Introduction to Polymorphism in Object-Oriented Programming

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Roadmap

In this lecture we'll design a simple object-oriented toolkit for displaying graphics in a terminal. Along the way we will cover:

- Encapsulation
  - Classes, Variables, Methods, Information hiding
- Inheritance
  - Superclasses, Subclasses, Substitution principle
- Polymorphism
  - Method overloading, Method overriding, Dynamic binding

Encapsulation

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to enclose in or as if in a capsule

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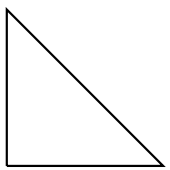
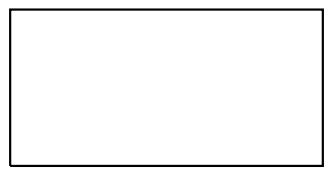
Classes

There are different types or *classes* of objects. For example, “shape”, “triangle”, “box”, and “text box” are possible classes.





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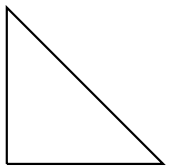

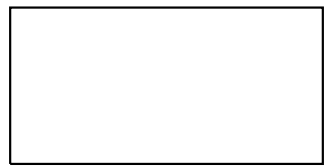

In C++, a class may be defined using the `class` keyword:

```
class Shape
{
};
```

Variables

Some properties of objects differ between two objects of the same class. For example, the heights and widths of a shape. These are *variables* of the shape.

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```
class Shape
{
    int height, width;
};
```

Methods

Objects may also perform actions—such as updating their variables.

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```
class Shape
{
    int height, width;
    // Initialize height and width
    void init(int h, int w)
    {
        height = h;
        width = w;
    }
};
```

Information hiding

By default an object's variables and methods can only be accessed from within the object's methods.

Using the `public` keyword you can make variables and methods accessible from outside the object.

Example

```
class Shape
{
    int height, width;
public:
    void init(int h, int w)
    {
        height = h;
        width = w;
    }
};
```

Consider the following `Account` class:

```
class Account
{
    int balance;     // Balance of account
public:
    int getBalance();     // Return balance of account
    void deposit(int amount);     // Add to balance
}
```

Assuming that `A` is of type `Account`, which of the following is a correct way of updating `A`?

A. `balance += 5;`

B. `A.balance += 5;`

C. `deposit(5);`

D. `A.deposit(5);`

E. `A.getBalance() += 5;`

Inheritance

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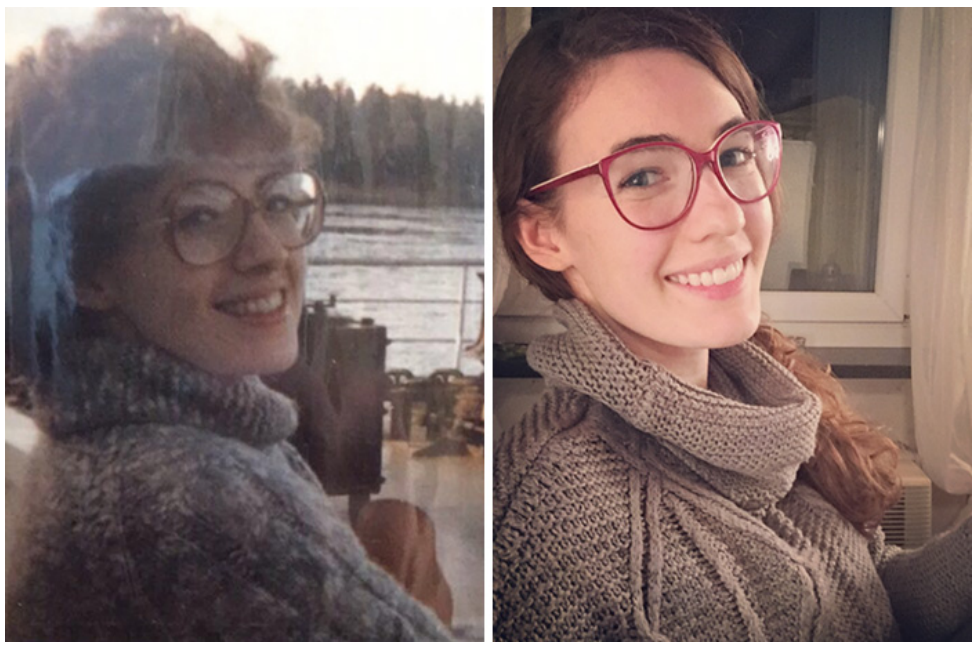
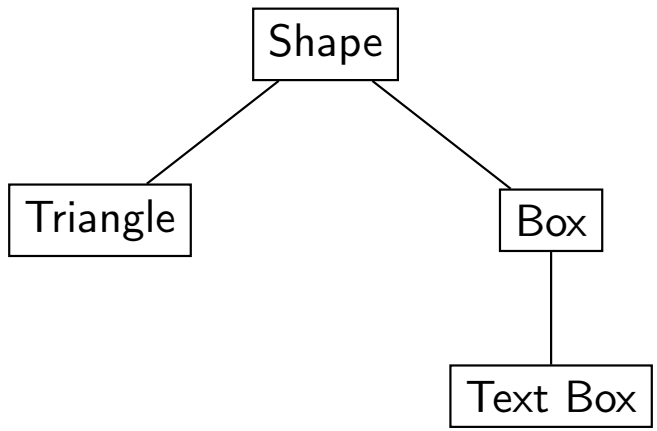


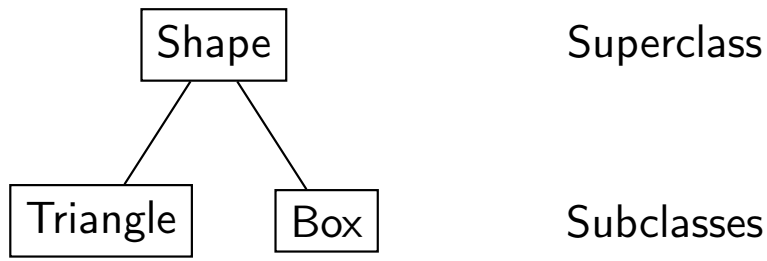
Class hierarchy

Certain classes like shapes can be organized into a hierarchy:



Superclasses and subclasses

A more generic class is called a *superclass*, while a more specialized class is called a *subclass*.



Example: Triangle and Box are subclasses of Shape.

What is the most natural relationship between the classes `Account`, `ChequingAccount`, and `SavingsAccount`?

A. `Account` and `ChequingAccount` are superclasses of `SavingsAccount`.

B. `Account` and `ChequingAccount` are subclasses of `SavingsAccount`.

C. `SavingsAccount` and `ChequingAccount` are superclasses of `Account`.

D. `SavingsAccount` and `ChequingAccount` are subclasses of `Account`.

Defining subclasses

To define a new subclass of a given class, the colon operator is used:

```
class Triangle : public Shape
{
};

class Box : public Shape
{
};
```

Inheritance

The methods of a superclass are automatically *inherited* by any of its subclasses.

In other words, a subclass has the variables and methods of the superclass it was derived from—but the reverse is not true.

Inheritance

Caveat: By default, variables and methods of a superclass are not visible to subclasses. They can be made visible (only to subclasses) by using the `protected` keyword.

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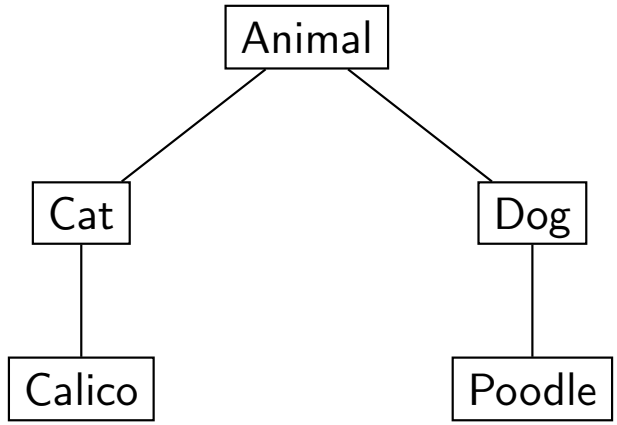
Caveat: By default, variables and methods of a superclass are not visible to subclasses. They can be made visible (only to subclasses) by using the `protected` keyword.

```
class Shape
{
protected:
    int height, width;
public:
    ...
};
```

Substitution principle

Since a subclass is a special case of a superclass, you can always use a subclass to stand in for a superclass if necessary.

In this class hierarchy which classes could **not** stand in for a `Dog`?



A. `Animal`
B. `Cat`, `Calico`
C. `Animal`, `Cat`, `Calico`
D. `Cat`, `Calico`, `Poodle`
E. `Animal`, `Cat`, `Calico`, `Poodle`

Example

```
class Box : public Shape
{
public:
    // Draw visual depiction of the box to the standard output
    void draw()
    {
        for(int i=0; i<height; i++)
            cout << string(width, '*') << endl;
    }
};

class Triangle : public Shape
{
public:
    // Draw visual depiction of the triangle to the standard output
    void draw()
    {
        for(int i=1; i<=height; i++)
            cout << string(i*width/height, '*') << endl;
    }
};
```

Example

```
int main()
{
    Triangle t;
    t.init(5,5);
    t.draw();

    Box b;
    b.init(10,10);
    b.draw();
}
```

If `b` is a `Box` and `s` is a `Shape` which line has a problem?

A. `Box b2 = b;`
B. `Shape s2 = s;`
C. `Box b2 = s;`
D. `Shape s2 = b;`

Polymorphism

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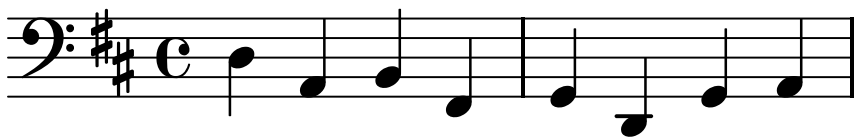


Method overloading

Two methods of a class can share the same name, so long as the number of parameters or parameter types are different.

Method overloading

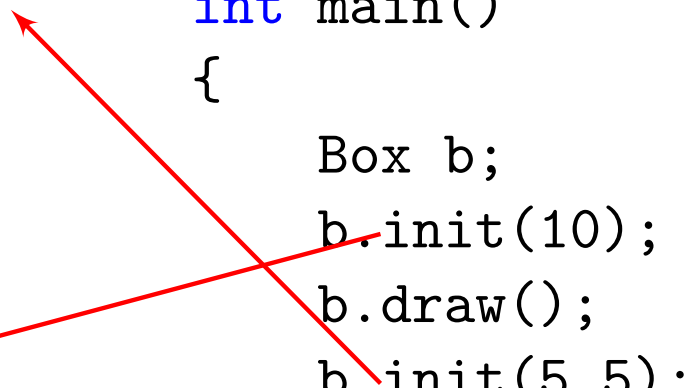
```
class Shape
{
    ...
    void init(int h, int w)
    {
        height = h;
        width = w;
    }
    void init(int hw)
    {
        height = hw;
        width = hw;
    }
}
```

```
int main()
{
    Box b;
    b.init(10);
    b.draw();
    b.init(5,5);
    b.draw();
}
```

Method overloading

```
class Shape
{
    ...
    void init(int h, int w)
    {
        height = h;
        width = w;
    }
    void init(int hw)
    {
        height = hw;
        width = hw;
    }
}
```

```
int main()
{
    Box b;
    b.init(10);
    b.draw();
    b.init(5,5);
    b.draw();
}
```



Consider the following code:

```
string mystery(int a) { return "A"; }
string mystery(string a) { return "B"; }
string mystery(string a, int b) { return "C"; }
string mystery(int a, string b) { return "D"; }
```

What does `mystery(1, "A")` return?

A. `"A"`
B. `"B"`
C. `"C"`
D. `"D"`

Method overriding

A subclass can *override* a method of a superclass.

The new method has the same name and parameters as the overridden method but can have a different implementation.

Method overriding

```
class TextBox : public Box
{
    string text;
public:
    void setText(string s)
    {
        text = s;
    }
    void draw()                    // Overridden
    {
        for(int i=0; i<height; i++)
        {    if(i==height/2)
                cout << text << endl;
            else
                cout << string(width, '*') << endl;
        }
    }
};
```

Method overriding

```
class Box : public Shape
{
    ...
    void draw()
    { ... }
};

class TextBox : public Box
{
    ...
    void draw()
    { ... }
};
```

```
int main()
{
    Box b;
    b.init(5);
    b.draw();
    TextBox tb;
    tb.init(5);
    tb.setText("Hello");
    tb.draw();
}
```

Method overriding

```
class Box : public Shape
{
    ...
    void draw()
    { ... }
};

class TextBox : public Box
{
    ...
    void draw()
    { ... }
};
```

```
int main()
{
    Box b;
    b.init(5);
    b.draw();
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    tb.draw();
}
```

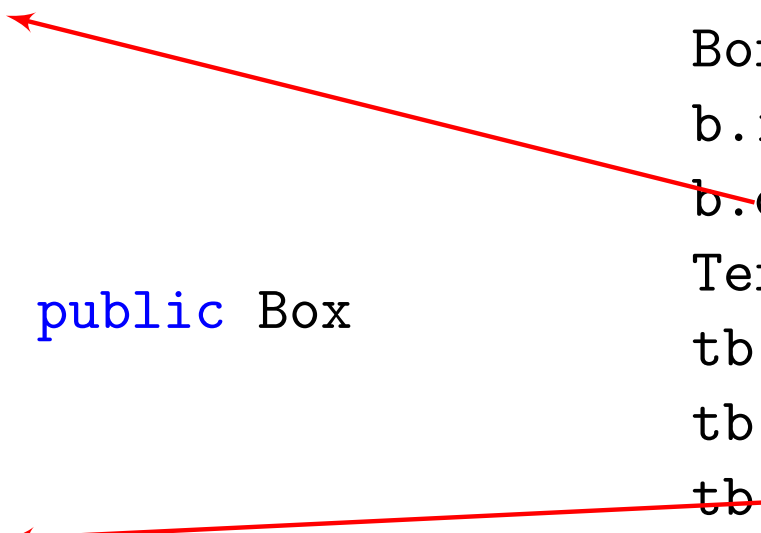

Consider the following:

```
class Shape { int height, width; };
class Box : public Shape { void draw() { ... } };
class Triangle: public Shape { void draw() { ... } };
```

Method overriding is used in these simplified class definitions:

A. True

B. False

Consider the following:

```
class Box : public Shape
{
public:
    void init(int hw) { ... }
};

class TextBox: public Shape
{
public:
    void init(int hw, string s) { ... }
};
```

Method overriding is used in these simplified class definitions:

A. True

B. False

Dynamic binding

By default, C++ will determine which method implementation is used at compile time based on the object's type.

However, a more specific choice could be made at run time because more information is known.

Dynamic binding

Declaring a method as `virtual` tells the compiler to use "dynamic binding" (on the method in this class and any of its subclasses) and make the choice at run time.

```
class Box : public Shape { ... virtual void draw() { ... } };
class TextBox : public Box { ... void draw() { ... } };

void DrawBox(Box& b)
{
    b.draw();
}
```

Which `draw` method will be called in `DrawBox`?

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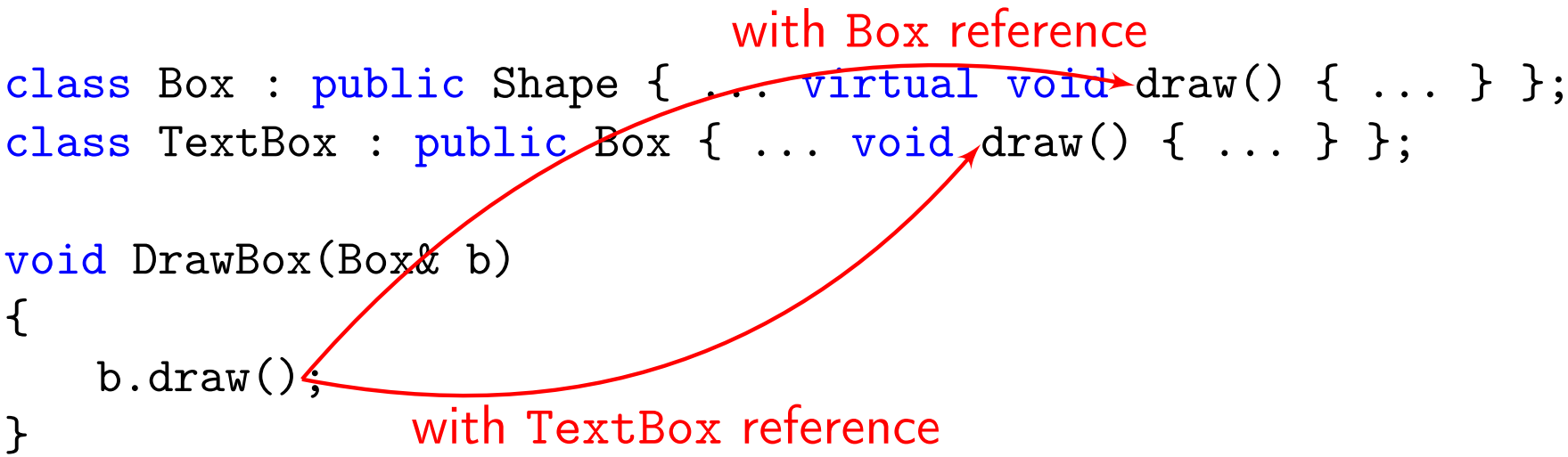

Which `draw` method will be called in `DrawBox`?

Depends on the type of object passed to `DrawBox`!

Dynamic binding

```
int main()
{
    Box b;
    b.init(5);
    DrawBox(b);

}
```

DrawBox will call the draw method of Box.

```
int main()
{
    TextBox tb;
    tb.init(5);
    tb.setText("Hello");
    DrawBox(tb);
}
```

DrawBox will call the draw method of TextBox.

Consider the following:

```
class Shape { int height, width; }
class Box : public Shape { ... virtual void draw() { ... } };
class TextBox : public Box { ... void draw() { ... } };
void DrawBox(Box& b) { b.draw(); }
Shape s;
TextBox tb;
```

What will be the result of running `DrawBox(s)` and, separately, `DrawBox(tb)`?

A. `Box`'s `draw` run in both cases.

B. `Box`'s `draw` run in first case, `TextBox`'s `draw` run in second case.

C. `TextBox`'s `draw` run in both cases.

D. Error in first case, `TextBox`'s `draw` in second case.

E. Error in first case, `Box`'s `draw` in second case.

Consider the following:

```
class Shape { int height, width; }
class Box : public Shape { ... virtual void draw() { ... } };
class TextBox : public Box { ... void draw() { ... } };
void DrawShape(Shape& s) { s.draw(); }

int main()
{
    Shape s;
    DrawShape(s);
}
```

What kind of error arises in this program?

A. Compile time error

B. Run time error

Summary

We discussed three kinds of polymorphism:

1. Method overloading:
   Methods/functions that have the same name but different parameters.

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1. Method overloading:
   Methods/functions that have the same name but different parameters.

2. Method overriding:
   Methods that have the same name and same parameters, but belong to a superclass and subclass.

3. Dynamic binding:
   Method overriding of a function that has been declared `virtual`.