Object-Oriented Programming CSE-703029

Faculty of Computer Science
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Lecture 4: Access Control & Reuse

Today's Topics

- Implementation hiding with packages and access specifiers.
- Composition
- Inheritance
- More on constructors
- Finals
- Class loading

Access Specifiers

- **public**, **protected**, **private** and “friendly”
- We haven’t used these yet, except for **main()** and **toString()**.
- **main()** needs to be **public**, so the runtime system can call it.
- **toString()** needs to be **public** since it is **public** in **Object**, and we are “overriding” it.

The “Need To Know” Principle

- Like military secrets, portions of your classes are best kept private.
- The public interface of a class should provide everything users need, but nothing they don’t.
- Access specifiers allow you to enforce the “need to know” principle.

Access Specifiers

- **public** members (variables and methods) are freely available for anyone's use.
- **private** members can be accessed (used) only by the methods of the containing class.
- **protected** members are public to subclasses, private to others.
- "Friendly" members have *package access*:
  - no access specifier
  - public within the containing package

Packages

- Java’s concept of “module”.
- A group of related classes.
- A package can have a name, but there is the unnamed package, which holds all the classes in your program that you haven’t put into a named package.

How Does It All Work?

- So far, we haven’t used packages and access specifiers. Why has this worked?
  - We kept all our **.class** files in the same folder; they are in the unnamed package.
  - All of our members were therefore friendly.
  - Only methods that are called from another package need access specifiers.
  - Make sure you have the current directory (‘.’) in your classpath.

The Basic Rules

- Class members should be **private** unless there is a need to know or use.
- Think carefully about the public interface.
- Use accessors/mutators (aka get and set methods) to control access to private member variables.
- Often we create methods that are only used internally; make these **private**.
- We'll worry about **protected** later.

Example

```
public class Fraction {
//Methods
    public Fraction()
    public Fraction(int n, int d)
    public String toString()
    public String toDecimal()
    public Fraction add(Fraction f)
    private int numerator;
    private int denominator;
    private int gcd(int a, int b)
}
```

How To Change A **Fraction**?

- This is a design decision.
- Some classes are "immutable" for good (or bad!) reasons. **String** is an example.
- If we want users to change a **Fraction** object's values, provide a "set" function:

```
public void set(int n, int d) {
    // test carefully for suitability, then:
    numerator = n;
    denominator = d;
}
```

Interface vs. Implementation

- For flexibility, we want the right to change an implementation if we find a better one.
- But we don't want to break client code.
- Access specifiers restrict what clients can rely on.
- Everything marked private is subject to change.

Example: **NNCollection**

- Our clients want to store last names and associated telephone numbers.
- The list may be large.
- They want
  - a class NameNumber for name & number pairs
  - NNCollection()
  - insert(NameNumber)
  - findNumber(String)

NameNumber

```
public class NameNumber {
    private String lastName;
    private String telNumber;
    public NameNumber() {}
    public NameNumber(String name, String num) {
        lastName = name;
        telNumber = num;
    }
    public String getLastName() {
        return lastName;
    }
    public String getTelNumber() {
        return telNumber;
    }
}
```

NNCollection

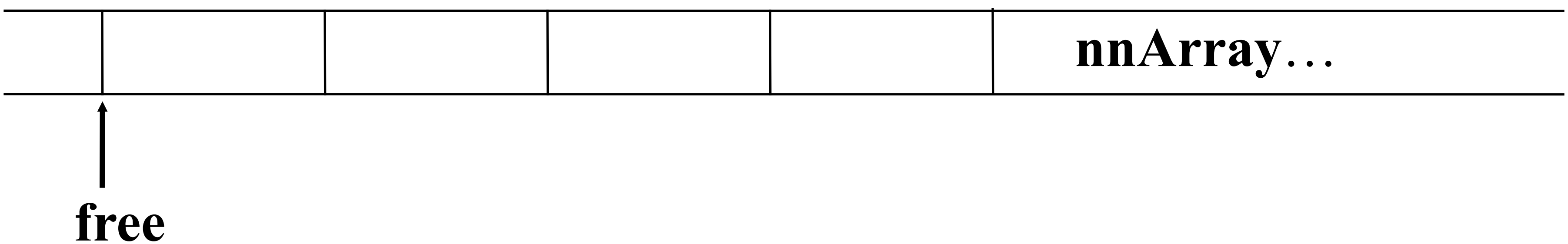
```
public class NNCollection {
   private NameNumber[] nnArray = new NameNumber[100];
   private int free;
   public NNCollection() {free = 0;}
   public void insert(NameNumber n) {
      int index = 0;
      for (int i = free++;
      i != 0 &&
      nnArray[i-1].getLastName().compareTo(n.getLastName()) > 0;
      i--) {
         nnArray[i] = nnArray[i-1];
         index = i;
      }
      nnArray[index] = n;
   }
```

NNCollection (cont.)

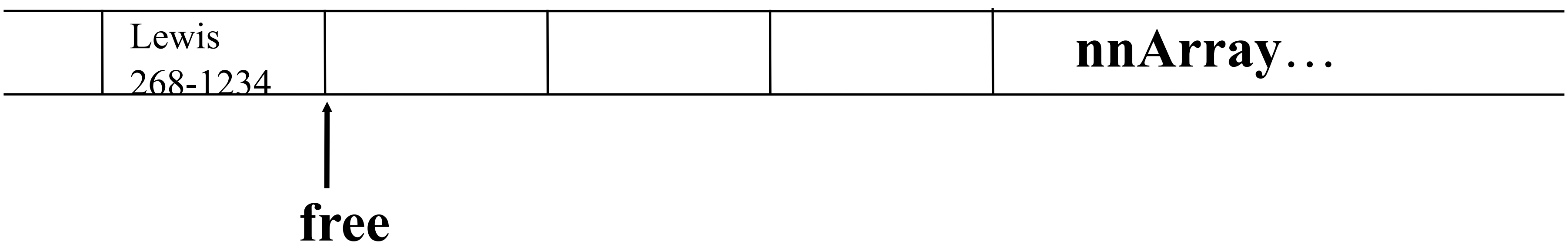
```
public String findNumber(String lName) {
      for (int i = 0; i != free; i++)
         if (nnArray[i].getLastName().equals(lName))
               return nnArray[i].getTelNumber();
      return new String("Name not found");
   }
}
```

NNCollection Insertion

Initial Array

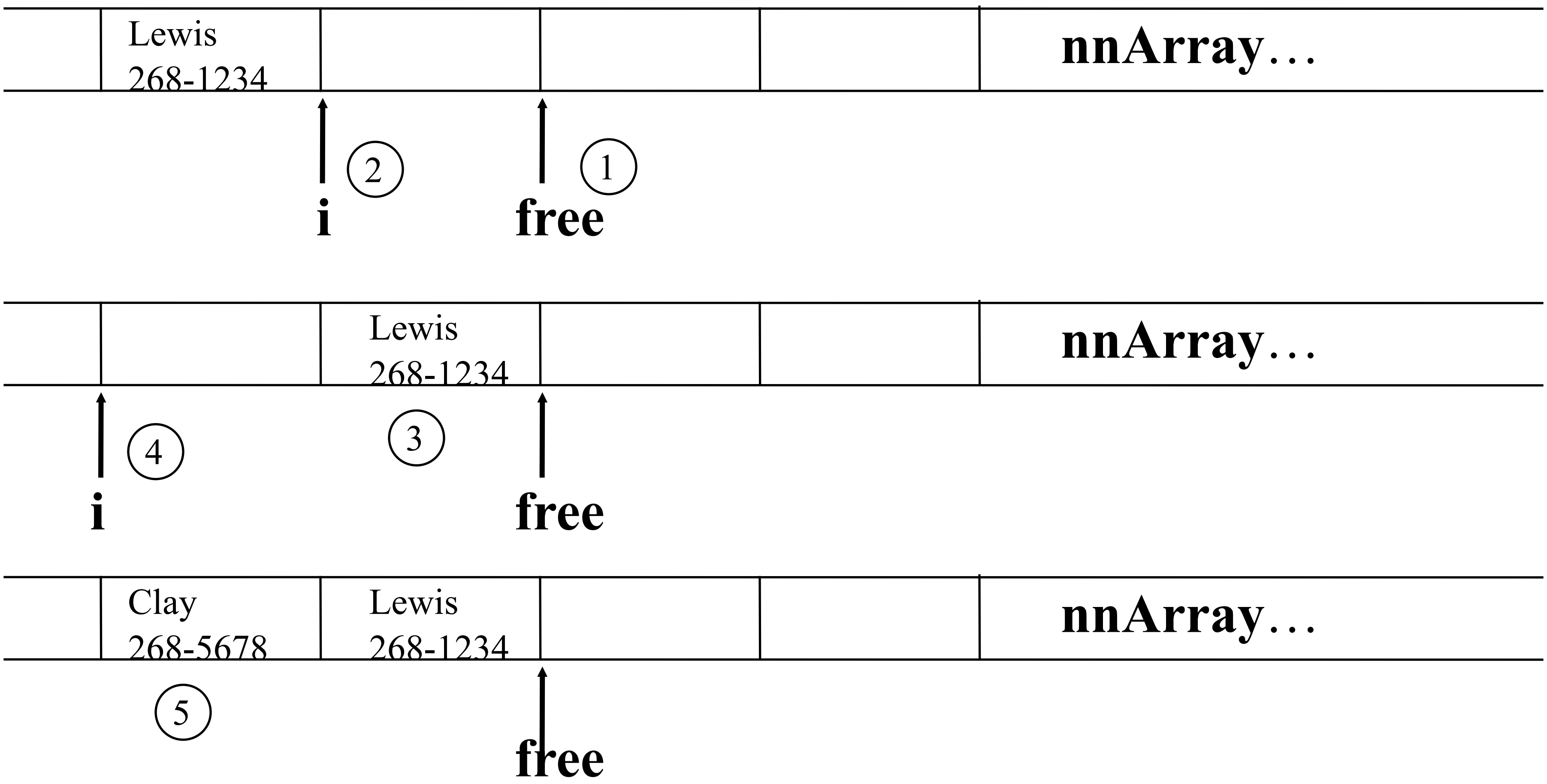


Insert “Lewis”



NNCollection Insertion (cont.)

Insert "Clay"



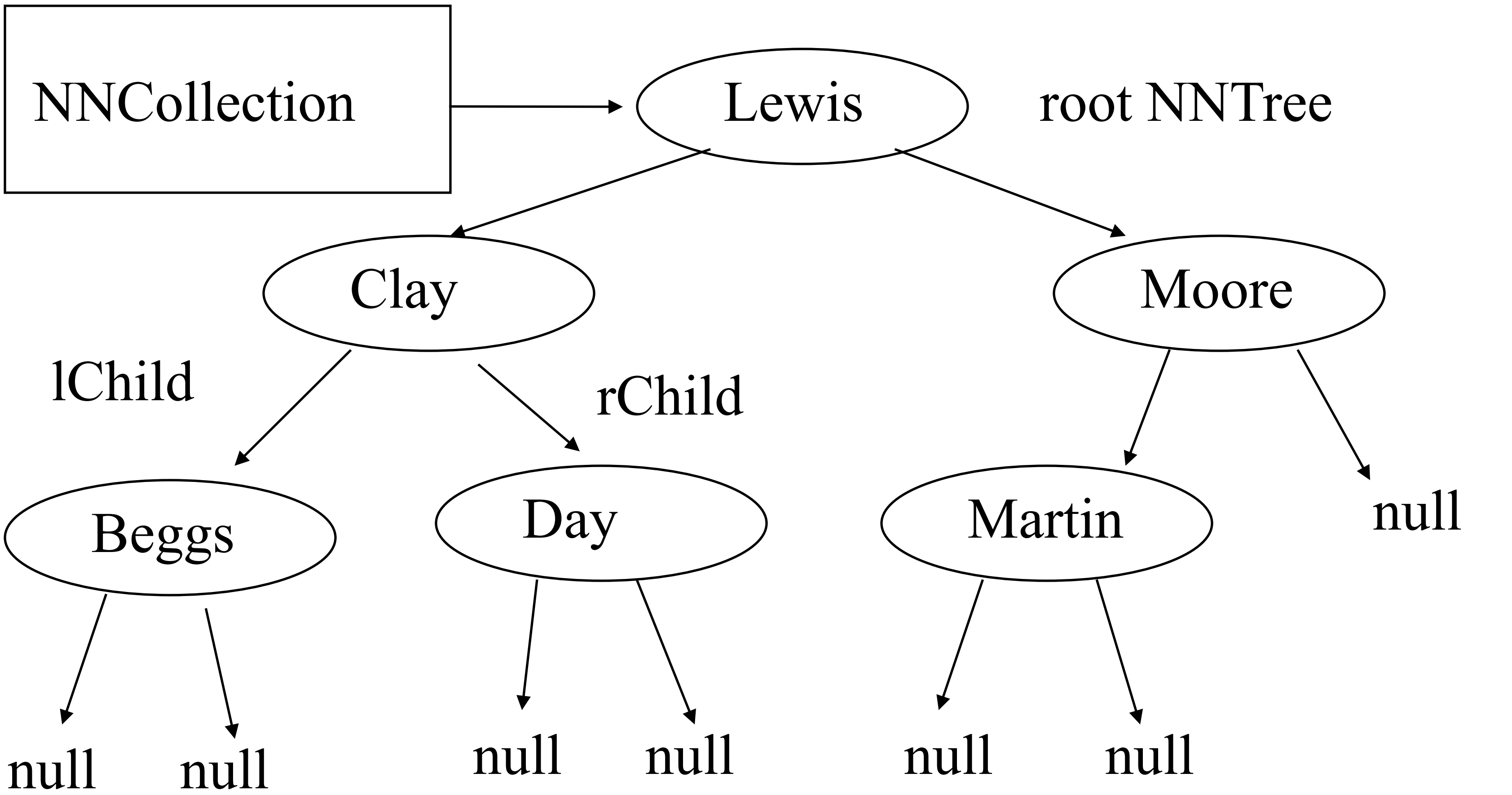
Yes, This Is Rotten

- It uses a fixed-size array.
- Array elements are interchanged every time a new name is entered. Slow.
- The array is searched sequentially. Slow.
- But, our clients can get started on *their* code.
- We go back and build a better implementation.

Better **NNCollection**

- Use a *binary tree*.
- Names “on the left” precede lexicographically.
- Roughly logarithmic insert and retrieve times.
- Very recursive, but not very expensive.

Binary Tree Layout

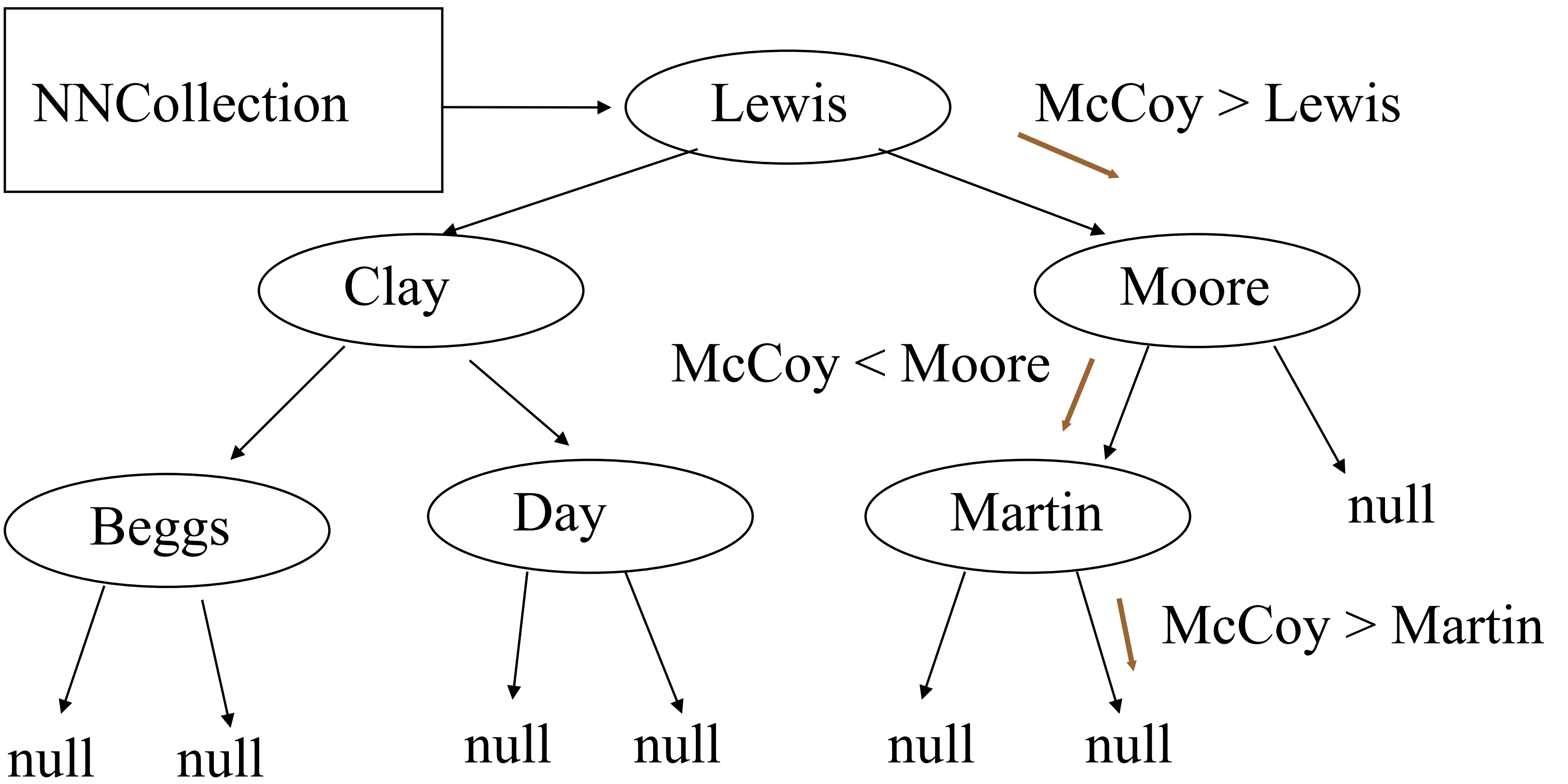


Note: Only the name of the **NameNumber** object is shown

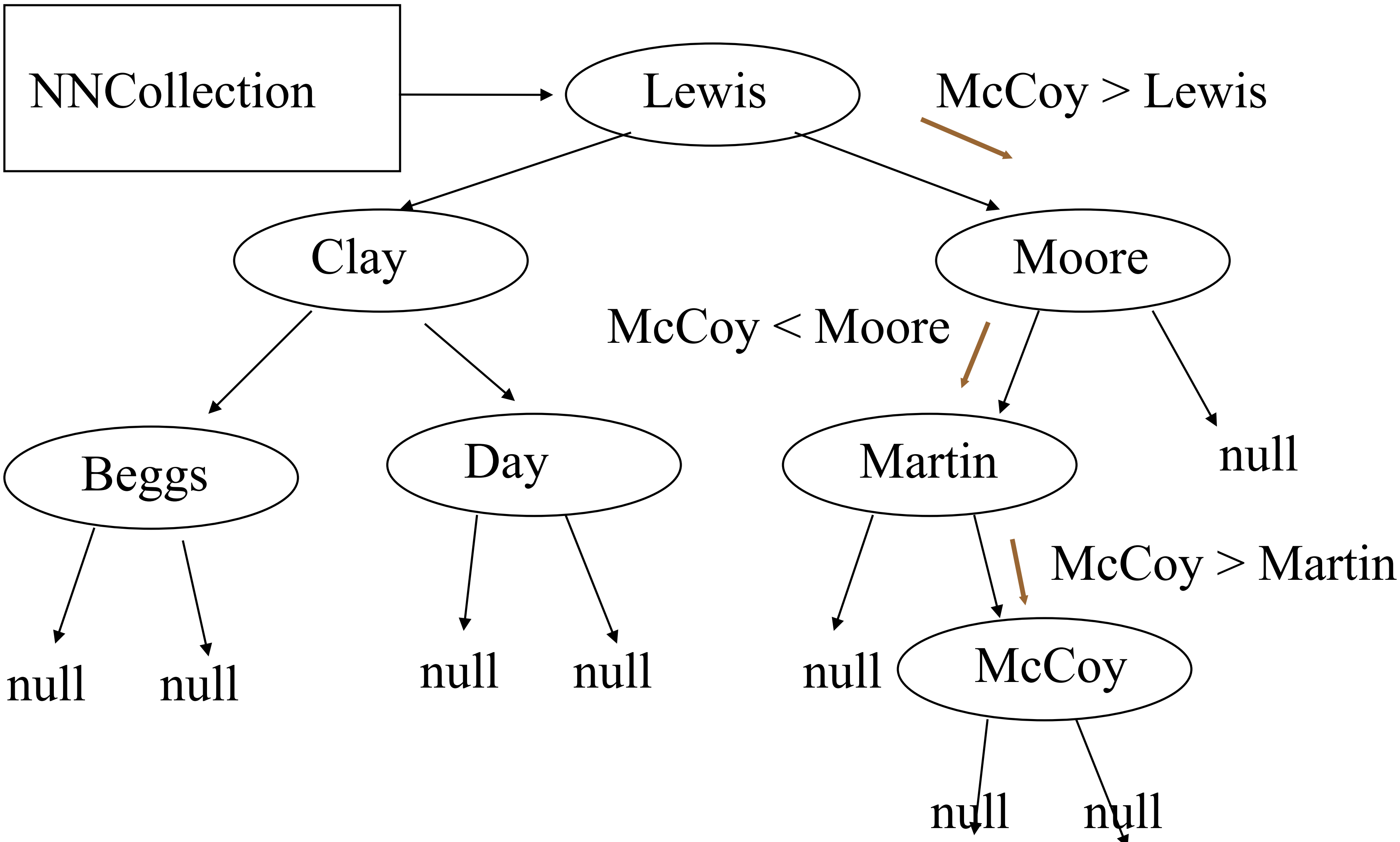
NNTree Class

- Each **NNTree** object
  - is a node, holding a **NameNumber** object.
  - keeps a reference to its left child and right child.
  - knows how to insert a **NameNumber** object.
  - knows how to find a **NameNumber** object.

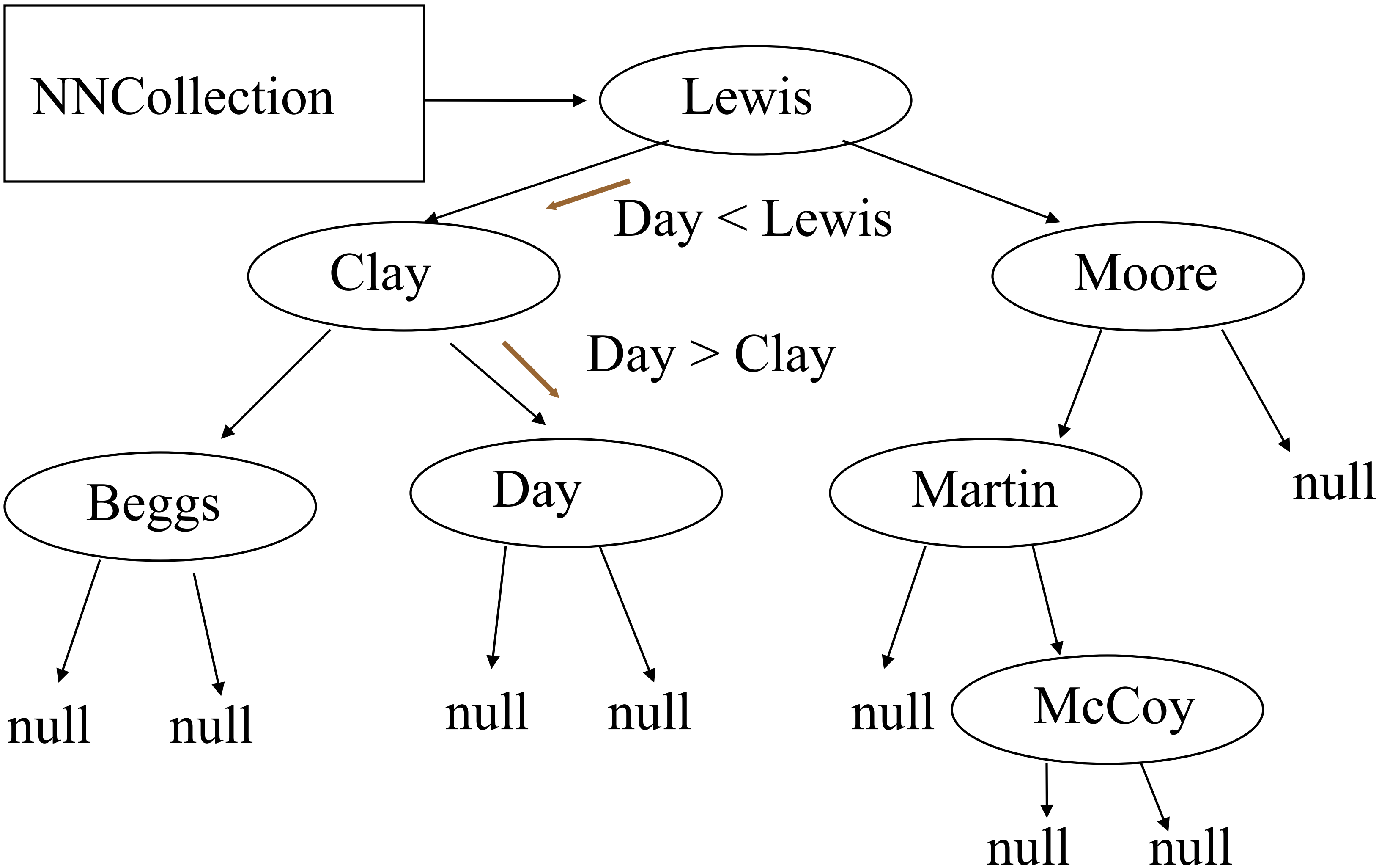
Inserting “McCoy”



Inserting “McCoy”



Finding "Day"



NNCollection
Lewis
Day < Lewis
Clay
Moore
Day > Clay
Beggs
Day
Martin
null
null
null
null
null
null
McCoy
null
null

NNTree Class Definition

```
public class NNTree {
    private NNTree lChild;
    private NNTree rChild;
    private NameNumber contents;
    public NNTree(NameNumber n) {
        contents = n;
    }
```

NNTree Class Definition (cont.)

```
public void insert(NameNumber n) {
        if (n.getLastName().compareTo(contents.getLastName()) < 0)
           if (lChild != null)
                    lChild.insert(n);
           else
              lChild = new NNTree(n);
        else
           if (rChild != null)
                    rChild.insert(n);
           else
              rChild = new NNTree(n);
}
```

NNTree Class Definition (cont.)

```
public String findNumber(String lName) {
    if (lName.compareTo(contents.getLastName()) < 0)
      if (lChild != null)
        return lChild.findNumber(lName);
        else
         return new String("Name not found");
    else if (lName.equals(contents.getLastName()))
      return contents.getTelNumber();
    else if (lName.compareTo(contents.getLastName()) > 0)
      if (rChild != null)
        return rChild.findNumber(lName);
        else
         return new String("Name not found");
    else
      return new String("Name not found");
}
```

NNCollection Again

```
public class NNCollection {
    private NNTree root;
    public NNCollection() {}
    public void insert(NameNumber n) {
        if (root != null) root.insert(n);
        else root = new NNTree(n);
    }
    String findNumber(String lName) {
        if (root != null)
            return root.findNumber(lName);
        else
            return new String("Name not found");
    }
}
```

More on Packages

- Bringing in a package of classes:

import java.util.*;

- Bringing in a single class:

import java.util.ArrayList;

- The compiler can find these things, through the classpath.
- If we're working from the command line, the classpath must be an environmental variable.

Creating a Package

- The very first line in all the files intended for the package named **myPackage**:

  package myPackage;
- Put all of the .class files in a directory named **myPackage**.
- Put the **myPackage** directory, as a subdirectory, in a directory given in the classpath.

Class Access

- Classes can be **public** or not.
- Non-**public** classes are available only within the package they are defined in.
- There can be only one **public** class in a "compilation unit" (a .java file).
- Non-**public** classes are "helper" classes, not for public use.

Class Reuse

- A noble goal, and in Java it's finally happening!
- Basically two ways: *composition* and *inheritance*.
- Composition is called "has-a".
- Inheritance is called "is-a".

Composition

- We've done plenty of this already:
  - The Monte **Game** class is composed of several **Doors** (among other things).
  - The Monte **PlayManyGames** class has-a **Game**.
- All you do is place a reference to a different kind of object in your class: Ta Da! You're using composition.

Inheritance

- An object of a new class that *inherits* from an existing class has all the “powers and abilities” of the parent class:
  - all data members
  - all methods
  - you can add additional data and methods if you wish
  - a derived class object “is-an” object of the parent class type, so can be used in function calls where a parent-class object is specified

Inheritance Syntax

```
class Cleanser {
    private String activeIngredient; //private
    public void dilute(int percent)     {// water-down}
    public void apply(DirtyThing d) {// pour it on}
    public void scrub(Brush b)          {// watch it work}
}
public class Detergent extends Cleanser {
    private String specialIngredient;
    public void scrub(Brush b) {
        // scrub gently, then
        super.scrub(b);  // the usual way
    }
    public void foam() { // make bubbles}
}
```

Access Control, Again

- **Detergent** does indeed have an **activeIngredient**, but it's not accessible.
- If **Detergent** needs to access it, it must be either
  - made **protected** (or friendly) in **Cleanser**, or
  - be accessible through get and set methods in **Cleanser**.
- **You can't inherit just to get access**!(PRIVATE)

What Is A **Detergent** Object?

- An object of type **Cleanser**, having all the members of **Cleanser**.
- An object of type **Detergent**, having all the additional members of **Detergent**.
- An object that "responds" to "messages" (ummm…method calls) as though it's a **Cleanser**, unless
  - new methods have been added to **Detergent as foam()** , or
  - **Cleanser** methods have been over-ridden.

Subclasses and Constructors

- Think of a **Detergent** object as containing a **Cleanser** *sub-object*.
- So, that sub-object has to be constructed when you create a **Detergent** object.
- The **Cleanser** object has to be created *first*, since constructing the remaining **Detergent** part might rely on it.
- “Always call the base class constructor first.”

Subclasses and Constructors

```
class Cleanser {
   private String activeIngredient;
   Cleanser() {
      System.out.println("Cleanser constructor");
   }
}
public class Detergent extends Cleanser {
   private String specialIngredient;
   Detergent() {
      System.out.println("Detergent constructor");
   }
   public static void main(String[] args) {
      Detergent d = new Detergent();
   }
}
```

Subclasses and Constructors

```
class Cleanser {
    private String activeIngredient;
    Cleanser(String active) {
        activeIngredient = active;
    }
}
public class Detergent extends Cleanser {
    private String specialIngredient;
    Detergent(String active, String special) {
        super(active);  // what if this isn't here?
        specialIngredient = special;
    }
}
```

Composition vs. Inheritance

- Think “has-a” vs. “is-a”.
- Consider the **NNCollection** class. Suppose now we need to store a **String/int** pair (names and ages, perhaps).
- Should we inherit, or compose?
- In either approach, we just need to be able to turn **String**s into **int**s, and vice versa (not hard).

Composition vs. Inheritance

```
class NACollection {
    private NNCollection nnc;
    NACollection() { // …}
    public void insert (NameAge n) { uses nnc's insert()}
    public int findAge(String name) { uses nnc's findNumber()}
}
```

or

```
class NACollection extends NNCollection {
    NACollection() { //…}
    public void insert(NameAge n) { uses super.insert()}
    public int findAge(String name) { uses super.findNumber()}
}
```

protected Class Members

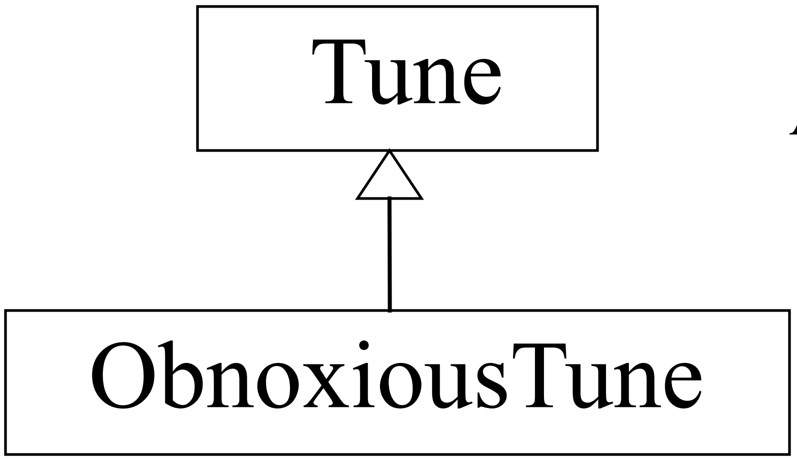
- **public** to subclasses.
- **private** to “the outside world”,
- except within the package (i.e., they are “friendly”.
- **private** is usually the best policy, unless you are looking for speed (but then why use Java!?).

Upcasting

```
class CellPhone {
    cellPhone() { //…}
    public void ring(Tune t) { t.play(); }
}
class Tune {
    Tune() { // …}
    public void play() { // …}
}
class ObnoxiousTune extends Tune{
    ObnoxiousTune() { // …}
    // …
}
```

An **ObnoxiousTune** “is-a” **Tune**

```
class DisruptLecture {
    public static void main() {
        CellPhone noiseMaker = new CellPhone();
        ObnoxiousTune ot = new ObnoxiousTune();
        noiseMaker.ring(ot);  // ot works though Tune called for
    }
}
```



A “UML” diagram

The **final** Keyword

- Vaguely like **const** in C++.
- It says “this is invariant”.
- Can be used for
  - data
  - methods
  - classes
- A kind of protection mechanism.

final

The final keyword is a non-access modifier used for classes, attributes and methods, which makes them non-changeable (impossible to inherit or override).

final

- Final Variable → To Create constant variable
- Final Methods → Prevent Mehod Overriding
- Final Classes → Prevent Inheritance

final Data (Compile-Time)

- For primitive types (**int**, **float**, etc.), the meaning is “this can’t change value”.

```
class Sedan {
    final int numDoors = 4;
```

- For references, the meaning is “this reference must always refer to the same object”.

```
    final Engine e = new Engine(300);
```

final Data (Run-Time)

- Called a “blank final;” the value is filled in during execution.

```
class Sedan {
    final int topSpeed;
    Sedan(int ts) {
        topSpeed = ts;
        // …
    }
}
class DragRace {
    Sedan chevy = new Sedan(120), ford = new Sedan(140);
    //! chevy.topSpeed = 150;
```

final Method Arguments

```
class Sedan {
    public void replaceTire(final Tire t) {
        //! t = new Tire();
```

- Same idea:
  - a **final** primitive has a constant value
  - a **final** reference always refers to the same object.
- Note well: a **final** reference does *not* say that the object *referred to* can’t change (*cf.* C++)

final Methods

- **final** methods cannot be overridden in subclasses. Maybe a bad idea?
- **final** methods can be inlined, allowing the compiler to insert the method code where it is called.
- This may improve execution speed.
- Only useful for small methods.
- **private** methods are implicitly **final**.

final Classes

- These can’t be inherited from (ummm, “subclassed”?.
- All methods are implicitly **final**, so inlining can be done.

Class Loading

- A **.class** file is loaded when
  - the first object of that type is created, or
  - when a static member is first used.
- When a derived class object is created, the base class file is immediately loaded (before the derived class constructor actually goes to work).

Variable-Length Argument Lists

```
class A { int i; }
public class VarArgs {
   static void f(Object[] x) {
      for (int i = 0; i < x.length; i++)
         System.out.println(x[i]);
   }
   public static void main(String[] args) {
       f(new Object[] {
         new Integer(47), new VarArgs(),
         new Float(3.14), new Double(11.11) } );
      f(new Object[] {"one", "two", "three" }) ;
      f(new Object[] {new A(), new A(), new A() } );
   }
}
```

Variable-Length Argument Lists

- This prints

  47

  VarArgs@fee6172e

  3.14

  11.11

  one

  two

  three

  A@fee61874

  A@fee61873

  A@fee6186a