Advanced Programming
CSE 201

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(Semester: Monsoon 2025)

Week 3 - Inheritance

Basics of Inheritance (in Java)

- Closely connected to polymorphism.

- Def_1: Referencing many related objects as one generic type.

- Def_2: Reference of ‘parent’ class utilizing attributes and methods of a ‘child’ class, depending on which one it is referencing.

Slide Acknowledgement

CS15, Brown University

Basics of Inheritance (in Java)

- Closely connected to polymorphism.

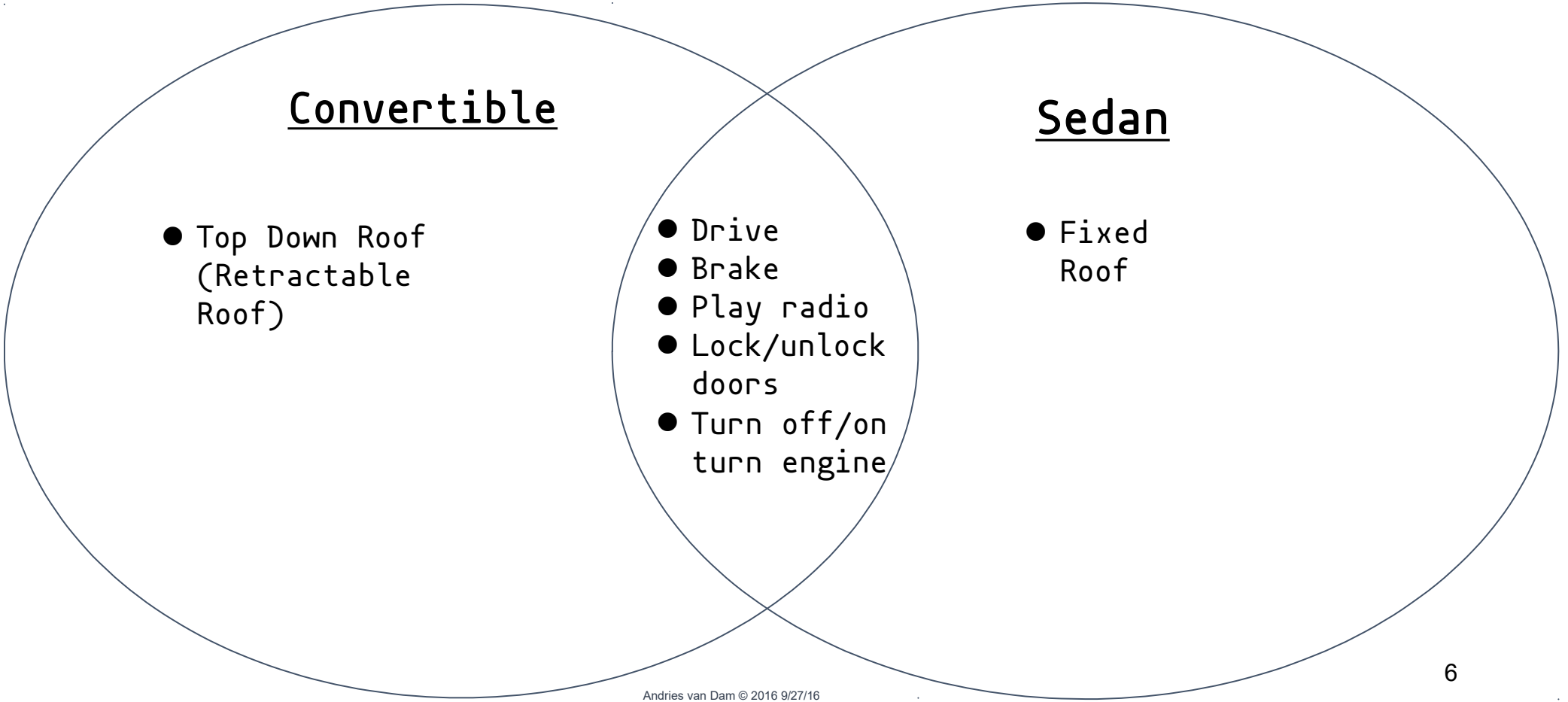
- Def_1: Referencing many related objects as one generic type.

- Def_2: Reference of ‘parent’ class utilizing attributes and methods of a ‘child’ class, depending on which one it is referencing.

Spot the Similarities

- What are the similarities between a convertible and a sedan?
- What are the differences?

Convertibles vs. Sedans



Can we model this in code?

- In some cases, objects can be very closely related to each other
  - Convertibles and sedans drive the same way
  - Flip phones and smartphones call the same way
- Imagine we have an Convertible and a Sedan class
  - Can we enumerate their similarities in one place?
  - How do we portray their relationship through code?

Convertible

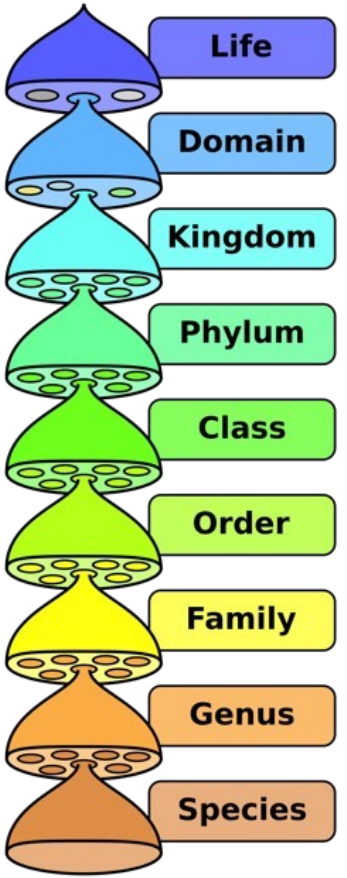
- putTopDown()
- turnOnEngine()
- turnOffEngine()
- drive()

Sedan

- parkInCompactSpace ()
- turnOnEngine()
- turnOffEngine()
- drive()

Inheritance

- In OOP, inheritance is a way of modeling very similar classes
- **Inheritance** models an **“is-a”** relationship
  - A sedan “is a” car
  - A dog “is a” mammal
- Remember: **Interfaces** model an **“acts-as”** relationship
- You’ve probably seen inheritance before!
  - Taxonomy from biology class



Animalia

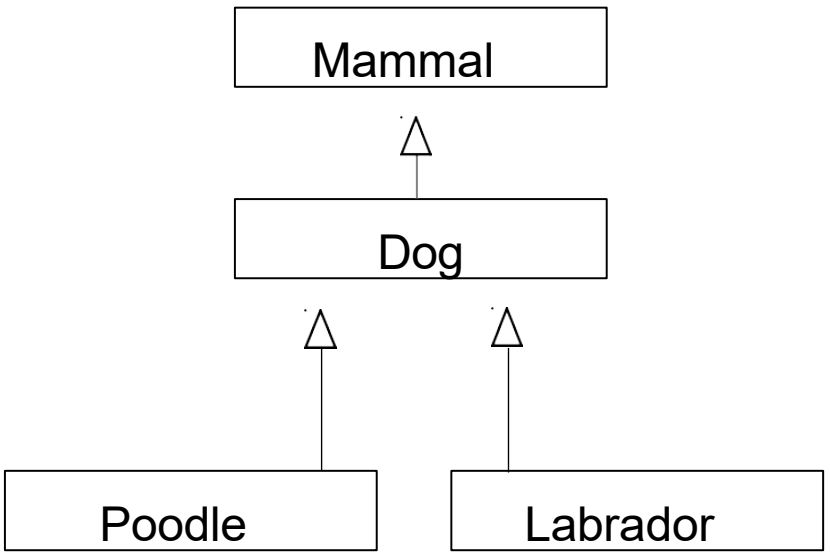
Chordata

Mammalia

⋮

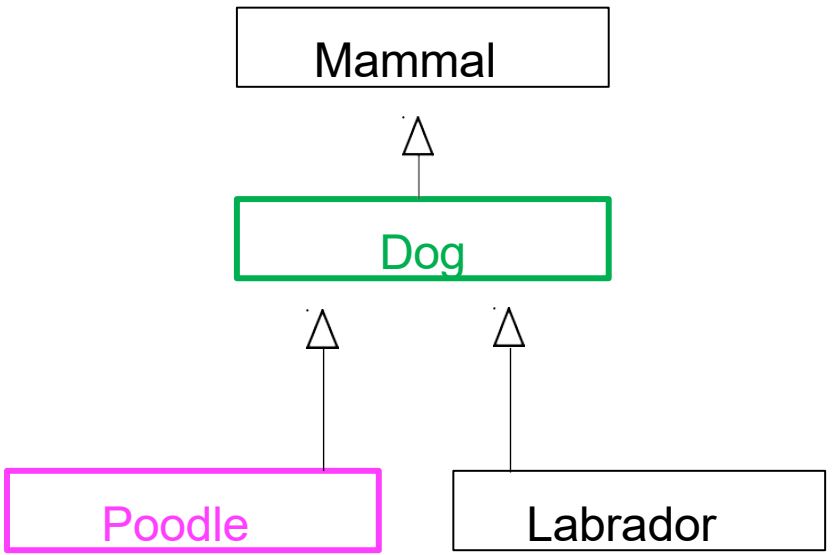
Canis

Modeling Inheritance (1/2)



- This is an inheritance diagram
  - Each box represents a class
- A Poodle "is-a" Dog, a Dog "is-a" Mammal
  - Transitively, a Poodle is a Mammal
- "Inherits from" = "is-a"
  - Poodle inherits from Dog
  - Dog inherits from Mammal
- This relationship is not bidirectional
  - A Poodle is a Dog, but not every Dog is a Poodle (could be a Labrador, a German Shepard, etc)

Modeling Inheritance (2/2)



- **Superclass/parent/base**: A class that is inherited from
- **Subclass/child/derived**: A class that inherits from another
- "A Poodle is a Dog"
  - Poodle is the subclass
  - Dog is the superclass
- A class can be both a superclass and a subclass
  - Ex. Dog
- In Java you can only inherit from one superclass (no multiple inheritance)
  - Other languages, like C++, allow for multiple inheritance, but too easy to mess up

Motivations for Inheritance

- A subclass inherits all of its parent's **public** and **protected** capabilities
  - If Car defines drive(), Convertible inherits drive() from Car and drives the same way. This holds true for all of Convertible's subclasses as well
- Inheritance and Interfaces both legislate class's behavior, although in very different ways
  - Interfaces allow the compiler to enforce method implementation
    - An implementing class will have all capabilities outlined in an interface
  - Inheritance assures the compiler that all **subclasses** of a **superclass** will have the superclass's public capabilities without having to respecify code - methods are inherited
    - A Convertible knows how to drive and drives the same way as Car because of inherited code
- Benefit of inheritance
  - Code reuse

    - If drive() is defined in Car, Convertible doesn't need to redefine it! Code is
    - inherited Only need to implement what is different, i.e. what makes Convertible special

Superclasses vs Subclasses

- A superclass factors out commonalities among its subclasses
  - describes everything that all subclasses have in common.

  NOTE: Java classes can have only one parent (super) class, unlike CPP.

- A subclass differentiates/specializes its superclass by:
  - **adding new methods:**
    -
  - **Overriding inherited methods:**
    -

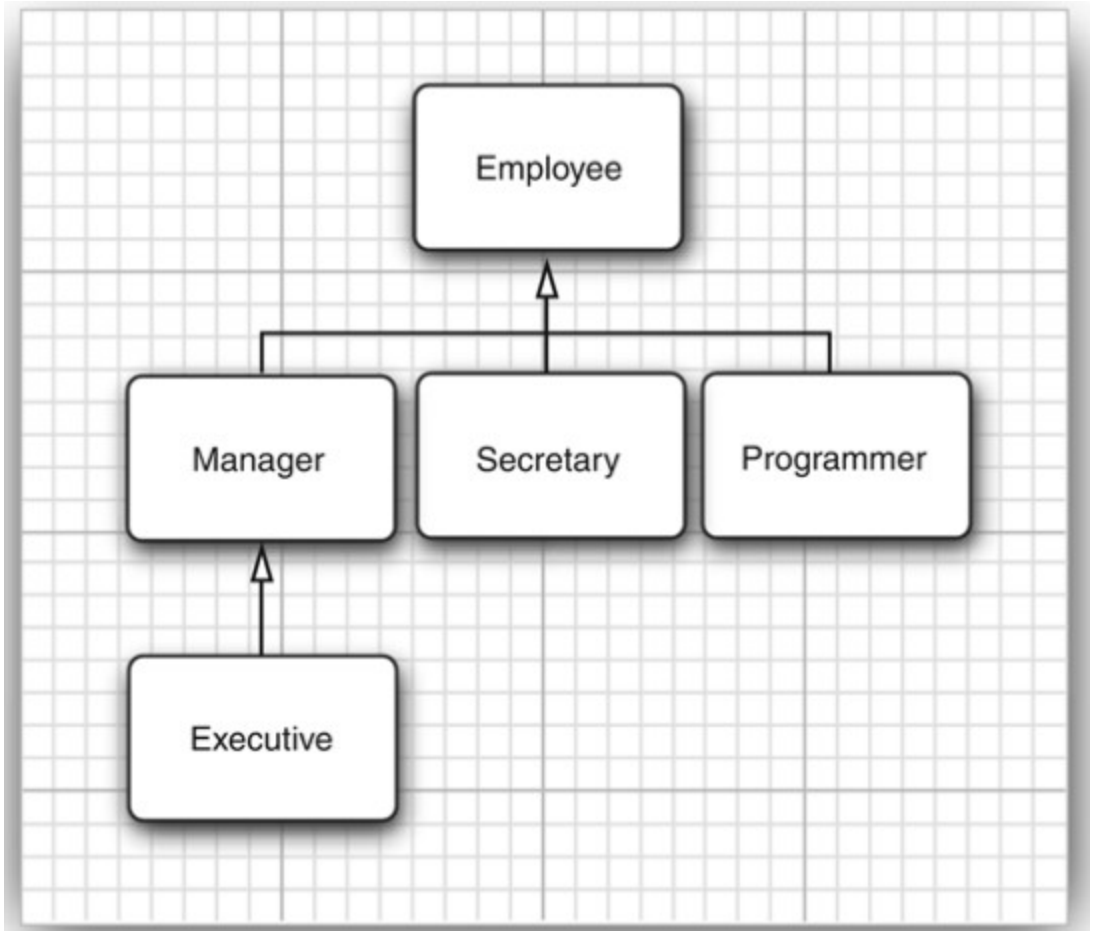
Method Overriding

- Override parent class ‘public’ methods (not private).
  - Child can access ‘public’ methods and attributes of parent class.
  - Using parent class attributes - super.<Attib_name>
  - Using parent class methods - super.f()
  - Calling parent class constructor

```
<subclass constructor>{
 super(<arguments>)
 }
```

```
public class Manager extends Employee
{
   private double bonus;
   . . .
   public void setBonus(double bonus)
   {
      this.bonus = bonus;
   }
}
public double getSalary()
{
   double baseSalary = super.getSalary();
   return baseSalary + bonus;
}
```

Inheritance and Polymorphism



- Polymorphism is an incredibly powerful tool.
- Allows for generic programming.
- Treat multiple classes as their generic type while still allowing specific method implementations to be executed.
- Polymorphism+Inheritance is strong generic coding

Inheritance and Polymorphism

```
1  package inheritance;
2
3  import java.time.*;
4
5  public class Employee
6  {
7     private String name;
8     private double salary;
9     private LocalDate hireDay;
10
11    public Employee(String name, double salary, int year, int month, int day)
12    {
13       this.name = name;
14       this.salary = salary;
15       hireDay = LocalDate.of(year, month, day);
16    }
17
18    public String getName()
19    {
20       return name;
21    }
22
23    public double getSalary()
24    {
25       return salary;
26    }
27
28    public LocalDate getHireDay()
29    {
30       return hireDay;
31    }
32
33    public void raiseSalary(double byPercent)
34    {
35       double raise = salary * byPercent / 100;
36       salary += raise;
37    }
38 }
```

Inheritance and Polymorphism

```
1  package inheritance;
2
3  public class Manager extends Employee
4  {
5     private double bonus;
6
7     /**
8      * @param name the employee's name
9      * @param salary the salary
10     * @param year the hire year
11     * @param month the hire month
12     * @param day the hire day
13     */
14    public Manager(String name, double salary, int year, int month, int day)
15    {
16       super(name, salary, year, month, day);
17       bonus = 0;
18    }
20    public double getSalary()
21    {
22       double baseSalary = super.getSalary();
23       return baseSalary + bonus;
24    }
25
26    public void setBonus(double b)
27    {
28       bonus = b;
29    }
30 }
```

Inheritance and Polymorphism

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4
5  public class Employee
6  {
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10
11    public Employee(String name, double salary, int year, int month, int day)
12    {
13       this.name = name;
14       this.salary = salary;
15       hireDay = LocalDate.of(year, month, day);
16    }
17
18    public String getName()
19    {
20       return name;
21    }
22
23    public double getSalary()
24    {
25       return salary;
26    }
27
28    public LocalDate getHireDay()
29    {
30       return hireDay;
31    }
32
33    public void raiseSalary(double byPercent)
34    {
35       double raise = salary * byPercent / 100;
36       salary += raise;
37    }
38 }
```

Inheritance and Polymorphism

```
Employee e;
e = new Employee(. . .);  // Employee object expected
e = new Manager(. . .); // OK, Manager can be used as well
```

```
Manager boss = new Manager(. . .);
Employee[] staff = new Employee[3];
staff[0] = boss;
```

```
boss.setBonus(5000); // OK
```

Why ?

```
staff[0].setBonus(5000); // ERROR
```

Rules for Method Calls

- 1. Compiler looks at types of objects and method names, determines the appropaite method based on the return type. The compiler also resolves.
- 2. Argument types.
- 3. Method types - ‘private’ , ‘static’ , ‘final’.
- 4. Polymorphic associations - dynamic binding at runtime.

Preventing Inheritance

- 1. What all a child class inherits:
  - Public objects and methods.
  - Private of parent is never inhreited.
  - Parent constructors (by default public, like everything else in Java).

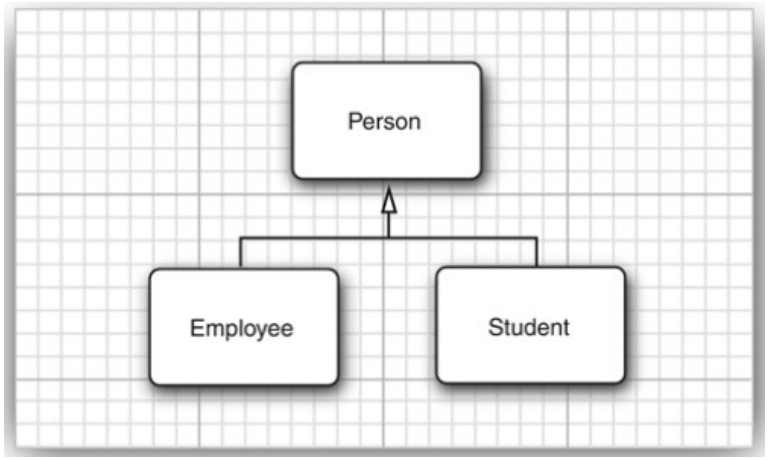
- Preventing inheritance:

```
public final class Executive extends Manager
{
   . . .
}
```

```
public class Employee
{
   . . .
   public final String getName()
   {
      return name;
   }
   . . .
}
```

  - You could also prevent specific methods
  - from being inherited *without* making them private.

Abstract Classes




```
public abstract class Person
{
   . . .
   public abstract String getDescription();
}
```

```
1  package abstractClasses;
2
3  public abstract class Person
4  {
5     public abstract String getDescription();
6     private String name;
7
8     public Person(String name)
9     {
10       this.name = name;
11    }
12
13    public String getName()
14    {
15       return name;
16    }
17 }
```

```
1  package abstractClasses;
2
3  import java.time.*;
4
5  public class Employee extends Person
6  {
7     private double salary;
8     private LocalDate hireDay;
9
10    public Employee(String name, double salary, int year, int month, int day)
11    {
12       super(name);
13       this.salary = salary;
14       hireDay = LocalDate.of(year, month, day);
15    }
16
17    public double getSalary()
18    {
19       return salary;
20    }
21
22    public LocalDate getHireDay()
23    {
24       return hireDay;
25    }
26
27    public String getDescription()
28    {
29       return String.format("an employee with a salary of $%.2f", salary);
30    }
31
32    public void raiseSalary(double byPercent)
33    {
34       double raise = salary * byPercent / 100;
35       salary += raise;
36    }
37 }
```

Protected Access

- ‘Protected’ methods and objects cannot be accessed by objects of the class much like ‘private’.
- ‘Protected’ methods and objects/variable can be accessed by child classes.

Object - the Cosmic Super Class

- Object - parent of all classes (implicit); not of primitive types - int, char, byte etc.

```
Object obj = new Employee("Harry Hacker", 35000);
Employee e = (Employee) obj;
```

- Can be assigned to object of *any* class.
- Arrays - regardless they are of primitive types or of classes, are of type Object.

```
Employee[] staff = new Employee[10];
obj = staff; // OK
obj = new int[10]; // OK
```

Object - equals() method

- Test if two objects ‘equal’ or same. Could mean many things - reference to same object (default), same value etc.
- Object class defines equal(). Other classes, can extend it with their own definition.

```
public class Employee
{
   . . .
   public boolean equals(Object otherObject)
   {
      // a quick test to see if the objects are identical
      if (this == otherObject) return true;

      // must return false if the explicit parameter is null
      if (otherObject == null) return false;

      // if the classes don't match, they can't be equal
      if (getClass() != otherObject.getClass())
         return false;

      // now we know otherObject is a non-null Employee
      Employee other = (Employee) otherObject;

      // test whether the fields have identical values
      return name.equals(other.name)
         && salary == other.salary
         && hireDay.equals(other.hireDay);
   }
}
```

Object - toString() method

- Used to for printing a string equivalent information of the class. E.g. System.out.println(s); the return type is String and the name is toString()

- class MyClass{
- ...
- public String toString(){
- return “XYZ”;
- }

- }

Object Wrappers and Autoboxing

- Object corresponding to a primitive type [Integer, Long, Flot, Double,Short, Byte and Boolean].
- Their objects are immutable - once a wrapper object has been created their values cannot be changed.
- They are ‘final’ and cannot be inherited.
- Integer[] list;
- list = new Integer[500];
- list[0] = 1;
- list[1] = 1;
- list[i]++;
- But list[i] == list[j] fails.

Object Wrappers and Autoboxing

- `list[i].intValue() == list[j].intValue();`

java.lang.Integer 1.0

- `int intValue()`

  returns the value of this `Integer` object as an `int` (overrides the `intValue` method in the `Number` class).
- `static String toString(int i)`

  returns a new `String` object representing the number `i` in base 10.
- `static String toString(int i, int radix)`

  lets you return a representation of the number `i` in the base specified by the `radix` parameter.
- `static int parseInt(String s)`
- `static int parseInt(String s, int radix)`

  returns the integer whose digits are contained in the string `s`. The string must represent an integer in base 10 (for the first method) or in the base given by the `radix` parameter (for the second method).
- `static Integer valueOf(String s)`
- `static Integer valueOf(String s, int radix)`

  returns a new `Integer` object initialized to the integer whose digits are contained in the string `s`. The string must represent an integer in base 10 (for the first method) or in the base given by the `radix` parameter (for the second method).

java.text.NumberFormat 1.1

- `Number parse(String s)`

  returns the numeric value, assuming the specified `String` represents a number.

Enum classes

- Enumerated types - alternatives to constants.
- public enum Size { SMALL, MEDIUM, LARGE, EXTRA_LARGE }

```
public enum Size
{

 SMALL("S"), MEDIUM("M"), LARGE("L"), EXTRA_LARGE("XL");

 private String abbreviation;

 private Size(String abbreviation) { this.abbreviation = abbreviation; }
 public String getAbbreviation() { return abbreviation; }
}


Size s = Enum.valueOf(Size.class, "SMALL");
```

Generic ArrayLists

- ArrayList is a *generic class* with a *type parameter*.
- An example of polymorphism.
- Provides a dynamically growing (or shrinking) array of objects.
- ArrayList<Integer> mylist = new ArrayList<Integer>();
- or
- ArrayList<Integer> mylist = new ArrayList<>();

Generic ArrayLists

java.util.ArrayList<E> 1.2

- `ArrayList<E>()`

  constructs an empty array list.
- `ArrayList<E>(int initialCapacity)`

  constructs an empty array list with the specified capacity.
- `boolean add(E obj)`

  appends `obj` at the end of the array list. Always returns `true`.
- `int size()`

  returns the number of elements currently stored in the array list. (Of course, this is never larger than the array list's capacity.)
- `void ensureCapacity(int capacity)`

  ensures that the array list has the capacity to store the given number of elements without reallocating its internal storage array.
- `void trimToSize()`

  reduces the storage capacity of the array list to its current size.

- Accessing ArrayList elements
- mylist.get(index);
- mylist.set(index,val);

- ArrayList.toString() already defined. Prints comma separated array element values.

Interfaces

```
public class Employee implements Comparable<Employee>
{
   private String name;
   private double salary;

   public Employee(String name, double salary)
   {
      this.name = name;
      this.salary = salary;
   }

   public String getName()
   {
      return name;
   }

   public double getSalary()
   {
      return salary;
   }

   public void raiseSalary(double byPercent)
   {
      double raise = salary * byPercent / 100;
      salary += raise;
   }

   /**
    * Compares employees by salary
    * @param other another Employee object
    * @return a negative value if this employee has a lower salary than
    * otherObject, 0 if the salaries are the same, a positive value otherwise
    */
   public int compareTo(Employee other)
   {
      return Double.compare(salary, other.salary);
   }
}
```

Interfaces

```
x = new Comparable(. . .); // ERROR

Comparable x; // OK

x = new Employee(. . .); // OK provided Employee implements Comparable
```

Interfaces - Single Inheritance with Multiple Interface Implementations.

- public interface Comparable{
- public int compareTo(Object otherobject);
- }

- class Manager extends Employee implements Comparable {
- ....
- }

Can be as many as the programmer feels like.

Interfaces -Default Methods

- *Somewhat* like a default constructor, but you cannot instantiate objects of interfaces!

```
public interface Comparable<T>
{
   default int compareTo(T other) { return 0; }
      // by default, all elements are the same
}
```

```
public interface Iterator<E>
{
   boolean hasNext();
   E next();
   default void remove() { throw new UnsupportedOperationException("remove"); }
   . . .
}
```

Popular Use Case - Callbacks.

- Callback function frameworks use interfaces.
- Event listeners - need to implement these interfaces and interface functions.

java.awt.event

```
public interface ActionListener
{
   void actionPerformed(ActionEvent event);
}
```

```
class TimePrinter implements ActionListener
{
   public void actionPerformed(ActionEvent event)
   {
      System.out.println("At the tone, the time is "
         + Instant.ofEpochMilli(event.getWhen()));
      Toolkit.getDefaultToolkit().beep();
   }
}
```

- Timer t = new Timer(1000,new TimePrinter());

Popular Use Case - Callbacks.

```
import java.awt.*;
import java.awt.event.*;
import java.time.*;
import javax.swing.*;

public class TimerTest
{
   public static void main(String[] args)
   {
      var listener = new TimePrinter();

      // construct a timer that calls the listener
      // once every second
      var timer = new Timer(1000, listener);
      timer.start();

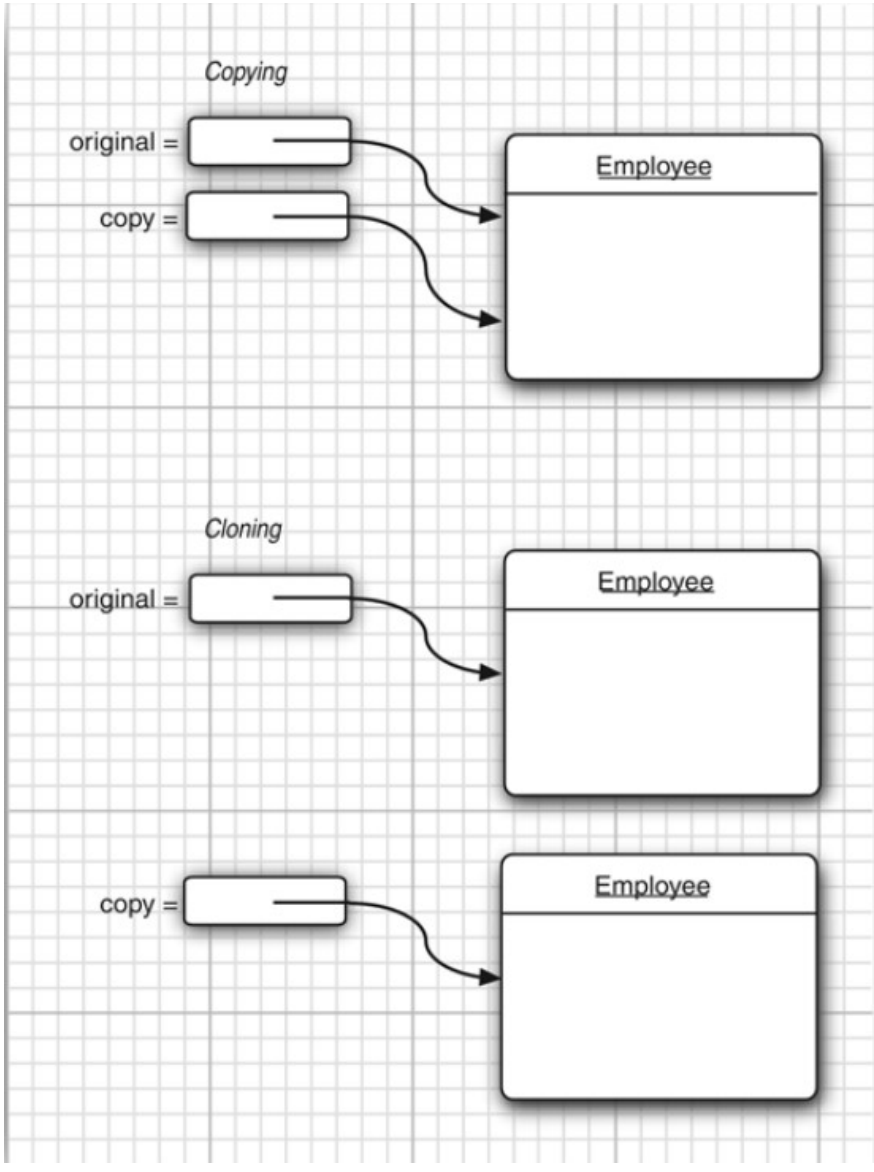
      // keep program running until the user selects "OK"
      JOptionPane.showMessageDialog(null, "Quit program?");
      System.exit(0);
   }
}

class TimePrinter implements ActionListener
{
   public void actionPerformed(ActionEvent event)
   {
      System.out.println("At the tone, the time is "
         + Instant.ofEpochMilli(event.getWhen()));
      Toolkit.getDefaultToolkit().beep();
   }
}
```

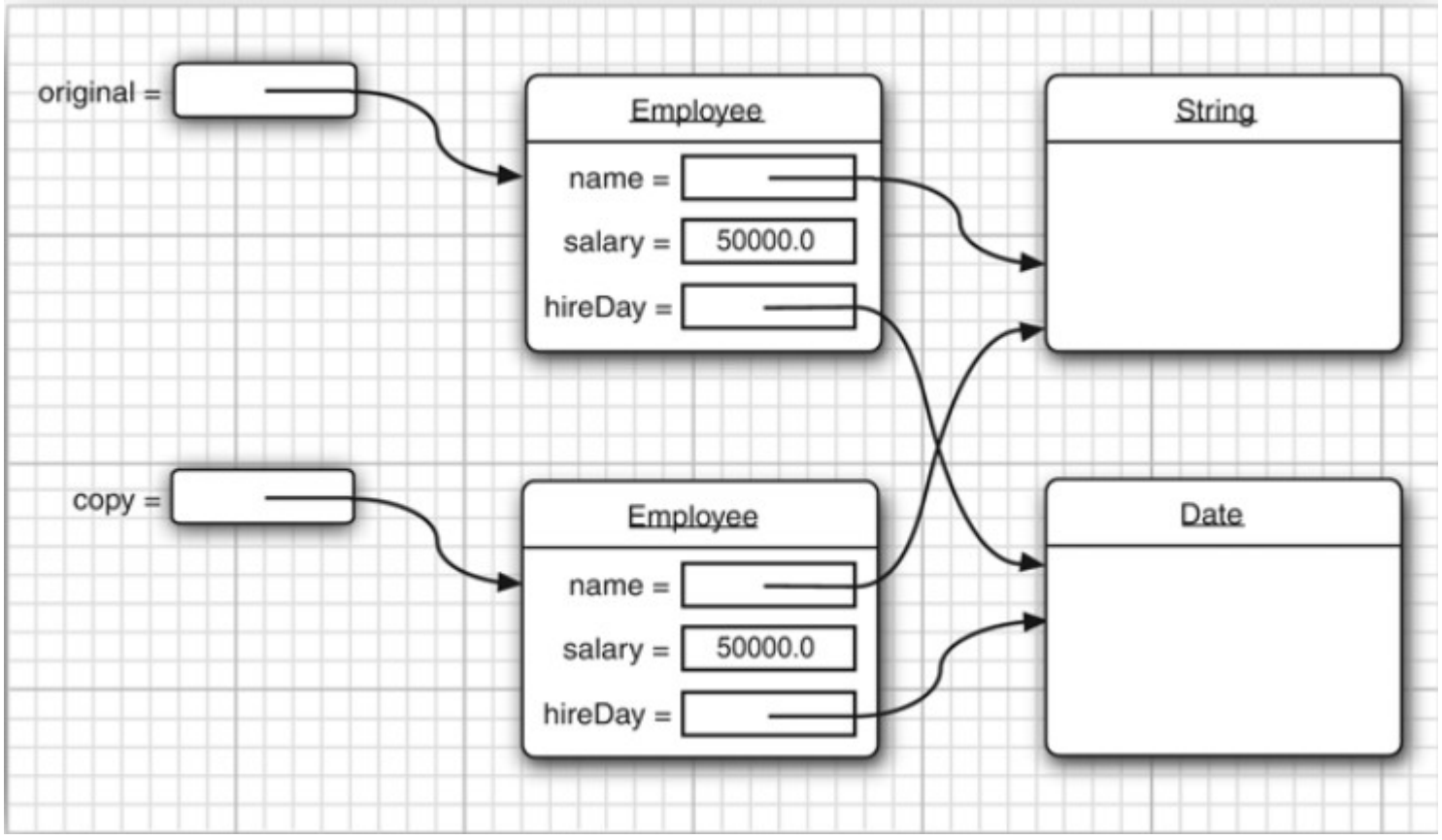
Object Cloning

```
var original = new Employee("John Public", 50000);
Employee copy = original;
copy.raiseSalary(10); // oops--also changed original
```

```
Employee copy = original.clone();
copy.raiseSalary(10); // OK--original unchanged
```



Object Cloning - Default:Shallow Copy



Object Cloning - Deep Copy: Implement Clonable

```
class Employee implements Cloneable
{
   // public access, change return type
   public Employee clone() throws CloneNotSupportedException
   {
      return (Employee) super.clone();
   }
   . . .
}
```

```
class Employee implements Cloneable
{
   . . .
   public Employee clone() throws CloneNotSupportedException
   {
      // call Object.clone()
      Employee cloned = (Employee) super.clone();

      // clone mutable fields
      cloned.hireDay = (Date) hireDay.clone();

      return cloned;
   }
}
```