}
```

Only `emply.h` has to be loaded; that file has the command to load `date.h`.

Outline

1. Load header files

2. Create `Employee` object

2.1 Attempt invalid `Date` setting

```
Date object constructor for date 7/24/1949
Date object constructor for date 3/12/1988
Employee object constructor: Bob Jones

Jones, Bob
Hired: 3/12/1988  Birth date: 7/24/1949

Test Date constructor with invalid values:
Month 14 invalid. Set to month 1.
Day 35 invalid. Set to day 1.
Date object constructor for date 1/1/1994

Date object destructor for date 1/1/1994
Employee object destructor: Jones, Bob
Date object destructor for date 3/12/1988
Date object destructor for date 7/24/1949
```

Notice how inner objects are created first and destroyed last.

Outline

Program Output