13

Object-Oriented Programming: Polymorphism

One Ring to rule them all,
One Ring to find them,
One Ring to bring them all
and in the darkness bind them.
—John Ronald Reuel Tolkien

The silence often of pure innocence
Persuades when speaking fails.
—William Shakespeare

General propositions do not decide concrete cases.
—Oliver Wendell Holmes

A philosopher of imposing stature doesn't think in a vacuum. Even his most abstract ideas are, to some extent, conditioned by what is or is not known in the time when he lives.
—Alfred North Whitehead

OBJECTIVES

In this chapter you'll learn:

- How polymorphism makes programming more convenient and systems more extensible.
- The distinction between abstract and concrete classes and how to create abstract classes.
- To use runtime type information (RTTI).
- How C++ implements `virtual` functions and dynamic binding.
- How `virtual` destructors ensure that all appropriate destructors run on an object.
- How polymorphism makes programming more convenient and systems more extensible.
- The distinction between abstract and concrete classes and how to create abstract classes.

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Assignment Checklist

Name: _____ **Date:** _____

Section: _____

Exercises	Assigned: Circle assignments	Date Due
Prelab Activities		
Matching	YES NO	
Fill in the Blank	11, 12, 13, 14, 15, 16, 17	
Short Answer	18, 19, 20, 21	
Programming Output	22, 23	
Correct the Code	24, 25, 26, 27	
Lab Exercises		
Lab Exercise — Polymorphic Banking	YES NO	
Debugging	YES NO	
Labs Provided by Instructor		
1.		
2.		
3.		
Postlab Activities		
Coding Exercises	1, 2, 3, 4, 5	
Programming Challenges	1, 2	

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Prelab Activities

Matching

Name: _____ **Date:** _____

Section: _____

After reading Chapter 13 of *C++ How to Program, Seventh Edition*, answer the given questions. These questions are intended to test and reinforce your understanding of key concepts and may be done either before the lab or during the lab.

For each term in the column on the left, write the corresponding letter for the description that best matches it from the column on the right.

	Term	Description
___	1. `virtual` function	a) Class that is defined, but never intended to be used by the programmer to create objects.
___	2. `virtual` function table	b) Function prototypes that end with "`= 0`."
___	3. Override a `virtual` function	c) Allows objects of different classes related by inheritance to respond differently to the same message.
___	4. Dynamic binding	d) Part of C++'s run-time type information.
___	5. `virtual` base-class destructor	e) Process of replacing an inherited base-class member function with a derived-class one.
___	6. Abstract base class	f) Programming "in the general."
___	7. Pure `virtual` function	g) An executing program uses this to select the proper function implementation each time a virtual function is called.
___	8. Polymorphism	h) Occurs only off pointer or reference handles.
___	9. Concrete class	i) Ensures proper cleanup when processing dynamically allocated objects in a class hierarchy, polymorphically.
___	10. `typeid`	j) Class from which objects can be instantiated.

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Prelab Activities

Name:

Fill in the Blank

Name: _____ **Date:** _____

Section: _____

Fill in the blank for each of the following statements:

11. _____ functions allow programs to be written to process objects of types that may not exist when the program is under development.

12. _____ is implemented via `virtual` functions and dynamic binding.

13. Classes from which objects can be _____ are called concrete classes.

14. A class is made abstract by declaring one or more _____.

15. Resolving `virtual` function references at compile-time is known as _____.

16. Objects of a(n) _____ class cannot be instantiated in a program.

17. A class with `0` pointers in the *vtable* is a(n) _____ class.

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Prelab Activities

Name:

Short Answer

Name: _____ **Date:** _____

Section: _____

In the space provided, answer each of the given questions. Your answers should be concise; aim for two or three sentences.

18. Discuss some of the problems that arise when using `switch` logic to process different objects. How do virtual functions and polymorphic programming eliminate the need for `switch` logic?

19. Briefly discuss what a *vtable* is and how it keeps track of `virtual` functions.

20. What problem arises in polymorphism when cleaning up dynamically allocated objects of a class hierarchy that has non-`virtual` destructors? How is it resolved?

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Prelab Activities

Name:

Short Answer

21. What are some of the program-design advantages of using polymorphism?

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Prelab Activities

Name:

Programming Output

Name: _____ **Date:** _____

Section: _____

For each of the given program segments, read the code and write the output in the space provided below each program. [*Note:* Do not execute these programs on a computer.]

For *Programming Output Exercises 22* and *23*, use the class definitions in Fig. L 13.1.

```
1  #include <iostream>
2  #include <string>
3  using namespace std;
4
5  // class Oyster definition
6  class Oyster
7  {
8  public:
9     // constructor
10    Oyster( string genusString )
11    {
12       genus = genusString;
13    } // end class Oyster constructor
14
15    // function getPhylum definition
16    string getPhylum() const
17    {
18       return "Mollusca";
19    } // end function getPhylum
20
21    // function getName definition
22    virtual string getName() const
23    {
24       return "Oyster class";
25    } // end function getName
26
27    // function getGenus definition
28    string getGenus() const
29    {
30       return genus;
31    } // end function getGenus
32
33    // print function
34    virtual void print() const = 0;
35 private:
36    string genus;
37 }; // end class Oyster
38
```

Fig. L 13.1 | `Oyster.cpp`. (Part 1 of 2.)

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Prelab Activities

Name:

Programming Output

```
39  // class VirginiaOyster definition
40  class VirginiaOyster : public Oyster
41  {
42  public:
43     // constructor calls base-class constructor
44     VirginiaOyster()
45        : Oyster( "Crassostrea" )
46     {
47        // empty
48     } // end class VirginiaOyster constructor
49
50     // function getName definition
51     virtual string getName() const
52     {
53        return "VirginiaOyster class";
54     } // end function getName
55
56     // print function
57     virtual void print() const
58     {
59        cout << "Phylum: " << getPhylum()
60             << "\tGenus: " << getGenus();
61     } // end print function
62  }; // end class VirginiaOyster
```

Fig. L 13.1 | `Oyster.cpp`. (Part 2 of 2.)

22. What is output by the following program? Use class `Oyster` and `VirginiaOyster` (Fig. L 13.1).

```
1  #include <iostream>
2  using namespace std;
3
4  #include "Oyster.cpp"
5
6  int main()
7  {
8     VirginiaOyster oyster;
9     Oyster *baseClassPtr;
10
11    baseClassPtr = &oyster;
12    baseClassPtr->print();
13
14    cout << endl;
15 } // end main
```

Your answer:

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Prelab Activities

Name:

Programming Output

23. What is output by the following program segment? Assume that the `Oyster` class member function `print` has been changed to that shown below.

```
// function print definition
virtual void print() const
{
   cout << "Oysters belong to Phylum " << getPhylum() << endl;
} // end function print
```

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

#include "oyster.cpp"

int main()
{
   VirginiaOyster *ptr;
   VirginiaOyster oyster;
   Oyster *oysterPtr;

   oysterPtr = &oyster;
   ptr = &oyster;

   ptr -> print();
   cout << endl;

   oysterPtr -> print();
   cout << endl << oysterPtr -> getPhylum();

   cout << endl;
} // end main
```

Your answer:

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Prelab Activities

Name:

Correct the Code

Name: _____ **Date:** _____

Section: _____

For each of the given program segments, determine if there is an error in the code. If there is an error, specify whether it is a logic or compilation error, circle the error in the program, and write the corrected code in the space provided after each problem. If the code does not contain an error, write "no error." [*Note*: It is possible that a program segment may contain multiple errors.]

24. The following code defines an abstract class named `Base`:

```
1  // class Base definition
2  class Base
3  {
4  public:
5     void print() const;
6  }; // end class Base
```

Your answer:

25. The following is a modified version of the definition of class `VirginiaOyster` from Fig. L 13.1. Assume member function `print` is defined in another file.

```
1  // class VirginiaOyster definition
2  class VirginiaOyster : public Oyster
3  {
4  public:
5     // constructor
6     virtual VirginiaOyster( string genusString )
7     {
8        genus = genusString;
9     } // end class VirginiaOyster constructor
10
```

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Prelab Activities

Name:

Correct the Code

```
11     // constructor
12     VirginiaOyster( char *genusString )
13     {
14        genus = genusString;
15     } // end class VirginiaOyster constructor
16
17     // print function
18     void print() const;
19  }; // end class VirginiaOyster
```

Your answer:

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Prelab Activities

Name:

Correct the Code

26. The following program defines two classes—`BaseClass` and `DerivedClass`—and instantiates an object of type `BaseClass`. [*Note:* Only the definitions for `BaseClass` and `DerivedClass` are shown; assume that another file is provided that contains the classes' implementations.]

```
1  // class BaseClass definition
2  class BaseClass
3  {
4  public:
5     BaseClass( int = 0, int = 0 );
6     virtual void display() = 0;
7  private:
8     int x;
9     int y;
10 }; // end class BaseClass
11
12 // class DerivedClass definition
13 class DerivedClass
14 {
15 public:
16    DerivedClass( int = 0, int = 0, int = 0 );
17    virtual void display();
18 private:
19    int z;
20 }; // end class BaseClass
21
22 int main()
23 {
24    BaseClass b( 5, 10 );
25    b.display();
26 } // end main
```

Your answer:

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Prelab Activities

Name:

Correct the Code

27. The following program segments define two classes: `Name` and `NameAndWeight`. `Name` should be an abstract base class and `NameAndWeight` should be a concrete derived class. Function `main` should declare an object of type `NameAndWeight` and print its `name` and `weight`. [*Note:* Only the definitions for `Name` and `NameAndWeight` are shown; assume files containing member function definitions have been provided elsewhere.]

```
1  // class Name definition
2  class Name
3  {
4  public:
5     Name( string );
6     virtual void printName() const = 0;
7  private:
8     string name;
9  }; // end class Name
10
11 // class NameAndWeight definition
12 class NameAndWeight : public Name
13 {
14 public:
15    NameAndWeight( string, int = 0 );
16    virtual void displayWeight() const;
17 private:
18    int weight;
19 }; // end class NameAndWeight
```

```
1  #include <iostream>
2  using namespace std;
3
4  int main()
5  {
6     NameAndWeight object( "name", 100 );
7
8     cout << "name: " << object.printName() << endl;
9     cout << "weight: " << object.displayWeight() << endl;
10 } // end main
```

Your answer:

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Lab Exercises

Lab Exercise — Polymorphic Banking

Name: _____ **Date:** _____

Section: _____

This problem is intended to be solved in a closed-lab session with a teaching assistant or instructor present. The problem is divided into five parts:

1. Lab Objectives
2. Description of the Problem
3. Sample Output
4. Program Template (Fig. L 13.2–Fig. L 13.8)
5. Problem-Solving Tips

The program template represents a complete working C++ program, with one or more key lines of code replaced with comments. Read the problem description and examine the sample output; then study the template code. Using the problem-solving tips as a guide, replace the `/* */` comments with C++ code. Compile and execute the program. Compare your output with the sample output provided. The source code for the template is available from the Companion Website for *C++ How to Program, Seventh Edition* at `www.pearsonhighered.com/deitel/`.

Lab Objectives

This lab was designed to reinforce programming concepts from Chapter 13 of *C++ How To Program, Seventh Edition*. In this lab, you will practice:

- Creating an `Account` base class that contains `virtual` functions and derived classes `SavingsAccount` and `CheckingAccount`.
- Defining `virtual` functions.
- Calling `virtual` functions.
- Downcasting with a pointer with the `dynamic_cast` operator.

Description of the Problem

Develop a polymorphic banking program using the `Account` hierarchy created in Exercise 12.10. Create a `vector` of `Account` pointers to `SavingsAccount` and `CheckingAccount` objects. For each `Account` in the `vector`, allow the user to specify an amount of money to withdraw from the `Account` using member function `debit` and an amount of money to deposit into the `Account` using member function `credit`. As you process each `Account`, determine its type. If an `Account` is a `SavingsAccount`, calculate the amount of interest owed to the `Account` using member function `calculateInterest`, then add the interest to the account balance using member function `credit`. After processing an `Account`, print the updated account balance obtained by invoking base class member function `getBalance`.

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Lab Exercises

Name:

Lab Exercise — Polymorphic Banking

Sample Output

```
Account 1 balance: $25.00
Enter an amount to withdraw from Account 1: 15.00
Enter an amount to deposit into Account 1: 10.50
Adding $0.61 interest to Account 1 (a SavingsAccount)
Updated Account 1 balance: $21.11

Account 2 balance: $80.00
Enter an amount to withdraw from Account 2: 90.00
Debit amount exceeded account balance.
Enter an amount to deposit into Account 2: 45.00
$1.00 transaction fee charged.
Updated Account 2 balance: $124.00

Account 3 balance: $200.00
Enter an amount to withdraw from Account 3: 75.50
Enter an amount to deposit into Account 3: 300.00
Adding $6.37 interest to Account 3 (a SavingsAccount)
Updated Account 3 balance: $430.87

Account 4 balance: $400.00
Enter an amount to withdraw from Account 4: 56.81
$0.50 transaction fee charged.
Enter an amount to deposit into Account 4: 37.83
$0.50 transaction fee charged.
Updated Account 4 balance: $380.02
```

Template

```
1  // Lab 1: Account.h
2  // Definition of Account class.
3  #ifndef ACCOUNT_H
4  #define ACCOUNT_H
5
6  class Account
7  {
8  public:
9     Account( double ); // constructor initializes balance
10    /* Write a function prototype for virtual function credit */
11    /* Write a function prototype for virtual function debit */
12    void setBalance( double ); // sets the account balance
13    double getBalance(); // return the account balance
14 private:
15    double balance; // data member that stores the balance
16 }; // end class Account
17
18 #endif
```

Fig. L 13.2 | Account.h.

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Lab Exercises

Name:

Lab Exercise — Polymorphic Banking

```
1  // Lab 1: Account.cpp
2  // Member-function definitions for class Account.
3  #include <iostream>
4  using namespace std;
5
6  #include "Account.h" // include definition of class Account
7
8  // Account constructor initializes data member balance
9  Account::Account( double initialBalance )
10 {
11    // if initialBalance is greater than or equal to 0.0, set this value
12    // as the balance of the Account
13    if ( initialBalance >= 0.0 )
14       balance = initialBalance;
15    else // otherwise, output message and set balance to 0.0
16    {
17       cout << "Error: Initial balance cannot be negative." << endl;
18       balance = 0.0;
19    } // end if...else
20 } // end Account constructor
21
22 // credit (add) an amount to the account balance
23 void Account::credit( double amount )
24 {
25    balance = balance + amount; // add amount to balance
26 } // end function credit
27
28 // debit (subtract) an amount from the account balance
29 // return bool indicating whether money was debited
30 bool Account::debit( double amount )
31 {
32    if ( amount > balance ) // debit amount exceeds balance
33    {
34       cout << "Debit amount exceeded account balance." << endl;
35       return false;
36    } // end if
37    else // debit amount does not exceed balance
38    {
39       balance = balance - amount;
40       return true;
41    } // end else
42 } // end function debit
43
44 // set the account balance
45 void Account::setBalance( double newBalance )
46 {
47    balance = newBalance;
48 } // end function setBalance
49
50 // return the account balance
51 double Account::getBalance()
52 {
53    return balance;
54 } // end function getBalance
```

Fig. L 13.3 | `Account.cpp`.

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Lab Exercises

Name:

Lab Exercise — Polymorphic Banking

```
// Lab 1: SavingsAccount.h
// Definition of SavingsAccount class.
#ifndef SAVINGS_H
#define SAVINGS_H

#include "Account.h" // Account class definition

class SavingsAccount : public Account
{
public:
   // constructor initializes balance and interest rate
   SavingsAccount( double, double );

   double calculateInterest(); // determine interest owed
private:
   double interestRate; // interest rate (percentage) earned by account
}; // end class SavingsAccount

#endif
```

Fig. L 13.4 | SavingsAccount.h.

```
// Lab 1: SavingsAccount.cpp
// Member-function definitions for class SavingsAccount.
#include "SavingsAccount.h" // SavingsAccount class definition

// constructor initializes balance and interest rate
SavingsAccount::SavingsAccount( double initialBalance, double rate )
   : Account( initialBalance ) // initialize base class
{
   interestRate = ( rate < 0.0 ) ? 0.0 : rate; // set interestRate
} // end SavingsAccount constructor

// return the amount of interest earned
double SavingsAccount::calculateInterest()
{
   return getBalance() * interestRate;
} // end function calculateInterest
```

Fig. L 13.5 | SavingsAccount.cpp.

```
// Lab 1: CheckingAccount.h
// Definition of CheckingAccount class.
#ifndef CHECKING_H
#define CHECKING_H

#include "Account.h" // Account class definition

class CheckingAccount : public Account
{
public:
   // constructor initializes balance and transaction fee
   CheckingAccount( double, double );

```

Fig. L 13.6 | CheckingAccount.h (Part 1 of 2.)

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Lab Exercises

Name:

Lab Exercise — Polymorphic Banking

```
14    /* Write a function prototype for virtual function credit,
15       which will redefine the inherited credit function */
16    /* Write a function prototype for virtual function debit,
17       which will redefine the inherited debit function */
18 private:
19    double transactionFee; // fee charged per transaction
20
21    // utility function to charge fee
22    void chargeFee();
23 }; // end class CheckingAccount
24
25 #endif
```

Fig. L 13.6 | `CheckingAccount.h`. (Part 2 of 2.)

```
1  // Lab 1: CheckingAccount.cpp
2  // Member-function definitions for class CheckingAccount.
3  #include <iostream>
4  using namespace std;
5
6  #include "CheckingAccount.h" // CheckingAccount class definition
7
8  // constructor initializes balance and transaction fee
9  CheckingAccount::CheckingAccount( double initialBalance, double fee )
10    : Account( initialBalance ) // initialize base class
11 {
12    transactionFee = ( fee < 0.0 ) ? 0.0 : fee; // set transaction fee
13 } // end CheckingAccount constructor
14
15 // credit (add) an amount to the account balance and charge fee
16 void CheckingAccount::credit( double amount )
17 {
18    Account::credit( amount ); // always succeeds
19    chargeFee();
20 } // end function credit
21
22 // debit (subtract) an amount from the account balance and charge fee
23 bool CheckingAccount::debit( double amount )
24 {
25    bool success = Account::debit( amount ); // attempt to debit
26
27    if ( success ) // if money was debited, charge fee and return true
28    {
29       chargeFee();
30       return true;
31    } // end if
32    else // otherwise, do not charge fee and return false
33       return false;
34 } // end function debit
35
36 // subtract transaction fee
37 void CheckingAccount::chargeFee()
38 {
39    Account::setBalance( getBalance() - transactionFee );
```

Fig. L 13.7 | `CheckingAccount.cpp`. (Part 1 of 2.)

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Lab Exercises

Name:

Lab Exercise — Polymorphic Banking

```
40       cout << "$" << transactionFee << " transaction fee charged." << endl;
41    } // end function chargeFee
```

Fig. L 13.7 | CheckingAccount.cpp. (Part 2 of 2.)

```
1   // Lab 1: polymorphicBanking.cpp
2   // Processing Accounts polymorphically.
3   #include <iostream>
4   #include <iomanip>
5   #include <vector>
6   using namespace std;
7
8   #include "Account.h" // Account class definition
9   #include "SavingsAccount.h" // SavingsAccount class definition
10  #include "CheckingAccount.h" // CheckingAccount class definition
11
12  int main()
13  {
14     // create vector accounts
15     /* Write declarations for a vector of four pointers
16        to Account objects, called accounts */
17
18     // initialize vector with Accounts
19     accounts[ 0 ] = new SavingsAccount( 25.0, .03 );
20     accounts[ 1 ] = new CheckingAccount( 80.0, 1.0 );
21     accounts[ 2 ] = new SavingsAccount( 200.0, .015 );
22     accounts[ 3 ] = new CheckingAccount( 400.0, .5 );
23
24     cout << fixed << setprecision( 2 );
25
26     // loop through vector, prompting user for debit and credit amounts
27     for ( size_t i = 0; i < accounts.size(); i++ )
28     {
29        cout << "Account " << i + 1 << " balance: $"
30           << /* Call the getBalance function through Account pointer i */;
31
32        double withdrawalAmount = 0.0;
33        cout << "\nEnter an amount to withdraw from Account " << i + 1
34           << ": ";
35        cin >> withdrawalAmount;
36        /* Call the debit function through Account pointer i */
37
38        double depositAmount = 0.0;
39        cout << "Enter an amount to deposit into Account " << i + 1
40           << ": ";
41        cin >> depositAmount;
42        /* Call the credit function through Account pointer i */
43
44        // downcast pointer
45        SavingsAccount *savingsAccountPtr =
46           /* Write a dynamic_cast operation to to attempt to downcast
47              Account pointer i to a SavingsAccount pointer */
48
```

Fig. L 13.8 | polymorphicBanking.cpp. (Part 1 of 2.)

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Lab Exercises

Name:

Lab Exercise — Polymorphic Banking

```
49         // if Account is a SavingsAccount, calculate and add interest
50         if ( /* Write a test to determine if savingsAccountPtr isn't 0 */ )
51         {
52            double interestEarned = /* Call member function calculateInterest
53                                     through savingsAccountPtr */;
54            cout << "Adding $" << interestEarned << " interest to Account "
55               << i + 1 << " (a SavingsAccount)" << endl;
56            /* Use the credit function to credit interestEarned to
57               the SavingsAccount pointed to by savingsAccountPtr*/
58         } // end if
59
60         cout << "Updated Account " << i + 1 << " balance: $"
61            << /* Call the getBalance function through Account pointer i */
62            << "\n\n";
63      } // end for
64   } // end main
```

Fig. L 13.8 | `polymorphicBanking.cpp`. (Part 2 of 2.)

Problem-Solving Tips

1. To achieve polymorphism, declare the functions that should be called polymorphically as `virtual`. To indicate a `virtual` function within a class definition, add "`virtual`" before the function prototype. When the `virtual` functions are redefined in a derived class, those member function prototypes should also be preceded by the keyword `virtual` as a good programming practice.
2. To determine if a pointer to an `Account` object is actually pointing to a `SavingsAccount` object, downcast it to a `SavingsAccount *` using the `dynamic_cast` operator. If the pointer returned by this operation is not the null pointer (i.e., `0`) then the object is a `SavingsAccount` object and that pointer can be used to access members unique to class `SavingsAccount`.
3. Remember that your compiler may require you to enable run-time type information (RTTI) for this particular project before this program will run correctly.

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Lab Exercises

Name:

Debugging

Name: _____ **Date:** _____

Section: _____

The program (Fig. L 13.9–Fig. L 13.15) in this section does not run properly. Fix all the compilation errors so that the program will compile successfully. Once the program compiles, compare the output with the sample output, and eliminate any logic errors that may exist. The sample output demonstrates what the program's output should be once the program's code has been corrected.

Sample Output

```
This animal is a lion
This animal's height and weight are as follows:
Height: 45      Weight: 300

Enter a new height (using standard units): 50
Enter a new weight (using standard units): 400
Here are the new height and weight values
50
400

This animal is a dog, its name is: Fido
This animal's height and weight are as follows:
Height: 60      Weight: 120

Enter a new height (using standard units): 50
Enter a new weight (using standard units): 116
Which units would you like to see the height in? (Enter 1 or 2)
        1. metric
        2. standard
2
Which units would you like to see the weight in? (Enter 1 or 2)
        1. metric
        2. standard
1
Here are the new height and weight values
50
52
```

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Lab Exercises

Name:

Debugging

Broken Code

```
1  // Debugging: Animal.h
2  #ifndef ANIMAL_H
3  #define ANIMAL_H
4
5  #include <string>
6  using namespace std;
7
8  // Note: class Animal is an abstract class
9  // class Animal definition
10 class Animal
11 {
12 public:
13    Animal( int = 0, int = 0 );
14
15    void setHeight( int );
16    virtual int getHeight() const = 0;
17
18    void setWeight( int );
19    virtual int getWeight() const = 0;
20
21    virtual void print() const = 0;
22 private:
23    int height;
24    int weight;
25 }; // end class Animal
26
27 #endif // ANIMAL_H
```

Fig. L 13.9 | Contents of `Animal.h`.

```
1  // Debugging: Animal.cpp
2  #include <iostream>
3  using namespace std;
4
5  #include "Animal.h"
6
7  // default constructor
8  Animal::Animal( int h, int w )
9  {
10    height = h;
11    weight = w;
12 } // end class Animal constructor
13
14 // function print definition
15 virtual void Animal::print() const
16 {
17    cout << "This animal's height and weight are as follows:\n"
18         << "Height: " << height << "\tWeight: " << weight
19         << endl << endl;
20 } // end function print
21
```

Fig. L 13.10 | Contents of `animal.cpp`. (Part 1 of 2.)

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Lab Exercises

Name:

Debugging

```
22  // return height
23  int Animal::getHeight() const
24  {
25     return height;
26  } // end function getHeight
27
28  // return weight
29  int Animal::getWeight() const
30  {
31     return weight;
32  } // end function getWeight
33
34  // function setHeight definition
35  virtual void Animal::setHeight( int h )
36  {
37     height = h;
38  } // end function setHeight
39
40  // function setWeight definition
41  virtual void Animal::setWeight( int w )
42  {
43     weight = w;
44  } // end function setWeight
```

Fig. L 13.10 | Contents of `animal.cpp`. (Part 2 of 2.)

```
1  // Debugging: Lion.h
2  #ifndef LION_H
3  #define LION_H
4
5  #include "Animal.h"
6
7  // class Lion definition
8  class Lion : public Animal
9  {
10 public:
11    Lion( int = 0, int = 0 );
12
13    virtual void print() const;
14 }; // end class Lion
15
16 #endif // LION_H
```

Fig. L 13.11 | Contents of `Lion.h`.

```
1  // Debugging: Lion.cpp
2  #include <iostream>
3  using namespace std;
4
5  #include "Lion.h"
6
```

Fig. L 13.12 | Contents of `Lion.cpp`. (Part 1 of 2.)

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Lab Exercises

Name:

Debugging

```
// default constructor
Lion::Lion( int h, int w )
   : Animal( h, w )
{
   // empty
} // end class Lion constructor

// function print definition
void Lion::print() const
{
   cout << "This animal is a lion\n";
   Animal::print();
} // end function print
```

Fig. L 13.12 | Contents of `Lion.cpp`. (Part 2 of 2.)

```
// Debugging: Dog.h
#ifndef DOG_H
#define DOG_H

#include "Animal.h"

// class Dog definition
class Dog : public Animal
{
public:
   Dog( int = 0, int = 0, string = "Toto" );

   virtual void print() const = 0;
   virtual void getHeight() const = 0;
   virtual void getWeight() const = 0;
   string getName() const;
   void setName( string );
private:
   bool useMetric( string ) const;
   string name;
   int metricHeight;
   int metricWeight;
}; // end class Dog

#endif // DOG_H
```

Fig. L 13.13 | Contents of `Dog.h`.

```
// Debugging Dog.cpp
#include <iostream>
using namespace std;

#include "Dog.h"

```

Fig. L 13.14 | Contents of `Dog.cpp`. (Part 1 of 3.)

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Lab Exercises

Name:

Debugging

```
// default constructor
Dog::Dog( int h, int w, string n )
   : Animal( h, w )
{
   setName( n );
   metricHeight = h * 2.5;
   metricWeight = w / 2.2;
} // end class Dog constructor

// return name
string Dog::getName() const
{
   return name;
} // end function getName

// function setName definition
void Dog::setName( string n )
{
   name = n;
} // end function setName

// function print definition
void Dog::print() const
{
   cout << "This animal is a dog, its name is: "
        << name << endl;
   Animal::print();
} // end function print

// return height
int Dog::getHeight()
{
   if ( useMetric( "height" ) )
      return metricHeight;
   else
      return Animal::getHeight();
} // end function print

// return weight
int Dog::getWeight()
{
   if ( useMetric( "weight" ) )
      return metricWeight;
   else
      return Animal::getWeight();
} // end function getWeight

// function useMetric definition
bool Dog::useMetric( string type ) const
{
   int choice = 0;

   cout << "Which units would you like to see the "
        << type << " in? (Enter 1 or 2)\n"
        << "\t1. metric\n"
        << "\t2. standard\n";
```

Fig. L 13.14 | Contents of Dog.cpp. (Part 2 of 3.)

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Lab Exercises

Name:

Debugging

```
63
64       cin >> choice;
65
66       if ( choice == 1 )
67          return true;
68       else
69          return false;
70    } // end function useMetric
```

Fig. L 13.14 | Contents of `Dog.cpp`. (Part 3 of 3.)

```
1   // Debugging: Debugging.cpp
2   #include <iostream>
3   using namespace std;
4
5   #include "Animal.h"
6   #include "Lion.h"
7   #include "Dog.h"
8
9   void setHeightWeight( Animal ) const;
10
11  int main()
12  {
13     Dog dog1( 60, 120, "Fido" );
14     Lion lion1( 45, 300 );
15
16     setHeightWeight( lion1 );
17     setHeightWeight( dog1 );
18  } // end main
19
20  // function setHeightWeight definition
21  void setHeightWeight( Animal )
22  {
23     int height;
24     int weight;
25
26     a->print();
27     cout << "Enter a new height (using standard units): ";
28     cin >> height;
29     a->setHeight( height );
30
31     cout << "Enter a new weight (using standard units): ";
32     cin >> weight;
33     a->setWeight( weight );
34
35     height = a->getHeight();
36     weight = a->getWeight();
37
38     cout << "Here are the new height and weight values:\n"
39          << height << endl
40          << weight << endl << endl;
41  } // end function setHeightWeight
```

Fig. L 13.15 | Contents of `debugging.cpp`.

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Postlab Activities

Coding Exercises

Name: _____ **Date:** _____

Section: _____

These coding exercises reinforce the lessons learned in the lab and provide additional programming experience outside the classroom and laboratory environment. They serve as a review after you have completed the *Prelab Activities* and *Lab Exercises* successfully.

For each of the following problems, write a program or a program segment that performs the specified action:

1. Write the header file for an abstract base class named `Base`. Include a `virtual` destructor and a `virtual print` function.

2. Write the header file for the class `Derived` that inherits `publicly` from class `Base` that you defined in *Coding Exercise 1*. Class `Derived` has one integer as its `private` data member and should have a `print` member function.

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Postlab Activities

Name:

Coding Exercises

3. Override class `Derived`'s `print` member function to print the value of the class's `private` data member.

4. Create a `Derived` object and assign its address to a `Base` pointer. Explain why this assignment is allowed by the compiler.

5. Assign the `Base` pointer from *Coding Exercise 4* to a `Derived` pointer, without using any cast operators. Explain why this assignment is not permitted by the compiler?

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Postlab Activities

Name:

Programming Challenges

Name: _____ **Date:** _____

Section: _____

The *Programming Challenges* are more involved than the *Coding Exercises* and may require a significant amount of time to complete. Write a C++ program for each of the problems in this section. The answers to these problems are available from the Companion Website for *C++ How to Program, Seventh Edition* at `www.pearsonhighered.com/deitel/`. Pseudocode, hints and/or sample outputs are provided to aid you in your programming.

1. Modify the payroll system of Fig. 13.13–Fig. 13.23 to include `private` data member `birthDate` in class `Employee`. Use class `Date` from Fig. 11.12–Fig. 11.13 to represent an employee's birthday. Assume that payroll is processed once per month. Create a `vector` of `Employee` references to store the various employee objects. In a loop, calculate the payroll for each `Employee` (polymorphically), and add a $100.00 bonus to the person's payroll amount if the current month is the month in which the `Employee`'s birthday occurs.

Hints:

- Since all employees have a birthday, the only class that needs to be modified to add a `birthDate` is the base class `Employee`.
- Add an appropriate member function for manipulating the birthday data such as `getBirthDate`.
- Modify the `Employee` class's constructor to ensure that the `birthDate` is initialized.
- Use standard library functions of `ctime` to determine the current month based on the computer's system clock.

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Postlab Activities

Name:

Programming Challenges

- Sample output:

```
Employees processed polymorphically via dynamic binding:

salaried employee: John Smith
birthday: June 15, 1944
social security number: 111-11-1111
weekly salary: 800.00
earned $800.00

hourly employee: Karen Price
birthday: December 29, 1960
social security number: 222-22-2222
hourly wage: 16.75; hours worked: 40.00
HAPPY BIRTHDAY!
earned $770.00

commission employee: Sue Jones
birthday: September 8, 1954
social security number: 333-33-3333
gross sales: 10000.00; commission rate: 0.06
earned $600.00

base-salaried commission employee: Bob Lewis
birthday: March 2, 1965
social security number: 444-44-4444
gross sales: 5000.00; commission rate: 0.04; base salary: 300.00
old base salary: $300.00
new base salary with 10% increase is: $330.00
earned $530.00

deleting object of class SalariedEmployee
deleting object of class HourlyEmployee
deleting object of class CommissionEmployee
deleting object of class BasePlusCommissionEmployee
```

2. Use the `Package` inheritance hierarchy created in Exercise 12.9 to create a program that displays the address information and calculates the shipping costs for several `Packages`. The program should contain a `vector` of `Package` pointers to objects of classes `TwoDayPackage` and `OvernightPackage`. Loop through the `vector` to process the `Packages` polymorphically. For each `Package`, invoke *get* functions to obtain the address information of the sender and the recipient, then print the two addresses as they would appear on mailing labels. Also, call each `Package`'s `calculateCost` member function and print the result. Keep track of the total shipping cost for all `Packages` in the vector, and display this total when the loop terminates.

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Postlab Activities

Name:

Programming Challenges

Hint:

- Sample output:

```
Package 1

Sender:
Lou Brown
1 Main St
Boston, MA 11111

Recipient:
Mary Smith
7 Elm St
New York, NY 22222

Cost: $4.25

Package 2

Sender:
Lisa Klein
5 Broadway
Somerville, MA 33333

Recipient:
Bob George
21 Pine Rd
Cambridge, MA 44444

Cost: $8.82

Package 3

Sender:
Ed Lewis
2 Oak St
Boston, MA 55555

Recipient:
Don Kelly
9 Main St
Denver, CO 66666

Cost: $11.64

Total shipping cost: $24.71
```

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