Polymorphism

- A reference variable of type T can refer to an object of any subclass of T.

```
Employee person = new Lawyer();
```

- **polymorphism**: The ability for the same code to be used with several different types of objects and behave differently depending on the type of object used.

Dynamic (or Run-Time) Type and Static (or Compile-Time) Type

```
Employee person = new Lawyer();
```

- The variable person has two types:
  - static type: Employee
    - This is the type that the compiler uses to determine if statements are legal Java statements.
    - Therefore, any method called with the person variable must be declared in the Employee class (or else the compiler will complain).
  - dynamic type: Lawyer
    - This is the type that the Java virtual machine uses to execute code when the program is run.
    - Any method called with the person variable will execute the version of that method defined in the Lawyer class.

Polymorphism

Motivation

- Given the following:

```
Lawyer laura = new Lawyer();
Marketer mark = new Marketer();
```

- Write a program that will print out the salaries and the color of the vacation form for each employee.

Polymorphism and arrays

```
public class EmployeeMain2 {
    public static void main(String[] args) {
        Employee[] employees = { new Lawyer(), new Secretary(),
                                 new Marketer(), new LegalSecretary() };
        for (int i = 0; i < employees.length; i++) {
            System.out.println("salary = " + employees[i].getSalary());
            System.out.println("vacation days = " +
                               employees[i].getVacationDays());
            System.out.println();
        }
    }
}
```

Output:

```
salary = 40000.0
vacation days = 15

salary = 40000.0
vacation days = 10

salary = 50000.0
vacation days = 10

salary = 45000.0
vacation days = 10
```


Exercise 1

- Assume that the following four classes have been declared:

```
public class Foo {
    public void method1() {
        System.out.println("foo 1");
    }

    public void method2() {
        System.out.println("foo 2");
    }

    public String toString() {
        return "foo";
    }
}

public class Bar extends Foo {
    public void method2() {
        System.out.println("bar 2");
    }
}
```

```
public class Baz extends Foo {
    public void method1() {
        System.out.println("baz 1");
    }

    public String toString() {
        return "baz";
    }
}

public class Mumble extends Baz {
    public void method2() {
        System.out.println("mumble 2");
    }
}
```


Properties of polymorphism

```
Employee person = new Lawyer();
System.out.println(person.getSalary());        // 40000.0
System.out.println(person.getVacationForm());  // "pink"
```

- You can call any method from `Employee` on the `person` variable, but not any method specific to `Lawyer` (such as `sue`).
- Once a method is called on the object, it behaves in its normal way (as a `Lawyer`, not as a normal `Employee`).

Polymorphism and parameters

```
public class EmployeeMain {
    public static void main(String[] args) {
        Lawyer laura = new Lawyer();
        Marketer mark = new Marketer();
        printInfo(laura);
        printInfo(mark);
    }

    public static void printInfo(Employee empl) {
        System.out.println("salary = " + empl.getSalary());
        System.out.println("days = " + empl.getVacationDays());
        System.out.println("form = " + empl.getVacationForm());
        System.out.println();
    }
}
```

Output:

```
salary = 40000.0
vacation days = 15
vacation form = pink

salary = 50000.0
vacation days = 10
vacation form = yellow
```

```
public class Foo {
    public void method1() {
        System.out.println("foo 1");
    }

    public void method2() {
        System.out.println("foo 2");
    }

    public String toString() {
        return "foo";
    }
}

public class Bar extends Foo {
    public void method2() {
        System.out.println("bar 2");
    }
}
```

```
public class Baz extends Foo {
    public void method1() {
        System.out.println("baz 1");
    }

    public String toString() {
        return "baz";
    }
}

public class Mumble extends Baz {
    public void method2() {
        System.out.println("mumble 2");
    }
}
```

```
Foo[] pity = { new Baz(),
               new Bar(),
               new Mumble(),
               new Foo() };

for (int i = 0; i < pity.length; i++) {
    System.out.println(pity[i]);
    pity[i].method1();
    pity[i].method2();
    System.out.println();
}
```

Output:

Exercise 1

- What would be the output of the following client code?

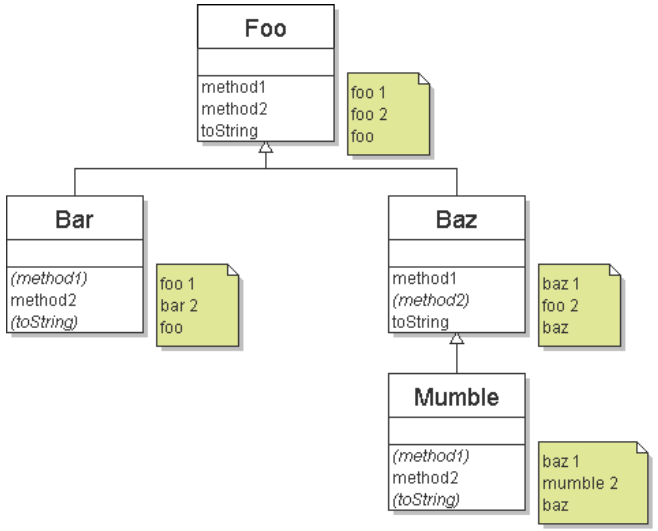
```
Foo[] pity = { new Baz(), new Bar(),
               new Mumble(), new Foo() };

for (int i = 0; i < pity.length; i++) {
    System.out.println(pity[i]);
    pity[i].method1();
    pity[i].method2();
    System.out.println();
}
```


Solution 1

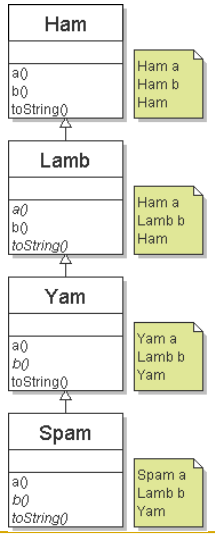
- The code produces the following output:

```
baz
baz 1
foo 2

foo
foo 1
bar 2

baz
baz 1
mumble 2

foo
foo 1
foo 2
```


Diagramming polymorphic code



Diagramming polymorphic code




```
public class Lamb extends Ham {
    public void b() {
        System.out.println("Lamb b");
    }
}

public class Ham {
    public void a() {
        System.out.println("Ham a");
    }

    public void b() {
        System.out.println("Ham b");
    }

    public String toString() {
        return "Ham";
    }
}
```

```
public class Spam extends Yam {
    public void a() {
        System.out.println("Spam a");
    }
}

public class Yam extends Lamb {
    public void a() {
        System.out.println("Yam a");
    }

    public String toString() {
        return "Yam";
    }
}
```

```
Ham[] food = { new Spam(),
               new Yam(),
               new Ham(),
               new Lamb() };
for (int i = 0; i < food.length;
i++) {
    System.out.println(food[i]);
    food[i].a();
    food[i].b();
    System.out.println();
}
```

Output:

Exercise 2

- Assume that the following four classes have been declared:

```
public class Lamb extends Ham {
    public void b() {
        System.out.println("Lamb b");
    }
}

public class Ham {
    public void a() {
        System.out.println("Ham a");
    }

    public void b() {
        System.out.println("Ham b");
    }

    public String toString() {
        return "Ham";
    }
}
```

```
public class Spam extends Yam {
    public void a() {
        System.out.println("Spam a");
    }
}

public class Yam extends Lamb {
    public void a() {
        System.out.println("Yam a");
    }

    public String toString() {
        return "Yam";
    }
}
```


Exercise 2

- What would be the output of the following client code?

```
Ham[] food = { new Spam(), new Yam(),
               new Ham(), new Lamb() };

for (int i = 0; i < food.length; i++) {
    System.out.println(food[i]);
    food[i].a();
    food[i].b();
    System.out.println();
}
```

Variable Shadowing:
Something to avoid!!

- Polymorphism applies to methods in Java
- ***But not to fields!***

```
public class A {
  int x = 1;
  int method() { return 1; }
}
public class B extends A {
  int x = 2;
  int method() { return 2; }
}
```

```
A a1 = new A();
A a2 = new B();

System.out.println(a1.method());
// prints 1
System.out.println(a2.method());
// prints 2

System.out.println(a1.x);
// prints 1
System.out.println(a2.x);
// prints 1 still!
```

Variable Shadowing:
Something to avoid!!

- Variable Shadowing:
  - When a class extends another class and defines a field with the same name, each object of the subclass contains *two* fields with that name.
  - The subclass's version of the field is said to *shadow* the superclass's version, making the superclass's version invisible within that class.
  - This is called variable shadowing.

Solution 2

- The code produces the following output:

```
Yam
Spam a
Lamb b

Yam
Yam a
Lamb b

Ham
Ham a
Ham b

Ham
Ham a
Lamb b
```

Variable Shadowing

Something to avoid!!

Variable Shadowing:
Something to avoid!!

```
public class A {
  int x = 1;
  int method() { return 1; }
}
public class B extends A {
  int x = 2;
  int method() { return 2; }
}
```

```
A a1 = new A();
A a2 = new B();
B b1 = (B)a2;

System.out.println(a1.method());
// prints 1
System.out.println(a2.method());
// prints 2

System.out.println(a1.x);
// prints 1
System.out.println(a2.x);
// prints 1 still!
System.out.println(b1.x);
// prints 2!
// because b1 has static type B
```

Overriding vs. Variable Shadowing

Overriding	Variable Shadowing
Applies to methods	Applies to fields
If subclass overrides a superclass method, it **does not** inherit the superclass method.	If a subclass shadows a superclass field, it **does** inherit the superclass field, but shadows it.
The behavior of a method call depends on the dynamic (run-time) type of the object.	The behavior of a field access depends on the static (compile-time) type of the reference to the object.

Variable Shadowing:
Something to avoid!!

Variable Shadowing and References

- If class B extends class A and both have a field of the same name, *references* to objects of type B can access one or the other of the fields.
- The version of the field that they reference depends on the type of the reference variable.

Variable Shadowing:
Something to avoid!!

```
public class A {
  int x = 1;
  int method() { return 1; }
}
public class B extends A {
  int x = 2;
  int method() { return 2; }
}
```

```
A a1 = new A();
A a2 = new B();

System.out.println(a1.method());
// prints 1
System.out.println(a2.method());
// prints 2

System.out.println(a1.x);
// prints 1
System.out.println(a2.x);
// prints 1 still!
// because reference a2 has
// compile-time type A.
```

Exercise 3

- What would be the output of the following client code?

```
Ham[] food = { new Spam(), new Yam(),
               new Ham()};

for (int i = 0; i < food.length; i++) {
     System.out.println(food[i]);
     food[i].a();
     food[i].b();
     System.out.println(food[i].a);
     System.out.println(food[i].b);
     System.out.println();
}
```



```
public class Ham {
    int a = 0;
    int b = 1;
    public void a() {
        System.out.println("Ham " + a);
    }

    public void b() {
        System.out.println("Ham " + b);
    }

    public String toString() {
        return "Ham " + a + " " + b;
    }
}
```

```
public class Spam extends Ham {
     int a = 2;
     public void a() {
         System.out.println("Spam " +a);
     }
}

public class Yam extends Spam {
     int b = 3;
     public void a() {
         System.out.println("Yam " + a);
     }

     public void b() {
         System.out.println("Yam " + b);
     }
}
```

```
Ham[] food = { new Spam(),
               new Yam(),
               new Ham()};

    for (int i = 0;
         i < food.length; i++) {
     System.out.println(food[i]);
     food[i].a();
     food[i].b();

    System.out.println(food[i].a);
    System.out.println(food[i].b);
}
```

Output:

Variable Shadowing:
Something to avoid!!

- By this time, hopefully you can see that variable shadowing on its own is not that all that complicated, no more than method overriding.
- But if you have to keep track of both method overriding and variable shadowing, then ***variable shadowing is very confusing***
- In general, programmers try to avoid it, and they use method overriding all the time.

Exercise 3

- Assume that the following classes have been declared:

```
public class Ham {
    int a = 0;
    int b = 1;
    public void a() {
        System.out.println("Ham " + a);
    }

    public void b() {
        System.out.println("Ham " + b);
    }

    public String toString() {
        return "Ham " + a + " " + b;
    }
}
```

```
public class Spam extends Ham {
     int a = 2;
     public void a() {
         System.out.println("Spam " +a);
     }
}

public class Yam extends Spam {
     int b = 3;
     public void a() {
         System.out.println("Yam " + a);
     }

     public void b() {
         System.out.println("Yam " + b);
     }
}
```