Unit 5, Part 2

Inheritance and Polymorphism

Computer Science S-111
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A Class for Modeling an Automobile

```
public class Automobile {
    private String make;
    private String model;
    private int year;
    private int mileage;
    private String plateNumber;
    private int numSeats;
    private boolean isSUV;

    public Automobile(String make, String model, int year,
      int numSeats, boolean isSUV) {
        this.make = make;
        this.model = model;
        if (year < 1900) {
           throw new IllegalArgumentException();
        }
        this.year = year;
        this.numSeats = numSeats;
        this.isSUV = isSUV;
        this.mileage = 0;
        this.plateNumber = "unknown";
    }

    public Automobile(String make, String model, int year) {
        this(make, model, year, 5, false);
    }                                          // continued…
```

A Class for Modeling an Automobile (cont.)

```
    public String getMake() {
        return this.make;
    }
    public String getModel() {
        return this.model;
    }
    public int getYear() {
        return this.year;
    }
    public int getMileage() {
        return this.mileage;
    }
    public String getPlateNumber() {
        return this.plateNumber;
    }
    public int getNumSeats() {
        return this.numSeats;
    }
    public boolean isSUV() {
        return this.isSUV;
    }                                          // continued…
```

A Class for Modeling an Automobile (cont.)

```
    public void setMileage(int newMileage) {
        if (newMileage < this.mileage) {
            throw new IllegalArgumentException();
        }
        this.mileage = newMileage;
    }
    public void setPlateNumber(String plate) {
        this.plateNumber = plate;
    }
    public String toString() {
        String str = this.make + " " + this.model;
        str += "( " + this.numSeats + " seats)";
        return str;
    }
}
```

- There are no mutators for the other fields. Why not?

Modeling a Related Class

- What if we now want to write a class to represent a taxi?
- The `Taxi` class will have the same fields and methods as the `Automobile` class.
- It will also have its own fields and methods:

```
taxiID        getID, setID
fareTotal     getFareTotal, addFare
numFares      getNumFares, getAverageFare
              resetFareInfo
```

- We may also want the `Taxi` versions of some of the `Automobile` methods to behave differently. Examples:
  - we may want the `toString` method to include values from different fields
  - we may want the `getNumSeats` method to return only the number of seats available for passengers

Inheritance

- To avoid redefining all of the `Automobile` fields and methods, we specify that the `Taxi` class *extends* the `Automobile` class:

```
public class Taxi extends Automobile {
```

- The `Taxi` class will *inherit* the fields and methods of the `Automobile` class.
  - it doesn't have to redefine them

A Class for Modeling a Taxi

```
public class Taxi extends Automobile {
    // We don't need to include the fields
    // from Automobile!
    private String taxiID;
    private double fareTotal;
    private int numFares;

    // constructor goes here...

    // We don't need to include the methods
    // from Automobile!

    public String getID() {
        return this.taxiID;
    }

    public void addFare(double fare) {
        if (fare < 0) {
            throw new IllegalArgumentException();
        }
        this.fareTotal += fare;
        this.numFares++;
    }
    ...
```

Using Inherited Methods

- Because `Taxi` extends `Automobile`, we can invoke a method defined in the `Automobile` class on a `Taxi` object.
  - example:

```
Taxi t = new Taxi(…);
t.setMileage(25000);
```

- This works even though there is no `setMileage` method defined in the `Taxi` class!
  - `Taxi` inherits it from `Automobile`

Overriding an Inherited Method

- A class can *override* an inherited method, replacing it with its own version.
- To override a method, the new method must have the same:
  - return type
  - name
  - number and types of parameters
- Example: our `Taxi` class can define its own `toString` method:

```
public String toString() {
    return "Taxi (id = " + this.taxiID + ")";
}
```

  - it overrides the `toString` method inherited from `Automobile`

Rethinking Our Design

- What if we also want to be able to capture information about other types of vehicles?
  - motorcycles
  - trucks
- The classes for these other vehicles should *not* inherit from `Automobile`. Why not?
- Solution: define a `Vehicle` class
  - fields and methods common to all vehicles are defined there
  - leave automobile-specific state and behavior in `Automobile`
    - everything else is inherited from `Vehicle`
  - define `Motorcycle` and `Truck` classes that also inherit from `Vehicle`

A Class for Modeling a Vehicle

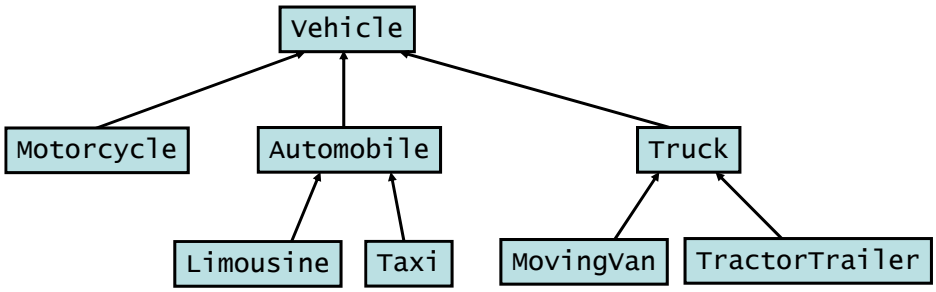
```
public class Vehicle {
    private String make;
    private String model;
    private int year;
    private int mileage;
    private String plateNumber;
    private int numWheels;  // this was not in Automobile

    public Vehicle(String make, String model, int year,
      int numWheels) {
        this.make = make;
        this.model = model;
        if (year < 1900) {
           throw new IllegalArgumentException();
        }
        this.year = year;
        this.numWheels = numWheels;
        this.mileage = 0;
        this.plateNumber = "unknown";
    }

    public String getMake() {
        return this.make;
    }

    // etc.
```

Revised `Automobile` Class

```
public class Automobile extends Vehicle {
    // make, model, etc. are now inherited from Vehicle

    // The following are specific to automobiles,
    // so we leave them here.
    private int numSeats;
    private boolean isSUV;

    // constructor goes here...

    // getMake(), etc. are now inherited from Vehicle

    // The following are specific to automobiles,
    // so we leave them here.
    public int getNumSeats() {
        return this.numSeats;
    }

    public boolean isSUV() {
        return this.isSUV;
    }
    ...
}
```

Inheritance Hierarchy

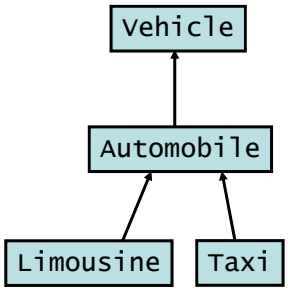
- Inheritance leads classes to be organized in a *hierarchy*:



- A class in Java inherits *directly* from at most one class.
- However, a class can inherit *indirectly* from a class higher up in the hierarchy.
  - example: `Taxi` inherits indirectly from `Vehicle`

Terminology

- When class C extends class D (directly or indirectly):
  - class D is known as a *superclass* or *base class* of C
    - super – comes *above* it in the hierarchy
  - class C is known as a *subclass* or *derived class* of D
    - sub – comes *below* it in the hierarchy
- Examples:
  - `Automobile` is a superclass of `Taxi` and `Limosine`
  - `Taxi` is a subclass of `Automobile` and `Vehicle`



Deciding Where to Define a Method

- Assume we only care about the number of axles in truck vehicles.
- Thus, we define the `getNumAxles` method in the `Truck` class, rather than in the `Vehicle` class.

```
public int getNumAxles() {
    return this.getNumWheels() / 2;
}
```

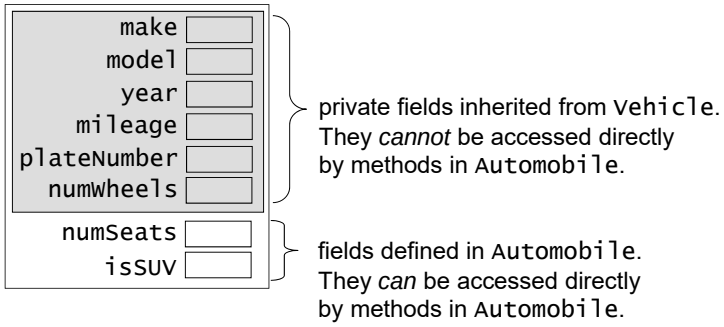
  - it will be inherited by subclasses of `Truck`
  - it won't be available to non-truck subclasses of `Vehicle`

- We override this method in the `TractorTrailer` class, because tractor trailers have four wheels on all but the front axle:

```
public int getNumAxles() {
    int numBackWheels = this.getNumWheels() - 2;
    return 1 + numBackWheels/4;
}
```

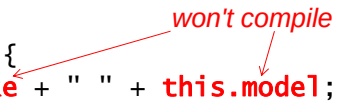
What is Accessible From a Superclass?

- A subclass has direct access to the *public* fields and methods of a superclass.
- A subclass does <u>not</u> have direct access to the *private* fields and methods of a superclass.
- Example: we can think of an `Automobile` object as follows:



What is Accessible From a Superclass? (cont.)

- Example: now that `make` and `model` are defined in `Vehicle`, we're no longer able to access them directly in the `Automobile` version of `toString`:




```
public String toString() {
    String str = this.make + " " + this.model;
    str += " ( " + this.numSeats + " seats)";
    return str;
}
```

- Instead, we need to make method calls to access the inherited fields:

```
public String toString() {
    String str = this.getMake() + " " +
      this.getModel();
    str += " ( " + this.numSeats + " seats)";
    return str;
}
```

What is Accessible From a Superclass? (cont.)

- Faulty approach: redefine the inherited fields in the subclass

```
public class Vehicle {
    private String make;
    private String model;
    …
}

public class Automobile extends Vehicle {
    private String make;    // NOT a good idea!
    private String model;
    …
}
```

- You should NOT do this!

Writing a Constructor for a Subclass

- Another example of illegally accessing inherited private fields:

```
public Automobile(String make, String model, int year,
  int numSeats, boolean isSUV) {
    this.make = make;
    this.model = model;
    ...
}
```

- To initialize inherited fields, a constructor should invoke a constructor from the superclass.

```
public Automobile(String make, String model, int year,
  int numSeats, boolean isSUV) {
    super(make, model, year, 4);   // 4 is for numWheels
    this.numSeats = numSeats;
    this.isSUV = isSUV;
}
```

  - use the keyword `super` followed by appropriate parameters for the superclass constructor
  - must be done as the very first line of the constructor

Writing a Constructor for a Subclass (cont.)

- If a subclass constructor doesn't explicitly invoke a superclass constructor, the compiler tries to insert a call to the superclass constructor with no parameters.
- If there isn't such a constructor, we get a compile-time error.
  - example: this constructor won't compile:

```
public Taxi(String make, String model, int year, String ID)
{
    this.taxiID = ID;
}
```

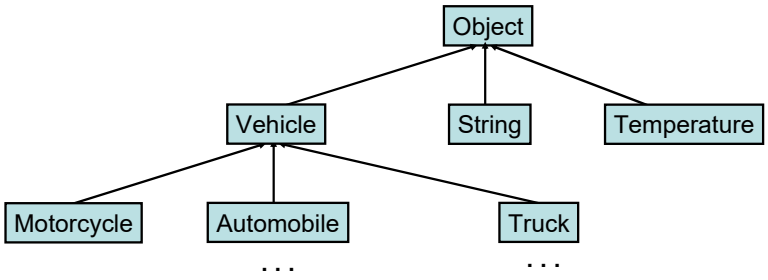
    - the compiler attempts to insert the following call:

```
super();
```

    - there isn't an `Automobile` constructor with no parameters

The `Object` Class

- If a class doesn't explicitly extend another class, it implicitly extends a special class called `Object`.
- Thus, the `Object` class is at the top of the class hierarchy.
  - *all* classes are subclasses of this class
  - the default `toString` and `equals` methods are defined in this class



Inheritance in the Java API

java.awt

Class Rectangle

```
java.lang.Object
  └java.awt.geom.RectangularShape
      └java.awt.geom.Rectangle2D
          └java.awt.Rectangle
```

All Implemented Interfaces:

Shape, Serializable, Cloneable

Direct Known Subclasses:

DefaultCaret

More Examples of Method Overriding

- `Vehicle` inherits the fields and methods of `Object`.
- The inherited `toString` method isn't very helpful.
- We define a `Vehicle` version that overrides the inherited one:

```
public String toString() {   // Vehicle version
    String str = this.make + " " + this.model;
    return str;
}
```

- When `toString` is invoked on a `Vehicle` object, the `Vehicle` version is executed:

```
Vehicle v = new Vehicle("Radio Flyer",
  "Classic Tricycle", 2002, 3);
System.out.println(v);
```

outputs: `Radio Flyer Classic Tricycle`

More Examples of Method Overriding (cont.)

- The `Automobile` class inherits the `Vehicle` version of `toString`.
- If we didn't define a `toString()` method in `Automobile`, the inherited version would be used.
- The `Automobile` version overrides the `Vehicle` version so that the number of seats can be included in the string:

```
public String toString() {
    String str = this.getMake() + " " +
      this.getModel();
    str += " ( " + this.numSeats + " seats)";
    return str;
}
```

Invoking an Overriden Method

- When a subclass overrides an inherited method, we can invoke the inherited version by using the keyword `super`.
- Example: the `Automobile` version of `toString()` begins with the same fields as the `Vehicle` version:

```
public String toString() {
    String str = this.getMake() + " " +
      this.getModel();
    str += " ( " + this.numSeats + " seats)";
    return str;
}
```

  - instead of calling the accessor methods, we can do this:

```
public String toString() {
    String str = super.toString();
    str += " ( " + this.numSeats + " seats)";
    return str;
}
```

Another Example of Inheritance

- A square is a special type of rectangle.
  - but the width and height must be the same
- Assume that we also want `Square` objects to have a field for the unit of measurement (e.g., `"cm"`).
- `Square` objects should mostly behave like `Rectangle` objects:

```
Rectangle r = new Rectangle(20, 30);
int area1 = r.area();

Square sq = new Square(40, "cm");
int area2 = sq.area();
```

- But there may be differences as well:

```
System.out.println(r);
```
➡ output:
`20 x 30`

```
System.out.println(sq);
```
➡ output:
`square with 40-cm sides`

Another Example of Inheritance (cont.)

```
public class Rectangle {
   private int width;
   private int height;
   ...
   public Rectangle(int initWidth, int initHeight) {
       ...
   }
   public int getWidth() {
       ...
   }
   ... // other methods
}
```

```
public class Square extends Rectangle {
   private String unit; // inherits other fields
   public Square(int side, String unit) {
       super(side, side);
       this.unit = unit;
   }
   public String toString() {  // overrides
       String s = "square with ";
       s += this.getWidth() + "-";
       s += this.unit + " sides";
       return s;
   } // inherits other methods
}
```

Another Example of Inheritance (cont.)

```
public class Rectangle {
   private int width;
   private int height;
   ...
   public Rectangle(int initWidth, int initHeight) {
       ...
   }
   public int getWidth() {
       ...
   }
   ... // other methods
}
```

```
public class Square extends Rectangle {
   private String unit; // inherits other fields
   public Square(int side, String unit) {
       super(side, side);
       this.unit = unit;
   }
   public String toString() {  // overrides
       String s = "square with ";
       s += this.getWidth() + "-";
       s += this.unit + " sides";
       return s;
   } // inherits other methods
}
```

Another Example of Method Overriding

- The `Rectangle` class has the following mutator method:

```
public void setWidth(int w) {
    if (w <= 0) {
        throw new IllegalArgumentException();
    }
    this.width = w;
}
```

- The `Square` class inherits it. Why should we override it?

Which of these works?

A.
```
// Square version, which overrides
// the version inherited from Rectangle
public void setWidth(int w) {
    this.width = w;
    this.height = w;
}
```

B.
```
// Square version, which overrides
// the version inherited from Rectangle
public void setWidth(int w) {
    this.setWidth(w);
    this.setHeight(w);
}
```

C. either version would work

D. neither version would work

Accessing Methods from the Superclass

- The solution: use `super` to access the inherited version of the method – the one we are overriding:

```
// Square version
public void setWidth(int w) {
    super.setWidth(w);  // call the Rectangle version
    super.setHeight(w);
}
```

- Only use `super` if you want to call a method from the superclass *that has been overridden*.
- If the method has *not* been overridden, use `this` as usual.

Accessing Methods from the Superclass

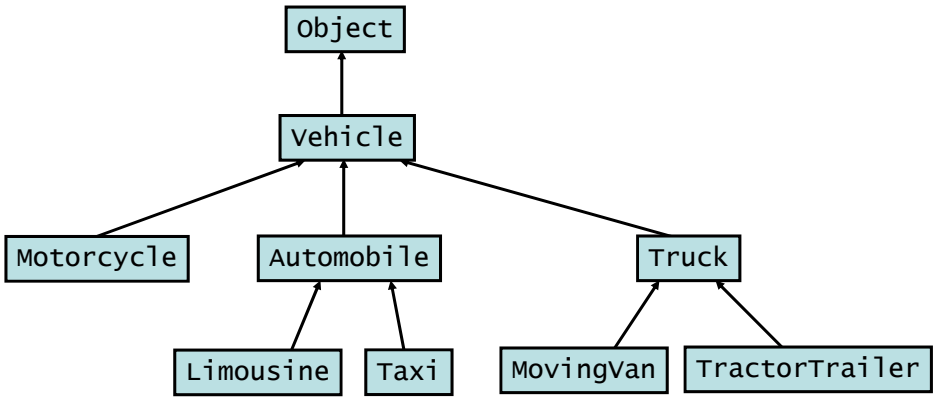
- We need to override *all* of the inherited mutators:

```
// Square versions
public void setWidth(int w) {
    super.setWidth(w);
    super.setHeight(w);
}

public void setHeight(int h) {
    super.setWidth(h);
    super.setHeight(h);
}

public void grow(int dw, int dh) {
    if (dw != dh) {
        throw new IllegalArgumentException();
    }
    super.setWidth(this.getWidth() + dw);
    super.setHeight(this.getHeight() + dh);
}
```

`getWidth()` and `getHeight()` are not overridden, so we use `this`.

is-a Relationships

- We use inheritance to capture *is-a* relationships.
  - an automobile *is a* vehicle
  - a taxi *is an* automobile
  - a tractor trailer *is a* truck



has-a Relationships

- Another type of relationship is a *has-a* relationship.
  - one type of object "owns" another type of object
  - example: a driver *has a* vehicle
- Inheritance should not be used to capture has-a relationships.
  - it does not make sense to make the `Driver` class a subclass of `Vehicle`
- Instead, we give the "owner" object a field that refers to the "owned" object:

```
public class Driver {
    String name;
    String ID;
    Vehicle v;
    ...
```

Polymorphism

- We've been using reference variables like this:

```
Automobile a = new Automobile("Ford", "Model T", …);
```

  - variable a is declared to be of type `Automobile`
  - it holds a reference to an `Automobile` object

- In addition, a reference variable of type T can hold a reference to an object from a *subclass* of T:

```
Automobile a = new Taxi("Ford", "Tempo", …);
```

  - this works because `Taxi` is a subclass of `Automobile`
  - a taxi is an automobile!

- The name for this feature of Java is *polymorphism*.
  - from the Greek for "many forms"
  - the same code can be used with objects of different types!

Polymorphism and Collections of Objects

- Polymorphism is useful when we have a collection of objects of different but related types.

- Example:
  - let's say that a company has a collection of vehicles of different types
  - we can store all of them in an array of type `Vehicle`:

```
Vehicle[] fleet = new Vehicle[5];
fleet[0] = new Automobile("Honda", "Civic", …);
fleet[1] = new Motorcycle("Harley", ...);
fleet[2] = new TractorTrailer("Mack", ...);
fleet[3] = new Taxi("Ford", …);
fleet[4] = new Truck("Dodge", …);
```

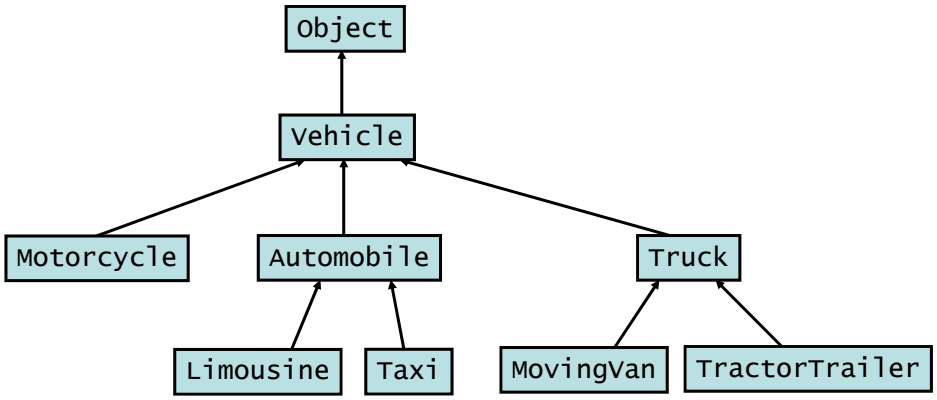
Processing a Collection of Objects

- We can determine the average age of the vehicles in the company's fleet by doing the following:

```
int totalAge = 0;
for (int i = 0; i < fleet.length; i++) {
    int age = CURRENT_YEAR - fleet[i].getYear();
    totalAge += age;
}
double averageAge = (double)totalAge / fleet.length;
```

- We can invoke `getYear()` on each object in the array, regardless of its type.
  - they are instances of `Vehicle` or a subclass of `Vehicle`
  - thus, they must all have a `getYear()` method

Practice with Polymorphism



- Which of these assignments would be allowed?

```
Vehicle v1 = new Motorcycle(…);
TractorTrailer t1 = new Truck(…);
Truck t2 = new MovingVan(…);
Taxi t3 = new Automobile(…);
Vehicle v2 = new TractorTrailer(…);
MovingVan m1 = new TractorTrailer(…);
```

Declared Type vs. Actual Type

- An object's declared type may not match its actual type:
  - declared type: type specified when declaring a variable
  - actual type: type specified when creating an object
- Recall this client code:

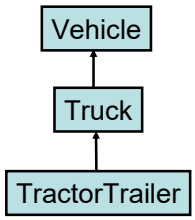
```
Vehicle[] fleet = new Vehicle[5];
fleet[0] = new Automobile("Honda", "Civic", 2005);
fleet[1] = new Motorcycle("Harley", …);
fleet[2] = new TractorTrailer("Mack", …);
```

- Here are the types:

object	declared type	actual type
`fleet[0]`	`Vehicle`	`Automobile`
`fleet[1]`	`Vehicle`	`Motorcycle`
`fleet[2]`	`Vehicle`	`TractorTrailer`

Determining if a Method Call is Valid

- The compiler uses the *declared* type of an object to determine if a method call is valid.
  - starts at the declared type, and goes up the inheritance hierarchy as needed looking for a version of the method
  - if it can't find a version, the method call will *not* compile



- Example: the following would *not* work:

```
Vehicle[] fleet = new Vehicle[5];
...
fleet[2] = new TractorTrailer("Mack",…);
...
System.out.println(fleet[2].getNumAxles());
```

  - the declared type of `fleet[2]` is `Vehicle`
  - there's no `getNumAxles()` method defined in or inherited by `Vehicle`

Determining if a Method Call is Valid (cont.)

- In such cases, we can use casting to create a reference with the necessary declared type:

```
Vehicle[] fleet = new Vehicle[5];
...
fleet[2] = new TractorTrailer("Mack", …);
...
TractorTrailer t = (TractorTrailer)fleet[2];
```

- The following *will* work:

```
System.out.println(t.getNumAxles());
```

  - the declared type of `t` is `TractorTrailer`
  - there is a `getNumAxles()` method defined in `TractorTrailer`, so the compiler is happy

Determining Which Method to Execute

- `Truck` also has a `getNumAxles` method, so this would be another way to handle the previous problem:

```
Vehicle[] fleet = new Vehicle[5];
...
fleet[2] = new TractorTrailer("Mack", …);
...
Truck t2 = (Truck)fleet[2];
System.out.println(t2.getNumAxles());
```

- The object represented by `t2` has:
  - a declared type of _____
  - an actual type of _____
- Both `Truck` and `TractorTrailer` have a getNumAxles. Which version will be executed?
- More generally, how does the interpreter decide which version of a method should be used?

Dynamic Binding

- At runtime, the Java interpreter selects the version of a method that is appropriate to the *actual* type of the object.
  - starts at the actual type, and goes up the inheritance hierarchy as needed until it finds a version of the method
  - known as *dynamic binding*
- Given the code from the previous slide

```
Vehicle[] fleet = new Vehicle[5]
...
fleet[2] = new TractorTrailer("Mack", …);
...
Truck t2 = (Truck)fleet[2];
System.out.println(t2.getNumAxles());
```

  the `TractorTrailer` version of `getNumAxles` would be run
  - `TractorTrailer` is the actual type of `t2`, and that class has its own version of `getNumAxles`

Dynamic Binding (cont.)

- Another example:

```
public static void printFleet(Vehicle[] fleet) {
    for (int i = 0; i < fleet.length; i++) {
        System.out.println(fleet[i]);
    }
}
```

  - the `toString()` method is implicitly invoked on each element of the array when we go to print it.
  - the appropriate version is selected by dynamic binding
  - note: the selection must happen at runtime, because the actual types of the objects may not be known when the code is compiled

Dynamic Binding (cont.)

- Recall our initialization of the array:

```
Vehicle[] fleet = new Vehicle[5];
fleet[0] = new Automobile("Honda", "Civic", …);
fleet[1] = new Motorcycle("Harley", …);
fleet[2] = new TractorTrailer("Mack", …);
...
```

- `System.out.println(fleet[0]);` will invoke the `Automobile` version of the `toString()` method.
- `Motorcycle` does not define its own `toString()` method, so `System.out.println(fleet[1]);` will invoke the `Vehicle` version of `toString()`, which is inherited by `Motorcycle`.
- `TractorTrailer` does not define its own `toString()` but `Truck` does, so `System.out.println(fleet[2]);` will invoke the `Truck` version of `toString()`, which is inherited by `TractorTrailer`.

Dynamic Binding (cont.)

- Dynamic binding also applies to method calls on the called object that occur within other methods.
- Example: the `Truck` class has the following `toString` method:

```
public String toString() {
    String str = this.getMake() + " " +
       this.getModel();
    str = str + ", capacity = " + this.capacity;
    str = str + ", " + this.getNumAxles() + " axles";
    return str;
}
```

- The `TractorTrailer` class inherits it and does *not* override it.
- When `toString` is called on a `TractorTrailer` object:
  - this `Truck` version of `toString()` will run
  - the *`TractorTrailer`* version of `getNumAxles()` will run when the code above is executed

The Power of Polymorphism

- Recall our `printFleet` method:

```
public static void printFleet(Vehicle[] fleet) {
    for (int i = 0; i < fleet.length; i++) {
        System.out.println(fleet[i]);
    }
}
```

  - polymorphism allows this method to use a single println statement to print the appropriate info. for *any* kind of vehicle.

- Without polymorphism, we would need a large if-else-if:

```
if (fleet[i] is an Automobile) {
    print the appropriate info for Automobiles
} else if (fleet[i] is a Truck) {
    print the appropriate info for Trucks
} else if ...
```

- Polymorphism allows us to easily write code that works for more than one type of object.

Polymorphism and the `Object` Class

- The `Object` class is a superclass of every other class.

- Thus, we can use an `Object` variable to store a reference to *any* object.

```
Object o1 = "Hello World";
Object o2 = new Temperature(20, 'C');
Object o3 = new Taxi("Ford", "Tempo", 2000, "T253");
```

Summary and Extra Practice

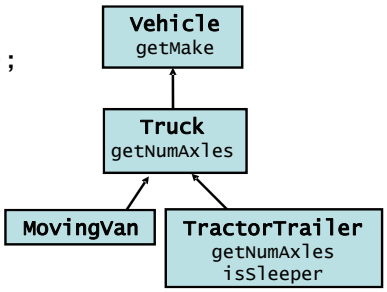
- To determine if a method call is valid:
  - start at the *declared* type
  - go up the hierarchy as needed to see if you can find the specified method in the declared type *or* a superclass
  - if you don't find it, the method call is *not* valid

- Given the following:

```
TractorTrailer t1 = new TractorTrailer(…);
Vehicle v = new Truck(…);
MovingVan m = new MovingVan(…);
Truck t2 = new TractorTrailer(…);
```

- Which of the following are valid?

```
v.getNumAxles()
m.getNumAxles()
t1.getMake()
t1.isSleeper()
t2.isSleeper()
```



Summary and Extra Practice (cont.)

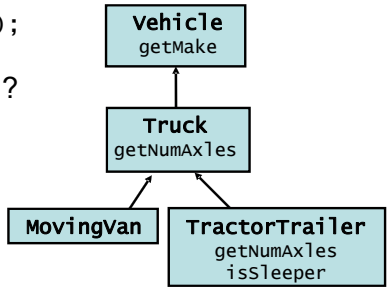
- To determine which version of a method will run (dynamic binding):
  - start at the *actual* type
  - go up the hierarchy as needed until you find the method
  - the first version you encounter is the one that will run

- Given the following:

```
TractorTrailer t1 = new TractorTrailer(…);
Vehicle v = new Truck(…);
MovingVan m = new MovingVan(…);
Truck t2 = new TractorTrailer(…);
```

- Which version of the method will run?

```
m.getNumAxles()
t1.getNumAxles()
t2.getNumAxles()
v.getMake()
t2.getMake()
```



More Practice

```
public class E extends G {
    public void method2() {
        System.out.print("E 2 ");
        this.method1();
    }
    public void method3() {
        System.out.print("E 3 ");
        this.method1();
    }
}
public class F extends G {
    public void method2() {
        System.out.print("F 2 ");
    }
}
public class G {
    public void method1() {
        System.out.print("G 1 ");
    }
    public void method2() {
        System.out.print("G 2 ");
    }
}
public class H extends E {
    public void method1() {
        System.out.print("H 1 ");
    }
}
```

More Practice (cont.)

- Which of these would compile and which would not?

```
E e1 = new E();
E e2 = new H();
E e3 = new G();
E e4 = new F();
G g1 = new H();
G g2 = new F();
H h1 = new H();
```

- To answer these questions, draw the inheritance hierarchy:

Here are the classes again…

```
public class E extends G {
    public void method2() {
        System.out.print("E 2 ");
        this.method1();
    }
    public void method3() {
        System.out.print("E 3 ");
        this.method1();
    }
}
public class F extends G {
    public void method2() {
        System.out.print("F 2 ");
    }
}
public class G {
    public void method1() {
        System.out.print("G 1 ");
    }
    public void method2() {
        System.out.print("G 2 ");
    }
}
public class H extends E {
    public void method1() {
        System.out.print("H 1 ");
    }
}
```

More Practice (cont.)

```
E e1 = new E();
G g1 = new H();
G g2 = new F();
```

- Which of the following would compile and which would not? For the ones that would compile, what is the output?

```
e1.method1();

e1.method2();

e1.method3();

g1.method1();

g1.method2();

g1.method3();

g2.method1();

g2.method2();

g2.method3();
```