13

Object-Oriented Programming: Polymorphism

Outline

13.1 Introduction

- **Polymorphism with inheritance hierarchies**
  - **"Program in the general" vs. "program in the specific"**
  - **Process objects of classes that are part of the same hierarchy as if they are all objects of the base class**
  - **Each object performs the correct tasks for that object's type**
    - **Different actions occur depending on the type of object**
  - **New classes can be added with little or not modification to existing code**

13.1 Introduction (Cont.)

- Example: `Animal` hierarchy
  - `Animal` base class – every derived class has function `move`
  - Different animal objects maintained as a `vector` of `Animal` pointers
  - Program issues same message (`move`) to each animal generically
  - Proper function gets called
    - A `Fish` will `move` by swimming
    - A `Frog` will `move` by jumping
    - A `Bird` will `move` by flying

13.2 Polymorphism Examples

- **Polymorphism occurs when a program invokes a virtual function through a base-class pointer or reference**
  - **C++ dynamically chooses the correct function for the class from which the object was instantiated**
- **Example: `SpaceObjects`**
  - **Video game manipulates objects of types that inherit from `SpaceObject`, which contains member function `draw`**
  - **Function `draw` implemented differently for the different classes**
  - **Screen-manager program maintains a container of `SpaceObject` pointers**
  - **Call `draw` on each object using `SpaceObject` pointers**
    - **Proper `draw` function is called based on object's type**
  - **A new class derived from `SpaceObject` can be added without affecting the screen manager**

13.3 Relationships Among Objects in an Inheritance Hierarchy

- **Demonstration**
  - **Invoking base-class functions from derived-class objects**
  - **Aiming derived-class pointers at base-class objects**
  - **Derived-class member-function calls via base-class pointers**
  - **Demonstrating polymorphism using virtual functions**
    - **Base-class pointers aimed at derived-class objects**
- **Key concept**
  - **An object of a derived class can be treated as an object of its base class**

Outline

Commission Employee.h

(1 of 2)

```
1  // Fig. 13.1: CommissionEmployee.h
2  // CommissionEmployee class definition represents a commission employee.
3  #ifndef COMMISSION_H
4  #define COMMISSION_H
5
6  #include <string> // C++ standard string class
7  using std::string;
8
9  class CommissionEmployee
10 {
11 public:
12    CommissionEmployee( const string &, const string &, const string &,
13       double = 0.0, double = 0.0 );
14
15    void setFirstName( const string & ); // set first name
16    string getFirstName() const; // return first name
17
18    void setLastName( const string & ); // set last name
19    string getLastName() const; // return last name
20
21    void setSocialSecurityNumber( const string & ); // set SSN
22    string getSocialSecurityNumber() const; // return SSN
23
24    void setGrossSales( double ); // set gross sales amount
25    double getGrossSales() const; // return gross sales amount
```

```
26
27    void setCommissionRate( double ); // set commission rate
28    double getCommissionRate() const; // return commission rate
29
30    double earnings() const; // calculate earnings
31    void print() const; // print CommissionEmployee object
32 private:
33    string firstName;
34    string lastName;
35    string socialSecurityNumber;
36    double grossSales; // gross weekly sales
37    double commissionRate; // commission percentage
38 }; // end class CommissionEmployee
39
40 #endif
```

Function **earnings** will be redefined in derived classes to calculate the employee's earnings

Function **print** will be redefined in derived class to print the employee's information

Outline

Employee.h

(2 of 2)

Outline

Commission Employee.cpp

(1 of 4)

```
1  // Fig. 13.2: CommissionEmployee.cpp
2  // Class CommissionEmployee member-function definitions.
3  #include <iostream>
4  using std::cout;
5
6  #include "CommissionEmployee.h" // CommissionEmployee class definition
7
8  // constructor
9  CommissionEmployee::CommissionEmployee(
10    const string &first, const string &last, const string &ssn,
11    double sales, double rate )
12    : firstName( first ), lastName( last ), socialSecurityNumber( ssn )
13 {
14    setGrossSales( sales ); // validate and store gross sales
15    setCommissionRate( rate ); // validate and store commission rate
16 } // end CommissionEmployee constructor
17
18 // set first name
19 void CommissionEmployee::setFirstName( const string &first )
20 {
21    firstName = first; // should validate
22 } // end function setFirstName
23
24 // return first name
25 string CommissionEmployee::getFirstName() const
26 {
27    return firstName;
28 } // end function getFirstName
```

Outline

Commission Employee.cpp

(2 of 4)

```
29
30 // set last name
31 void CommissionEmployee::setLastName( const string &last )
32 {
33    lastName = last;  // should validate
34 } // end function setLastName
35
36 // return last name
37 string CommissionEmployee::getLastName() const
38 {
39    return lastName;
40 } // end function getLastName
41
42 // set social security number
43 void CommissionEmployee::setSocialSecurityNumber( const string &ssn )
44 {
45    socialSecurityNumber = ssn; // should validate
46 } // end function setSocialSecurityNumber
47
48 // return social security number
49 string CommissionEmployee::getSocialSecurityNumber() const
50 {
51    return socialSecurityNumber;
52 } // end function getSocialSecurityNumber
53
54 // set gross sales amount
55 void CommissionEmployee::setGrossSales( double sales )
56 {
57    grossSales = ( sales < 0.0 ) ? 0.0 : sales;
58 } // end function setGrossSales
```

Outline

Commission Employee.cpp

(3 of 4)

```
59
60 // return gross sales amount
61 double CommissionEmployee::getGrossSales() const
62 {
63    return grossSales;
64 } // end function getGrossSales
65
66 // set commission rate
67 void CommissionEmployee::setCommissionRate( double rate )
68 {
69    commissionRate = ( rate > 0.0 && rate < 1.0 ) ? rate : 0.0;
70 } // end function setCommissionRate
71
72 // return commission rate
73 double CommissionEmployee::getCommissionRate() const
74 {
75    return commissionRate;
76 } // end function getCommissionRate
77
78 // calculate earnings
79 double CommissionEmployee::earnings() const
80 {
81    return getCommissionRate() * getGrossSales();
82 } // end function earnings
```

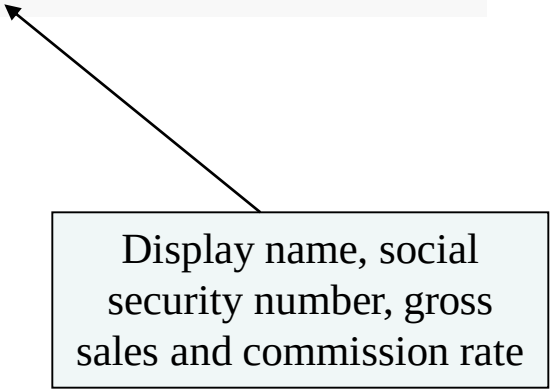
Calculate earnings based on commission rate and gross sales

Outline

```
83
84 // print CommissionEmployee object
85 void CommissionEmployee::print() const
86 {
87    cout << "commission employee: "
88       << getFirstName() << ' ' << getLastName()
89       << "\nsocial security number: " << getSocialSecurityNumber()
90       << "\ngross sales: " << getGrossSales()
91       << "\ncommission rate: " << getCommissionRate();
92 } // end function print
```

Commission Employee.cpp

(4 of 4)



Outline

BasePlus Commission Employee.h

(1 of 1)

```
1  // Fig. 13.3: BasePlusCommissionEmployee.h
2  // BasePlusCommissionEmployee class derived from class
3  // CommissionEmployee.
4  #ifndef BASEPLUS_H
5  #define BASEPLUS_H
6
7  #include <string> // C++ standard string class
8  using std::string;
9
10 #include "CommissionEmployee.h" // CommissionEmployee class declaration
11
12 class BasePlusCommissionEmployee : public CommissionEmployee
13 {
14 public:
15    BasePlusCommissionEmployee( const string &, const string &,
16       const string &, double = 0.0, double = 0.0, double = 0.0 );
17
18    void setBaseSalary( double ); // set base salary
19    double getBaseSalary() const; // return base salary
20
21    double earnings() const; // calculate earnings
22    void print() const; // print BasePlusCommissionEmployee object
23 private:
24    double baseSalary; // base salary
25 }; // end class BasePlusCommissionEmployee
26
27 #endif
```

Redefine functions **earnings** and **print**

```
1  // Fig. 13.4: BasePlusCommissionEmployee.cpp
2  // Class BasePlusCommissionEmployee member-function definitions.
3  #include <iostream>
4  using std::cout;
5
6  // BasePlusCommissionEmployee class definition
7  #include "BasePlusCommissionEmployee.h"
8
9  // constructor
10 BasePlusCommissionEmployee::BasePlusCommissionEmployee(
11    const string &first, const string &last, const string &ssn,
12    double sales, double rate, double salary )
13    // explicitly call base-class constructor
14    : CommissionEmployee( first, last, ssn, sales, rate )
15 {
16    setBaseSalary( salary ); // validate and store base salary
17 } // end BasePlusCommissionEmployee constructor
18
19 // set base salary
20 void BasePlusCommissionEmployee::setBaseSalary( double salary )
21 {
22    baseSalary = ( salary < 0.0 ) ? 0.0 : salary;
23 } // end function setBaseSalary
24
25 // return base salary
26 double BasePlusCommissionEmployee::getBaseSalary() const
27 {
28    return baseSalary;
29 } // end function getBaseSalary
```

Outline

BasePlus Commission Employee.cpp

(1 of 2)

Outline

```
30
31 // calculate earnings
32 double BasePlusCommissionEmployee::earnings() const
33 {
34    return getBaseSalary() + CommissionEmployee::earnings();
35 } // end function earnings
36
37 // print BasePlusCommissionEmployee object
38 void BasePlusCommissionEmployee::print() const
39 {
40    cout << "base-salaried ";
41
42    // invoke CommissionEmployee's print function
43    CommissionEmployee::print();
44
45    cout << "\nbase salary: " << getBaseSalary();
46 } // end function print
```

BasePlus Commission .cpp

(2 of 2)

Redefined `earnings` function incorporates base salary

Redefined `print` function displays additional **`BasePlusCommissionEmployee`** details

Outline

fig13_05.cpp

(1 of 5)

```
1  // Fig. 13.5: fig13_05.cpp
2  // Aiming base-class and derived-class pointers at base-class
3  // and derived-class objects, respectively.
4  #include <iostream>
5  using std::cout;
6  using std::endl;
7  using std::fixed;
8
9  #include <iomanip>
10 using std::setprecision;
11
12 // include class definitions
13 #include "CommissionEmployee.h"
14 #include "BasePlusCommissionEmployee.h"
15
16 int main()
17 {
18    // create base-class object
19    CommissionEmployee commissionEmployee(
20       "Sue", "Jones", "222-22-2222", 10000, .06 );
21
22    // create base-class pointer
23    CommissionEmployee *commissionEmployeePtr = 0;
```

Outline

fig13_05.cpp

(2 of 5)

```
24
25    // create derived-class object
26    BasePlusCommissionEmployee basePlusCommissionEmployee(
27       "Bob", "Lewis", "333-33-3333", 5000, .04, 300 );
28
29    // create derived-class pointer
30    BasePlusCommissionEmployee *basePlusCommissionEmployeePtr = 0;
31
32    // set floating-point output formatting
33    cout << fixed << setprecision( 2 );
34
35    // output objects commissionEmployee and basePlusCommissionEmployee
36    cout << "Print base-class and derived-class objects:\n\n";
37    commissionEmployee.print(); // invokes base-class print
38    cout << "\n\n";
39    basePlusCommissionEmployee.print(); // invokes derived-class print
40
41    // aim base-class pointer at base-class object and print
42    commissionEmployeePtr = &commissionEmployee; // perfectly natural
43    cout << "\n\n\nCalling print with base-class pointer to "
44       << "\nbase-class object invokes base-class print function:\n\n";
45    commissionEmployeePtr->print(); // invokes base-cla
```

Aiming base-class pointer at base-class object and invoking base-class functionality

Outline

fig13_05.cpp

(3 of 5)

```
46
47    // aim derived-class pointer at derived-class object and print
48    basePlusCommissionEmployeePtr = &basePlusCommissionEmployee; // natural
49    cout << "\n\n\nCalling print with derived-class pointer to "
50       << "\nderived-class object invokes derived-class "
51       << "print function:\n\n";
52    basePlusCommissionEmployeePtr->print(); // invokes derived-class print
53
54    // aim base-class pointer at derived-class object and print
55    commissionEmployeePtr = &basePlusCommissionEmployee;
56    cout << "\n\n\nCalling print with base-class pointer to "
57       << "derived-class object\ninvokes base-class print "
58       << "function on that derived-class object:\n\n";
59    commissionEmployeePtr->print(); // invokes base-class print
60    cout << endl;
61    return 0;
62 } // end main
```

Aiming derived-class pointer at derived-class object and invoking derived-class functionality

Aiming base-class pointer at derived-class object and invoking base-class functionality

```
Print base-class and derived-class objects:

commission employee: Sue Jones
social security number: 222-22-2222
gross sales: 10000.00
commission rate: 0.06

base-salaried commission employee: Bob Lewis
social security number: 333-33-3333
gross sales: 5000.00
commission rate: 0.04
base salary: 300.00


Calling print with base-class pointer to
base-class object invokes base-class print function:

commission employee: Sue Jones
social security number: 222-22-2222
gross sales: 10000.00
commission rate: 0.06
```

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Outline

fig13_05.cpp

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```
Calling print with derived-class pointer to
derived-class object invokes derived-class print function:

base-salaried commission employee: Bob Lewis
social security number: 333-33-3333
gross sales: 5000.00
commission rate: 0.04
base salary: 300.00


Calling print with base-class pointer to derived-class object
invokes base-class print function on that derived-class object:

commission employee: Bob Lewis
social security number: 333-33-3333
gross sales: 5000.00
commission rate: 0.04
```

Outline

fig13_05.cpp

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13.3.2 Aiming Derived-Class Pointers at Base-Class Objects

- **Aim a derived-class pointer at a base-class object**
  - **C++ compiler generates error**
    - `CommissionEmployee` **(base-class object) is not a** `BasePlusCommissionEmployee` **(derived-class object)**
  - **If this were to be allowed, programmer could then attempt to access derived-class members which do not exist**
    - **Could modify memory being used for other data**

Outline

fig13_06.cpp

(1 of 2)

```
1  // Fig. 13.6: fig13_06.cpp
2  // Aiming a derived-class pointer at a base-class object.
3  #include "CommissionEmployee.h"
4  #include "BasePlusCommissionEmployee.h"
5
6  int main()
7  {
8     CommissionEmployee commissionEmployee(
9        "Sue", "Jones", "222-22-2222", 10000, .06 );
10    BasePlusCommissionEmployee *basePlusCommissionEmployeePtr = 0;
11
12    // aim derived-class pointer at base-class object
13    // Error: a CommissionEmployee is not a BasePlusCommissionEmployee
14    basePlusCommissionEmployeePtr = &commissionEmployee;
15    return 0;
16 } // end main
```

Cannot assign base-class object to derived-class pointer because *is-a* relationship does not apply

Outline

Commission Employee.h

```
1  // Fig. 13.19: CommissionEmployee.h
2  // CommissionEmployee class derived from Employee.
3  #ifndef COMMISSION_H
4  #define COMMISSION_H
5
6  #include "Employee.h" // Employee class definition
7
8  class CommissionEmployee : public Employee
9  {
10 public:
11    CommissionEmployee( const string &, const string &,
12       const string &, double = 0.0, double = 0.0 );
13
14    void setCommissionRate( double ); // set commission rate
15    double getCommissionRate() const; // return commission rate
16
17    void setGrossSales( double ); // set gross sales amount
18    double getGrossSales() const; // return gross sales amount
19
20    // keyword virtual signals intent to override
21    virtual double earnings() const; // calculate earnings
22    virtual void print() const; // print CommissionEmployee object
23 private:
24    double grossSales; // gross weekly sales
25    double commissionRate; // commission percentage
26 }; // end class CommissionEmployee
27
28 #endif // COMMISSION_H
```

CommissionEmployee inherits from **Employee**, must override **earnings** to be concrete

Functions will be overridden (or defined for first time)

Outline

Commission Employee.cpp

(1 of 2)

```
1  // Fig. 13.20: CommissionEmployee.cpp
2  // CommissionEmployee class member-function definitions.
3  #include <iostream>
4  using std::cout;
5
6  #include "CommissionEmployee.h" // CommissionEmployee class definition
7
8  // constructor
9  CommissionEmployee::CommissionEmployee( const string &first,
10    const string &last, const string &ssn, double sales, double rate )
11    : Employee( first, last, ssn )
12 {
13    setGrossSales( sales );
14    setCommissionRate( rate );
15 } // end CommissionEmployee constructor
16
17 // set commission rate
18 void CommissionEmployee::setCommissionRate( double rate )
19 {
20    commissionRate = ( ( rate > 0.0 && rate < 1.0 ) ? rate : 0.0 );
21 } // end function setCommissionRate
22
23 // return commission rate
24 double CommissionEmployee::getCommissionRate() const
25 {
26     return commissionRate;
27 } // end function getCommissionRate
```

Maintain new data member, **commissionRate**

Outline

```
28
29 // set gross sales amount
30 void CommissionEmployee::setGrossSales( double sales )
31 {
32    grossSales = ( ( sales < 0.0 ) ? 0.0 : sales );
33 } // end function setGrossSales
34
35 // return gross sales amount
36 double CommissionEmployee::getGrossSales() const
37 {
38     return grossSales;
39 } // end function getGrossSales
40
41 // calculate earnings;
42 // override pure virtual function earnings in Employee
43 double CommissionEmployee::earnings() const
44 {
45    return getCommissionRate() * getGrossSales();
46 } // end function earnings
47
48 // print CommissionEmployee's information
49 void CommissionEmployee::print() const
50 {
51    cout << "commission employee: ";
52    Employee::print(); // code reuse
53    cout << "\ngross sales: " << getGrossSales()
54       << "; commission rate: " << getCommissionRate();
55 } // end function print
```

Maintain new data member, **grossSales**

Overridden **earnings** and **print** functions incorporate commission rate and gross sales

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yee.cpp

(2 of 2)

13.6.5 Creating Indirect Concrete Derived Class `BasePlusCommissionEmployee`

- `BasePlusCommissionEmployee` inherits from `CommissionEmployee`
  - Includes base salary
    - Overridden `earnings` function that incorporates base salary
    - Overridden `print` function that incorporates base salary
  - Concrete class, because derived class is concrete
    - Not necessary to override `earnings` to make it concrete, can inherit implementation from `CommissionEmployee`
      - Although we do override `earnings` to incorporate base salary

Outline

BasePlus Commission Employee.h

```
1  // Fig. 13.21: BasePlusCommissionEmployee.h
2  // BasePlusCommissionEmployee class derived from Employee.
3  #ifndef BASEPLUS_H
4  #define BASEPLUS_H
5
6  #include "CommissionEmployee.h" // CommissionEmployee class definition
7
8  class BasePlusCommissionEmployee : public CommissionEmployee
9  {
10 public:
11    BasePlusCommissionEmployee( const string &, const string &,
12       const string &, double = 0.0, double = 0.0, double = 0.0 );
13
14    void setBaseSalary( double ); // set base salary
15    double getBaseSalary() const; // return base salary
16
17    // keyword virtual signals intent to override
18    virtual double earnings() const; // calculate earnings
19    virtual void print() const; // print BasePlusCommissionEmployee object
20 private:
21    double baseSalary; // base salary per week
22 }; // end class BasePlusCommissionEmployee
23
24 #endif // BASEPLUS_H
```

BasePlusCommissionEmployee inherits from **CommissionEmployee**, already concrete

Functions will be overridden

Outline

BasePlus Commission Employee.cpp

(1 of 2)

```
1  // Fig. 13.22: BasePlusCommissionEmployee.cpp
2  // BasePlusCommissionEmployee member-function definitions.
3  #include <iostream>
4  using std::cout;
5
6  // BasePlusCommissionEmployee class definition
7  #include "BasePlusCommissionEmployee.h"
8
9  // constructor
10 BasePlusCommissionEmployee::BasePlusCommissionEmployee(
11    const string &first, const string &last, const string &ssn,
12    double sales, double rate, double salary )
13    : CommissionEmployee( first, last, ssn, sales, rate )
14 {
15    setBaseSalary( salary ); // validate and store base salary
16 } // end BasePlusCommissionEmployee constructor
17
18 // set base salary
19 void BasePlusCommissionEmployee::setBaseSalary( double salary )
20 {
21    baseSalary = ( ( salary < 0.0 ) ? 0.0 : salary );
22 } // end function setBaseSalary
23
24 // return base salary
25 double BasePlusCommissionEmployee::getBaseSalary() const
26 {
27     return baseSalary;
28 } // end function getBaseSalary
```

Maintain new data member, **baseSalary**

Outline

```
29
30 // calculate earnings;
31 // override pure virtual function earnings in Employee
32 double BasePlusCommissionEmployee::earnings() const
33 {
34    return getBaseSalary() + CommissionEmployee::earnings();
35 } // end function earnings
36
37 // print BasePlusCommissionEmployee's information
38 void BasePlusCommissionEmployee::print() const
39 {
40    cout << "base-salaried ";
41    CommissionEmployee::print(); // code reuse
42    cout << "; base salary: " << getBaseSalary();
43 } // end function print
```

BasePlus Commission Employee.cpp

Overridden **earnings** and **print** functions incorporate base salary

13.6.6 Demonstrating Polymorphic Processing

- Create objects of types `SalariedEmployee`, `HourlyEmployee`, `CommissionEmployee` and `BasePlusCommissionEmployee`
  - Demonstrate manipulating objects with static binding
    - Using name handles rather than pointers or references
    - Compiler can identify each object's type to determine which `print` and `earnings` functions to call
  - Demonstrate manipulating objects polymorphically
    - Uses a `vector` of `Employee` pointers
    - Invoke `virtual` functions using pointers and references

Outline

fig13_23.cpp

(1 of 7)

```
1  // Fig. 13.23: fig13_23.cpp
2  // Processing Employee derived-class objects individually
3  // and polymorphically using dynamic binding.
4  #include <iostream>
5  using std::cout;
6  using std::endl;
7  using std::fixed;
8
9  #include <iomanip>
10 using std::setprecision;
11
12 #include <vector>
13 using std::vector;
14
15 // include definitions of classes in Employee hierarchy
16 #include "Employee.h"
17 #include "SalariedEmployee.h"
18 #include "HourlyEmployee.h"
19 #include "CommissionEmployee.h"
20 #include "BasePlusCommissionEmployee.h"
21
22 void virtualViaPointer( const Employee * const ); // prototype
23 void virtualViaReference( const Employee & ); // prototype
```

Outline

fig13_23.cpp

(2 of 7)

```
24
25 int main()
26 {
27    // set floating-point output formatting
28    cout << fixed << setprecision( 2 );
29
30    // create derived-class objects
31    SalariedEmployee salariedEmployee(
32       "John", "Smith", "111-11-1111", 800 );
33    HourlyEmployee hourlyEmployee(
34       "Karen", "Price", "222-22-2222", 16.75, 40 );
35    CommissionEmployee commissionEmployee(
36       "Sue", "Jones", "333-33-3333", 10000, .06 );
37    BasePlusCommissionEmployee basePlusCommissionEmployee(
38       "Bob", "Lewis", "444-44-4444", 5000, .04, 300 );
39
40    cout << "Employees processed individually using static binding:\n\n";
41
42    // output each Employee's information and earnings using static binding
43    salariedEmployee.print();
44    cout << "\nearned $" << salariedEmployee.earnings() << "\n\n";
45    hourlyEmployee.print();
46    cout << "\nearned $" << hourlyEmployee.earnings() << "\n\n";
47    commissionEmployee.print();
48    cout << "\nearned $" << commissionEmployee.earnings() << "\n\n";
49    basePlusCommissionEmployee.print();
50    cout << "\nearned $" << basePlusCommissionEmployee.earnings()
51       << "\n\n";
```

Using objects (rather than pointers or references) to demonstrate static binding

Outline

```
52
53    // create vector of four base-class pointers
54    vector < Employee * > employees( 4 );
55
56    // initialize vector with Employees
57    employees[ 0 ] = &salariedEmployee;
58    employees[ 1 ] = &hourlyEmployee;
59    employees[ 2 ] = &commissionEmployee;
60    employees[ 3 ] = &basePlusCommissionEmployee;
61
62    cout << "Employees processed polymorphically via dynamic binding:\n\n";
63
64    // call virtualViaPointer to print each Employee's information
65    // and earnings using dynamic binding
66    cout << "Virtual function calls made off base-class pointers:\n\n";
67
68    for ( size_t i = 0; i < employees.size(); i++ )
69       virtualViaPointer( employees[ i ] );
70
71    // call virtualViaReference to print each Employee's information
72    // and earnings using dynamic binding
73    cout << "Virtual function calls made off base-class references:\n\n";
74
75    for ( size_t i = 0; i < employees.size(); i++ )
76       virtualViaReference( *employees[ i ] ); // note dereferencing
77
78    return 0;
79 } // end main
```

`vector` of **`Employee`** pointers, will be used to demonstrate dynamic binding

Demonstrate dynamic binding using first pointers, then references

Outline

```
80
81 // call Employee virtual functions print and earnings off a
82 // base-class pointer using dynamic binding
83 void virtualViaPointer( const Employee * const baseClassPtr )
84 {
85    baseClassPtr->print();
86    cout << "\nearned $" << baseClassPtr->earnings() << "\n\n";
87 } // end function virtualViaPointer
88
89 // call Employee virtual functions print and earnings off a
90 // base-class reference using dynamic binding
91 void virtualViaReference( const Employee &baseClassRef )
92 {
93    baseClassRef.print();
94    cout << "\nearned $" << baseClassRef.earnings() << "\n\n";
95 } // end function virtualViaReference
```

fig13_23.cpp

(4 of 7)

Using references and pointers cause **`virtual`** functions to be invoked polymorphically

```
Employees processed individually using static binding:

salaried employee: John Smith
social security number: 111-11-1111
weekly salary: 800.00
earned $800.00

hourly employee: Karen Price
social security number: 222-22-2222
hourly wage: 16.75; hours worked: 40.00
earned $670.00

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

base-salaried commission employee: Bob Lewis
social security number: 444-44-4444
gross sales: 5000.00; commission rate: 0.04; base salary: 300.00
earned $500.00
```

(Continued at top of next slide...)

Outline

fig13_23.cpp

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(...continued from bottom of previous slide)

```
Employees processed polymorphically using dynamic binding:

Virtual function calls made off base-class pointers:

salaried employee: John Smith
social security number: 111-11-1111
weekly salary: 800.00
earned $800.00

hourly employee: Karen Price
social security number: 222-22-2222
hourly wage: 16.75; hours worked: 40.00
earned $670.00

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

base-salaried commission employee: Bob Lewis
social security number: 444-44-4444
gross sales: 5000.00; commission rate: 0.04; base salary: 300.00
earned $500.00
```

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Outline

`fig13_23.cpp`

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(...Continued from bottom of previous page)

```
Virtual function calls made off base-class references:

salaried employee: John Smith
social security number: 111-11-1111
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Outline

fig13_23.cpp

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