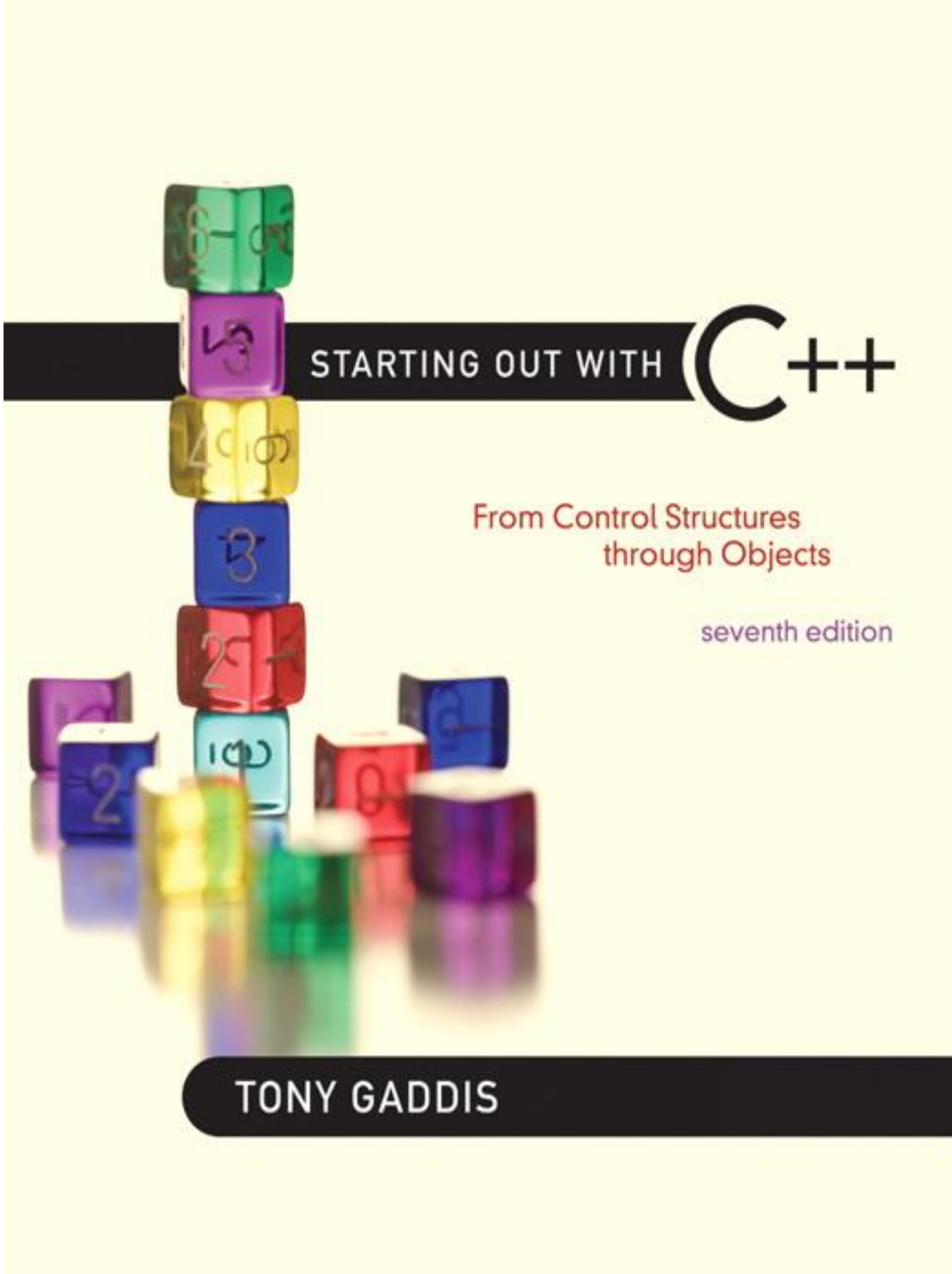
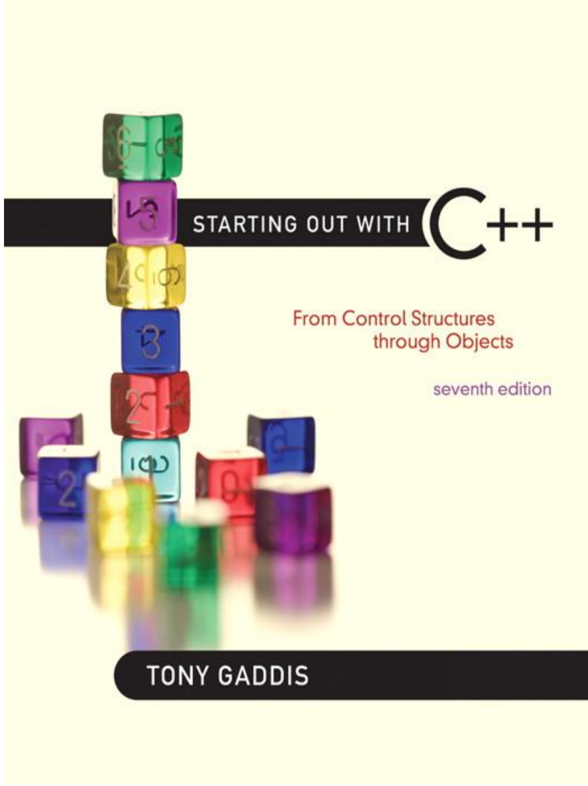
Chapter 14:

More About Classes



Addison-Wesley
is an imprint of
PEARSON



14.1

Instance and Static Members

Instance and Static Members

- instance variable:
  - a member variable in a class. Each object has its own copy.
- **`static`** variable:
  - one variable shared among all objects of a class
- **`static`** member function:
  - can be used to access **`static`** member variable; can be called before any objects are defined

static member variable

Contents of Tree.h

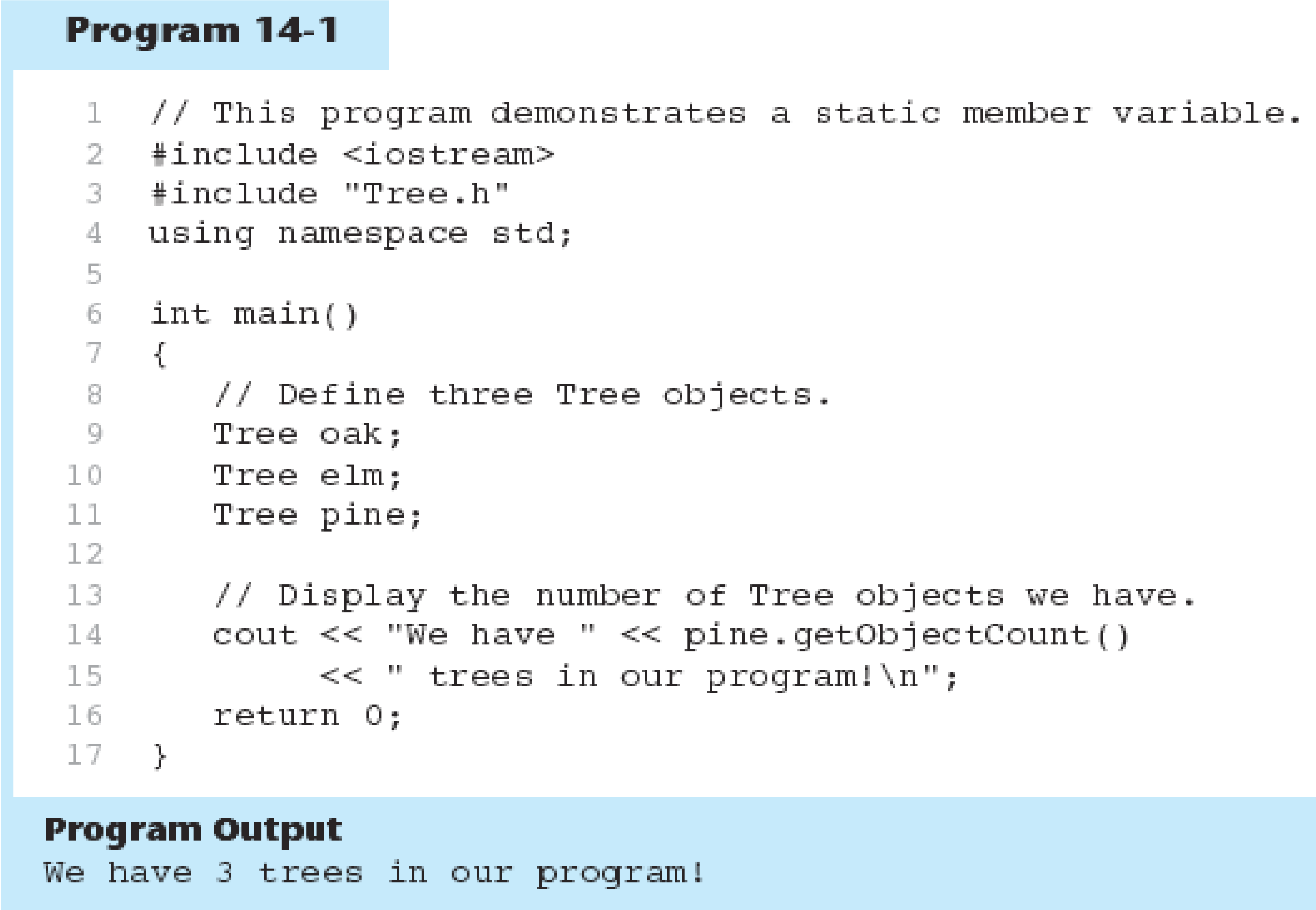
Static member declared here.

```
// Tree class
class Tree
{
private:
   static int objectCount;    // Static member variable.
public:
   // Constructor
   Tree()
      { objectCount++; }

   // Accessor function for objectCount
   int getObjectCount() const //not a static member
      { return objectCount; }
};

// Definition of the static member variable, written
// outside the class.
int Tree::objectCount = 0;
```

Static member defined here.

Copyright © 2012 Pearson Education, Inc.

Program 14-1 static members



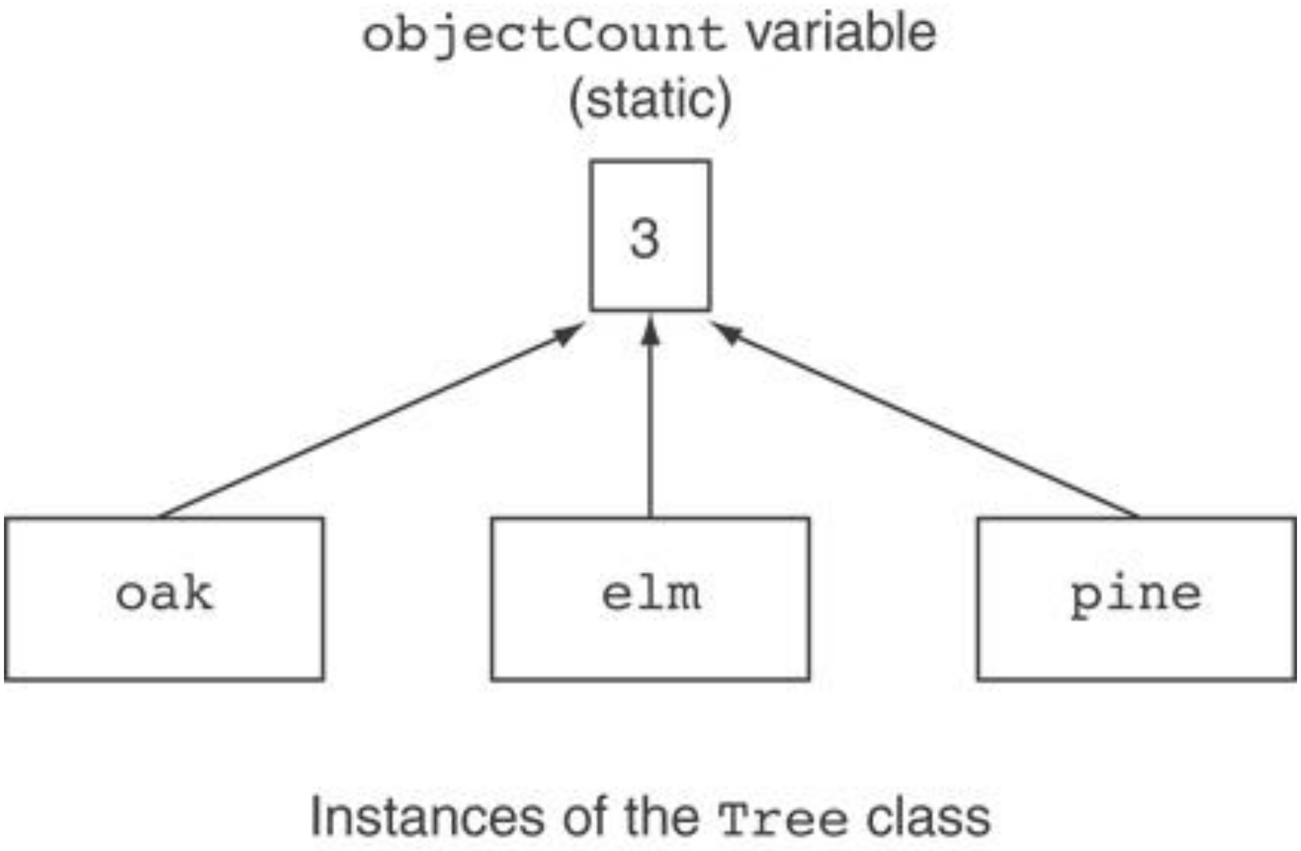
Program 14-1

```cpp
// This program demonstrates a static member variable.
#include <iostream>
#include "Tree.h"
using namespace std;

int main()
{
   // Define three Tree objects.
   Tree oak;
   Tree elm;
   Tree pine;

   // Display the number of Tree objects we have.
   cout << "We have " << pine.getObjectCount()
        << " trees in our program!\n";
   return 0;
}
```

Program Output

```
We have 3 trees in our program!
```

Three Instances of the Tree Class, But Only One `objectCount` Variable



static member function

- Declared with static before return type:

```
static int getObjectCount() const
{ return objectCount; }
```

- Static member functions can only access static member data
- Can be called independent of objects:

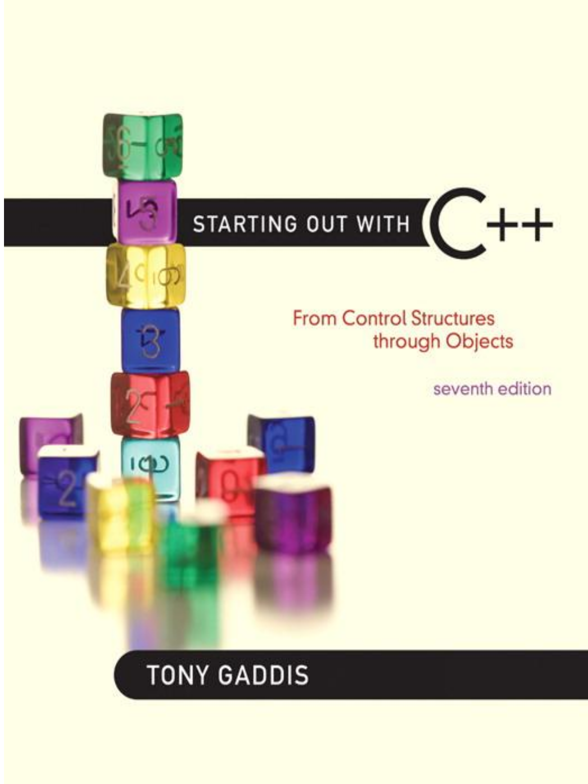
```
int num = Tree::getObjectCount();
```

Modified Version of Tree.h

```cpp
// Tree class
class Tree
{
private:
   static int objectCount;    // Static member variable.
public:
   // Constructor
   Tree()
      { objectCount++; }

   // Accessor function for objectCount
   static int getObjectCount() const
      { return objectCount; }
};

// Definition of the static member variable, written
// outside the class.
int Tree::objectCount = 0;
```

Now we can call the function like this:

```cpp
cout << "There are " << Tree::getObjectCount()
     << " objects.\n";
```



14.2

Friends of Classes

Friends of Classes

- Friend:
  - a function or class that is not a member of a class, but has access to private members of the class

- A friend function can be a stand-alone function or a member function of another class
- It is declared a friend of a class with `friend` keyword in the function prototype

friend Function Declarations

- Stand-alone function:

```
friend void setAVal(intVal&, int);
// declares setAVal function to be
// a friend of this class
```

- Member function of another class:

```
friend void SomeClass::setNum(int num)
// setNum function from SomeClass
// class is a friend of this class
```

friend Class Declarations

- Class as a friend of a class:

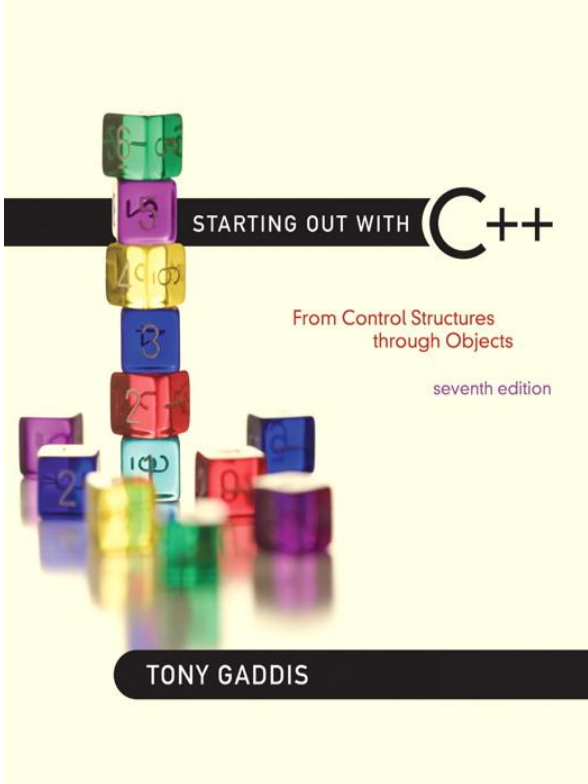
```
class FriendClass
{
    ...
};
class NewClass
{
    public:
      friend class FriendClass; // declares
    // entire class FriendClass as a friend
    // of this class
    …
};
```

Programs 14-2 to 14-4

- Budget Version 1 14-2
  - corporate budget
  - division budget

- Budget Version 2 14-3
  - adds main office

- Budget Version 3 14-4
  - adds friend function
  - adds AuxiliarryOffice class



14.3

Memberwise Assignment

Memberwise Assignment

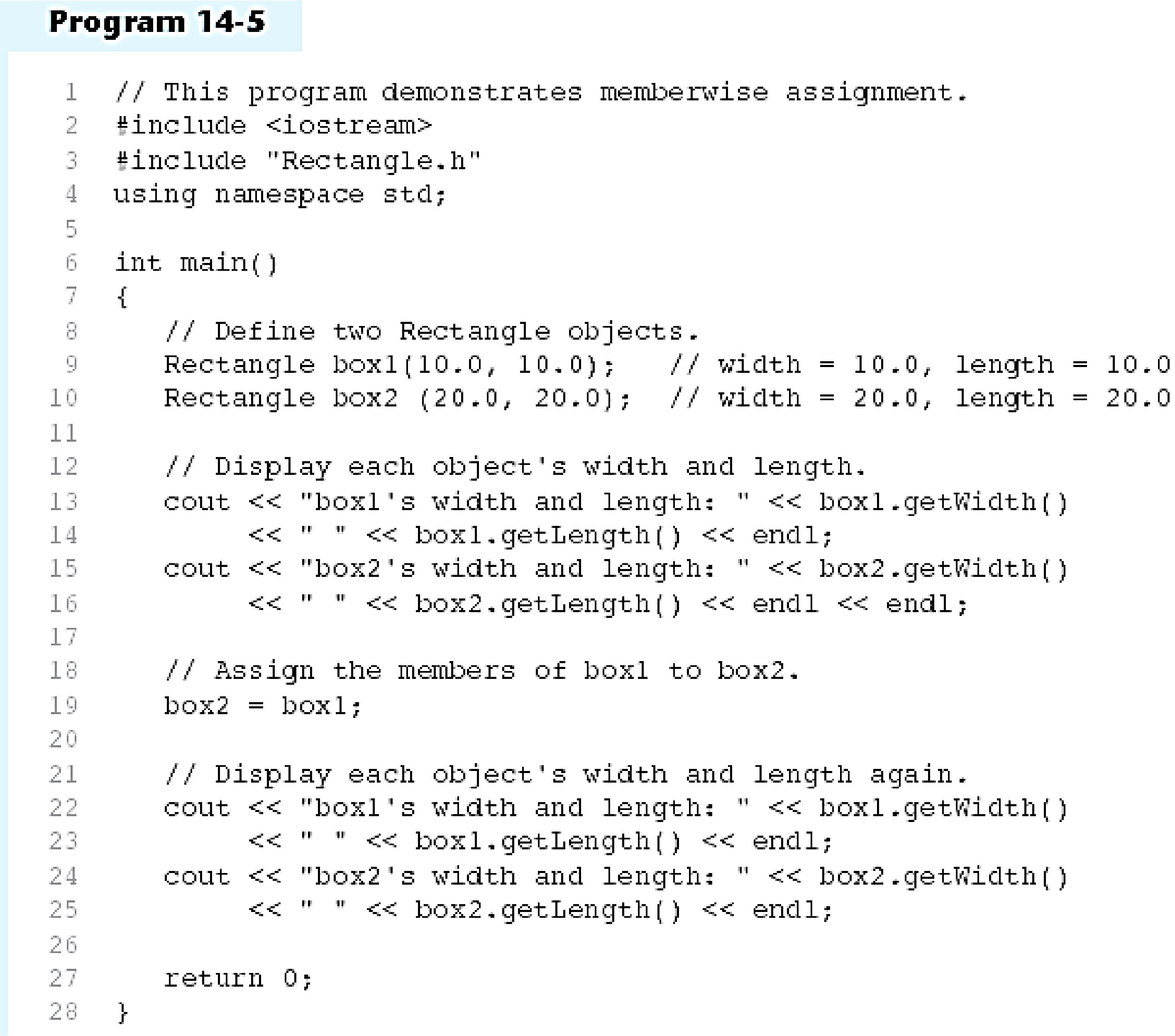
- Can use `=` to assign one object to another, or to initialize an object with an object's data
- Copies member to member. *e.g.*,

  `instance2 = instance1;` means:

  copy all member values from `instance1` and assign to the corresponding member variables of `instance2`

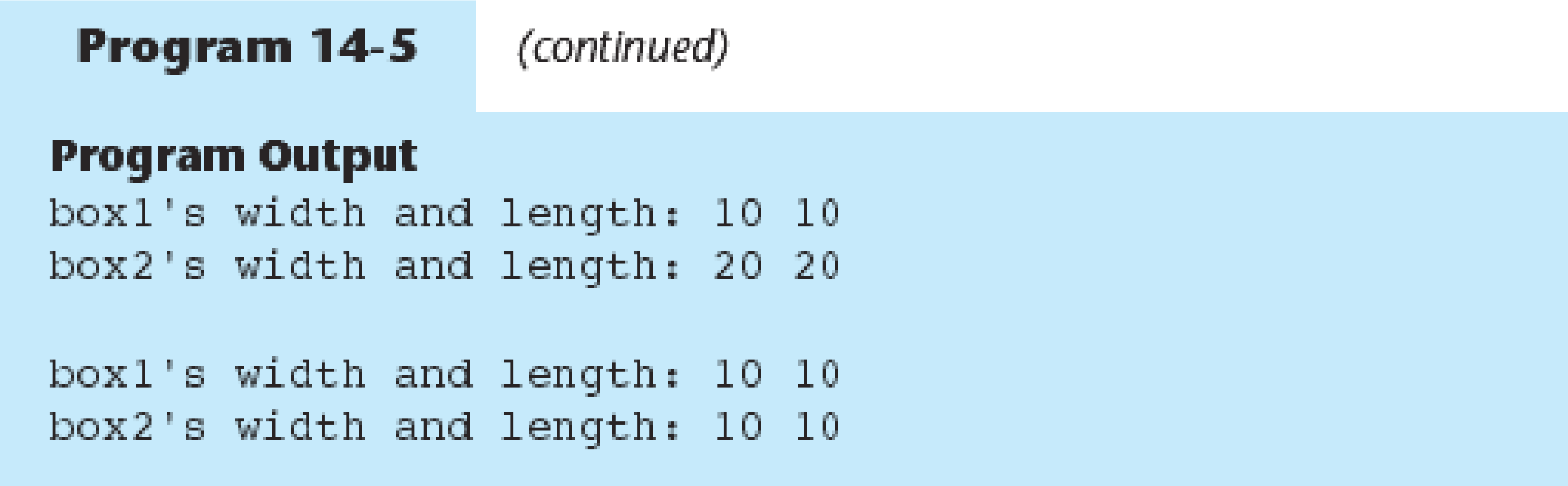
- Use at initialization:

```
Rectangle r2 = r1;
```



Program 14-5

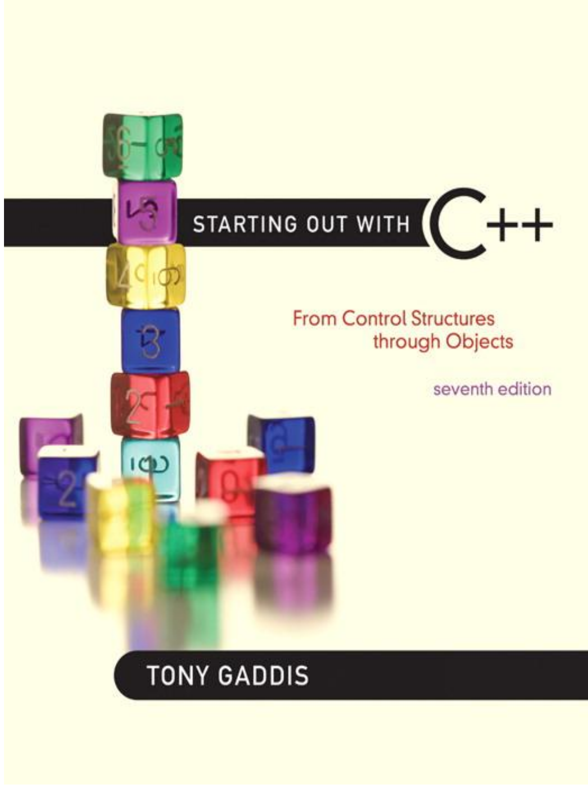
```cpp
// This program demonstrates memberwise assignment.
#include <iostream>
#include "Rectangle.h"
using namespace std;

int main()
{
   // Define two Rectangle objects.
   Rectangle box1(10.0, 10.0);   // width = 10.0, length = 10.0
   Rectangle box2 (20.0, 20.0);  // width = 20.0, length = 20.0

   // Display each object's width and length.
   cout << "box1's width and length: " << box1.getWidth()
        << " " << box1.getLength() << endl;
   cout << "box2's width and length: " << box2.getWidth()
        << " " << box2.getLength() << endl << endl;

   // Assign the members of box1 to box2.
   box2 = box1;

   // Display each object's width and length again.
   cout << "box1's width and length: " << box1.getWidth()
        << " " << box1.getLength() << endl;
   cout << "box2's width and length: " << box2.getWidth()
        << " " << box2.getLength() << endl;

   return 0;
}
```



Program 14-5 *(continued)*

Program Output

```
box1's width and length: 10 10
box2's width and length: 20 20

box1's width and length: 10 10
box2's width and length: 10 10
```



14.4

Copy Constructors

Copy Constructors

- Special constructor used when a newly created object is initialized to the data of another object of same class

- Default copy constructor copies field-to-field

- Default copy constructor works fine in many cases

Copy Constructors

Problem: what if object contains a pointer?

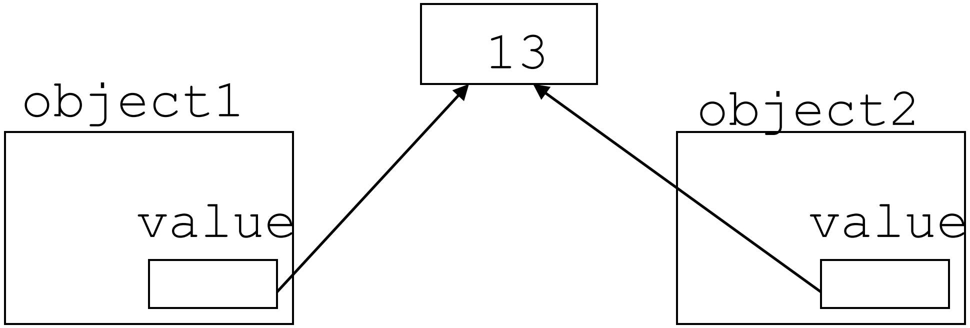
```
class SomeClass
{ public:
     SomeClass(int val = 0)
     {value = new int; *value = val;}
     int getVal();
     void setVal(int);

   private:
     int *value;
}
```

Copy Constructors

What we get using memberwise copy with objects containing dynamic memory:

//shallow copy

```
SomeClass object1(5);
SomeClass object2 = object1;
object2.setVal(13);
cout << object1.getVal(); // also 13
```



Programmer-Defined Copy Constructor

- Allows us to solve problem with objects containing pointers:

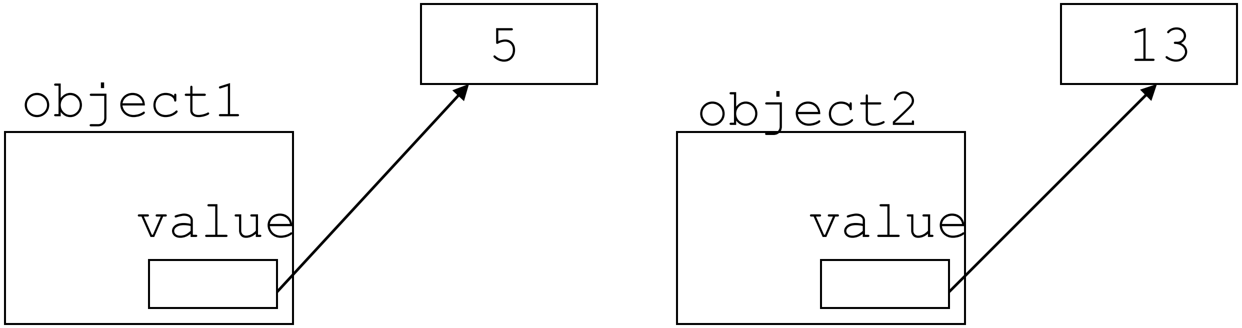
```
SomeClass::SomeClass(const SomeClass &obj)
{
     value = new int;
     *value = obj.value;
}
```

- Copy constructor takes a reference parameter to an object of the class

Programmer-Defined Copy Constructor

- Each object now points to separate dynamic memory:

```
SomeClass object1(5);
SomeClass object2 = object1;

object2.setVal(13);
cout << object1.getVal(); // still 5
```



Programmer-Defined Copy Constructor

- Since copy constructor has a reference to the object it is copying from,

  ```
  SomeClass::SomeClass(SomeClass &obj)
  ```

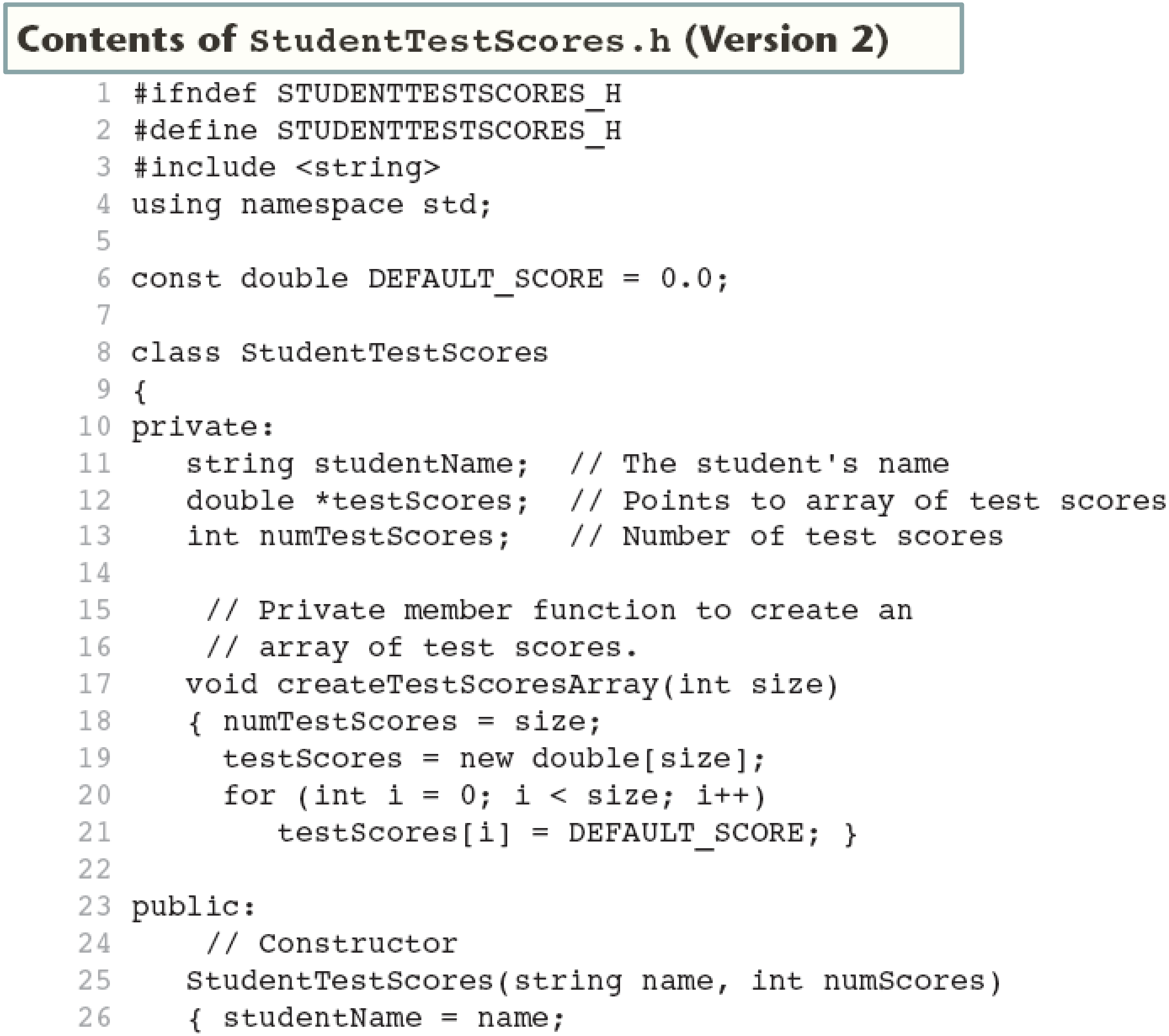
  it can modify that object.

- To prevent this from happening, make the object parameter `const`:

  ```
  SomeClass::SomeClass(const SomeClass &obj)
  ```

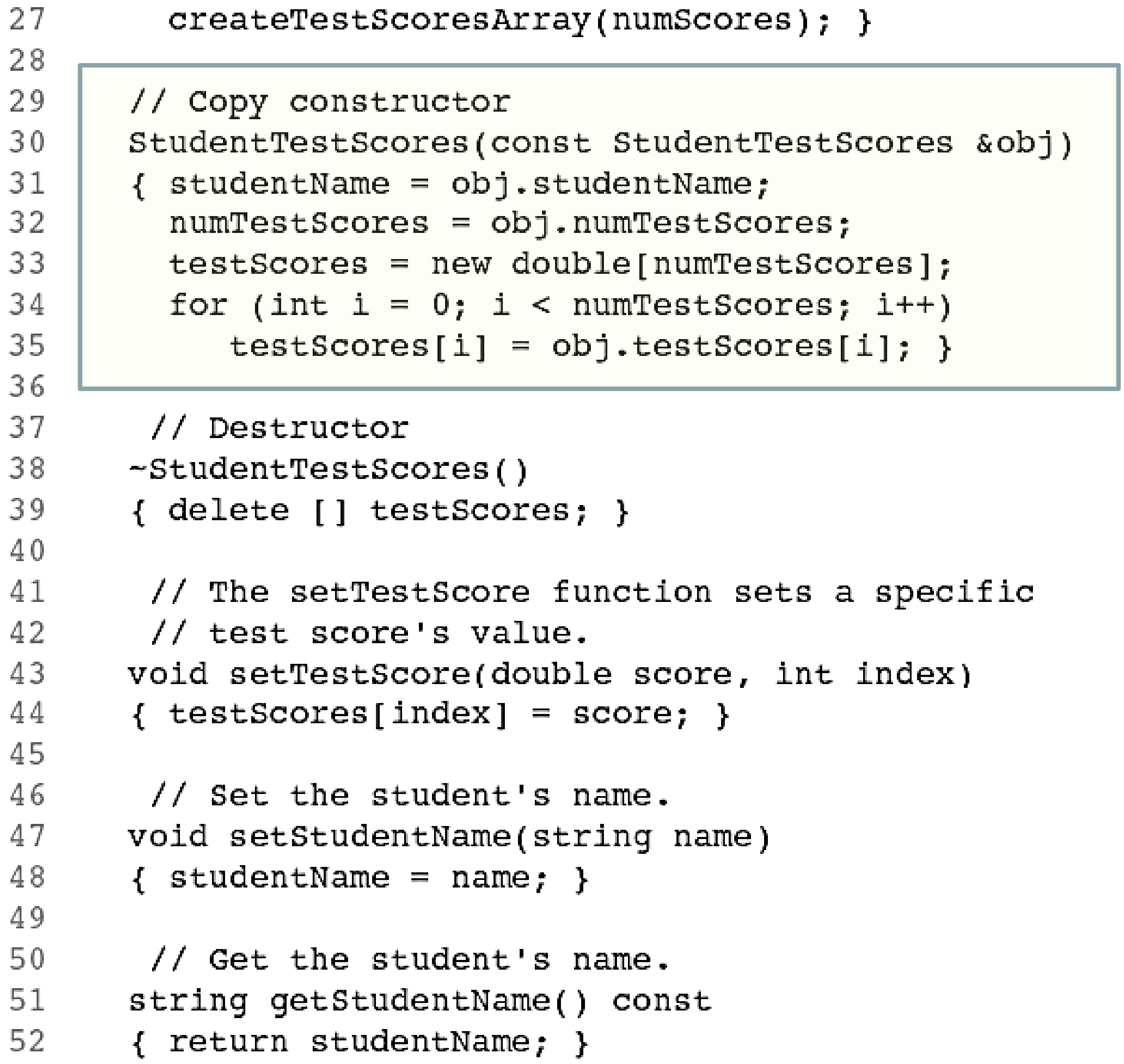
StudentTestScores.h Version 1

- Problem:
  - one of it's members has a pointer and the class does not have a copy constructor
  - only does a "shallow copy"
  - this header file is not part of the presentation

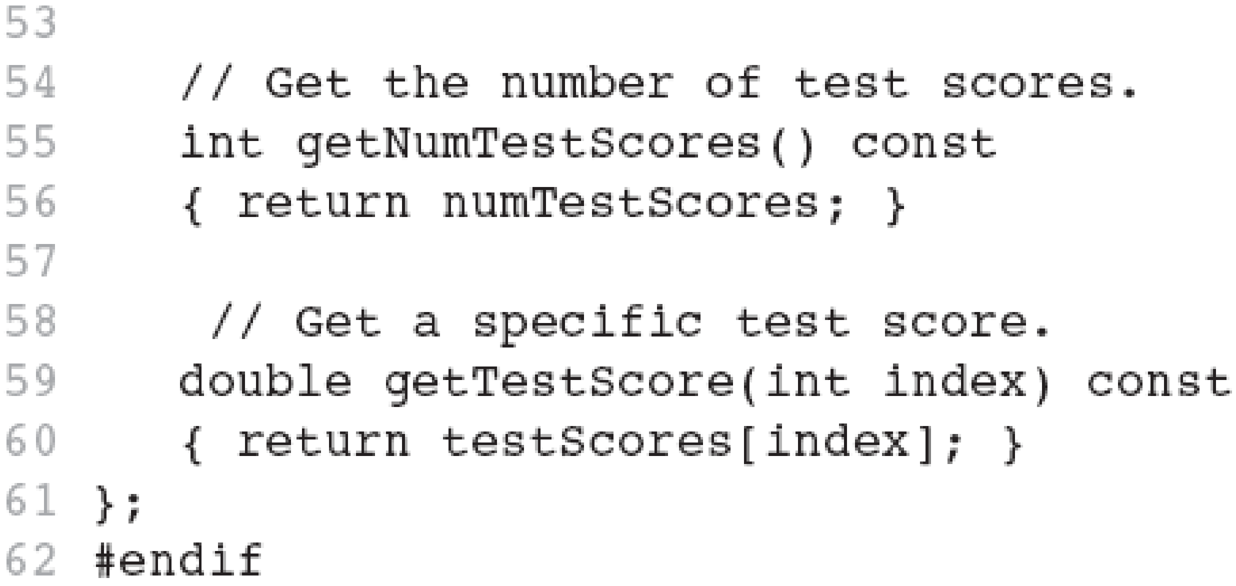


Contents of `StudentTestScores.h` (Version 2)

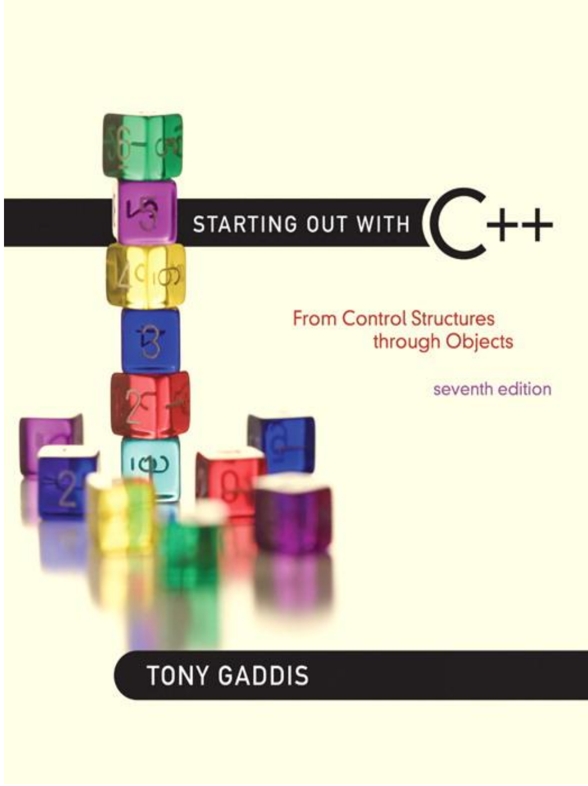
```
#ifndef STUDENTTESTSCORES_H
#define STUDENTTESTSCORES_H
#include <string>
using namespace std;

const double DEFAULT_SCORE = 0.0;

class StudentTestScores
{
private:
   string studentName;  // The student's name
   double *testScores;  // Points to array of test scores
   int numTestScores;   // Number of test scores

    // Private member function to create an
    // array of test scores.
   void createTestScoresArray(int size)
   { numTestScores = size;
     testScores = new double[size];
     for (int i = 0; i < size; i++)
        testScores[i] = DEFAULT_SCORE; }

public:
    // Constructor
   StudentTestScores(string name, int numScores)
   { studentName = name;
```



```
  createTestScoresArray(numScores); }

// Copy constructor
StudentTestScores(const StudentTestScores &obj)
{ studentName = obj.studentName;
  numTestScores = obj.numTestScores;
  testScores = new double[numTestScores];
  for (int i = 0; i < numTestScores; i++)
     testScores[i] = obj.testScores[i]; }

 // Destructor
~StudentTestScores()
{ delete [] testScores; }

 // The setTestScore function sets a specific
 // test score's value.
void setTestScore(double score, int index)
{ testScores[index] = score; }

 // Set the student's name.
void setStudentName(string name)
{ studentName = name; }

 // Get the student's name.
string getStudentName() const
{ return studentName; }
```



```

   // Get the number of test scores.
   int getNumTestScores() const
   { return numTestScores; }

    // Get a specific test score.
   double getTestScore(int index) const
   { return testScores[index]; }
};
#endif
```



14.5

Operator Overloading

Types of Overloaded Operators

- Overloaded operators may be:
  - member functions (1 argument)
    - `( ), [ ], ->` (required)
    - any assignment operator (required)
  - global functions (2 arguments)
    - stream operators `>>` `<<`

Operator Overloading

- Operators such as `=`, `+`, and others can be redefined when used with objects of a class
- The name of the function for the overloaded operator is `operator` followed by the operator symbol, *e.g.*,

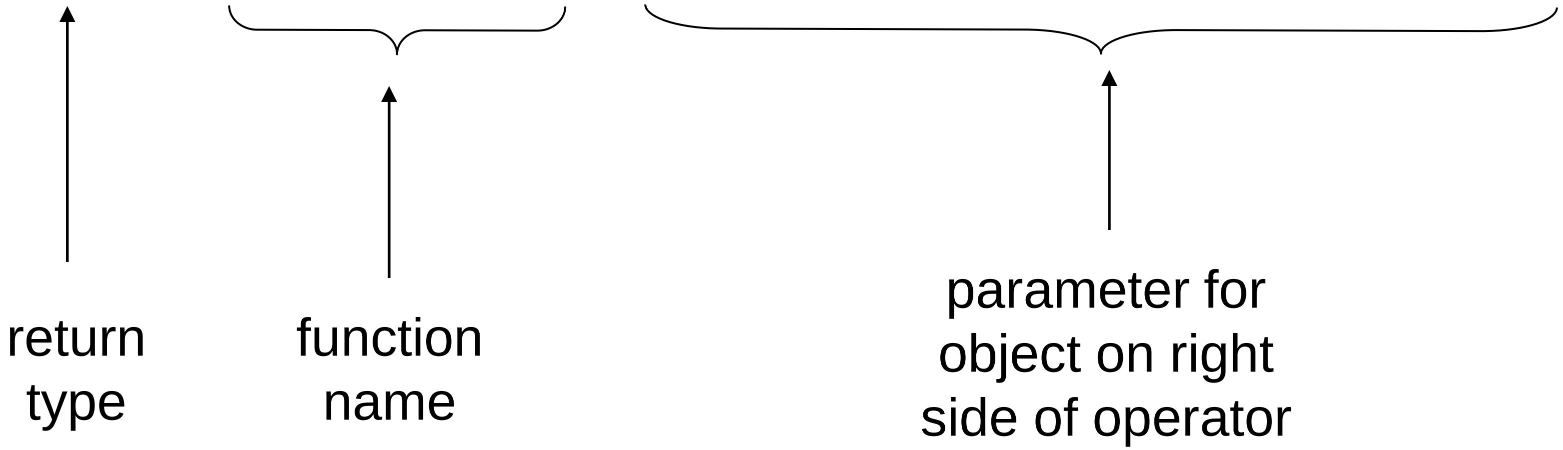
  `operator+` to overload the + operator, and

  `operator=` to overload the = operator
- Prototype for the overloaded operator goes in the declaration of the class that is overloading it
- Overloaded operator function definition goes with other member functions

Operator Overloading

- Prototype:

```
void operator=  (const SomeClass &rval)
```



return type

function name

parameter for object on right side of operator

- Operator is called via object on left side

Invoking an Overloaded Operator

- Operator can be invoked as a member function:

```
object1.operator=(object2);
```

- It can also be used in more conventional manner:

```
object1 = object2;
```

StudentTestScores Version 3

- uses an overloaded **=** operator
- Program 14-6

Returning a Value

- Overloaded operator can return a value

```
class Point2d
{
    public:
      double operator-(const point2d &right)
      { return sqrt(pow((x-right.x),2)
               + pow((y-right.y),2)); }
...
    private:
      int x, y;
};

Point2d point1(2,2), point2(4,4);
// Compute and display distance between 2 points.
cout << point2 – point1 << endl; // displays 2.82843
```

Assignment Operator Returning a Value

- Return type the same as the left operand supports notation like:

  ```
  object1 = object2 = object3;
  ```

- Function declared as follows:

  ```
  const SomeClass operator=(const someClass &rval)
  ```

- In function, include as last statement:

  ```
  return *this; //copy of the object
  ```

StudentTestScores Version 4

- overloaded = operator returns a constant StudentTestScores object
- uses ***this** to refer to the object being returned (returns itself)
- Program 14-7
- More on this pointer follows on next slide

The `this` Pointer

- `this`:
  - predefined pointer available to a class’s member functions
- Always points to the instance (object) of the class whose function is being called
- Is passed as a hidden argument to all non-static member functions //implicit parameter
- Can be used to access members that may be hidden by parameters with same name (shadowing)

this Pointer Example

```
class SomeClass
{
    private:
        int num;

    public:
        void setNum(int num)
        { this -> num = num; }
        ...
};
```

Notes on Overloaded Operators

- Can change meaning of an operator
- Cannot change the number of operands of the operator
- Only certain operators can be overloaded. Cannot overload the following operators:

```
?:   .   .*   :: sizeof
```

Overloading Types of Operators

- Overloaded mathematical operators should return a `numeric` value
- `++`, `--` operators overloaded differently for prefix vs. postfix notation
- Overloaded relational operators should return a `bool` value
- Overloaded stream operators `>>`, `<<` must return a reference to `istream` / `ostream` objects and take `istream` / `ostream` objects as parameters

- FeetInches.h Version 1
  - overloads + and – operators using member functions
  - The operators return a new FeetInches object
  - Program 14-8

Overloading Pre-Test ++ Operator

- Using FeetInches class

```
FeetInches FeetInches::operator++()
{
      ++inches;
      simplify();
      return *this
}
```

Overloading Post-Test ++ Operator

- Using FeetInches class

nameless integer parameter

```
FeetInches FeetInches::operator++(int)
{
     FeetInches temp(feet, inches)
     ++inches; //or inches++
     simplify();
     return temp
}
```

- FeetInches.h Version 2
  - overloads pre-test and post-test **++** operator
  - Program 14-9
  - The operators return a new FeetInches object

Overloading operator >

```
bool FeetInches::operator > (const FeetInches &right)
{
      bool status;

      if (feet > right.feet)
         status = true;
      else
         if (feet == right.feet && inches > right.inches)
            status = true;
         else
            status = false;

      return status;
}
```

Overloading   operator <

```
bool FeetInches::operator < (const FeetInches &right)
{
     bool status;

     if (feet < right.feet)
        status = true;
     else
        if (feet == right.feet && inches < right.inches)
           status = true;
        else
           status = false;

     return status;
}
```

Overloading operator ==

```
bool FeetInches::operator == (const FeetInches &right)
{
   bool status;

   if (feet == right.feet && inches == right.inches)
      status = true;
   else
      status = false;

   return status;
}
```

- FeetInches.h Version 3
  - overloads **<** **>** **==** operators
  - Program 14-10
  - The operators return a bool value

Overloading operator >>

Some compilers require you to prototype the stream operator functions outside the class. These declarations have been added for this reason

```
class FeetInches;  //forward declaration

//Function prototypes for overloaded stream operators
istream &operator >> (istream &, FeetInches &)
```

```
istream &operator >> (istream &stream, FeetInches &obj)
{
   //prompt the user for the feet
   cout   << "Feet: ";
   stream >> obj.feet;

    //prompt the user for the inches
   cout   << "Inches: ";
   stream >> obj.inches;

   obj.simplify();

   return stream;
}
```

Overloading operator <<

Some compilers require you to prototype the stream operator functions outside the class. These declarations have been added for this reason

```
class FeetInches;  //forward declaration

//Function prototypes for overloaded stream operators
ostream &operator << (ostream &, const FeetInches &)
```

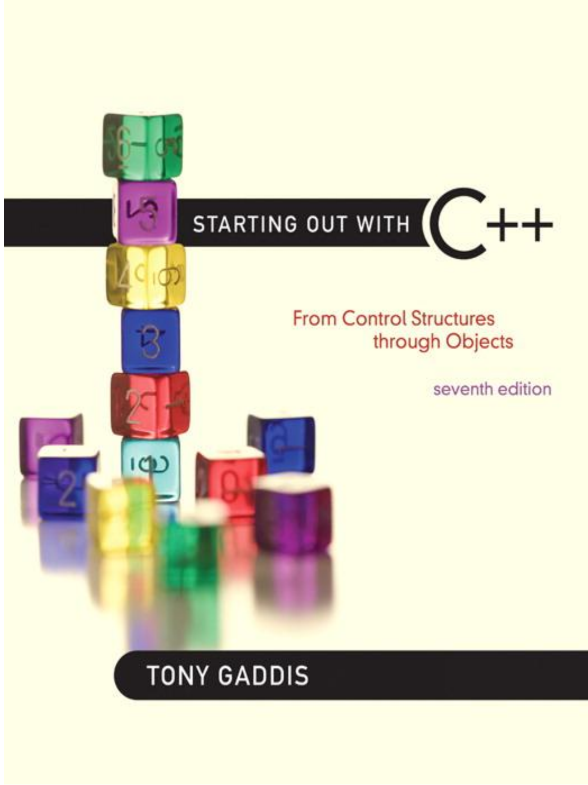
```
ostream &operator << (ostream &stream, const FeetInches &obj)
{
   stream << obj.feet
          << " feet, "
          << obj.inches
          << " inches";

   return stream;
}
```

- FeetInches.h Version 4
  - overloads **<<** **>>** operators
  - Program 14-11
  - The operators return a reference to a stream object (istream / ostream)
  - The operators are defined outside of the class. **friend** declarations are used

Overloaded `[]` Operator

- Can create classes that behave like arrays, provide bounds-checking on subscripts
- Must consider constructor, destructor
- Overloaded `[]` returns a reference to an object, not an object itself
- `[]` dereference an array element

- IntArray.h
  - overloads `[ ]` operator
  - Program 14-12
  - Program 14-13
    - demonstrates use of an invalid subscript
  - The operator returns a reference to an integer (or exits if an invalid subscript is used)



14.6

Object Conversion

Object Conversion

- Type of an object can be converted to another type
- Automatically done for built-in data types
- Must write an operator function to perform conversion
- To convert a `FeetInches` object to an `int`:

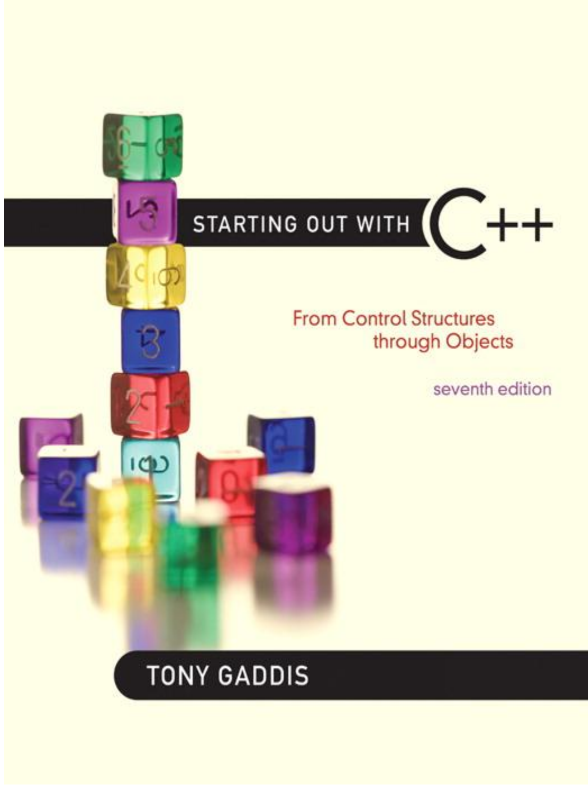
```
FeetInches::operator int() //cast FeetInches object to an int
{return feet;}  //truncates remainder (inches)
```

Note: no return type is specified in the function header for a conversion function. Also a conversion function does not take any arguments.

- Assuming distance is a `FeetInches` object, allows statements like:

```
int d = distance;
```

- FeetInches.h Version 5
  - provides conversion operators
    - `int ()`   //conversion to int
    - `double ()`   //conversion to double
  - Program 14-14
  - operators return a FeetInches object converted to an int or double



14.7

Aggregation

Aggregation (aka composition)

- Aggregation:
  - a class is a member of a different class

- Supports the modeling of ‘has a’ relationship between classes – enclosing class ‘has a’ enclosed class

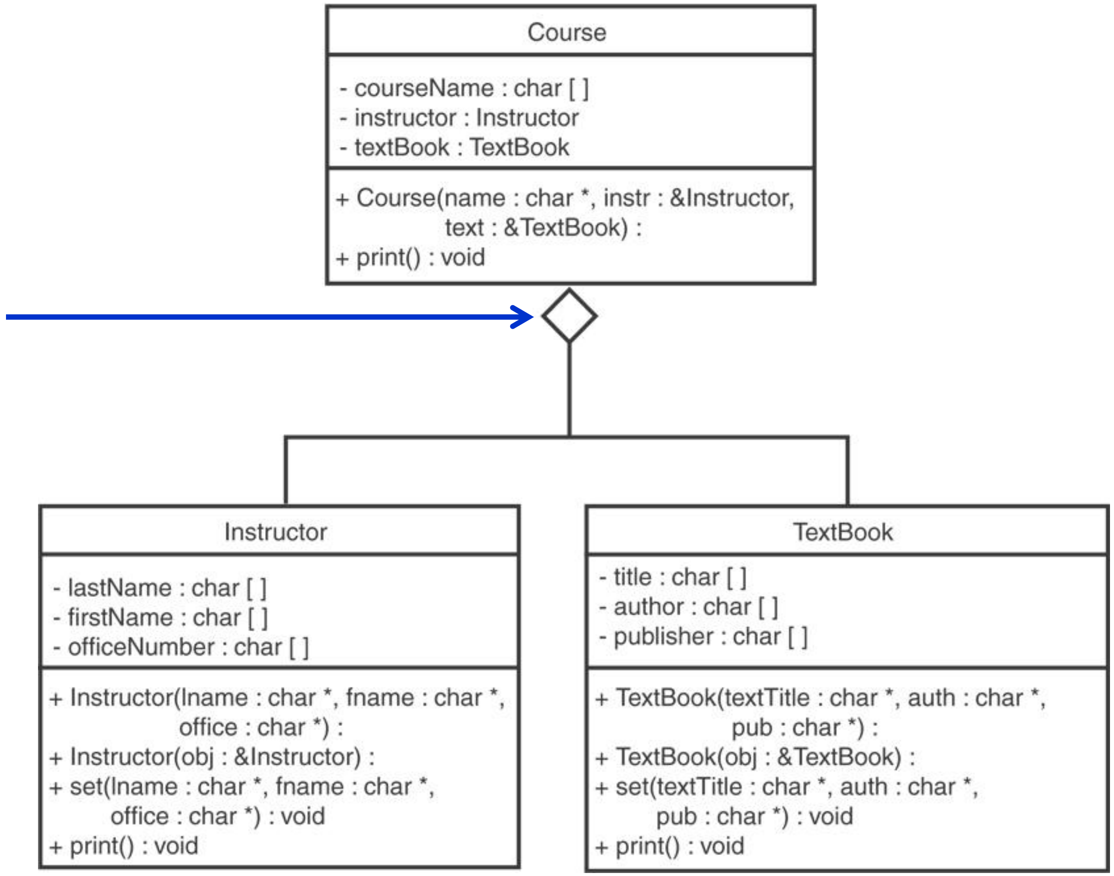
- Same notation as for structures within structures

Aggregation

```
class StudentInfo
{
   private:
     string firstName, LastName;
     string address, city, state, zip;
  ...
};
```

```
class Student
{
   private:
     StudentInfo personalData;
  ...
};
```

See the **Instructor**, **TextBook**, and **Course** classes in Chapter 14.


Course
- courseName : char [ ]
- instructor : Instructor
- textBook : TextBook
+ Course(name : char *, instr : &Instructor,
text : &TextBook) :
+ print() : void
Instructor
- lastName : char [ ]
- firstName : char [ ]
- officeNumber : char [ ]
+ Instructor(lname : char *, fname : char *,
office : char *) :
+ Instructor(obj : &Instructor) :
+ set(lname : char *, fname : char *,
office : char *) : void
+ print() : void
TextBook
- title : char [ ]
- author : char [ ]
- publisher : char [ ]
+ TextBook(textTitle : char *, auth : char *,
pub : char *) :
+ TextBook(obj : &TextBook) :
+ set(textTitle : char *, auth : char *,
pub : char *) : void
+ print() : void

- instructor.h
- course.h
- textbook.h
- program 14-15

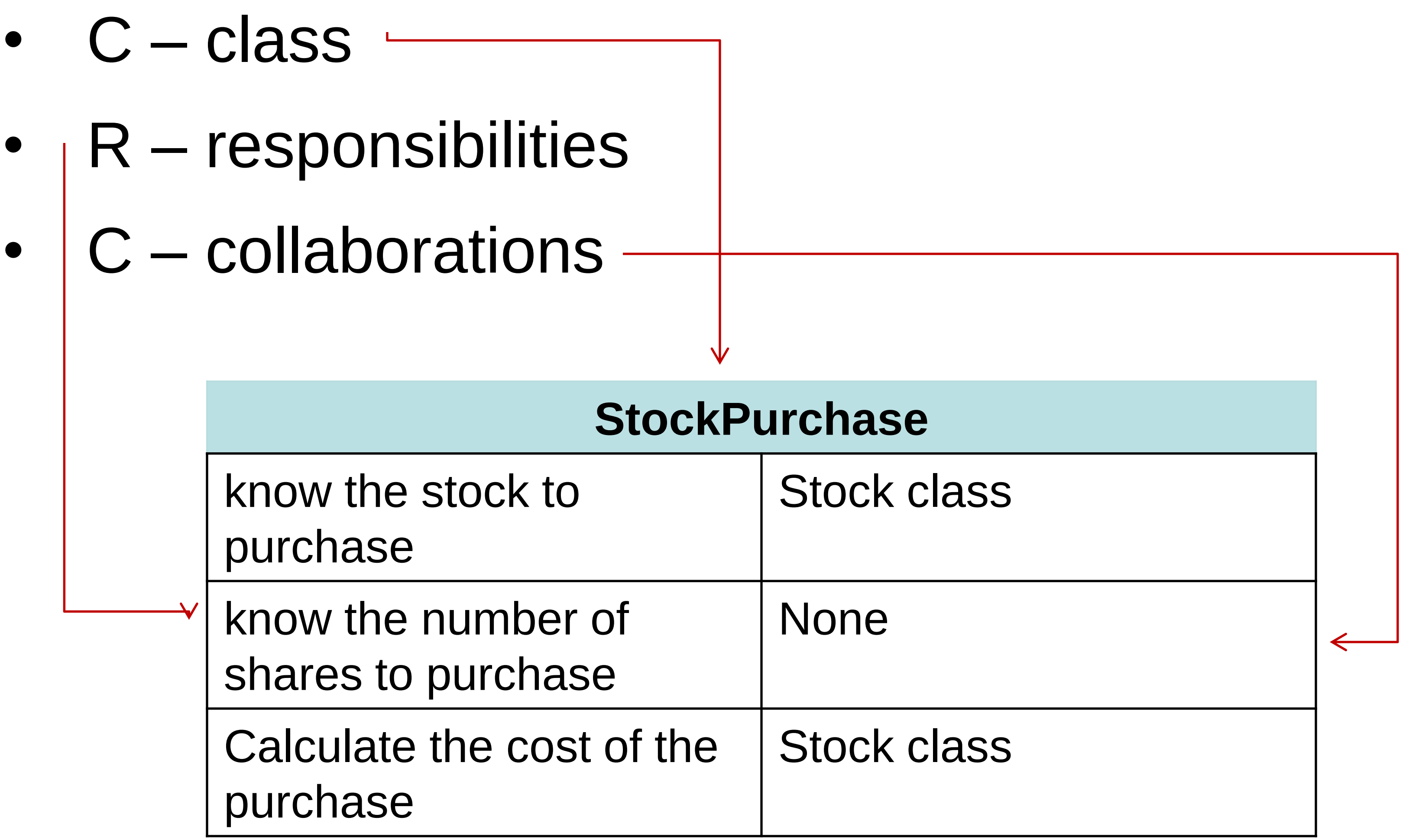
- Stock.h
- StockPurchase.h
- program 14-16

Class Responsibilities

- The things that the class is responsible for knowing (attributes)

- The things that the class is responsible for doing (behaviors)

CRC Cards



- C – class
- R – responsibilities
- C – collaborations

StockPurchase	
know the stock to purchase	Stock class
know the number of shares to purchase	None
Calculate the cost of the purchase	Stock class