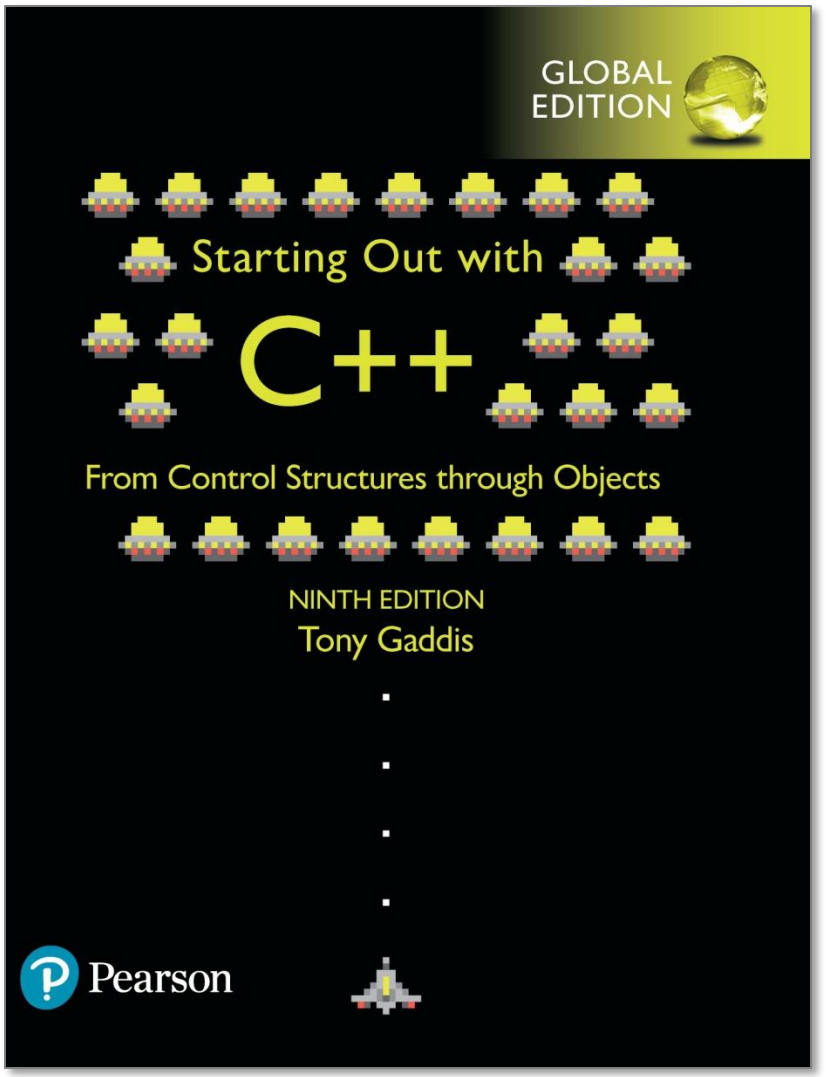
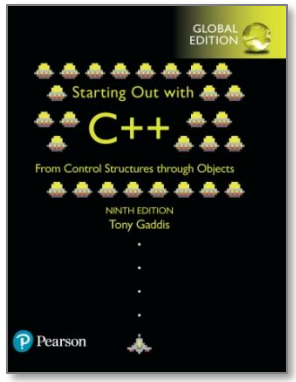
Chapter 14:

More About Classes





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`

```
 1  // Tree class
 2  class Tree
 3  {
 4  private:
 5     static int objectCount;     // Static member variable.
 6  public:
 7     // Constructor
 8     Tree()
 9        { objectCount++; }
10
11     // Accessor function for objectCount
12     int getObjectCount() const
13        { return objectCount; }
14  };
15
16  // Definition of the static member variable, written
17  // outside the class.
18  int Tree::objectCount = 0;
```

Static member declared here.

Static member defined here.

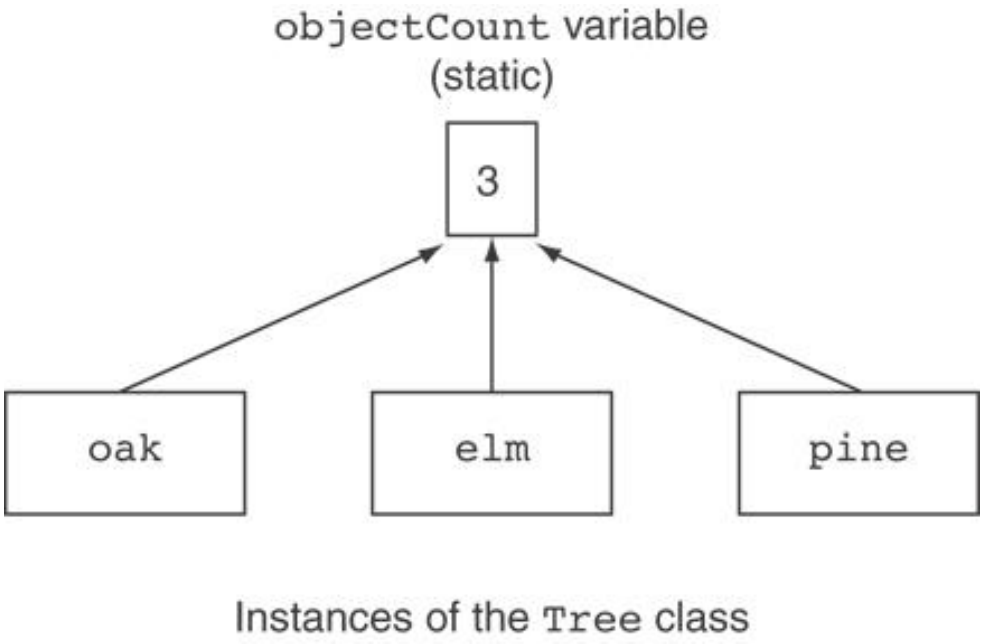
Program 14-1

```
1  // This program demonstrates a static member variable.
2  #include <iostream>
3  #include "Tree.h"
4  using namespace std;
5
6  int main()
7  {
8     // Define three Tree objects.
9     Tree oak;
10    Tree elm;
11    Tree pine;
12
13    // Display the number of Tree objects we have.
14    cout << "We have " << pine.getObjectCount()
15         << " trees in our program!\n";
16    return 0;
17 }
```

Program Output

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

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



Instances of the `Tree` class

`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:

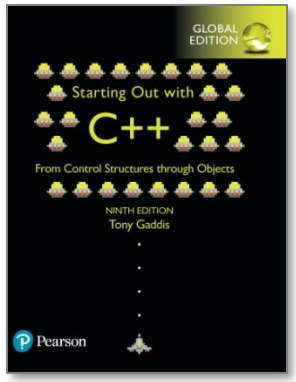
```
int num = Tree::getObjectCount();
```

Modified Version of `Tree.h`

```
 1  // Tree class
 2  class Tree
 3  {
 4  private:
 5     static int objectCount;    // Static member variable.
 6  public:
 7     // Constructor
 8     Tree()
 9        { objectCount++; }
10
11     // Accessor function for objectCount
12     static int getObjectCount() const
13        { return objectCount; }
14  };
15
16  // Definition of the static member variable, written
17  // outside the class.
18  int Tree::objectCount = 0;
```

Now we can call the function like this:

```
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
```

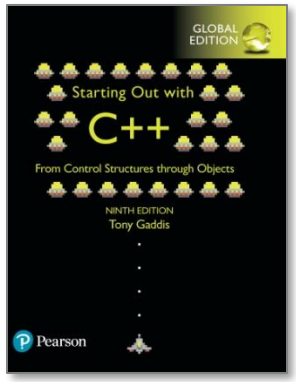
- Member function of another class:

```
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
  ...
};
```



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

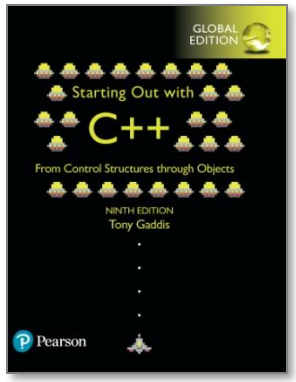
```
1  // This program demonstrates memberwise assignment.
2  #include <iostream>
3  #include "Rectangle.h"
4  using namespace std;
5
6  int main()
7  {
8     // Define two Rectangle objects.
9     Rectangle box1(10.0, 10.0);   // width = 10.0, length = 10.0
10    Rectangle box2 (20.0, 20.0);  // width = 20.0, length = 20.0
11
12    // Display each object's width and length.
13    cout << "box1's width and length: " << box1.getWidth()
14         << " " << box1.getLength() << endl;
15    cout << "box2's width and length: " << box2.getWidth()
16         << " " << box2.getLength() << endl << endl;
17
18    // Assign the members of box1 to box2.
19    box2 = box1;
20
21    // Display each object's width and length again.
22    cout << "box1's width and length: " << box1.getWidth()
23         << " " << box1.getLength() << endl;
24    cout << "box2's width and length: " << box2.getWidth()
25         << " " << box2.getLength() << endl;
26
27    return 0;
28 }
```

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

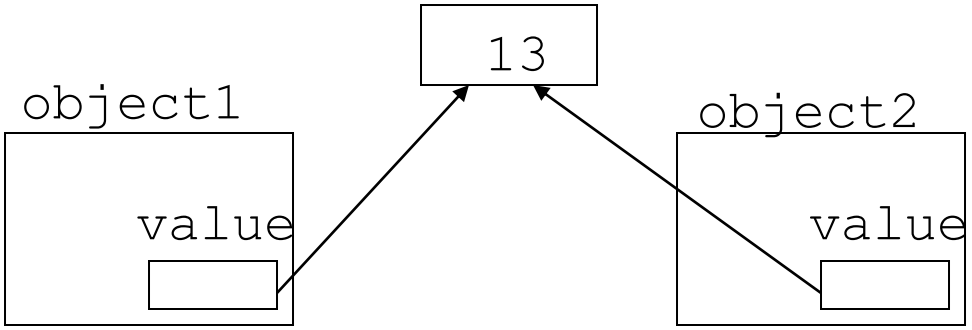
Problem: what if object contains a pointer?

```
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:

```
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:

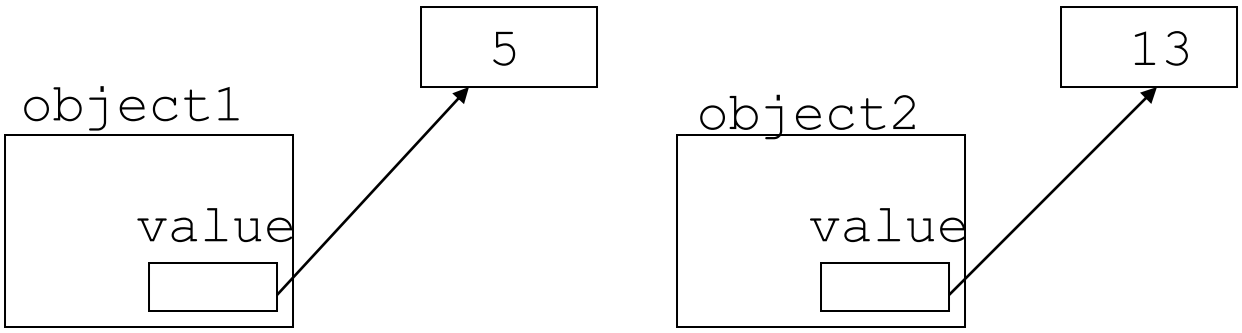
```
SomeClass::SomeClass(const SomeClass &obj)
{
   value = new int;
   *value = obj.value;
}
```

- 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`:

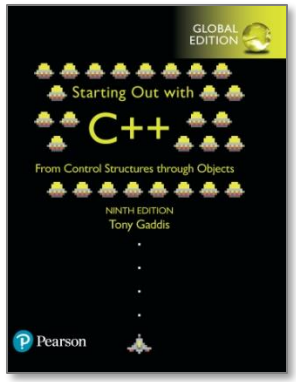
```
SomeClass::SomeClass
                    (const SomeClass &obj)
```

Contents of StudentTestScores.h (Version 2)

```
1  #ifndef STUDENTTESTSCORES_H
2  #define STUDENTTESTSCORES_H
3  #include <string>
4  using namespace std;
5
6  const double DEFAULT_SCORE = 0.0;
7
8  class StudentTestScores
9  {
10 private:
11    string studentName;  // The student's name
12    double *testScores;  // Points to array of test scores
13    int numTestScores;   // Number of test scores
14
15     // Private member function to create an
16     // array of test scores.
17    void createTestScoresArray(int size)
18    { numTestScores = size;
19      testScores = new double[size];
20      for (int i = 0; i < size; i++)
21         testScores[i] = DEFAULT_SCORE; }
22
23 public:
24     // Constructor
25    StudentTestScores(string name, int numScores)
26    { studentName = name;
```

```
27      createTestScoresArray(numScores); }
28
29    // Copy constructor
30    StudentTestScores(const StudentTestScores &obj)
31    { studentName = obj.studentName;
32      numTestScores = obj.numTestScores;
33      testScores = new double[numTestScores];
34      for (int i = 0; i < numTestScores; i++)
35         testScores[i] = obj.testScores[i]; }
36
37     // Destructor
38    ~StudentTestScores()
39    { delete [] testScores; }
40
41     // The setTestScore function sets a specific
42     // test score's value.
43    void setTestScore(double score, int index)
44    { testScores[index] = score; }
45
46     // Set the student's name.
47    void setStudentName(string name)
48    { studentName = name; }
49
50     // Get the student's name.
51    string getStudentName() const
52    { return studentName; }
```

```
53
54      // Get the number of test scores.
55      int getNumTestScores() const
56      { return numTestScores; }
57
58       // Get a specific test score.
59      double getTestScore(int index) const
60      { return testScores[index]; }
61  };
62  #endif
```



14.5

Operator Overloading

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

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

The `this` Pointer

- Example, `student1` and `student2` are both `StudentTestScores` objects.
- The following statement causes the `getStudentName` member function to operate on `student1`:

```
cout << student1.getStudentName() << endl;
```

- When `getStudentName` is operating on `student1`, the `this` pointer is pointing to `student1`.

The `this` Pointer

- Likewise, the following statement causes the `getStudentName` member function to operate on `student2`:

```
cout << student2.getStudentName() << endl;
```

- When `getStudentName` is operating on `student2`, the `this` pointer is pointing to `student2`.

- The `this` pointer always points to the object that is being used to call the member function.

Operator Overloading

- Prototype:

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

- 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;
```

Returning a Value

- Overloaded operator can return a value

```
class Point2d
{
private:
    int x, y;

...
public:
  double operator-(const point2d &right)
  { return sqrt(pow((x-right.x),2)
          + pow((y-right.y),2)); }
};
Point2d point1(2,2), point2(4,4);
// Compute and display distance between 2 points.
cout << point2 – point1 << endl; // displays 2.82843
```

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;
```

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:

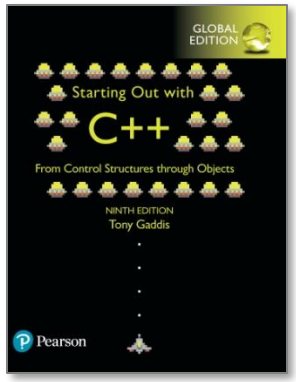
```
?:   .   .*   :: sizeof
```

Overloading Types of Operators

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

Overloaded [] Operator

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



14.6

Object Conversion

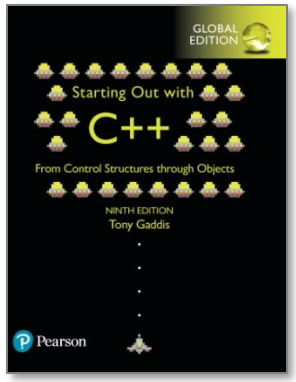
Object Conversion

- 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 an `FeetInches` object to an `int`:

```
FeetInches::operator int()
{return feet;}
```

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

```
int d = distance;
```



14.7

Aggregation

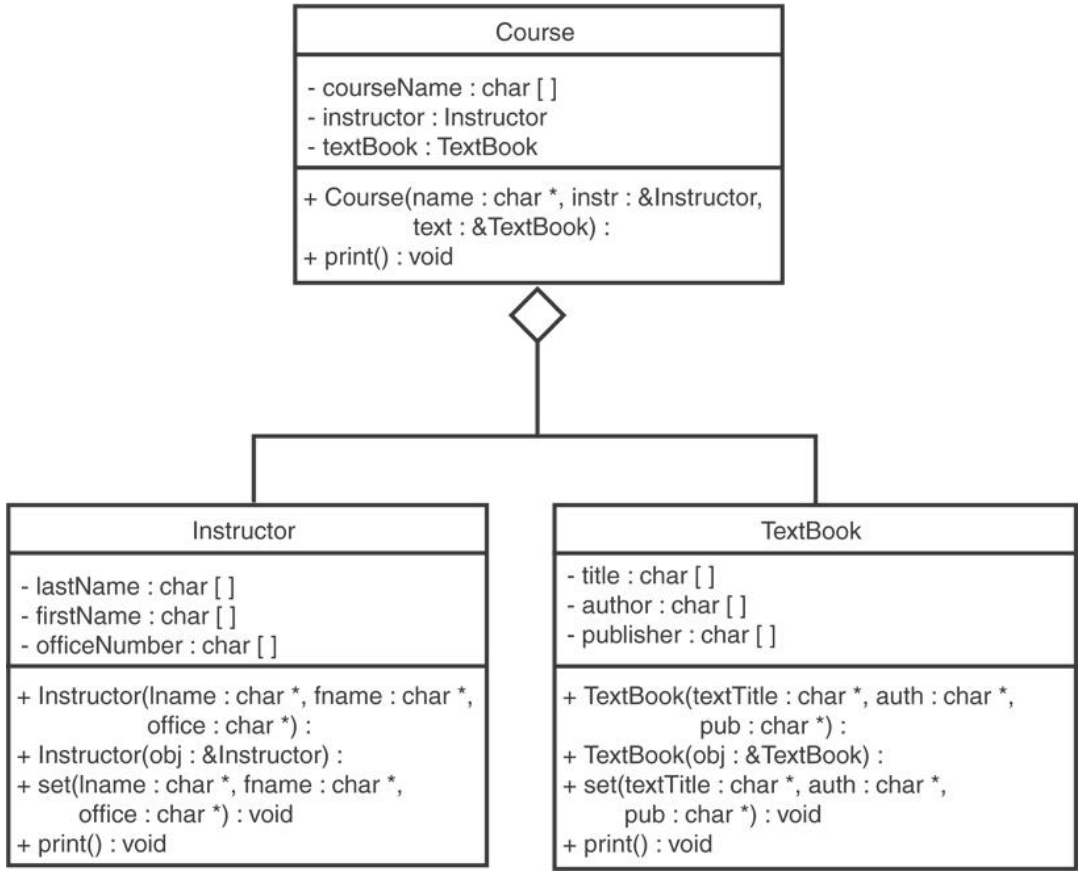
Aggregation

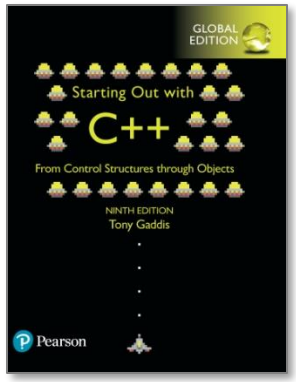
- Aggregation: a class is a member of a class
- Supports the modeling of ‘has a’ relationship between classes – enclosing class ‘has a’ enclosed class
- Same notation as for structures within structures

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.





14.10

Rvalue References and Move Semantics

Temporary Values

- Consider this code:

```
int x;
x = 2 * 6;
```

- When the expression `2 * 6` is evaluated, the value 12 is stored in memory as a temporary value.
- The temporary value is then stored in the `x` variable.
- Then, the temporary value is discarded.

Temporary Values

- Consider this:

```
 1 int square(int a)
 2 {
 3   return a * a;
 4 }
 5
 6 int main()
 7 {
 8   int x = 0;
 9
10   x = square(5);
11   cout << x << endl;
12   return 0;
13  }
```

- The `square` function is called, and the value 5 is passed as an argument.
- The `square` function calculates 5 * 5 and stores the result, 25, as a temporary value.
- The temporary value is copied (assigned) to the variable `x`.
- The temporary value is no longer needed, so the system discards it.

Lvalues and Rvalues

- Two types of values stored in memory during the execution of a program:
  - Values that persist beyond the statement that created them, and have names that make them accessible to other statements in the program. In C++, these values are called *lvalues*.
  - Values that are temporary, and cannot be accessed beyond the statement that created them. In C++, these values are called *rvalues*.

Rvalue References

- Rvalue Reference: a reference variable that can refer only to temporary objects that would otherwise have no name.
- Rvalue references are used to write move constructors and move assignment operators (otherwise known as move semantics).
- Anytime you write a class with a pointer or reference to a piece of data outside the class, you should implement move semantics.
- Move semantics increase the performance of these types of classes.

Move Assignment vs. Copy Assignment

- From the `Person` class, in Chapter 14:

```
// Move assignment operator
Person& operator=(Person&& right)
{   if (this != &right)
    {
        swap(name, right.name);
    }
    return *this;
}
```

```
// Copy assignment operator
Person & operator=(const Person &right)
{   if (this != &right)
    {
        name = new char[strlen(right.name) + 1];
        strcpy(name, right.name);
    }
    return *this;
}
```

Move Constructor vs. Copy Constructor

- From the `Person` class, in Chapter 14:

```
// Move constructor
Person(Person&& temp)
{   // Steal the name pointer from temp.
    name = temp.name;

    // Nullify the temp object's name pointer.
    temp.name = nullptr;
}
```

```
// Copy constructor
Person(const Person &obj)
{ name = new char[strlen(obj.name) + 1];
  strcpy(name, obj.name); }
```