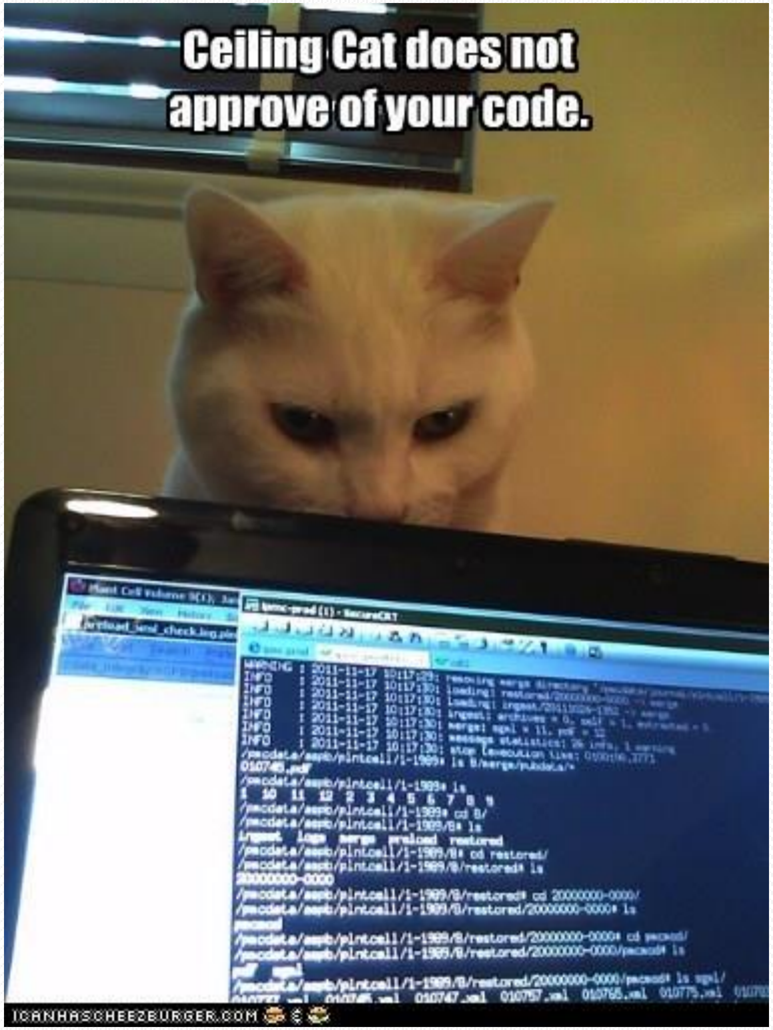
CSE 142, Spring 2013

Chapter 9

9-3: Polymorphism

reading: 9.3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Polymorphism

- **polymorphism**: Ability for the same code to be used with different types of objects and behave differently with each.
  - `System.out.println` can print any type of object.
    - Each one displays in its own way on the console.
  - `CritterMain` can interact with any type of critter.
    - Each one moves, fights, etc. in its own way.

Coding with polymorphism

- A variable of type *T* can hold an object of any subclass of *T*.

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

  - You can call any methods from the `Employee` class on `ed`.

- When a method is called on `ed`, it behaves as a `Lawyer`.

```
System.out.println(ed.getSalary());           // 50000.0
System.out.println(ed.getVacationForm());     // pink
```

Polymorphism and parameters

- You can pass any subtype of a parameter's type.

```
public class EmployeeMain {
    public static void main(String[] args) {
        Lawyer lisa = new Lawyer();
        Secretary steve = new Secretary();
        printInfo(lisa);
        printInfo(steve);
    }

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

OUTPUT:

```
salary: 50000.0                 salary: 50000.0
v.days: 15                      v.days: 10
v.form: pink                    v.form: yellow
```

Polymorphism and arrays

- Arrays of superclass types can store any subtype as elements.

```
public class EmployeeMain2 {
    public static void main(String[] args) {
        Employee[] e = { new Lawyer(),   new Secretary(),
                         new Marketer(), new LegalSecretary() };

        for (int i = 0; i < e.length; i++) {
            System.out.println("salary: " + e[i].getSalary());
            System.out.println("v.days: " + e[i].getVacationDays());
            System.out.println();
        }
    }
}
```

Output:

```
salary: 50000.0
v.days: 15

salary: 50000.0
v.days: 10

salary: 60000.0
v.days: 10

salary: 55000.0
v.days: 10
```

A polymorphism problem

- Suppose 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");
    }
}
```

A polymorphism problem

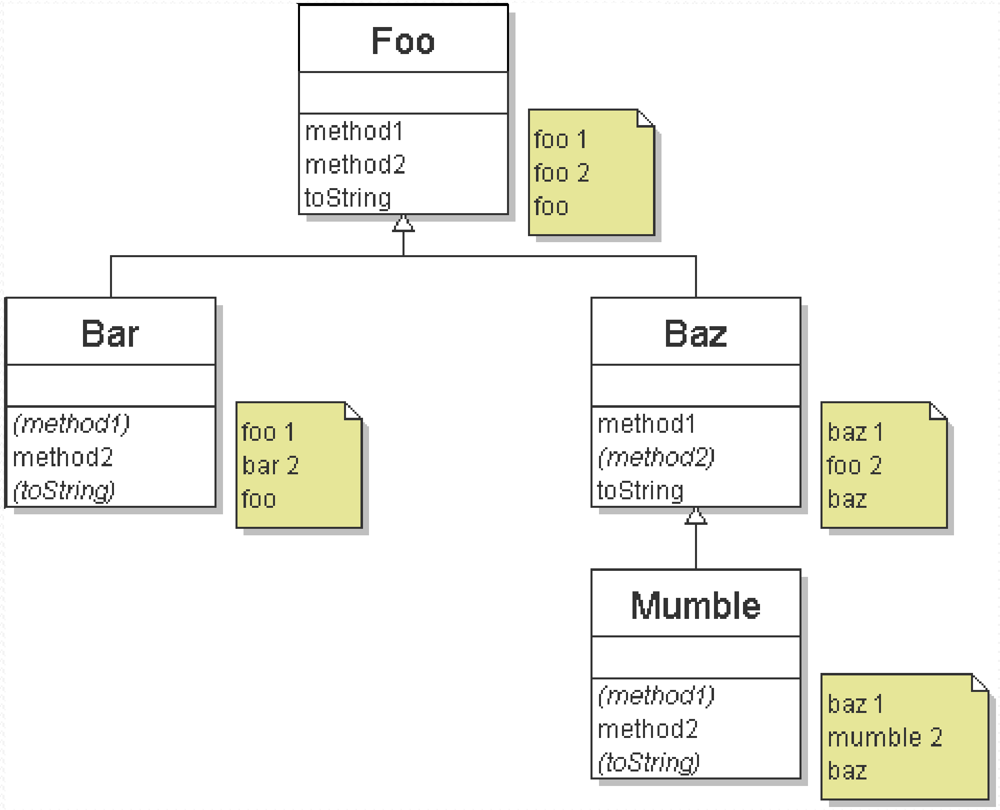
```
public class Baz extends Foo {
    public void method1() {
        System.out.println("baz 1");
    }

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

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

- 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();
}
```

Diagramming the classes

- Add classes from top (superclass) to bottom (subclass).
- Include all inherited methods.



Finding output with tables

method	Foo	Bar	Baz	Mumble
method1	foo 1	*foo 1*	baz 1	*baz 1*
method2	foo 2	bar 2	*foo 2*	mumble 2
toString	foo	*foo*	baz	*baz*

Polymorphism answer

```
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:

```
baz
baz 1
foo 2

foo
foo 1
bar 2

baz
baz 1
mumble 2

foo
foo 1
foo 2
```

Another problem

- The order of the classes is jumbled up.
- The methods sometimes call other methods (tricky!).

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

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

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

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

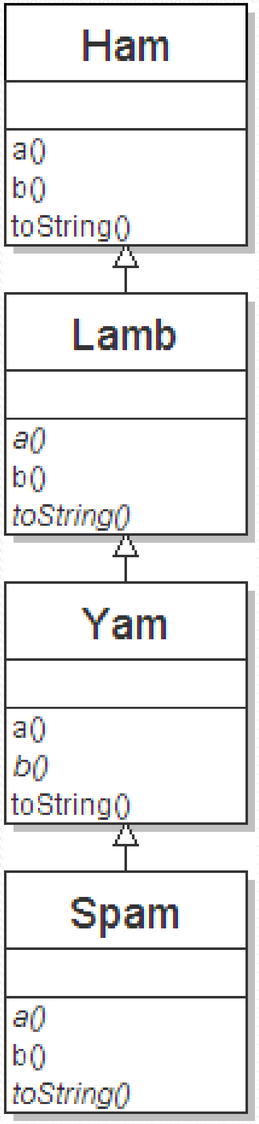
Another problem 2

```
public class Spam extends Yam {
    public void b() {
        System.out.print("Spam b   ");
    }
}
public class Yam extends Lamb {
    public void a() {
        System.out.print("Yam a   ");
        super.a();
    }
    public String toString() {
        return "Yam";
    }
}
```

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

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

Class diagram



Polymorphism at work

- Lamb inherits Ham's a. a calls b. But Lamb overrides b...

```
public class Ham {
    public void a() {
        System.out.print("Ham a    ");
        b();
    }

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

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

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

- Lamb's output from a:

```
Ham a    Lamb b
```

The table

method	Ham	Lamb	Yam	Spam
a	Ham a **b()**	*Ham a* ***b()***	Yam a Ham a **b()**	*Yam a* *Ham a* ***b()***
b	Ham b	Lamb b	Lamb b	Spam b
toString	Ham	*Ham*	Yam	*Yam*

The answer

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

- Output:

```
Ham
Ham a   Lamb b
Lamb b

Ham
Ham a   Ham b
Ham b

Yam
Yam a   Ham a   Spam b
Spam b

Yam
Yam a   Ham a   Lamb b
Lamb b
```

Casting references

- A variable can only call that type's methods, not a subtype's.

```
Employee ed = new Lawyer();
int hours = ed.getHours();  // ok; this is in Employee
ed.sue();                   // compiler error
```

  - The compiler's reasoning is, variable `ed` could store any kind of employee, and not all kinds know how to `sue` .

- To use `Lawyer` methods on `ed`, we can type-cast it.

```
Lawyer theRealEd = (Lawyer) ed;
theRealEd.sue();                  // ok

((Lawyer) ed).sue();              // shorter version
```

More about casting

- The code crashes if you cast an object too far down the tree.

```
Employee eric = new Secretary();
((Secretary) eric).takeDictation("hi");      // ok
((LegalSecretary) eric).fileLegalBriefs();  // exception

// (Secretary object doesn't know how to file briefs)
```

- You can cast only up and down the tree, not sideways.

```
Lawyer linda = new Lawyer();
((Secretary) linda).takeDictation("hi");     // error
```

- Casting doesn't actually change the object's behavior.
  It just gets the code to compile/run.

```
((Employee) linda).getVacationForm()     // pink (Lawyer's)
```

Building Java Programs

Chapter 8

Lecture 8-4: Static Methods and Fields

Critter exercise: `Hipster`

- All hipsters want to get to the bar with the cheapest PBR

- That bar is at a randomly-generated board location

  (On the 60-by-50 world)

- They go north then east until they reach the bar

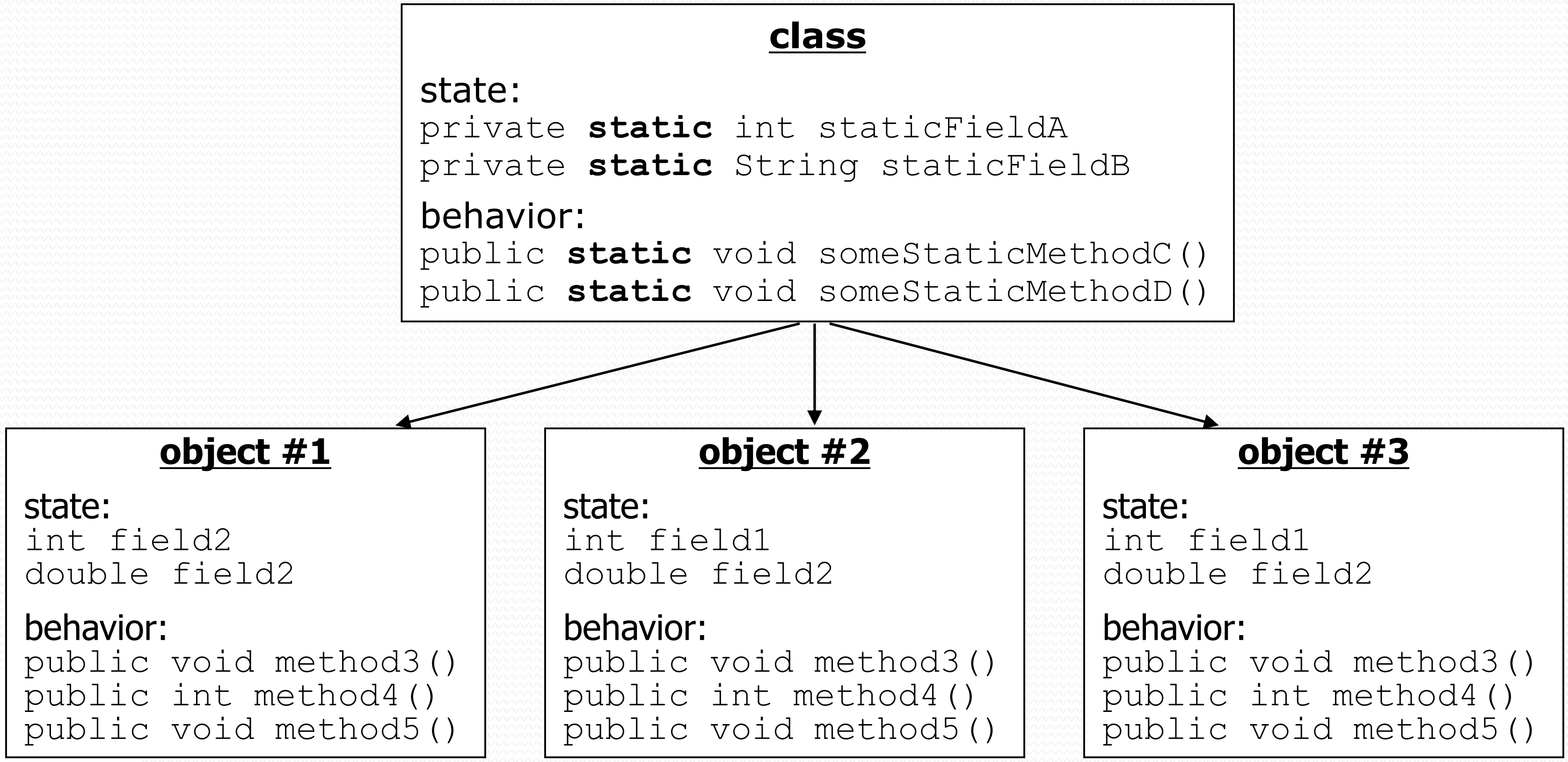
A flawed solution

```
import java.util.*;   // for Random

public class Hipster extends Critter {
    private int cheapBarX;
    private int cheapBarY;

    public Hipster() {
        Random r = new Random();
        cheapBarX = r.nextInt(60);
        cheapBarY = r.nextInt(50);
    }

    public Direction getMove() {
        if (getY() != cheapBarY) {
            return Direction.NORTH;
        } else if (getX() != cheapBarX) {
            return Direction.EAST;
        } else {
            return Direction.CENTER;
        }
    }
}
```

- Problem: Each hipster goes to a different bar.
  We want all hipsters to share the same bar location.

Static members

- **static**: Part of a class, rather than part of an object.
  - Object classes can have static methods *and fields*.
  - Not copied into each object; shared by all objects of that class.



class

state:

```
private static int staticFieldA
private static String staticFieldB
```

behavior:

```
public static void someStaticMethodC()
public static void someStaticMethodD()
```

object #1

state:

```
int field2
double field2
```

behavior:

```
public void method3()
public int method4()
public void method5()
```

object #2

state:

```
int field1
double field2
```

behavior:

```
public void method3()
public int method4()
public void method5()
```

object #3

state:

```
int field1
double field2
```

behavior:

```
public void method3()
public int method4()
public void method5()
```

Static fields

```
private static type name;
```

or,

```
private static type name = value;
```

- Example:

```
private static int theAnswer = 42;
```

- **static field**: Stored in the class instead of each object.
  - A "shared" global field that all objects can access and modify.
  - Like a class constant, except that its value can be changed.

Accessing static fields

- From inside the class where the field was declared:

```
fieldName                       // get the value
fieldName = value;              // set the value
```

- From another class (if the field is `public`):

```
ClassName.fieldName             // get the value
ClassName.fieldName = value;    // set the value
```

  - generally static fields are not `public` unless they are `final`

- Exercise: Modify the `BankAccount` class shown previously so that each account is automatically given a unique ID.
- Exercise: Write the working version of `Hipster`.

BankAccount solution

```
public class BankAccount {
    // static count of how many accounts are created
    // (only one count shared for the whole class)
    private static int objectCount = 0;

    // fields (replicated for each object)
    private String name;
    private int id;

    public BankAccount() {
        objectCount++;        // advance the id, and
        id = objectCount;     // give number to account
    }

    ...

    public int getID() {      // return this account's id
        return id;
    }
}
```

Hipster solution

```
import java.util.*;   // for Random

public class Hipster extends Critter {
    // static fields (shared by all hipsters)
    private static int cheapBarX = -1;
    private static int cheapBarY = -1;

    // object constructor/methods (replicated into each hipter)
    public Hipster() {
        if (cheapBarX < 0 || cheapBarY < 0) {
            Random r = new Random();   // the 1st hipster created
            cheapBarX = r.nextInt(60);    // chooses the bar location
            cheapBarY = r.nextInt(50);    // for all hipsters to go to
        }
    }

    public Direction getMove() {
        if (getY() != cheapBarY) {
            return Direction.NORTH;
        } else if (getX() != cheapBarX) {
            return Direction.EAST;
        } else {
            return Direction.CENTER;
        }
    }
}
```

Static methods

```
// the same syntax you've already used for methods
public static type name(parameters) {
    statements;
}
```

- **static method**: Stored in a class, not in an object.
  - Shared by all objects of the class, not replicated.
  - Does not have any *implicit parameter*, `this`;
    therefore, cannot access any particular object's fields.

- Exercise: Make it so that clients can find out how many total `BankAccount` objects have ever been created.

BankAccount solution

```
public class BankAccount {
    // static count of how many accounts are created
    // (only one count shared for the whole class)
    private static int objectCount = 0;

    // clients can call this to find out # accounts created
    public static int getNumAccounts() {
        return objectCount;
    }

    // fields (replicated for each object)
    private String name;
    private int id;

    public BankAccount() {
        objectCount++;     // advance the id, and
        id = objectCount;  // give number to account
    }

    ...
    public int getID() {   // return this account's id
        return id;
    }
}
```

Summary of Java classes

- A class is used for any of the following in a large program:
  - a *program* : Has a main and perhaps other static methods.
    - example: `GuessingGame`, `BabyNames`, `DNA`, `CritterMain`
    - does not usually declare any static fields (except `final`)
  - an *object class* : Defines a new type of objects.
    - example: `Point`, `BankAccount`, `Date`, `Critter`, `Hipster`
    - declares object fields, constructor(s), and methods
    - might declare static fields or methods, but these are less of a focus
    - should be encapsulated (all fields and static fields `private`)
  - a *module* : Utility code implemented as static methods.
    - example: `Math`