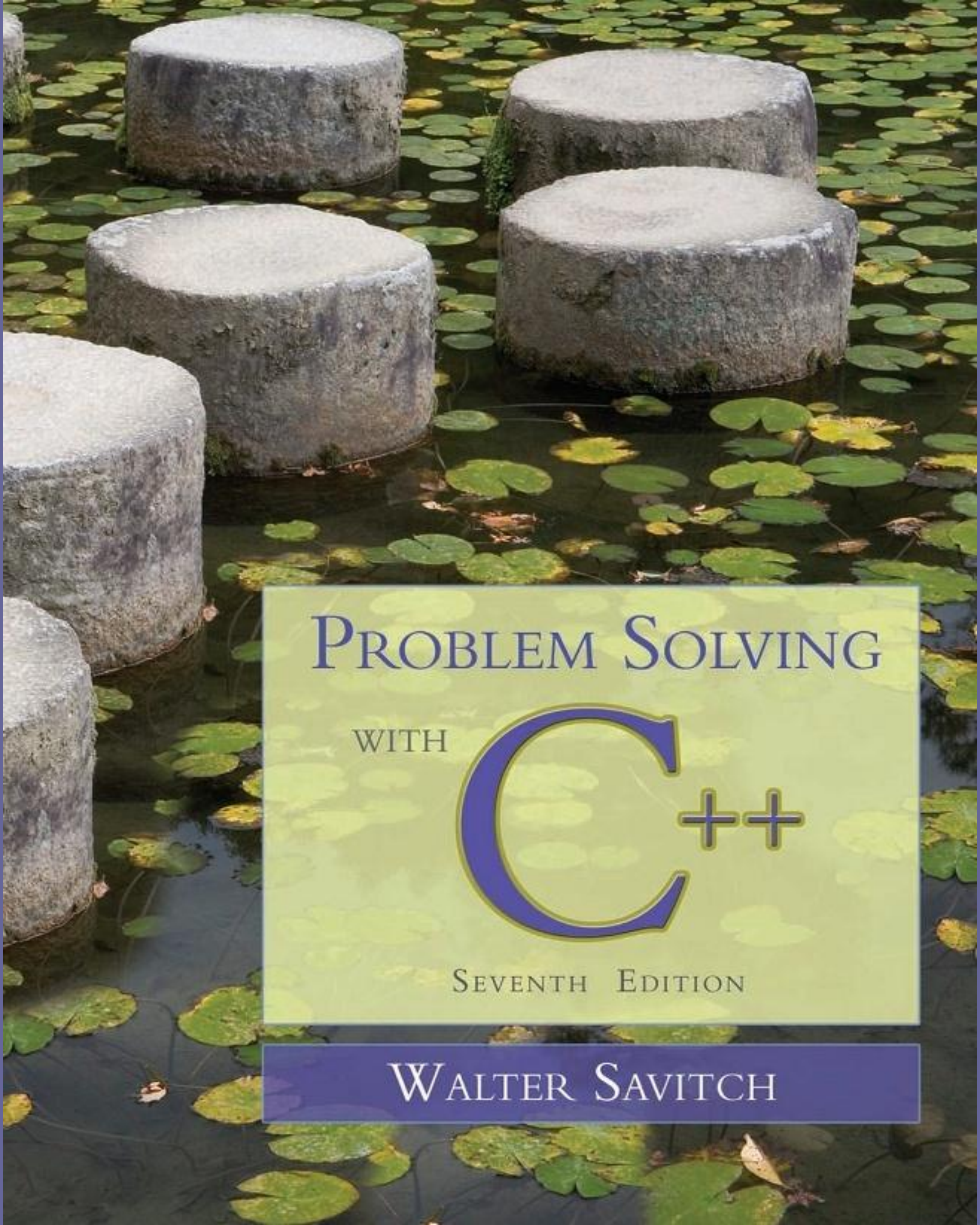


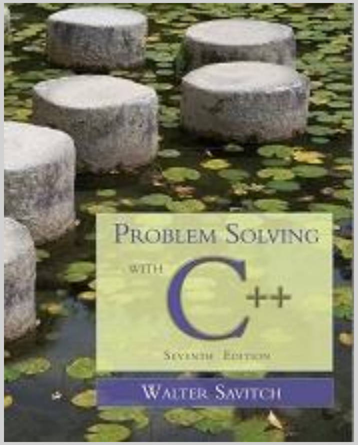
PROBLEM SOLVING WITH C++

SEVENTH EDITION

WALTER SAVITCH

Chapter 15

Inheritance



Overview

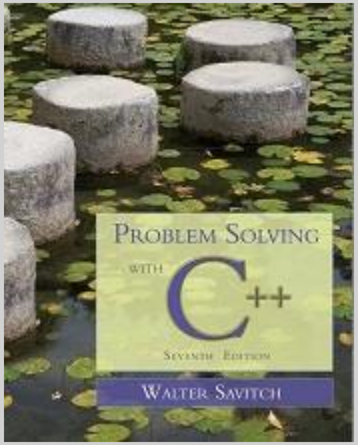
15.1 Inheritance Basics

15.2 Inheritance Details

15.3 Polymorphism

15.1

Inheritance



Inheritance Basics

- Inheritance is the process by which a new class, called a derived class, is created from another class, called the base class
  - A derived class automatically has all the member variables and functions of the base class
  - A derived class can have additional member variables and/or member functions
  - The derived class is a child of the base or parent class

Employee Classes

- To design a record-keeping program with records for salaried and hourly employees…
  - Salaried and hourly employees belong to a class of people who share the property "employee"
  - A subset of employees are those with a fixed wage
  - Another subset of employees earn hourly wages
- All employees have a name and SSN
  - Functions to manipulate name and SSN are the same for hourly and salaried employees

A Base Class

- We will define a class called Employee for all employees
- The Employee class will be used to define classes for hourly and salaried employees

- A definition of the employee class is found in

Display 15.1 **Display 15.2**

Function print_check

- Function print_check will have different definitions to print different checks for each type of employee
  - An Employee object lacks sufficient information to print a check
  - Each derived class will have sufficient information to print a check

Class HourlyEmployee

- HourlyEmployee is derived from Class Employee
  - HourlyEmployee inherits all member functions and member variables of Employee
  - The class definition begins

    class HourlyEmployee : public Employee

    - :public Employee shows that HourlyEmployee is derived from class Employee
  - HourlyEmployee declares additional member variables wage_rate and hours

Display 15.3

Inherited Members

- A derived class inherits all the members of the parent class
  - The derived class does not re-declare or re-define members inherited from the parent, except…
  - The derived class re-declares and re-defines member functions of the parent class that will have a different definition in the derived class
  - The derived class can add member variables and functions

Implementing a Derived Class

- Any member functions added in the derived class are defined in the implementation file for the derived class
  - Definitions are not given for inherited functions that are not to be changed

- The HourlyEmployee class is defined in **Display 15.5**

Class SalariedEmployee

- The class SalariedEmployee is also derived from Employee
  - Function print_check is redefined to have a meaning specific to salaried employees
  - SalariedEmployee adds a member variable salary
- The interface for SalariedEmployee is found in **Display 15.4**

Display 15.6 (1-2) contains the implementation

Parent and Child Classes

- Recall that a child class automatically has all the members of the parent class
- The parent class is an ancestor of the child class
- The child class is a descendent of the parent class
- The parent class (Employee) contains all the code common to the child classes
  - You do not have to re-write the code for each child

Derived Class Types

- An hourly employee is an employee
  - In C++, an object of type HourlyEmployee can be used where an object of type Employee can be used
  - An object of a class type can be used wherever any of its ancestors can be used
  - An ancestor cannot be used wherever one of its descendents can be used

Derived Class Constructors

- A base class constructor is not inherited in a derived class
  - The base class constructor can be invoked by the constructor of the derived class
  - The constructor of a derived class begins by invoking the constructor of the base class in the initialization section:

```
  HourlyEmployee::HourlyEmployee : Employee( ),
                                                  wage_rate( 0),
                                                   hours( )

{ //no code needed }
```

Any Employee constructor could be invoked

Default Initialization

- If a derived class constructor does not invoke a base class constructor explicity, the base class default constructor will be used
- If class B is derived from class A and class C is derived from class B
  - When a object of class C is created
    - The base class A's constructor is the first invoked
    - Class B's constructor is invoked next
    - C's constructor completes execution

Private is Private

- A member variable (or function) that is private in the parent class is not accessible to the child class
  - The parent class member functions must be used to access the private members of the parent
  - This code would be illegal:

```
void HourlyEmployee::print_check( )
  {
          net_pay = hours * wage_rage;
```

    - net_pay is a private member of Employee!

The protected Qualifier

- protected members of a class appear to be private outside the class, but are accessible by derived classes
  - If member variables name, net_pay, and ssn are listed as protected (not private) in the Employee class, this code, illegal on the previous slide, becomes legal:

```
HourlyEmployee::print_check( )
{
            net_pay = hours * wage_rage;
```

Programming Style

- Using protected members of a class is a convenience to facilitate writing the code of derived classes.
- Protected members are not necessary
  - Derived classes can use the public methods of their ancestor classes to access private members
- Many programming authorities consider it bad style to use protected member variables

Redefinition of Member Functions

- When defining a derived class, only list the the inherited functions that you wish to change for the derived class
  - The function is declared in the class definition
  - HourlyEmployee and SalariedEmployee each have their own definitions of print_check
- Display 15.7 (1-2) demonstrates the use of the derived classes defined in earlier displays.

Redefining or Overloading

- A function redefined in a derived class has the same number and type of parameters
  - The derived class has only one function with the same name as the base class
- An overloaded function has a different number and/or type of parameters than the base class
  - The derived class has two functions with the same name as the base class
    - One is defined in the base class, one in the derived class

Function Signatures

- A function signature is the function's name with the sequence of types in the parameter list, not including any const or '&'
  - An overloaded function has multiple signatures
- Some compilers allow overloading based on including const or not including const

Access to a Redefined Base Function

- When a base class function is redefined in a derived class, the base class function can still be used
  - To specify that you want to use the base class version of the redefined function:

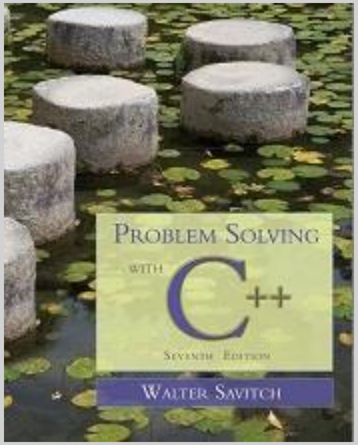
```
HourlyEmployee sally_h;
sally_h.Employee::print_check( );
```

Section 15.1 Conclusion

- Can you
  - Explain why the declaration for get_name is not part of the definition of SalariedEmployee?
  - Give a definition for a class TitledEmployee derived from class SalariedEmployee with one additional string called title?   Add two member functions get_title and set_title. It should redefine set_name.

15.2

Inheritance Details



Inheritance Details

- Some special functions are, for all practical purposes, not inherited by a derived class
  - Some of the special functions that are not effectively inherited by a derived class include
    - Destructors
    - Copy constructors
    - The assignment operator

Copy Constructors and Derived Classes

- If a copy constructor is not defined in a derived class, C++ will generate a default copy constructor
  - This copy constructor copies only the contents of member variables and will not work with pointers and dynamic variables
  - The base class copy constructor will not be used

Operator = and Derived Classes

- If a base class has a defined assignment operator = and the derived class does not:
  - C++ will use a default operator that will have nothing to do with the base class assignment operator

Destructors and Derived Classes

- A destructor is not inherited by a derived class
- The derived class should define its own destructor

The Assignment Operator

- In implementing an overloaded assignment operator in a derived class:
  - It is normal to use the assignment operator from the base class in the definition of the derived class's assignment operator
  - Recall that the assignment operator is written as a member function of a class

The Operator = Implementation

- This code segment shows how to begin the implementation of the = operator for a derived class:

  ```
   Derived& Derived::operator= (const Derived& rhs)
   {
       Base::operator=(rhs)
  ```

  - This line handles the assignment of the inherited member variables by calling the base class assignment operator
  - The remaining code would assign the member variables introduced in the derived class

The Copy Constructor

- Implementation of the derived class copy constructor is much like that of the assignment operator:

  ```
  Derived::Derived(const Derived& object)
                           :Base(object), <other initializing>
  {…}
  ```

  - Invoking the base class copy constructor sets up the inherited member variables
    - Since object is of type Derived it is also of type Base

Destructors in Derived Classes

- If the base class has a working destructor, defining the destructor for the defined class is relatively easy
  - When the destructor for a derived class is called, the destructor for the base class is automatically called
  - The derived class destructor need only use delete on dynamic variables added in the derived class, and data they may point to

Destruction Sequence

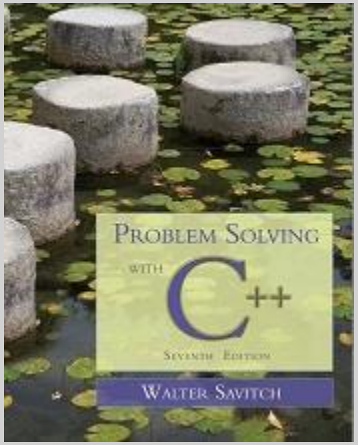
- If class B is derived from class A and class C is derived from class B…
  - When the destructor of an object of class C goes out of scope
    - The destructor of class C is called
    - Then the destructor of class B
    - Then the destructor of class A
  - Notice that destructors are called in the reverse order of constructor calls

Section 15.2 Conclusion

- Can you
  - List some special functions that are not inherited by a derived class?
  - Write code to invoke the base class copy constructor in defining the derived class's copy constructor?

15.3

Polymorphism



Polymorphism

- Polymorphism refers to the ability to associate multiple meanings with one function name using a mechanism called late binding
- Polymorphism is a key component of the philosophy of object oriented programming

A Late Binding Example

- Imagine a graphics program with several types of figures
  - Each figure may be an object of a different class, such as a circle, oval, rectangle, etc.
  - Each is a descendant of a class Figure
  - Each has a function draw( ) implemented with code specific to each shape
  - Class Figure has functions common to all figures

A Problem

- Suppose that class Figure has a function center
  - Function center moves a figure to the center of the screen by erasing the figure and redrawing it in the center of the screen
  - Function center is inherited by each of the derived classes
    - Function center uses each derived object's draw function to draw the figure
    - The Figure class does not know about its derived classes, so it cannot know how to draw each figure

Virtual Functions

- Because the Figure class includes a method to draw figures, but the Figure class cannot know how to draw the figures, virtual functions are used
- Making a function virtual tells the compiler that you don't know how the function is implemented and to wait until the function is used in a program, then get the implementation from the object.
  - This is called late binding

Virtual Functions in C++

- As another example, let's design a record-keeping program for an auto parts store
  - We want a versatile program, but we do not know all the possible types of sales we might have to account for
    - Later we may add mail-order and discount sales
    - Functions to compute bills will have to be added later when we know what type of sales to add
    - To accommodate the future possibilities, we will make the bill function a virtual function

The Sale Class

- All sales will be derived from the base class Sale
- The bill function of the Sale class is virtual
- The member function savings and operator < each use bill
- The Sale class interface and implementation are shown in **Display 15.8** **Display 15.9**

Virtual Function bill

- Because function bill is virtual in class Sale, function savings and operator <, defined only in the base class, can in turn use a version of bill found in a derived class
  - When a DiscountSale object calls its savings function, defined only in the base class, function savings calls function bill
  - Because bill is a virtual function in class Sale, C++ uses the version of bill defined in the object that called savings

DiscountSale::bill

- Class DiscountSale has its own version of virtual function bill
  - Even though class Sale is already compiled, Sale::savings( ) and Sale::operator< can still use function bill from the DiscountSale class
  - The keyword virtual tells C++ to wait until bill is used in a program to get the implementation of bill from the calling object
  - DiscountSale is defined and used in

Display 15.10

Display 15.11

Virtual Details

- To define a function differently in a derived class and to make it virtual
  - Add keyword virtual to the function declaration in the base class
  - virtual is not needed for the function declaration in the derived class, but is often included
  - virtual is not added to the function definition
  - Virtual functions require considerable overhead so excessive use reduces program efficiency

Overriding

- Virtual functions whose definitions are changed in a derived class are said to be overridden

- Non-virtual functions whose definitions are changed in a derived class are redefined

Type Checking

- C++ carefully checks for type mismatches in the use of values and variables
- This is referred to as strong type checking
  - Generally the type of a value assigned to a variable must match the type of the variable
    - Recall that some automatic type casting occurs
- Strong type checking interferes with the concepts of inheritance

Type Checking and Inheritance

- Consider

```
class Pet
  {
        public:
              virtual void print();
               string name;
   }

and
  class Dog :public Pet
  {
     public:
                virtual void print();
                string breed;
   }
```

A Sliced Dog is a Pet

- C++ allows the following assignments:

  ```
  vdog.name = "Tiny";
  vdog.breed = "Great Dane";
  vpet = vdog;
  ```

- However, vpet will loose the breed member of vdog since an object of class Pet has no breed member
  - This code would be illegal: cout << vpet.breed;

- This is the slicing problem

The Slicing Problem

- It is legal to assign a derived class object into a base class variable
  - This slices off data in the derived class that is not also part of the base class
  - Member functions and member variables are lost

Extended Type Compatibility

- It is possible in C++ to avoid the slicing problem
  - Using pointers to dynamic variables we can assign objects of a derived class to variables of a base class without loosing members of the derived class object

Dynamic Variables and Derived Classes

- Example:

```
Pet   *ppet;
Dog *pdog;
pdog = new Dog;
pdog->name = "Tiny";
pdog->breed = "Great
                   Dane";
ppet = pdog;
```

```
void Dog::print( )
{
   cout << "name: "
            <<  name << endl;
   cout << "breed: "
            << breed << endl;
}
```

- ppet->print( );   is legal and produces:

```
name:  Tiny
breed:  Great Dane
```

Display 15.12 (1-2)

Use Virtual Functions

- The previous example:

```
ppet->print( );
```

  worked because print was declared as a virtual function

- This code would still produce an error:

```
cout << "name: " << ppet->name
     << "breed: " << ppet->breed;
```

Why?

- ppet->breed is still illegal because ppet is a pointer to a Pet object that has no breed member
- Function print( ) was declared virtual by class Pet
    - When the computer sees ppet->print( ), it checks the virtual table for classes Pet and Dog and finds that ppet points to an object of type Dog
        - Because ppet points to a Dog object, code for Dog::print( )
          is used

Remember Two Rules

- To help make sense of object oriented programming with dynamic variables, remember these rules
  - If the domain type of the pointer p_ancestor is a base class for the for the domain type of pointer p_descendant,
    the following assignment of pointers is allowed

    ```
    p_ancestor = p_descendant;
    ```

    and no data members will be lost
  - Although all the fields of the p_descendant are there, virtual functions are required to access them

Virtual Compilation

- When using virtual functions, you will have to define each virtual function before compiling
  - Declaration is no longer sufficient
  - Even if you do not call the virtual function you may see error message:
    "undefined reference to Class_Name virtual table"

Virtual Destructors

- Destructors should be made virtual
  - Consider Base *pBase = new Derived;

    …

    delete pBase;
  - If the destructor in Base is virtual, the destructor for Derived is invoked as pBase points to a Derived object, returning Derived members to the freestore
    - The Derived destructor in turn calls the Base destructor

Non-Virtual Destructors

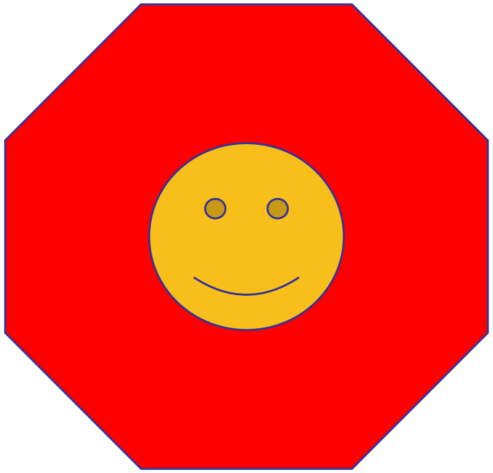
- If the Base destructor is not virtual, only the Base destructor is invoked

- This leaves Derived members, not part of Base, in memory

Section 15.3 Conclusion

- Can you
  - Explain why you cannot assign a base class object to a derived class object?
  - Describe the problem with assigning a derived class object to a base class object?

Chapter 15 -- End



Display 15.1

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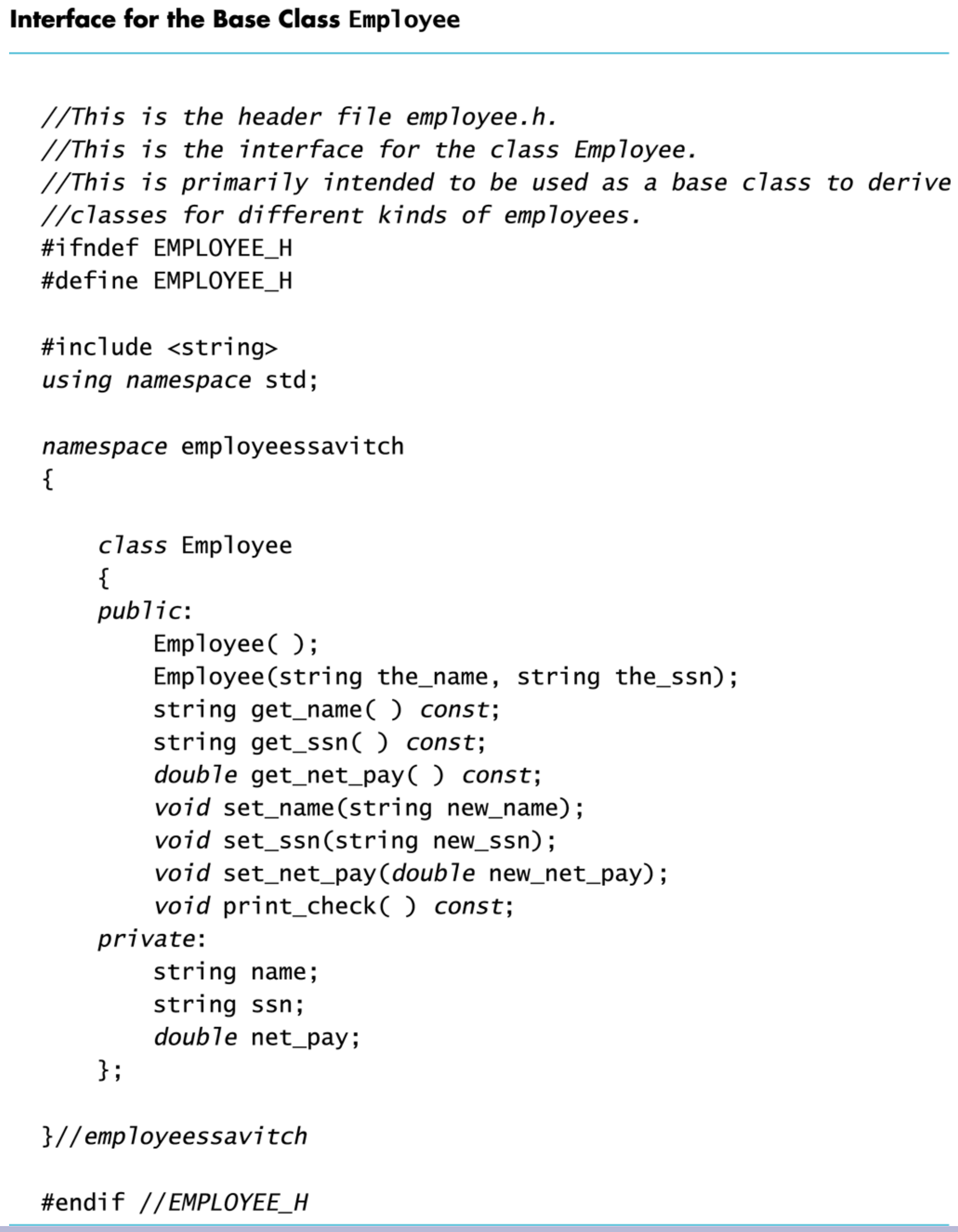

Interface for the Base Class `Employee`

```
//This is the header file employee.h.
//This is the interface for the class Employee.
//This is primarily intended to be used as a base class to derive
//classes for different kinds of employees.
#ifndef EMPLOYEE_H
#define EMPLOYEE_H

#include <string>
using namespace std;

namespace employeessavitch
{

    class Employee
    {
    public:
        Employee( );
        Employee(string the_name, string the_ssn);
        string get_name( ) const;
        string get_ssn( ) const;
        double get_net_pay( ) const;
        void set_name(string new_name);
        void set_ssn(string new_ssn);
        void set_net_pay(double new_net_pay);
        void print_check( ) const;
    private:
        string name;
        string ssn;
        double net_pay;
    };

}//employeessavitch

#endif //EMPLOYEE_H
```

Display 15.2 (1/2)

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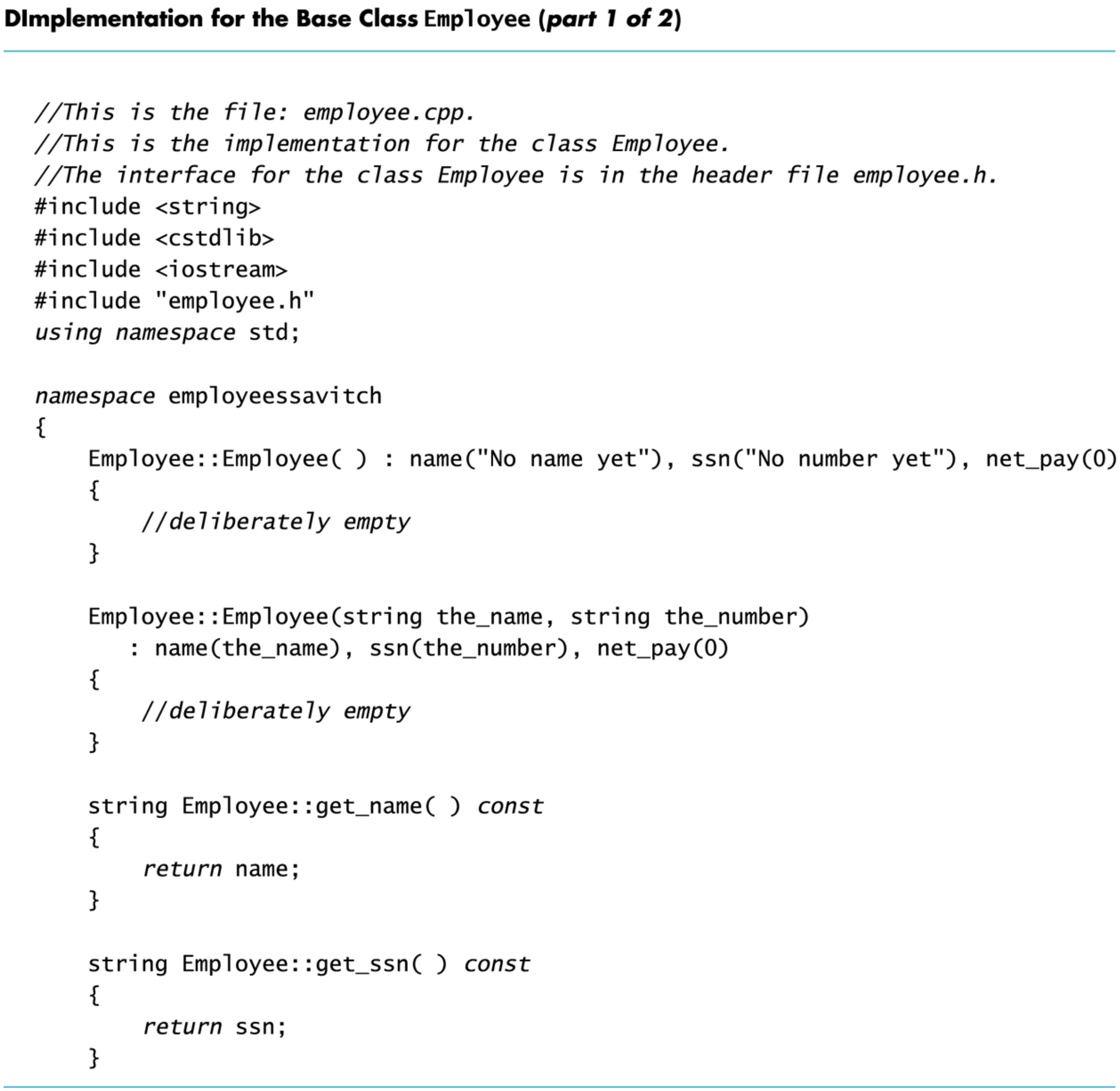

DImplementation for the Base Class Employee (*part 1 of 2*)

```
//This is the file: employee.cpp.
//This is the implementation for the class Employee.
//The interface for the class Employee is in the header file employee.h.
#include <string>
#include <cstdlib>
#include <iostream>
#include "employee.h"
using namespace std;

namespace employeessavitch
{
    Employee::Employee( ) : name("No name yet"), ssn("No number yet"), net_pay(0)
    {
        //deliberately empty
    }

    Employee::Employee(string the_name, string the_number)
       : name(the_name), ssn(the_number), net_pay(0)
    {
        //deliberately empty
    }

    string Employee::get_name( ) const
    {
        return name;
    }

    string Employee::get_ssn( ) const
    {
        return ssn;
    }
```

Display 15.2 (2/2)

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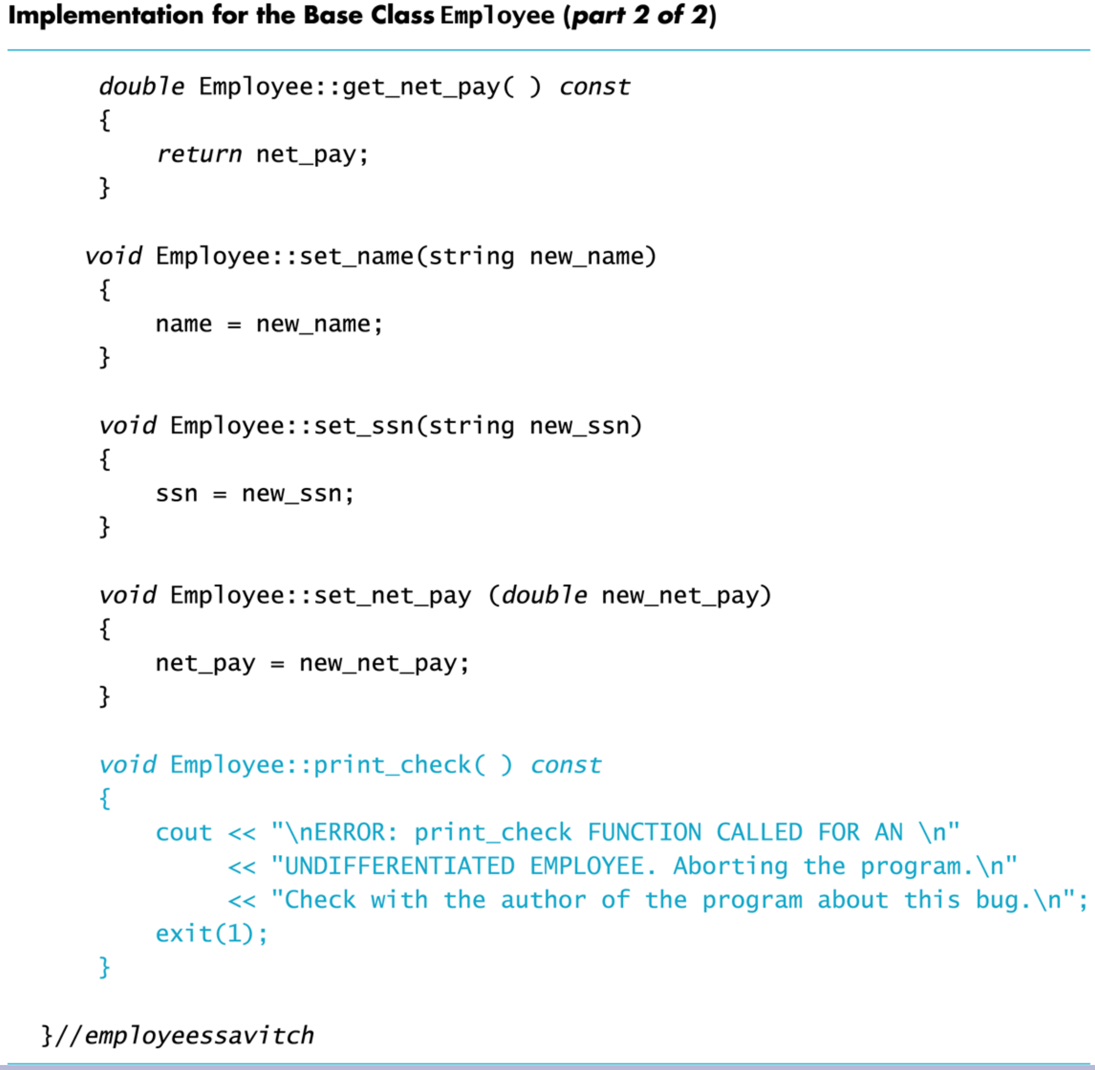

Implementation for the Base Class `Employee` **(*part 2 of 2*)**

```
    double Employee::get_net_pay( ) const
    {
        return net_pay;
    }

   void Employee::set_name(string new_name)
    {
        name = new_name;
    }

    void Employee::set_ssn(string new_ssn)
    {
        ssn = new_ssn;
    }

    void Employee::set_net_pay (double new_net_pay)
    {
        net_pay = new_net_pay;
    }

    void Employee::print_check( ) const
    {
        cout << "\nERROR: print_check FUNCTION CALLED FOR AN \n"
             << "UNDIFFERENTIATED EMPLOYEE. Aborting the program.\n"
             << "Check with the author of the program about this bug.\n";
        exit(1);
    }

}//employeessavitch
```

Display 15.3

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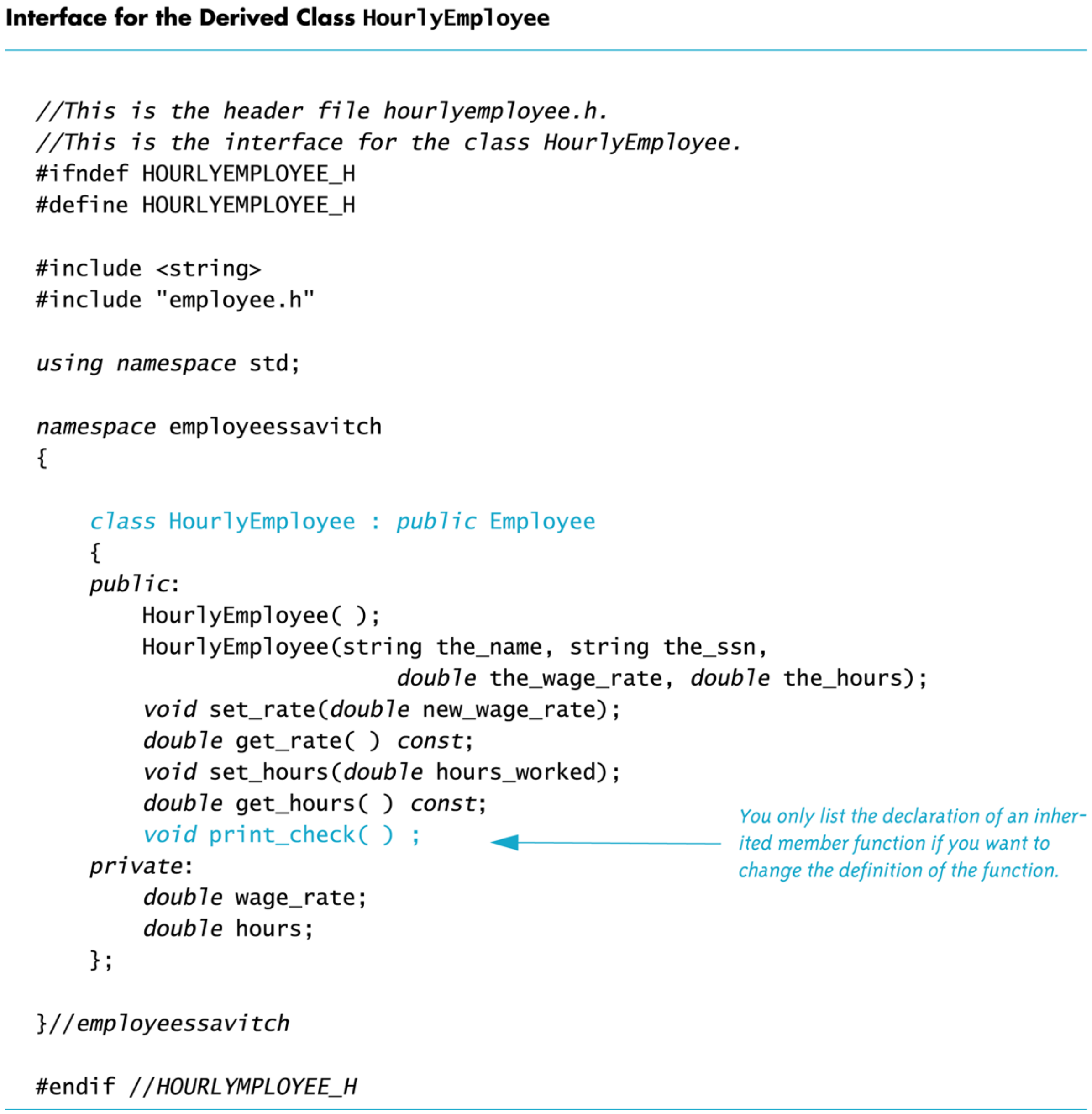

Interface for the Derived Class `HourlyEmployee`

```
//This is the header file hourlyemployee.h.
//This is the interface for the class HourlyEmployee.
#ifndef HOURLYEMPLOYEE_H
#define HOURLYEMPLOYEE_H

#include <string>
#include "employee.h"

using namespace std;

namespace employeessavitch
{

    class HourlyEmployee : public Employee
    {
    public:
        HourlyEmployee( );
        HourlyEmployee(string the_name, string the_ssn,
                          double the_wage_rate, double the_hours);
        void set_rate(double new_wage_rate);
        double get_rate( ) const;
        void set_hours(double hours_worked);
        double get_hours( ) const;
        void print_check( ) ;
    private:
        double wage_rate;
        double hours;
    };

}//employeessavitch

#endif //HOURLYMPLOYEE_H
```

You only list the declaration of an inherited member function if you want to change the definition of the function.

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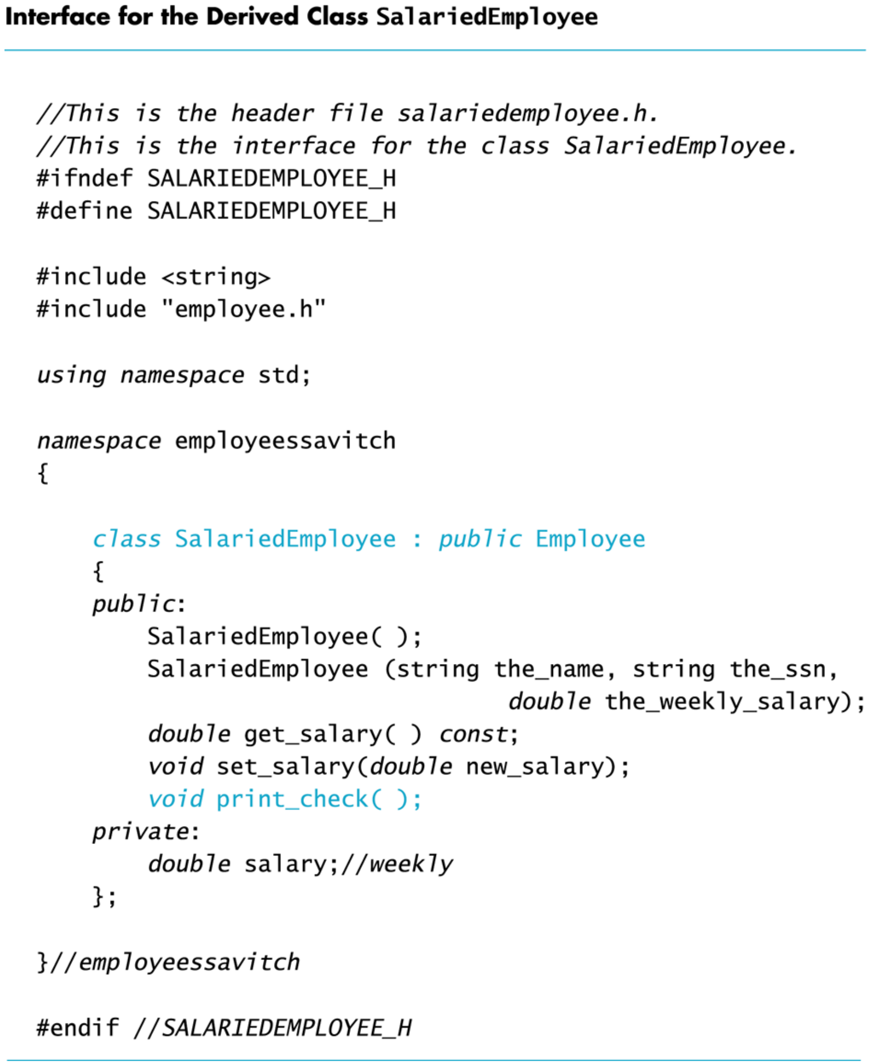

Interface for the Derived Class SalariedEmployee

```
//This is the header file salariedemployee.h.
//This is the interface for the class SalariedEmployee.
#ifndef SALARIEDEMPLOYEE_H
#define SALARIEDEMPLOYEE_H

#include <string>
#include "employee.h"

using namespace std;

namespace employeessavitch
{

    class SalariedEmployee : public Employee
    {
    public:
        SalariedEmployee( );
        SalariedEmployee (string the_name, string the_ssn,
                                   double the_weekly_salary);
        double get_salary( ) const;
        void set_salary(double new_salary);
        void print_check( );
    private:
        double salary;//weekly
    };

}//employeessavitch

#endif //SALARIEDEMPLOYEE_H
```

Display 15.5 (1/2)

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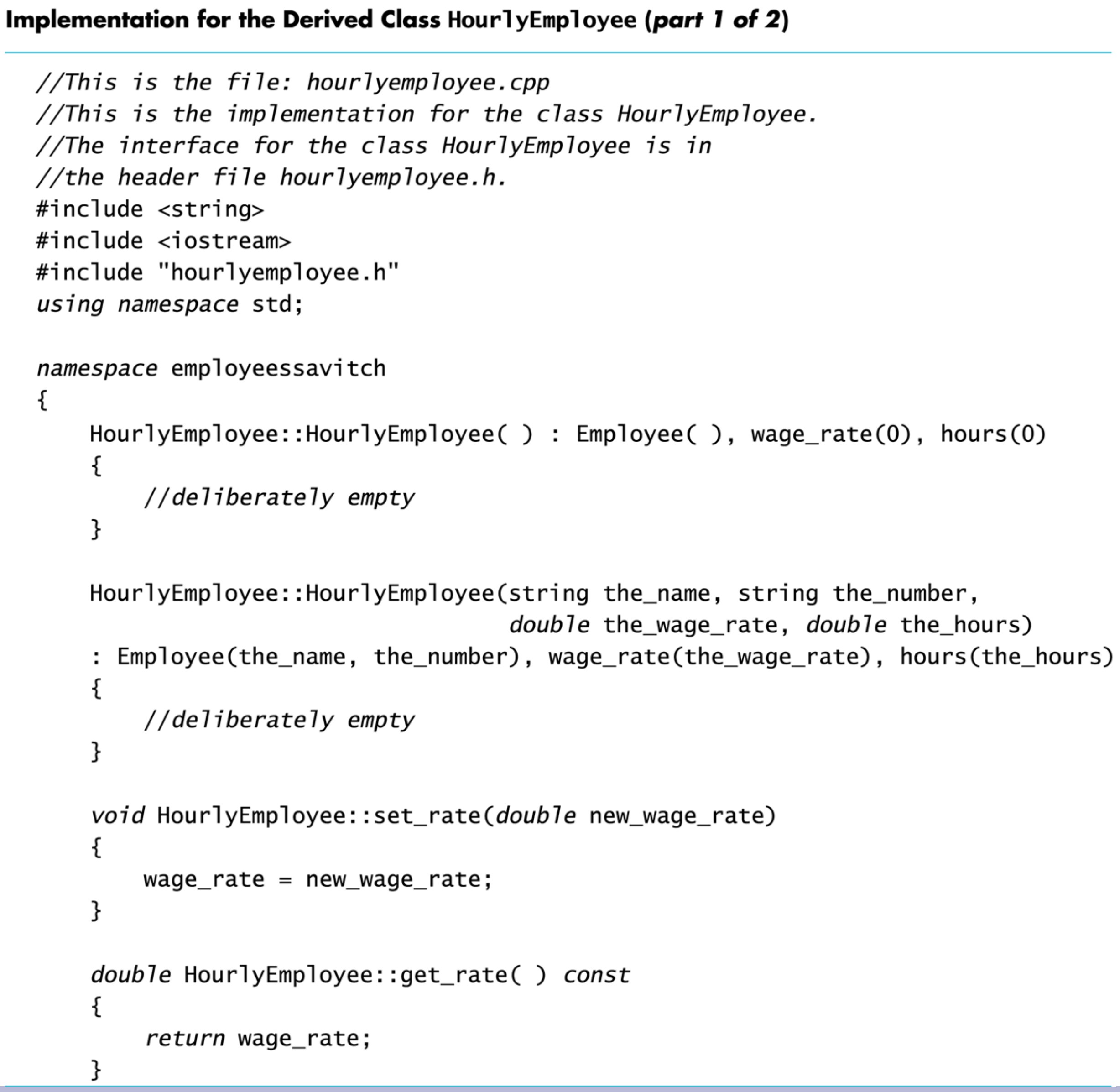

Implementation for the Derived Class `HourlyEmployee` (*part 1 of 2*)

```
//This is the file: hourlyemployee.cpp
//This is the implementation for the class HourlyEmployee.
//The interface for the class HourlyEmployee is in
//the header file hourlyemployee.h.
#include <string>
#include <iostream>
#include "hourlyemployee.h"
using namespace std;

namespace employeessavitch
{
    HourlyEmployee::HourlyEmployee( ) : Employee( ), wage_rate(0), hours(0)
    {
        //deliberately empty
    }

    HourlyEmployee::HourlyEmployee(string the_name, string the_number,
                                   double the_wage_rate, double the_hours)
    : Employee(the_name, the_number), wage_rate(the_wage_rate), hours(the_hours)
    {
        //deliberately empty
    }

    void HourlyEmployee::set_rate(double new_wage_rate)
    {
        wage_rate = new_wage_rate;
    }

    double HourlyEmployee::get_rate( ) const
    {
        return wage_rate;
    }
```

Display 15.5 (2/2)

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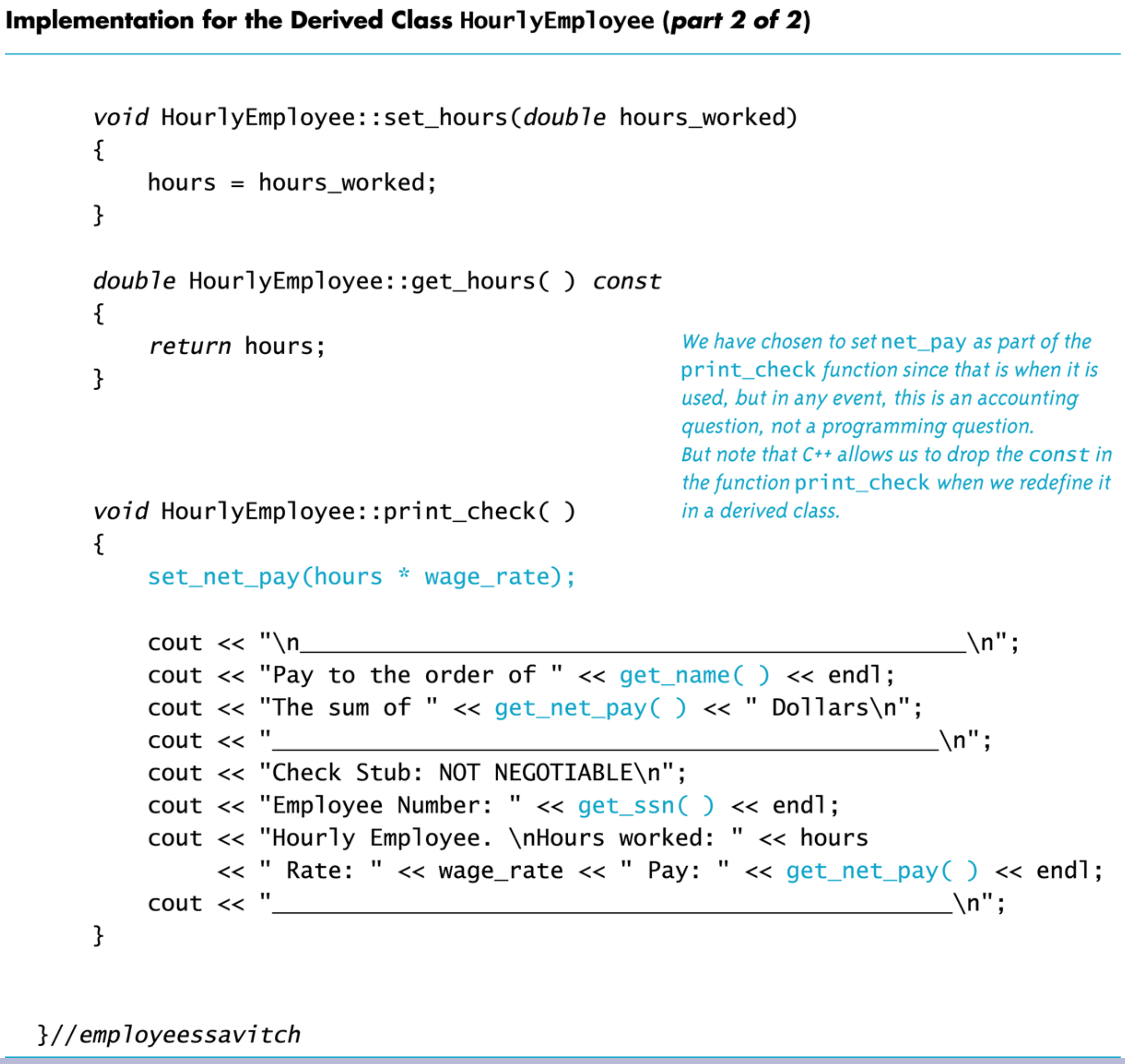

Implementation for the Derived Class `HourlyEmployee` (*part 2 of 2*)

```
    void HourlyEmployee::set_hours(double hours_worked)
    {
        hours = hours_worked;
    }

    double HourlyEmployee::get_hours( ) const
    {
        return hours;
    }



    void HourlyEmployee::print_check( )
    {
        set_net_pay(hours * wage_rate);

        cout << "\n________________________________________________\n";
        cout << "Pay to the order of " << get_name( ) << endl;
        cout << "The sum of " << get_net_pay( ) << " Dollars\n";
        cout << "________________________________________________\n";
        cout << "Check Stub: NOT NEGOTIABLE\n";
        cout << "Employee Number: " << get_ssn( ) << endl;
        cout << "Hourly Employee. \nHours worked: " << hours
             << " Rate: " << wage_rate << " Pay: " << get_net_pay( ) << endl;
        cout << "_________________________________________________\n";
    }


}//employeessavitch
```

We have chosen to set `net_pay` as part of the `print_check` function since that is when it is used, but in any event, this is an accounting question, not a programming question.
But note that C++ allows us to drop the `const` in the function `print_check` when we redefine it in a derived class.

Display 15.6 (1/2)

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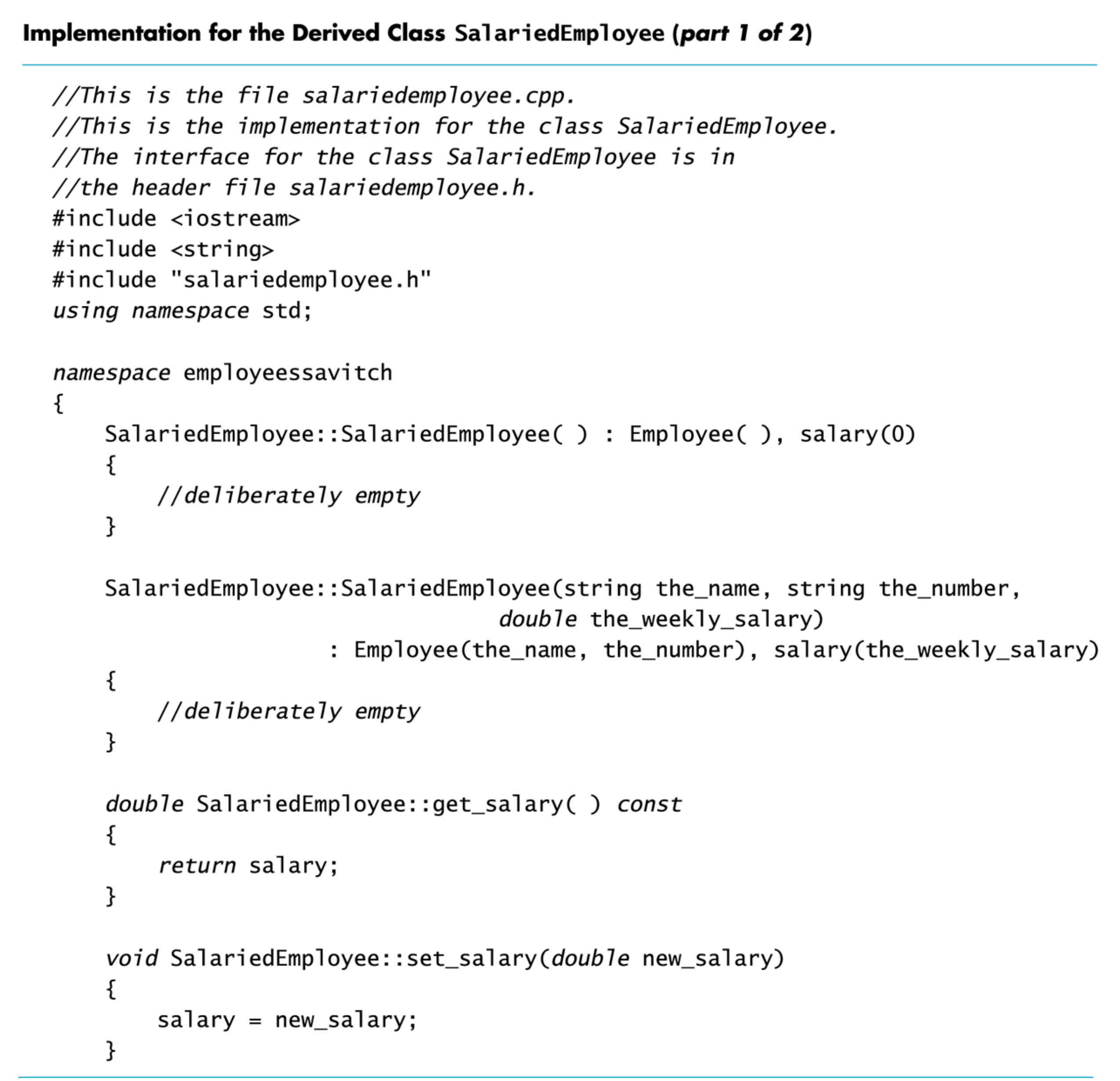

Implementation for the Derived Class SalariedEmployee (*part 1 of 2*)

```
//This is the file salariedemployee.cpp.
//This is the implementation for the class SalariedEmployee.
//The interface for the class SalariedEmployee is in
//the header file salariedemployee.h.
#include <iostream>
#include <string>
#include "salariedemployee.h"
using namespace std;

namespace employeessavitch
{
    SalariedEmployee::SalariedEmployee( ) : Employee( ), salary(0)
    {
        //deliberately empty
    }

    SalariedEmployee::SalariedEmployee(string the_name, string the_number,
                                  double the_weekly_salary)
                     : Employee(the_name, the_number), salary(the_weekly_salary)
    {
        //deliberately empty
    }

    double SalariedEmployee::get_salary( ) const
    {
        return salary;
    }

    void SalariedEmployee::set_salary(double new_salary)
    {
        salary = new_salary;
    }
```

Display 15.6 (2/2)

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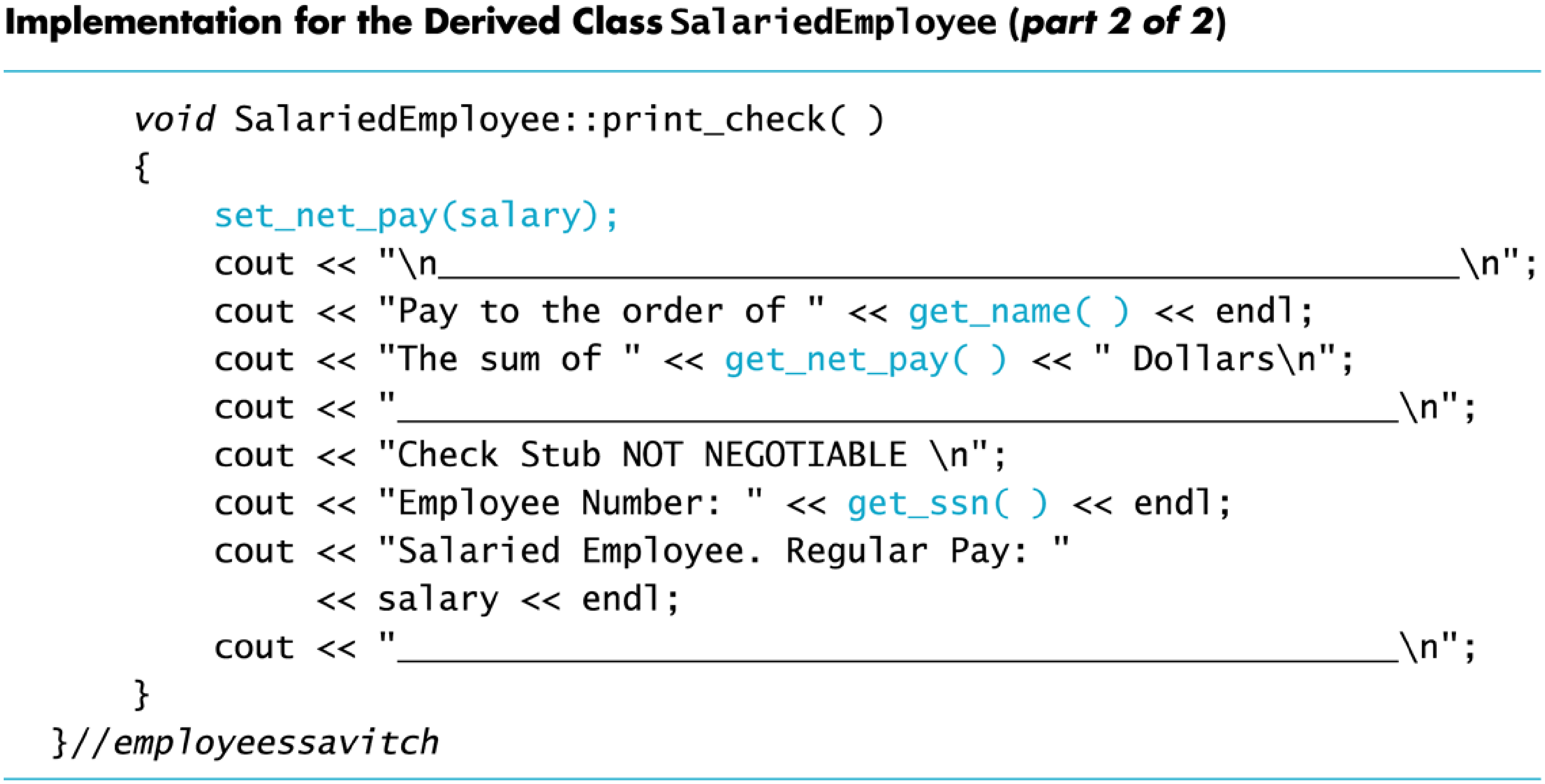

Implementation for the Derived Class SalariedEmployee (*part 2 of 2*)

```
    void SalariedEmployee::print_check( )
    {
        set_net_pay(salary);
        cout << "\n_________________________________________________\n";
        cout << "Pay to the order of " << get_name( ) << endl;
        cout << "The sum of " << get_net_pay( ) << " Dollars\n";
        cout << "_________________________________________________\n";
        cout << "Check Stub NOT NEGOTIABLE \n";
        cout << "Employee Number: " << get_ssn( ) << endl;
        cout << "Salaried Employee. Regular Pay: "
             << salary << endl;
        cout << "_________________________________________________\n";
    }
}//employeessavitch
```

Display 15.7 (1/2)

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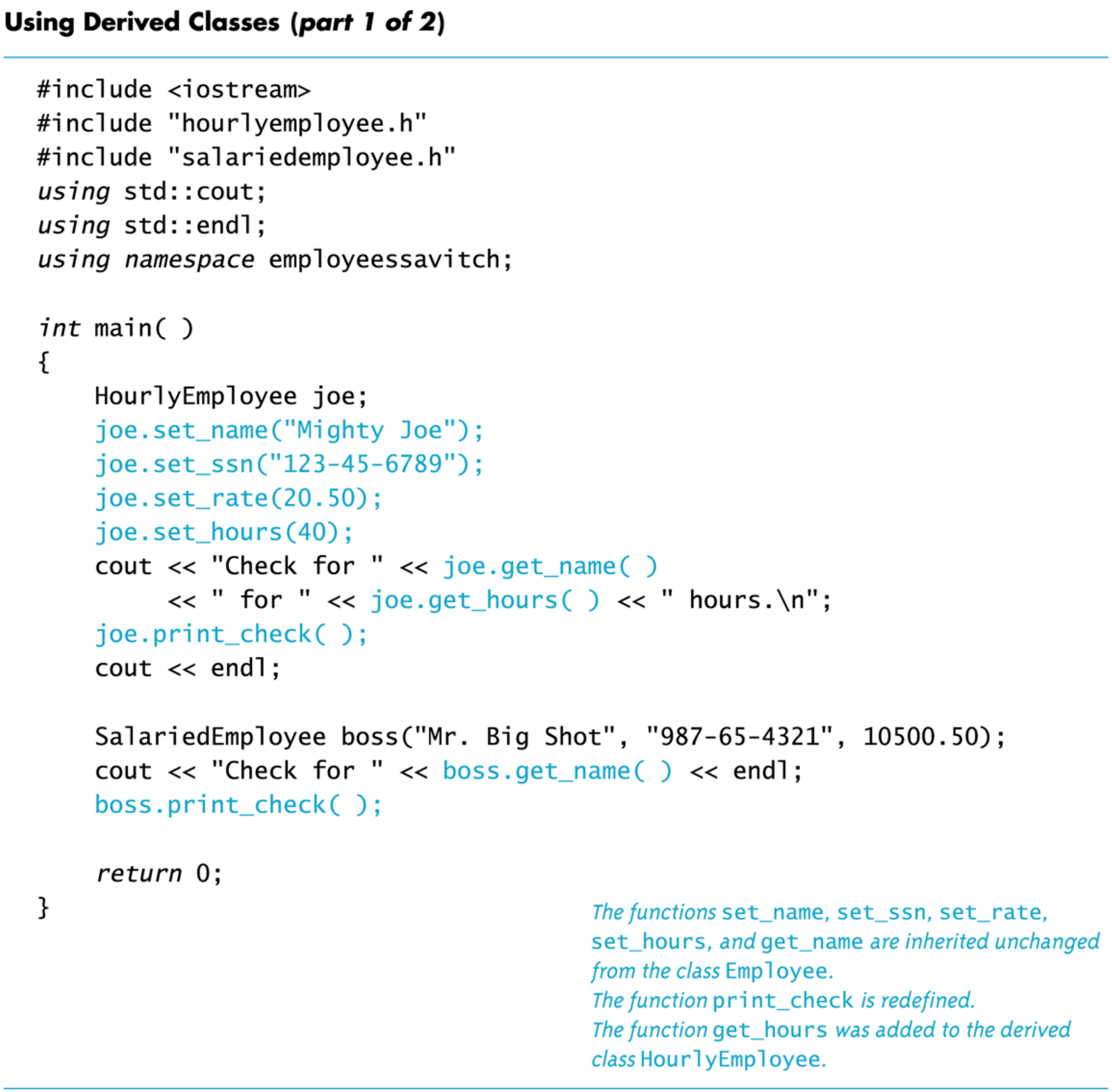

Using Derived Classes (*part 1 of 2*)

```
#include <iostream>
#include "hourlyemployee.h"
#include "salariedemployee.h"
using std::cout;
using std::endl;
using namespace employeessavitch;

int main( )
{
    HourlyEmployee joe;
    joe.set_name("Mighty Joe");
    joe.set_ssn("123-45-6789");
    joe.set_rate(20.50);
    joe.set_hours(40);
    cout << "Check for " << joe.get_name( )
         << " for " << joe.get_hours( ) << " hours.\n";
    joe.print_check( );
    cout << endl;

    SalariedEmployee boss("Mr. Big Shot", "987-65-4321", 10500.50);
    cout << "Check for " << boss.get_name( ) << endl;
    boss.print_check( );

    return 0;
}
```

The functions set_name, set_ssn, set_rate, set_hours, *and* get_name *are inherited unchanged from the class* Employee.
The function print_check *is redefined.*
The function get_hours *was added to the derived class* HourlyEmployee.

Display 15.7 (2/2)

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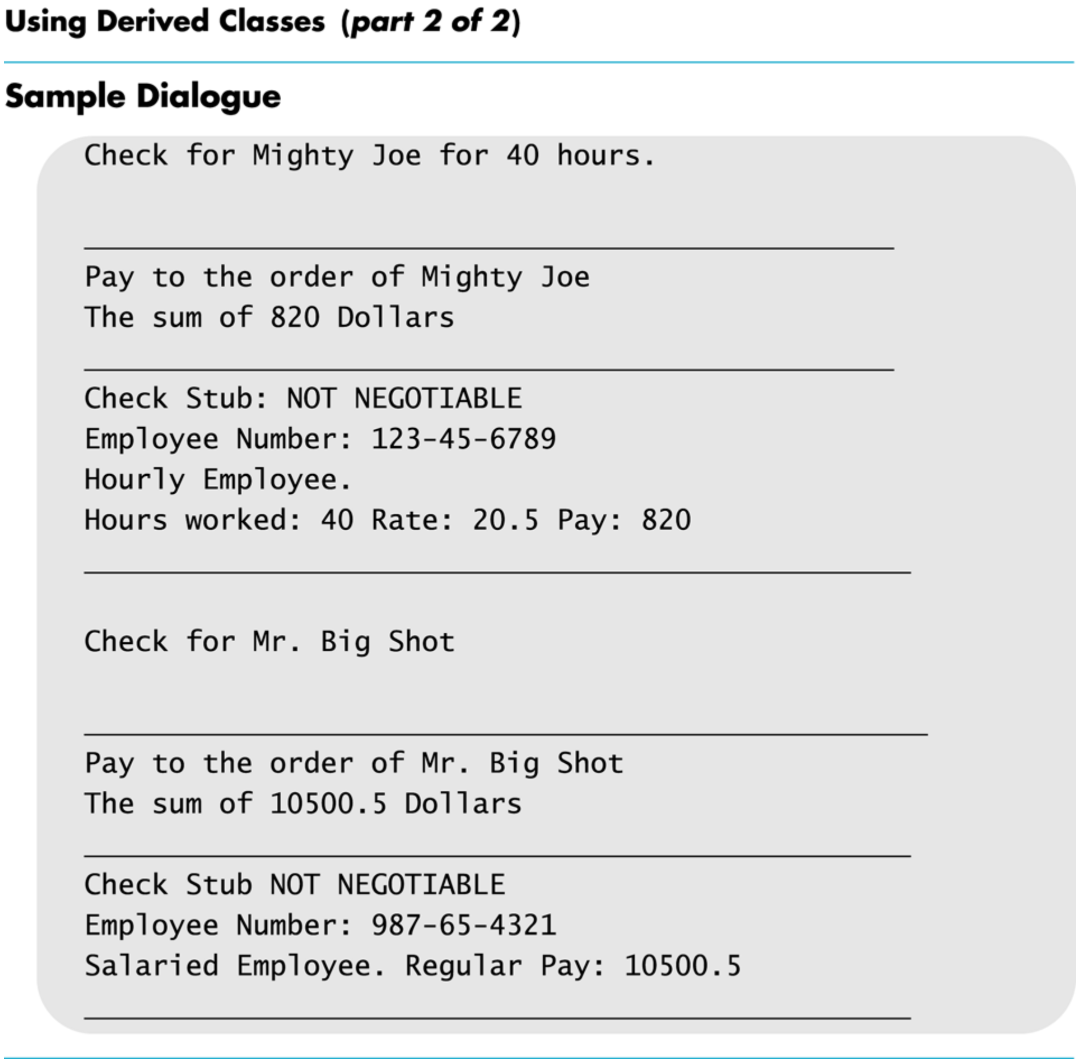

Using Derived Classes (*part 2 of 2*)

Sample Dialogue

```
Check for Mighty Joe for 40 hours.


________________________________________________
Pay to the order of Mighty Joe
The sum of 820 Dollars
________________________________________________
Check Stub: NOT NEGOTIABLE
Employee Number: 123-45-6789
Hourly Employee.
Hours worked: 40 Rate: 20.5 Pay: 820
_________________________________________________


Check for Mr. Big Shot


__________________________________________________
Pay to the order of Mr. Big Shot
The sum of 10500.5 Dollars
_________________________________________________
Check Stub NOT NEGOTIABLE
Employee Number: 987-65-4321
Salaried Employee. Regular Pay: 10500.5
_________________________________________________
```

Display 15.8

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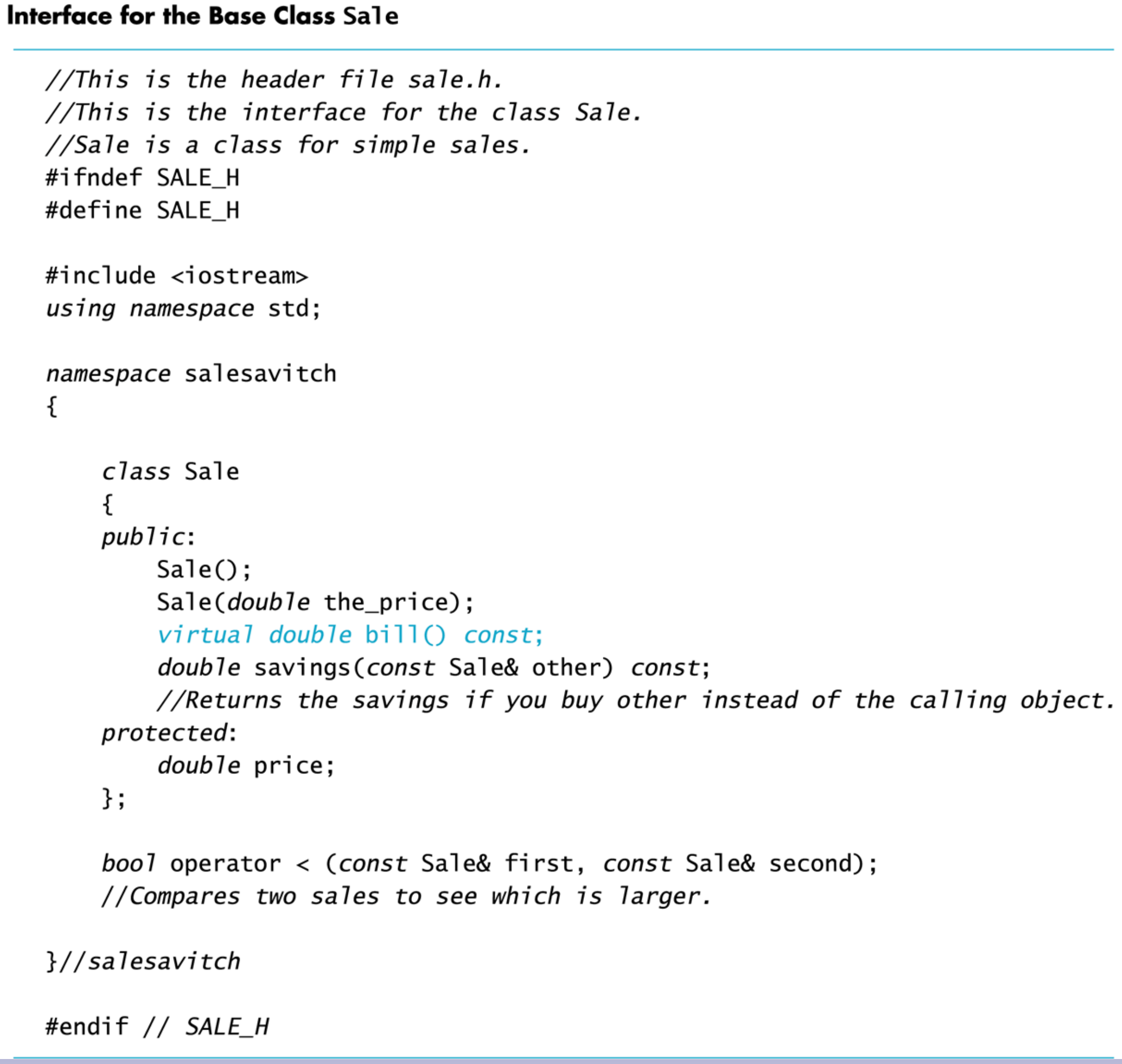

Interface for the Base Class Sale

```
//This is the header file sale.h.
//This is the interface for the class Sale.
//Sale is a class for simple sales.
#ifndef SALE_H
#define SALE_H

#include <iostream>
using namespace std;

namespace salesavitch
{

    class Sale
    {
    public:
        Sale();
        Sale(double the_price);
        virtual double bill() const;
        double savings(const Sale& other) const;
        //Returns the savings if you buy other instead of the calling object.
    protected:
        double price;
    };

    bool operator < (const Sale& first, const Sale& second);
    //Compares two sales to see which is larger.

}//salesavitch

#endif // SALE_H
```

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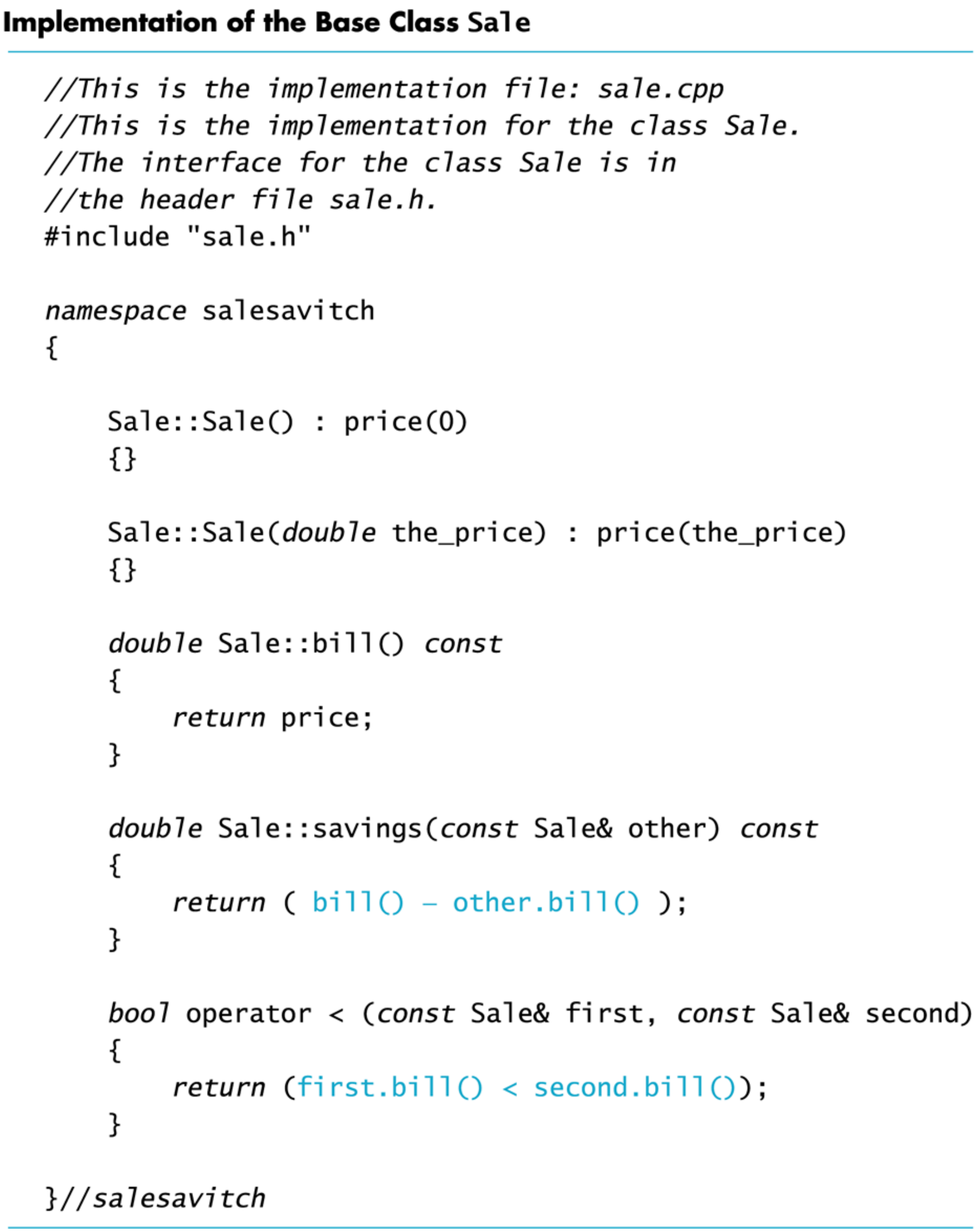

Implementation of the Base Class Sale

```
//This is the implementation file: sale.cpp
//This is the implementation for the class Sale.
//The interface for the class Sale is in
//the header file sale.h.
#include "sale.h"

namespace salesavitch
{

    Sale::Sale() : price(0)
    {}

    Sale::Sale(double the_price) : price(the_price)
    {}

    double Sale::bill() const
    {
        return price;
    }

    double Sale::savings(const Sale& other) const
    {
        return ( bill() - other.bill() );
    }

    bool operator < (const Sale& first, const Sale& second)
    {
        return (first.bill() < second.bill());
    }

}//salesavitch
```

Display 15.10

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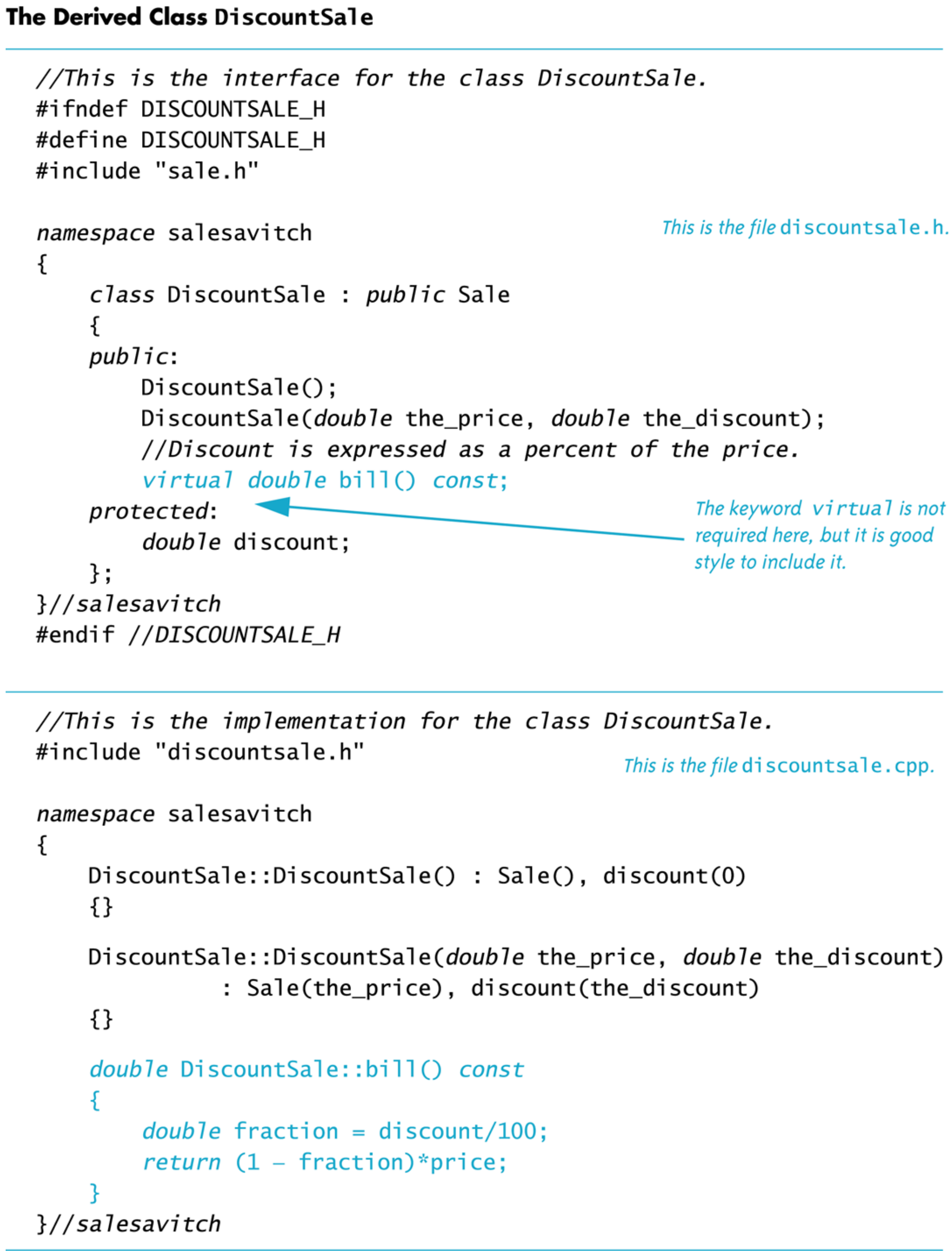

The Derived Class DiscountSale

```
//This is the interface for the class DiscountSale.
#ifndef DISCOUNTSALE_H
#define DISCOUNTSALE_H
#include "sale.h"

namespace salesavitch
{
    class DiscountSale : public Sale
    {
    public:
        DiscountSale();
        DiscountSale(double the_price, double the_discount);
        //Discount is expressed as a percent of the price.
        virtual double bill() const;
    protected:
        double discount;
    };
}//salesavitch
#endif //DISCOUNTSALE_H
```

This is the file discountsale.h.

The keyword virtual is not required here, but it is good style to include it.

```
//This is the implementation for the class DiscountSale.
#include "discountsale.h"

namespace salesavitch
{
    DiscountSale::DiscountSale() : Sale(), discount(0)
    {}

    DiscountSale::DiscountSale(double the_price, double the_discount)
              : Sale(the_price), discount(the_discount)
    {}

    double DiscountSale::bill() const
    {
        double fraction = discount/100;
        return (1 - fraction)*price;
    }
}//salesavitch
```

This is the file discountsale.cpp.

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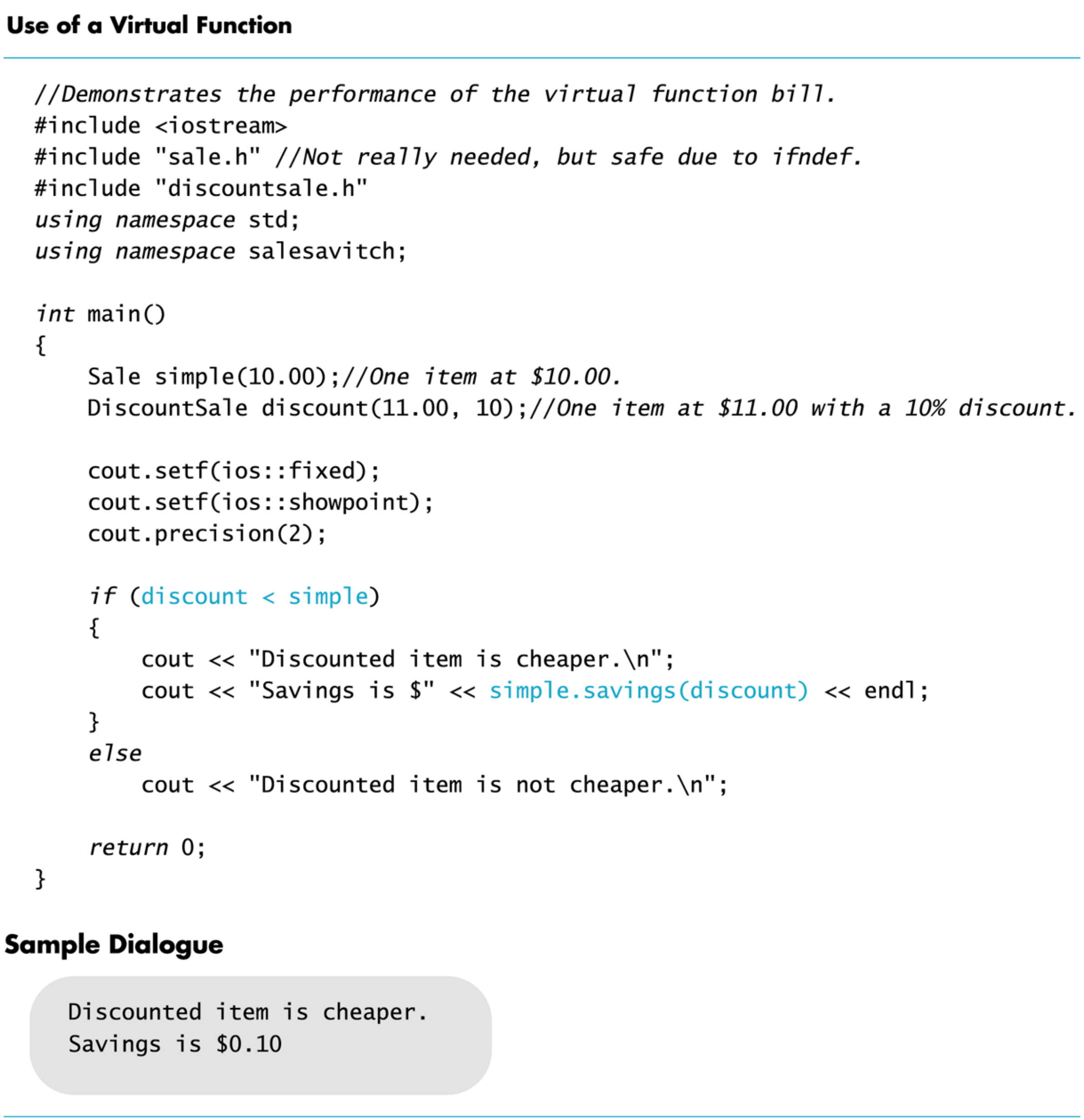

Use of a Virtual Function

```
//Demonstrates the performance of the virtual function bill.
#include <iostream>
#include "sale.h" //Not really needed, but safe due to ifndef.
#include "discountsale.h"
using namespace std;
using namespace salesavitch;

int main()
{
    Sale simple(10.00);//One item at $10.00.
    DiscountSale discount(11.00, 10);//One item at $11.00 with a 10% discount.

    cout.setf(ios::fixed);
    cout.setf(ios::showpoint);
    cout.precision(2);

    if (discount < simple)
    {
        cout << "Discounted item is cheaper.\n";
        cout << "Savings is $" << simple.savings(discount) << endl;
    }
    else
        cout << "Discounted item is not cheaper.\n";

    return 0;
}
```

Sample Dialogue

```
Discounted item is cheaper.
Savings is $0.10
```

Display 15.12 (1/2)

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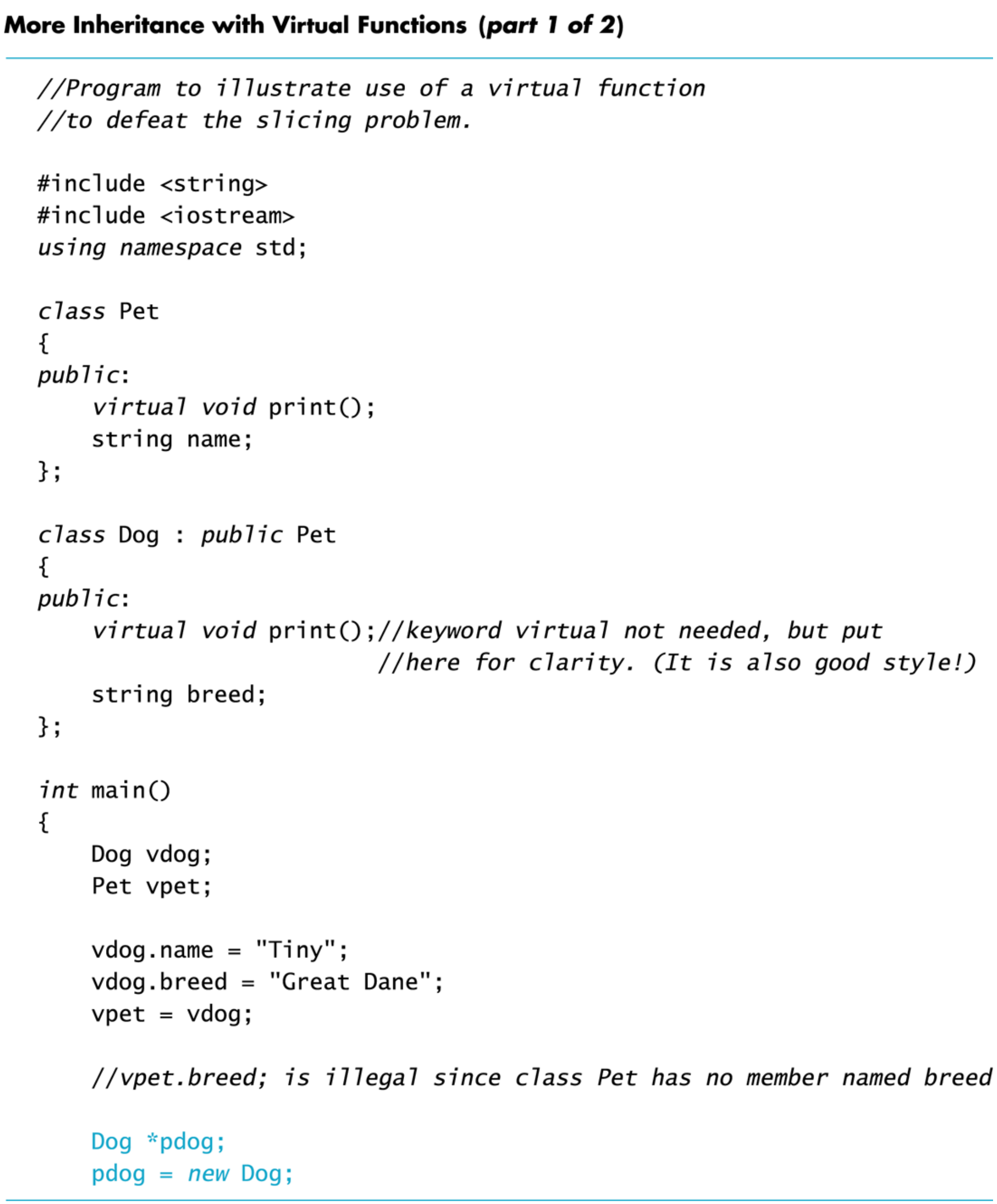

More Inheritance with Virtual Functions (*part 1 of 2*)

```
//Program to illustrate use of a virtual function
//to defeat the slicing problem.

#include <string>
#include <iostream>
using namespace std;

class Pet
{
public:
    virtual void print();
    string name;
};

class Dog : public Pet
{
public:
    virtual void print();//keyword virtual not needed, but put
                         //here for clarity. (It is also good style!)
    string breed;
};

int main()
{
    Dog vdog;
    Pet vpet;

    vdog.name = "Tiny";
    vdog.breed = "Great Dane";
    vpet = vdog;

    //vpet.breed; is illegal since class Pet has no member named breed

    Dog *pdog;
    pdog = new Dog;
```

Display 15.12 (2/2)

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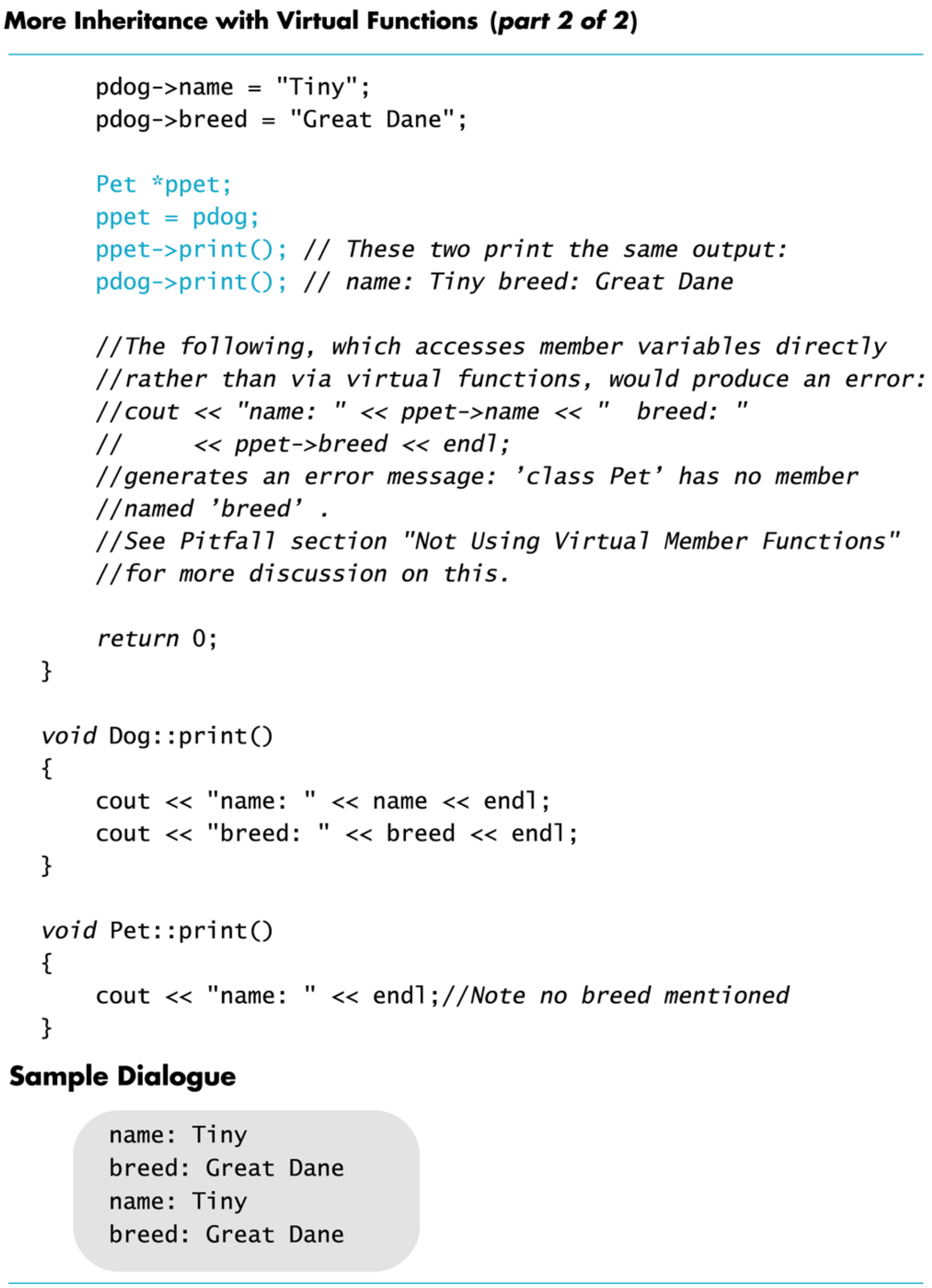

More Inheritance with Virtual Functions (*part 2 of 2*)

```
    pdog->name = "Tiny";
    pdog->breed = "Great Dane";

    Pet *ppet;
    ppet = pdog;
    ppet->print(); // These two print the same output:
    pdog->print(); // name: Tiny breed: Great Dane

    //The following, which accesses member variables directly
    //rather than via virtual functions, would produce an error:
    //cout << "name: " << ppet->name << "  breed: "
    //      << ppet->breed << endl;
    //generates an error message: 'class Pet' has no member
    //named 'breed' .
    //See Pitfall section "Not Using Virtual Member Functions"
    //for more discussion on this.

    return 0;
}

void Dog::print()
{
    cout << "name: " << name << endl;
    cout << "breed: " << breed << endl;
}

void Pet::print()
{
    cout << "name: " << endl;//Note no breed mentioned
}
```

Sample Dialogue

```
name: Tiny
breed: Great Dane
name: Tiny
breed: Great Dane
```