OVERVIEW

1 Array List & Generics
2 Access Modifiers & Packages
3 Stacks & Queues
4 Recursion
5 OpenNLP & Maven
6 Lambda Expression & Stream
7 Binary Tress & Level Order
8 Hashing
9 Runtime Exception
10 XML

Objectives:
- Introduce Abstract Data Types (ADTs) and review interfaces
- Introduce Java's `ArrayList` class
- Learn about linked lists and inner classes
- Introduce Generics

# Dynamic Data Structures and Generics

Reading:
Savitch ch. 12

# Abstract Data Type (ADT)

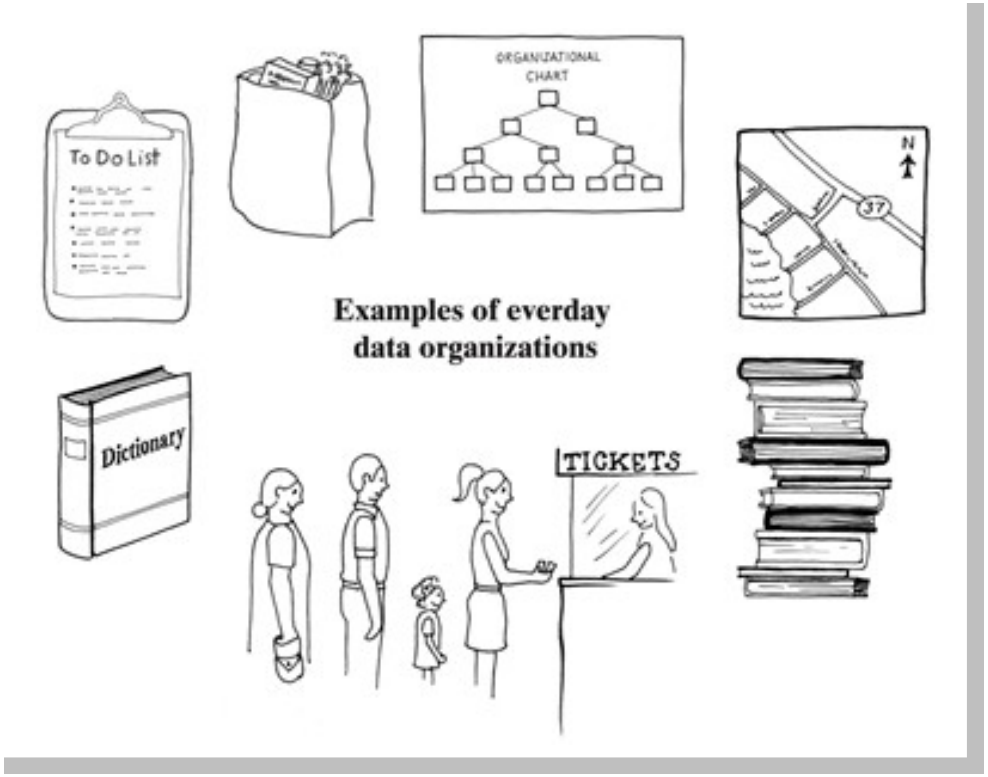
- Computers store/organize items similarly to the examples.
- Ways of organizing data are represented by Abstract Data Types (**ADT**s).
- An ADT specifies
  - data that is stored
  - operations that can be done on the data

# An ADT is Abstract

- The data type is abstract.
  - Implementation details are NOT part of an ADT.
  - An ADT does NOT specify how the data is to be represented.
- We can discuss ADTs independently of any programming language.

# Types of ADTs

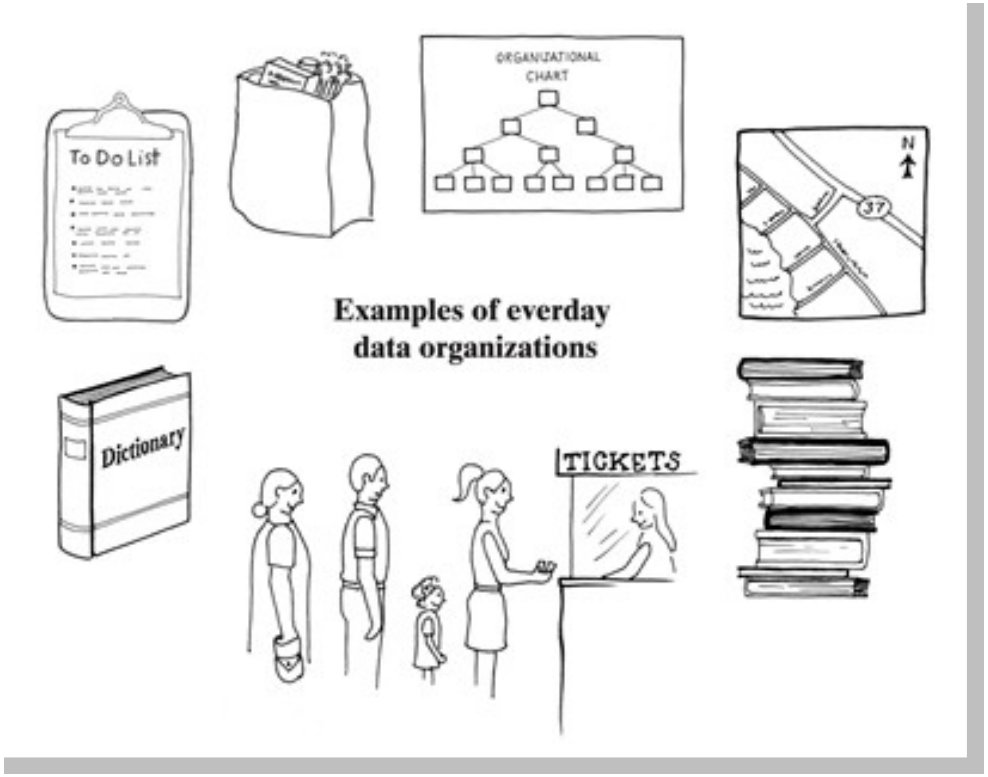
7个:
Bag, List, Stack, Queue,
Dictionary, Tree, Graph




- Bag
  - Unordered collection, may contain duplicates
- List
  - A collection that numbers its items
- Stack
  - Orders items chronologically
  - Last In, First out

# Types of ADTs

7个:
Bag, List, Stack, Queue,
Dictionary, Tree, Graph




- Queue
  - Orders items chronologically
  - First in, First out
- Dictionary
  - Pairs of items – one is a key
  - Can be sorted or not
- Tree
  - Arranged in a hierarchy
- Graph
  - Generalization of a tree

# ADT Terminology

- **Data structure**: implementation of an ADT within a programming language.
- **Collection**: an ADT that contains a group of objects
- **Container**: a class that implements the collection
- The terms Collection and Container can be used interchangeably

# Interfaces

- In Java, an ADT is represented as an *interface*, e.g., **`List<T>`**
- In a Java interface, the operations are expressed as *abstract methods*.
- An *abstract method* is a method that does not have an implementation. 抽象方法不含执行
  与`void`与否无关
- In an interface, all of the methods are abstract.

```
In `interface` we define set of methods,
which then have to be realised through `class`
```

# Interface - Example

- The following interface, called **ListADT** has 3 abstract methods, **add**, **remove**, and **get**:

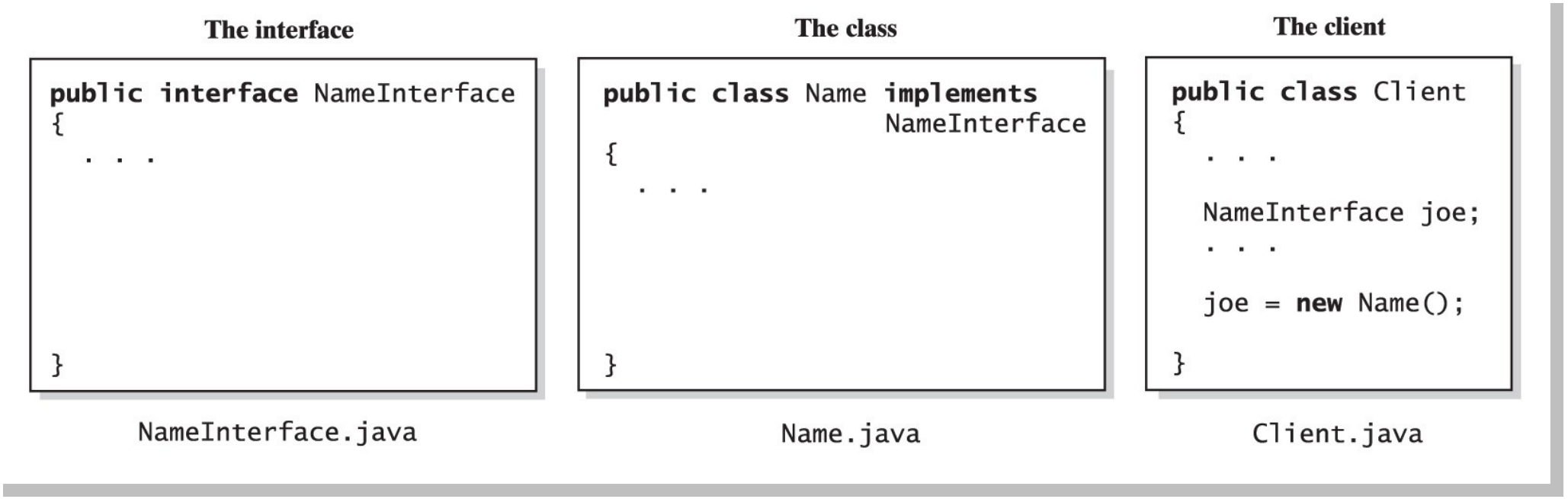
```
// file ListADT.java
public interface ListADT {
    public void add(String element);
    public void remove(String element);
    public String get(int index);
}
```

# Implementing an Interface

- A class implements an interface by providing method implementations for each of the abstract methods.
- A class that implements an interface uses the reserved word **`implements`** followed by the interface name. i.e. `implements` + interface name
- A class can implement more than 1 interface:

```
public class MyClass
   implements interface1, interface2, … { …
```

# Implementing an Interface



**The interface**

```
public interface NameInterface
{
   . . .




}
```

NameInterface.java

**The class**

```
public class Name implements
                    NameInterface
{
   . . .




}
```

Name.java

**The client**

```
public class Client
{
   . . .

   NameInterface joe;
   . . .

   joe = new Name();

}
```

Client.java

- The object **`joe`** has the types **`NameInterface`** and **`Name`**

# Comparable<T> Interface

- The **Comparable<T>** interface is defined in the java standard class library.
- It contains one method, **compareTo**, which takes an object as parameter and returns an integer
  - e.g.: **int result = obj1.compareTo(obj2);**
- The intention of this interface is to provide a common way to compare one object to another
- The integer that is returned should be negative if **obj1** is less than **obj2**, 0 if they are equal, and positive if **obj1** is greater than **obj2**
- The **String** class implements this interface

# `List<T>` Interface

- The **`List<T>`** interface is part of the **`java.util`** package
- The intention of this interface is to provide a common way to store and maintain an ordered collection (sequence/list) of data
- It contains several abstract methods, e.g.: **`add`**, **`contains`**, **`get`**, **`indexOf`**, **`remove`**, **`set`**, **`size`**, etc.
- The **`ArrayList`** class implements this interface

# `ArrayList` Introduction

- A *data structure* is used to organize data in a specific way
- An array is a *static* data structure
- *Dynamic* data structures can grow and shrink while a program is running
- **`ArrayLists`** are dynamic
- **`ArrayLists`** are similar to arrays, but are more flexible

```
– We can think of ArrayLists as arrays that grow
and shrink while a program is running.
– At the time an array is created, its length is
fixed. Reize when too small, wasted when too large.
```

# ArrayLists

- **ArrayLists** perform the resizing operation that we implemented ourselves up to now
- **ArrayLists** serve the same purposes as arrays, but can change in length while a program runs.
- The added flexibility comes at a price:
  - **ArrayLists** are less efficient than arrays
  - The base type of an **ArrayList** can't be a primitive type (use wrapper classes)

# Using `ArrayLists`

- The definition of class **`ArrayList`** must be imported:

```
import java.util.*;
```

- To create and name an **`ArrayList`**:

```
ArrayList<String> list =
                    new ArrayList<String>(50);
```

- The **`ArrayList list`** stores objects of type **`String`** and has an initial capacity of 50.
  - The capacity will grow if more than 50 items are added.

# Creating an `ArrayList`

- Syntax:

```
ArrayList<BaseType> name =
        new ArrayList<BaseType>();
```

or:

```
ArrayList<BaseType> name =
        new ArrayList<BaseType>(initialCapacity);
```

Data types:
- Primitive: byte, short, …
- Class
  > Abstract class, interface
  > Nested class
  > Standard:
String,
Wrapper class,
File,
Data, Calendar
  > Collection class
ArrayList, HashMap, HashSet

  - ***BaseType*** can be any class type.
    - Use the wrapper classes (**Integer**, **Double**,...) to store primitive types.

byte – Byte
short – Short
int – Integar
long – Long
float – Float
double – Double
boolean – Boolean
char – Character

Wrapper classes provide a way to use primitive data types as objects.

# Adding and Getting Elements

Create a list of **Word** objects and add **Words**:

```
ArrayList<Word> list = new ArrayList<Word>();
list.add(new Word("the"));
list.add(new Word("dog"));
list.add(new Word("bites"));
```

```
index:
0
1
2
```

Get the second element:

```
Word aWord = list.get(1); // dog
aWord = list.get(3); //ERROR: index >= size()
```

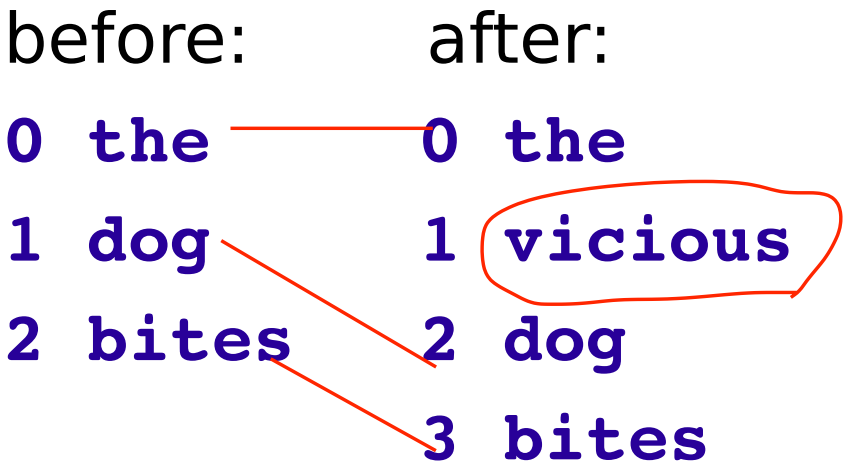
```
get: 0 <= index < size
```

# Adding and Getting Elements

Inserting into the middle:

```
list.add(1, new Word("vicious"));
```

- The **Word** "vicious" is now at index 1
- The other **Words** get moved down



# Adding and Getting Elements

Inserting into the middle:

```
0 the
1 vicious
2 dog
3 bites
```

- `list.add(5, new Word("children"));`
  - error – index must be less than size
- `list.add(4, new Word("children"));`
  - ok - adds to the end of the list

```
insert: 0 <= index <= size()
```

# Removing an Element

```
list.remove(1);
```

| before: | after: | |
|---|---|---|
| 0 the | 0 the | |
| ~~1 vicious~~ | 1 dog | |
| 2 dog | 2 bites | the rest move up |
| 3 bites | 3 children | |
| 4 children | | |

remove: 0 <= index < size()

# Removing an Element

这几页1/4: 找到first occurrence of `dog`,
replace it with `cat`

Remove the first occurrence of a **Word** with the form “children”:

```
list.remove(new Word(“children”));
```

| before: | after: |
|---|---|
| 0 the | 0 the |
| 1 dog | 1 dog |
| 2 bites | 2 bites |
| 3 children | |

**Word** must have a well-defined **equals** method!

# Finding an Element

这几页2/4: 找到first occurrence of `dog`, replace it with `cat`

Find out if there is an occurrence of a **Word** with the form “dog”, or “cat”:

**0 the**

**1 dog**

**2 bites**

```
boolean dogFound = list.contains(
                        new Word(“dog”)); // true
boolean catFound = list.contains(
                        new Word(“cat”)); // false
```

# Finding an Element

这几页3/4: 找到first occurrence of `dog`, replace it with `cat`

Get the index of the first occurrence of a **Word** with the form “dog”, or “cat”:

```
0 the
1 dog
2 bites
```

```
int dogIndex = list.indexOf(new Word(“dog”));
// dogIndex is 1
int catIndex = list.indexOf(new Word(“cat”));
// catIndex is -1 (not in the list)
```

# Setting an Element

这几页4/4：找到first occurrence of `dog`, replace it with `cat`

Set the element at index **dogIndex** to a **Word** with the form “cat”:

```
int dogIndex = list.indexOf(new Word(“dog”));
if (dogIndex >= 0) {
    list.set(dogIndex, new Word(“cat”));
}
```

获取dog的index，直接set为指定单词
不需要remove或者replace

| before: | after: |
|---|---|
| 0 the | 0 the |
| 1 dog | 1 cat |
| 2 bites | 2 bites |

# `ArrayList` Exercises

1. Write a static method that takes a **`String`** array and returns an **`ArrayList`** of type **`String`** with the same elements.

`String[]`

`ArrayList<String>`

2. Write a static method that takes an **`ArrayList`** of type **`String`** AND a **`String`**, and deletes all instances of the string in the **`ArrayList`**.

`no return, so `void``

# Exercise 1 – sample solution

String[] s 表示该方法接收一个 String 类型的数组作为参数。

```
public static ArrayList<String>
                    arrayToArrayList(String[] s) {

    ArrayList<String> result =
                    new ArrayList<String>(s.length);

    for (int i=0; i < s.length; i++) {
        result.add(s[i]);
    }

    return result;

}
```

s[i] 表示访问数组 s 中索引为 i 的元素

# Exercise 2 – sample solution

```
public static void
      removeFromArrayList(ArrayList<String> list,
                          String s) {

    int foundAtIndex = list.indexOf(s);

    while (foundAtIndex >= 0) {
        list.remove(foundAtIndex);
        foundAtIndex = list.indexOf(s);
    }

}
```

find the next match and update index

# Parameterized Classes
# Generics

- Java's **`ArrayList`** class allows us to specify the type of the objects stored in the list; it is a *parameterized class*:

  **`ArrayList<BaseType>`**

- Its parameter, the **`BaseType`**, can be replaced by any class type
- These definitions are called *generic definitions*, or simply *generics*

# Generics

Automatically generate parametrised data structures and methods.

```
Parameters: to parameterise a data type,
- included in class definitions,
- in classes and methods,
  use a type parameter instead of a specific data type
```

# String Pouch

A Pouch which can hold a String

```
package de.uni_tuebingen.sfs.java2.StringPouch;

public class Pouch {
    private String value;

    public Pouch() {}

    public Pouch( String value ) { this.value = value; }

    public void set( String value ) { this.value = value; }

    public String get() { return value; }

    public boolean isEmpty() { return value == null; }

    public void empty() { value = null; }

}
```

# Object Pouch

A Pouch which can hold an Object

```
package de.uni_tuebingen.sfs.java2.ObjectPouch;

public class Pouch {
    private Object value;

    public Pouch() {}

    public Pouch( Object value ) { this.value = value; }

    public void set( Object value ) { this.value = value; }

    public Object get() { return value; }

    public boolean isEmpty() { return value == null; }

    public void empty() { value = null; }

}
```

# Use ObjectPouch

```
package de.uni_tuebingen.sfs.java2;

import de.uni_tuebingen.sfs.java2.ObjectPouch.Pouch;

public class ObjectPouchMain {
    public static void main(String[] args) {
        Pouch pouch = new Pouch(Integer.valueOf("12"));
        Pouch stringPouch = new Pouch("Umu");
        //Integer intValue = pouch.get();
        System.out.println("Pouch value: "+pouch.get());
        System.out.println("Pouch value: "+stringPouch.get());
    }
}
```

Whats nice is, we can create Pouches for different types. But we cannot refer to the original type of our Pouch data. The statement `Integer intValue = pouch.get();` does not compile. This is obviously not the perfect solution

因为 pouch 的数据类型是 Object，Object 可以包含多种数据类型。我们创建了一个值为整数 12 的 Pouch 对象，又创建了一个值为字符串 "umu" 的 Pouch 对象。因此，当 Integer intValue = pouch.get(); 时，没有指定 Object 中具体的数据类型，编译器无法进行类型转换，所以无法编译通过。(No explicit (type) casting)

# Generic Pouch

What we want is:

Type safety. When we add an Integer we want to get an Integer back.

Flexibility. Update code in one place. All different datatypes share the same code base

```
public class Pouch<T> {
    private T value;

    public Pouch() {}

    public Pouch( T value ) { this.value = value; }

    public void set( T value ) { this.value = value; }

    public T get() { return value; }

    public boolean isEmpty() { return value != null; }

    public void empty() { value = null; }

}
```

# Type of a Generic

When we declare a generic class we add <T> after the classname.

T stands for type. But it can also be <K> for key or <E> for element. The name of the character does not matter. K,E,T does not matter. Be consistent.

T specifically stands for **generic** type. According to Java Docs - A **generic** type is a **generic** class or interface that is parameterized over types.

When we create an Instance the <T> is replace with the actual data type.

When we declare `Pouch<String>` the T in <T> becomes `String`.

# Using a generic Pouch

```
package de.uni_tuebingen.sfs.java2;

import de.uni_tuebingen.sfs.java2.GenericPouch.Pouch;

public class GenericPouchMain {
    public static void main(String[] args) {
        // Pouch which holds a String
        Pouch<String> stringPouch = new Pouch<>("Umu");
        // Pouch which holds an Integer
        Pouch<Integer> integerPouch = new Pouch<>(Integer.valueOf("12"));
        //Pouch which holds a Pouch which holds a String
        Pouch<Pouch<String>> pouchPouch = new Pouch<>(new Pouch<>("Fasel"));
        System.out.println("Pouch value: "+stringPouch.get());
        System.out.println("Pouch value: "+integerPouch.get());
        System.out.println("Pouch value: "+pouchPouch.get());
    }
}
```

```
// Add integer to the String Pouch
stringPouch.set(stringPouch.get() + 12);
```

```
class Pouch<T> {
    private T value;
    public Pouch(T value) { this.value = value;}
    public T get() {return value;}
    public void set(T value) {this.value = value;}
}
```

Experiment with the code. Try to add different types. Add integer to String Pouch. See if you actually get an Integer from the integerPouch .. 

# Generic and interfaces

You can use generics the same way as we did it with classes:

```
public interface Set<E> extends Collection<E>
{
 …
}
```

```
public class HashSet<E> extends AbstractSet<E>
                        implements Set<E>,
                        Cloneable,
                        java.io.Serializable
{
 …
}
```

# Collection Classes

- A new group of classes implement the **`Collection`** interface.
- These classes are know as *collection* classes
- **`ArrayList`** is a collection class
- There is a special for-loop syntax that can be used with collection classes

# Collection Classes – “for-each” loop

- Example:

```
ArrayList<String> list =
                              new ArrayList<String>();
list.add(“hello”);
list.add(“world”);

//we say: “for each String element in list”
for (String element : list) {
    System.out.println(element);
}
```

```
Syntax:  for (BaseType variable : collectionObject) {
                    //Statement
         }
```

# Linked Data Structures

- A linked data structure is a group of objects (called *nodes*) that are connected by references (called *links*)

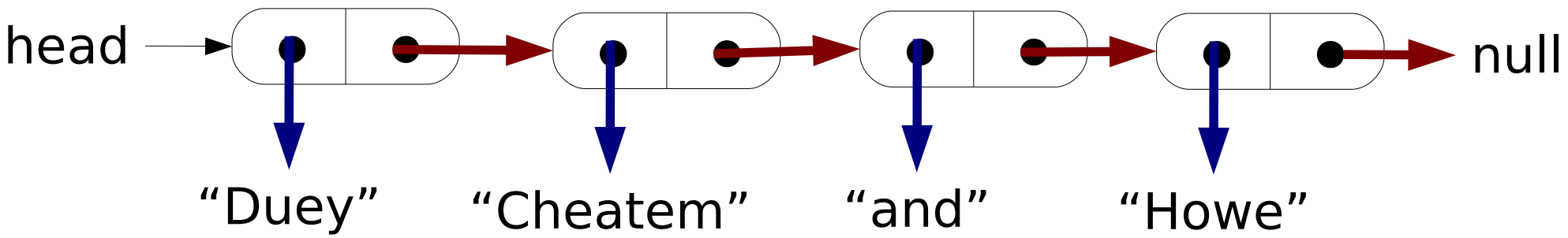
i.e. a group of nodes connect by links

- Java has a predefined **`LinkedList`** class, which is part of the **`java.util`** package
- In order to learn how linked data structures work, we will construct our own linked list class.

# String Linked List

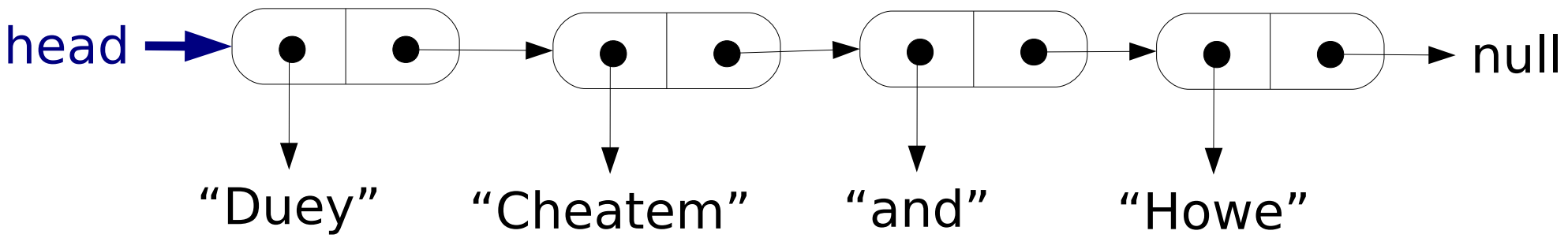
- We will call our linked list class **`StringLinkedList`**.
- **`StringLinkedList`** *has-a* reference to the first node in the list – also called the **`head`** of the list.
- We will define a separate class called **`ListNode`** to represent a node.
- A **`ListNode`** *has* data and a link to the next node.

# Linked Lists




- The two references in each node are its instance variables.
  - One refers to the node's data (“Duey”, “Cheatem”, ...)
  - The other refers to the next node in the list. It links one node to the next.

# Linked Lists




- The reference called **`head`** is an *instance variable* of the **`StringLinkedList`** class. It references an object of the node type.
- **`head`** is a reference to the first node in the list, but is not itself one of the nodes.

# The `ListNode` Class

## Savitch p 837

- Two instance variables to reference the node's **`data`** and **`link`**
- Simple constructors
- Getters and setters for the instance variables

# The First and Last Nodes

- There has to be a way of determining which node is the last node in the list.
- The node that has a **`null link`** instance variable is the last node.
- The value of the **`link`** instance variable is tested for **`null`** with **`==`**

```
if (link == null) //this is the last node
```

- **`head`** is the reference to the first node.
- **`if (head == null)`**, the list is empty.

# `StringLinkedList` - methods

Savitch p 839

- **`addANodeToStart`**
- **`length`**
- **`deleteHeadNode`**
- **`showList`**
- **`onList`**
- **`find (private)`**

# StringLinkedList - addANodeToStart

## add the first node

```
public void addANodeToStart(String addData)  {
     head = new ListNode(addData, head);
}
```

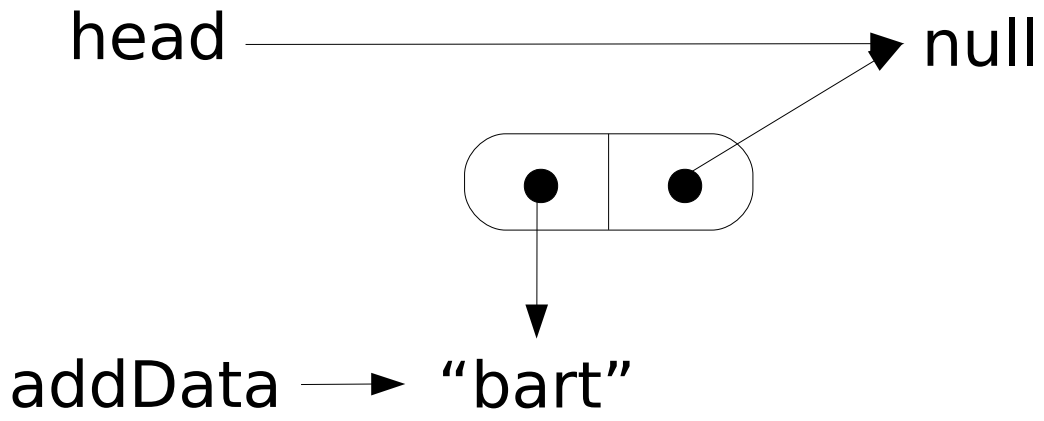
Before:

# StringLinkedList - addANodeToStart

## add the first node

```
public void addANodeToStart(String addData)  {
    head = new ListNode(addData, head);
}
```

Create new node:

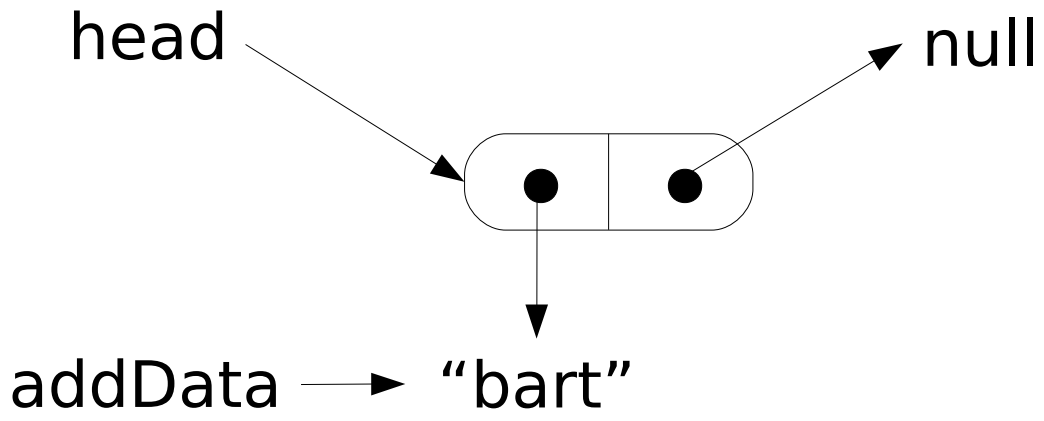


# StringLinkedList - addANodeToStart

## add the first node

```
public void addANodeToStart(String addData)  {
    head = new ListNode(addData, head);
}
```

After:

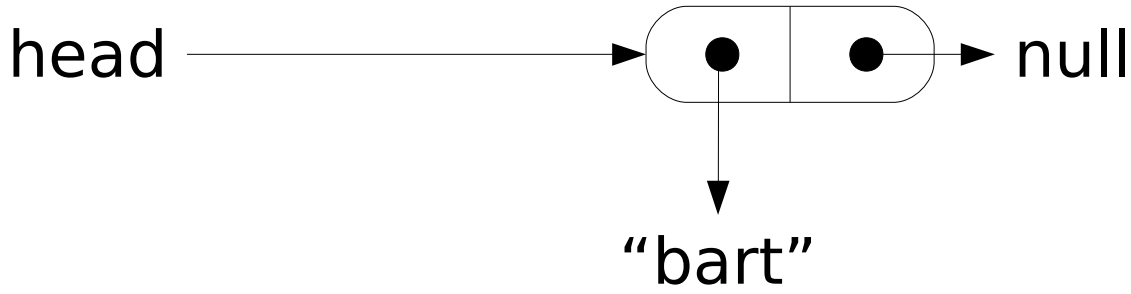


# StringLinkedList - addANodeToStart

## add a second node

```
public void addANodeToStart(String addData)  {
    head = new ListNode(addData, head);
}
```

Before:



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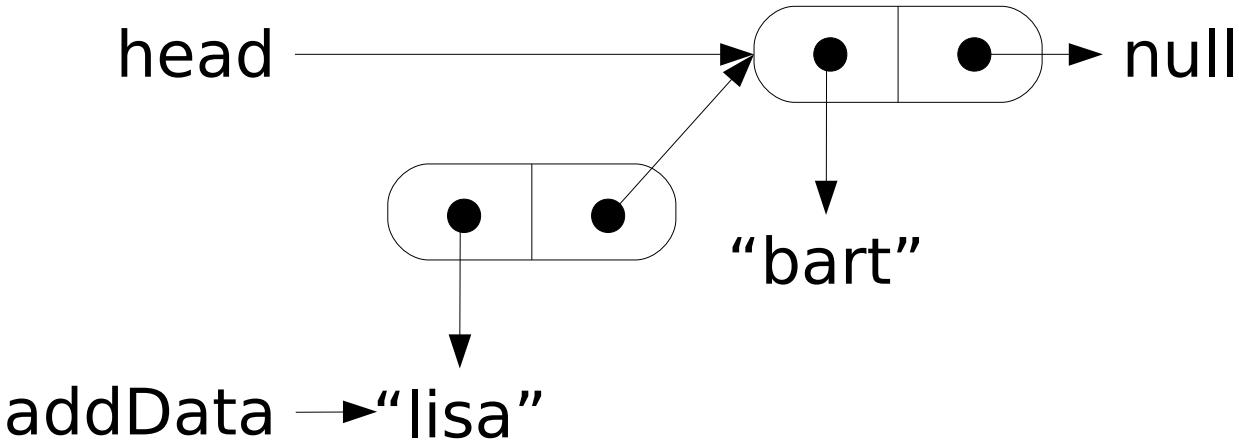
Create new node:



# StringLinkedList - addANodeToStart

## add a second node

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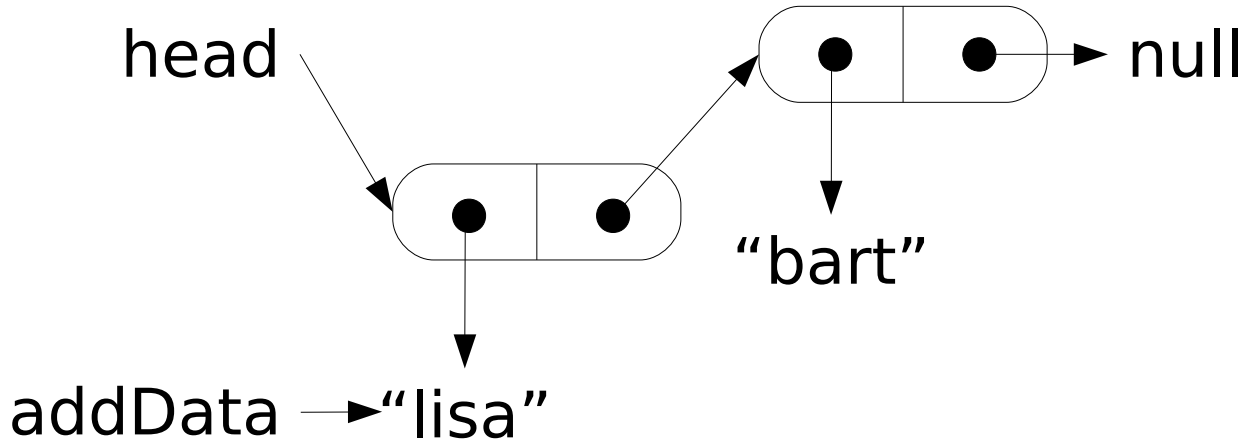
```

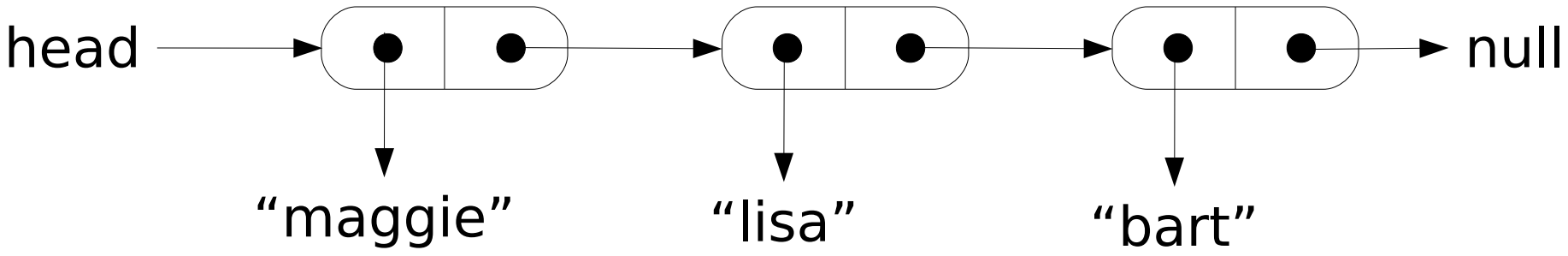
After:



# StringLinkedList - length

```
public int  length()  {
    int count = 0;
    ListNode position = head;
    while (position != null) {
        count++;
        position = position.getLink();
    }
    return count;
}
```

**count: 0**



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        position = position.getLink();
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    return count;
}
```
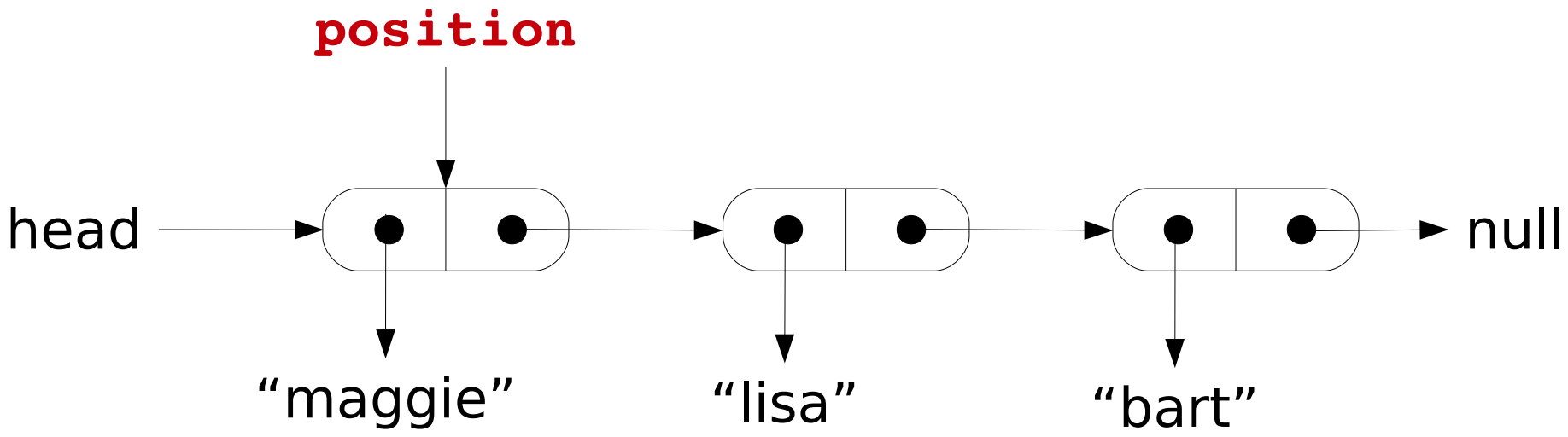

**count: 0**



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```
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    int count = 0;
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    while (position != null) {
        count++;
        position = position.getLink();
    }
    return count;
}
```
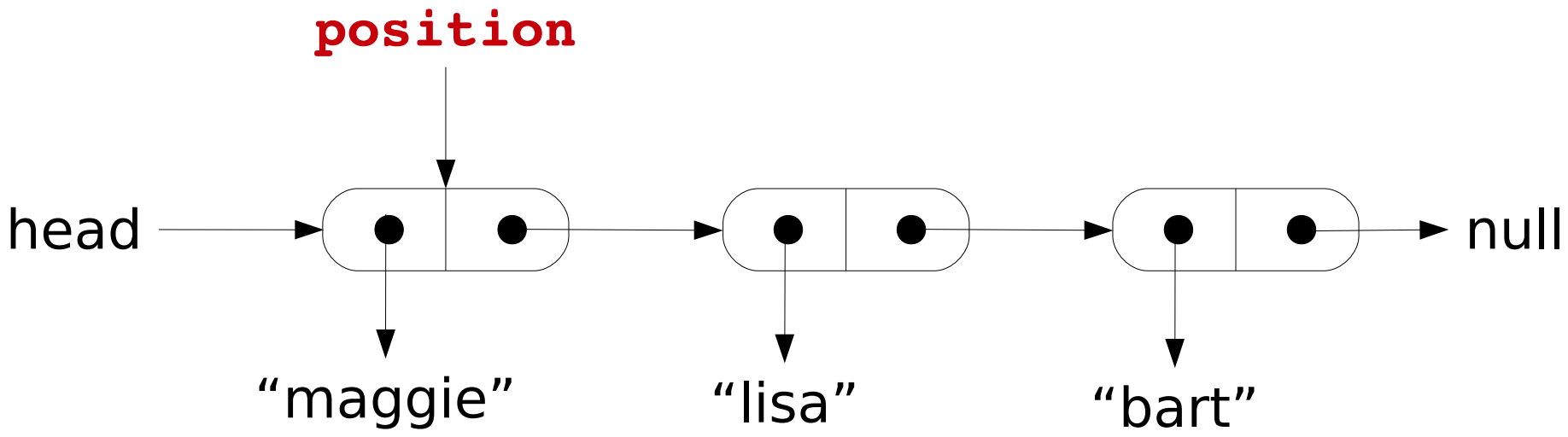
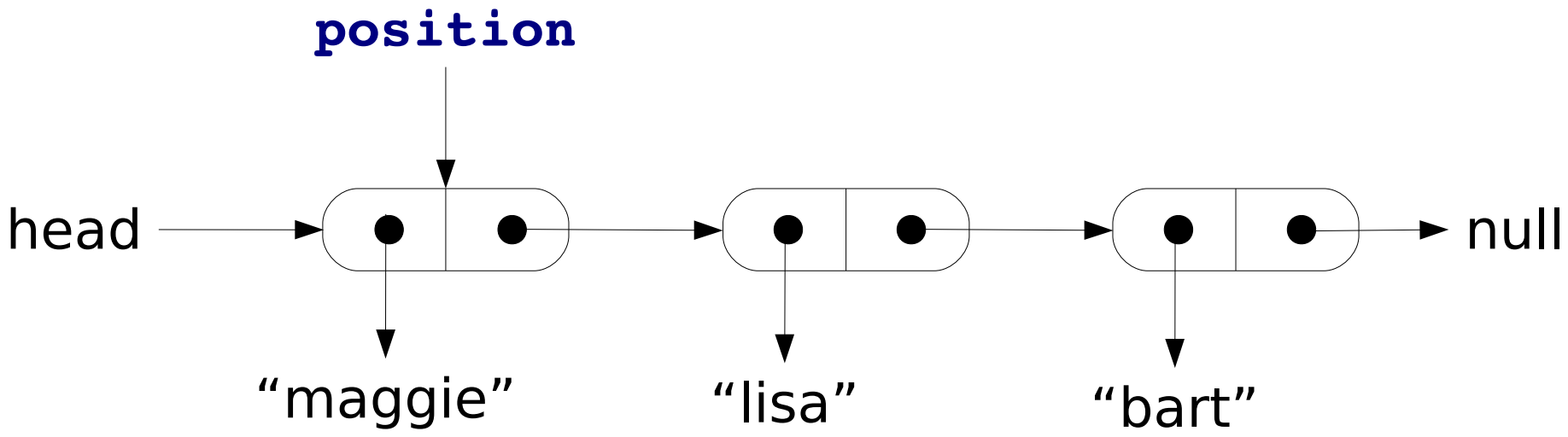

**count: 0**



# StringLinkedList - length

```
public int  length()  {
    int count = 0;
    ListNode position = head;
    while (position != null) {
        count++;
        position = position.getLink();
    }
    return count;
}
```

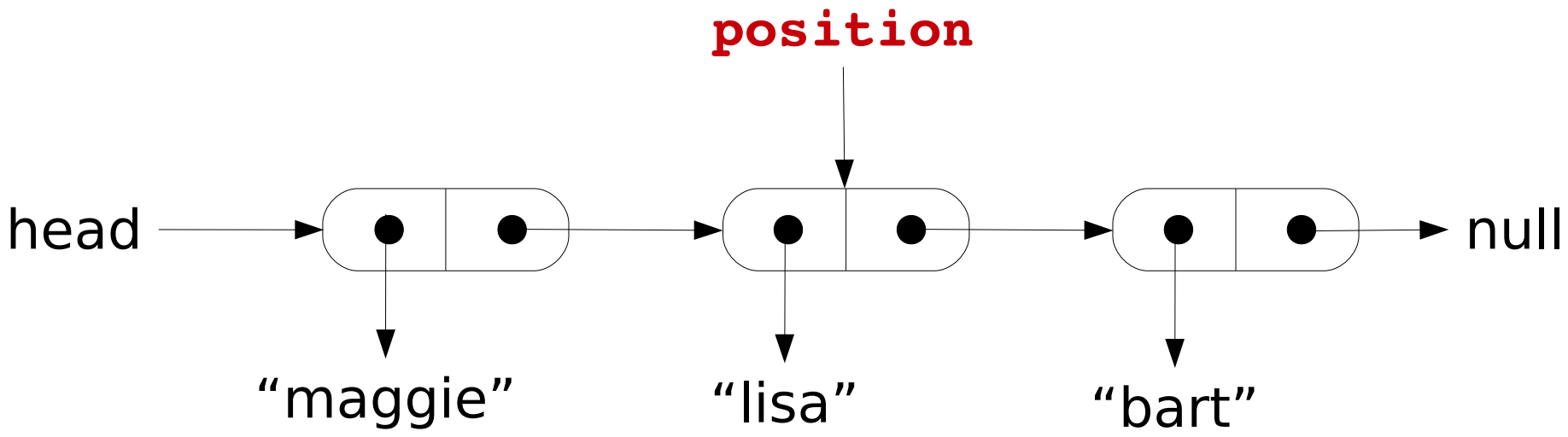
**count: 1**



# StringLinkedList - length

```
public int  length()  {
    int count = 0;
    ListNode position = head;
    while (position != null) {
        count++;
        position = position.getLink();
    }
    return count;
}
```

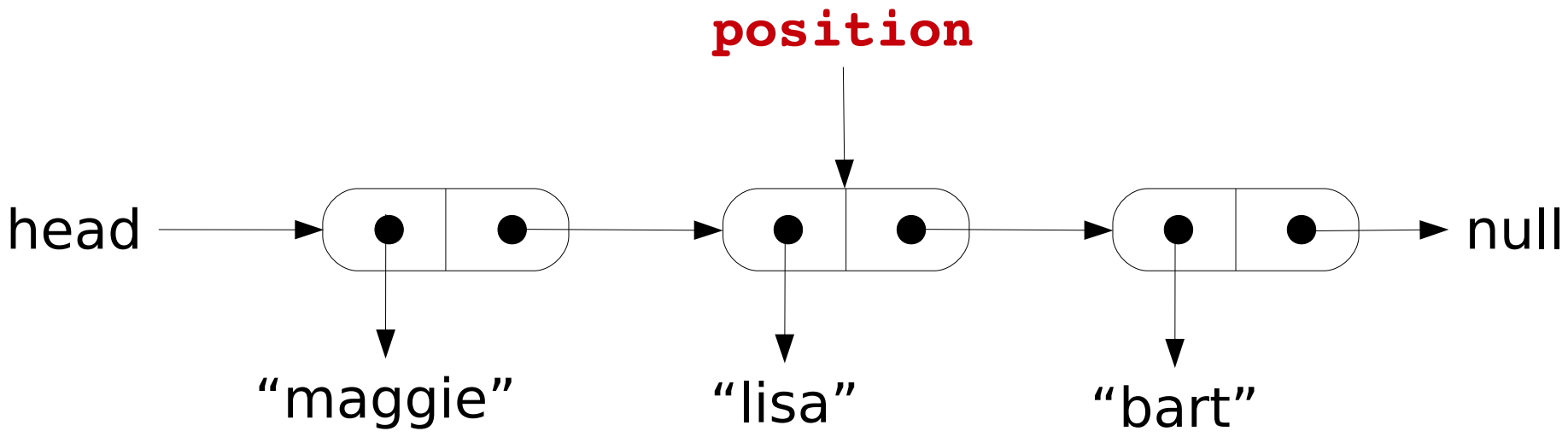
**count: 1**



# StringLinkedList - length

```
public int  length()  {
    int count = 0;
    ListNode position = head;
    while (position != null) {
        count++;
        position = position.getLink();
    }
    return count;
}
```

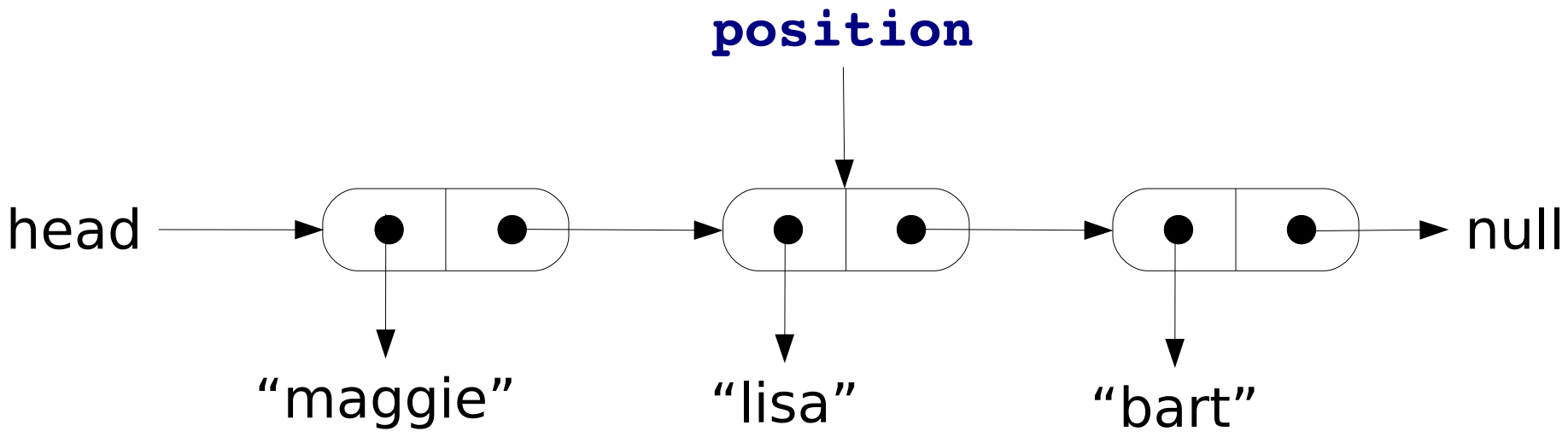
**count: 1**



# StringLinkedList - length

```
public int  length()  {
    int count = 0;
    ListNode position = head;
    while (position != null) {
        count++;
        position = position.getLink();
    }
    return count;
}
```

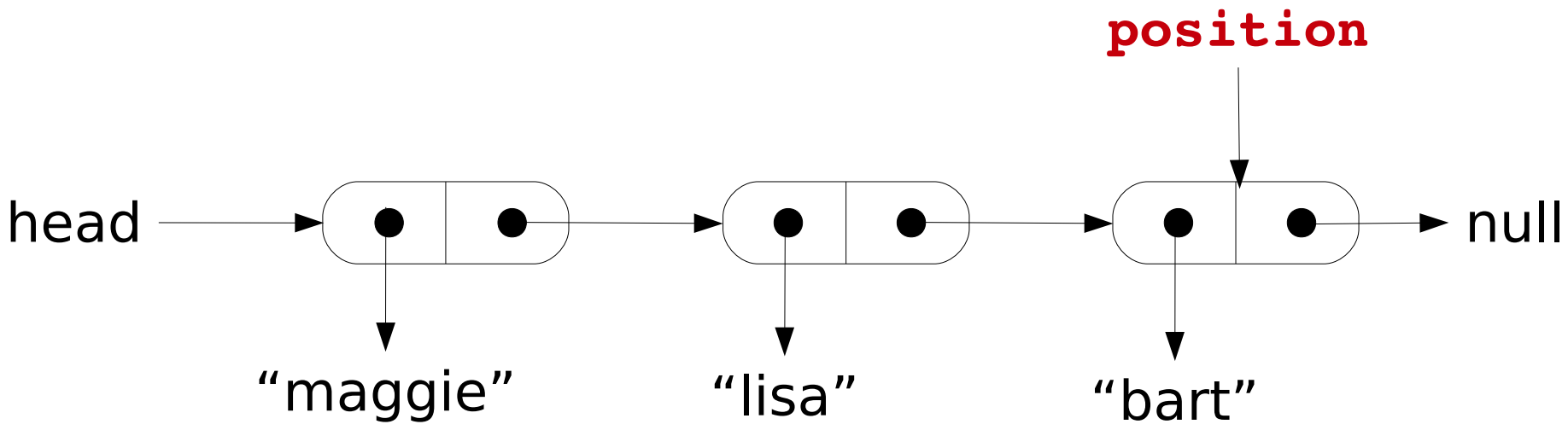
**count: 2**



# StringLinkedList - length

```
public int  length()  {
    int count = 0;
    ListNode position = head;
    while (position != null) {
        count++;
        position = position.getLink();
    }
    return count;
}
```

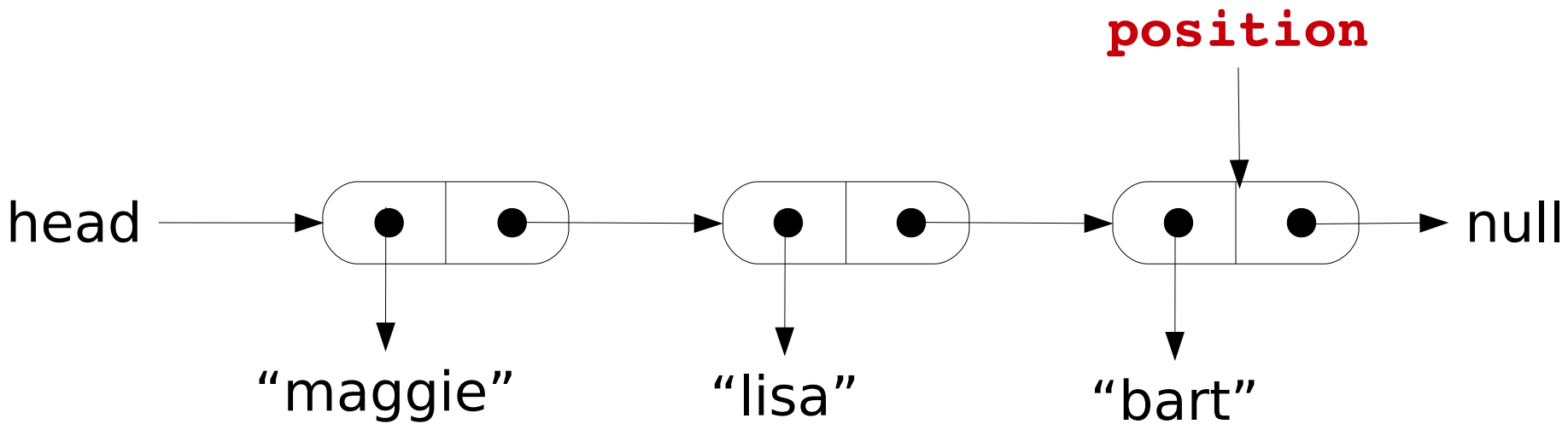
**count: 2**



# StringLinkedList - length

```
public int  length()  {
    int count = 0;
    ListNode position = head;
    while (position != null) {
        count++;
        position = position.getLink();
    }
    return count;
}
```

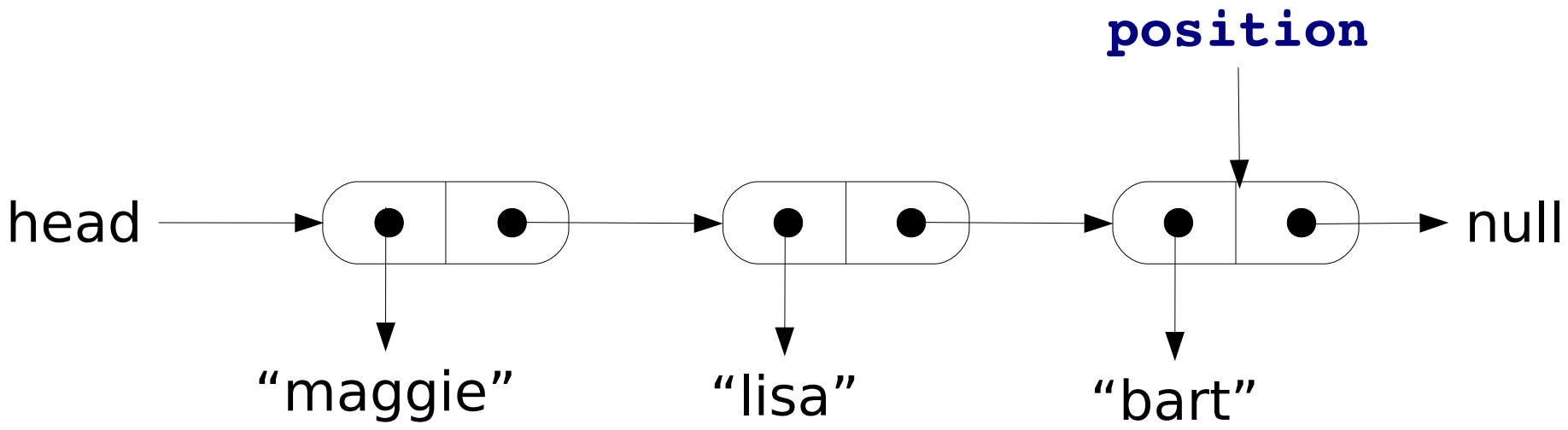
**count: 2**



# StringLinkedList - length

```
public int  length()  {
    int count = 0;
    ListNode position = head;
    while (position != null) {
        count++;
        position = position.getLink();
    }
    return count;
}
```

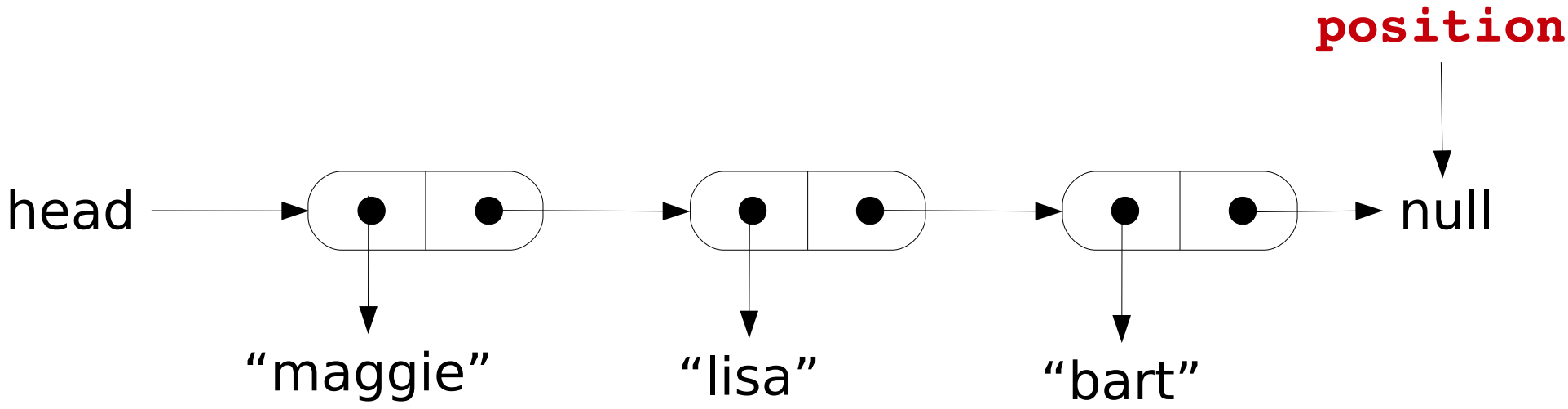
**count: 3**



# StringLinkedList - length

```
public int  length()  {
    int count = 0;
    ListNode position = head;
    while (position != null) {
        count++;
        position = position.getLink();
    }
    return count;
}
```

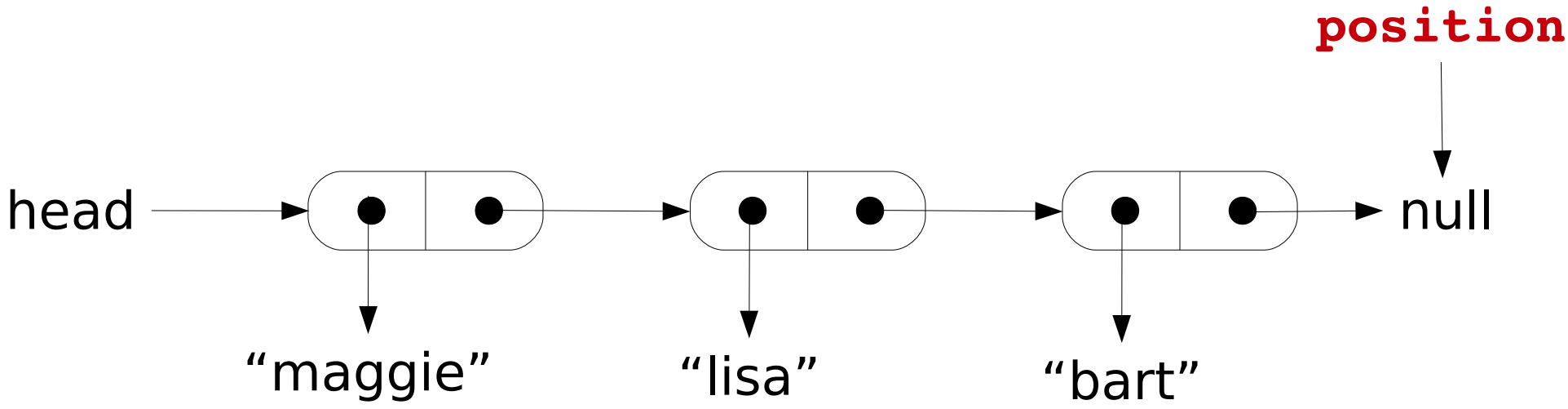
**count: 3**



# StringLinkedList - length

```
public int  length()  {
    int count = 0;
    ListNode position = head;
    while (position != null) {
        count++;
        position = position.getLink();
    }
    return count;
}
```

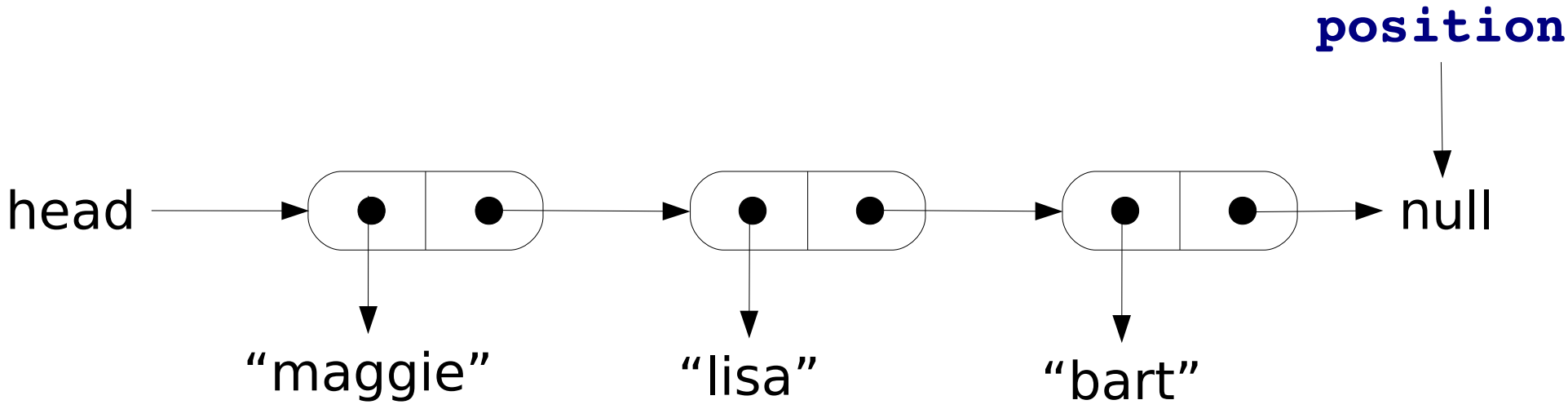
**count: 3**



# StringLinkedList - length

```
public int  length()  {
    int count = 0;
    ListNode position = head;
    while (position != null) {
        count++;
        position = position.getLink();
    }
    return count;
}
```

**count: 3**



# StringLinkedList - deleteHeadNode

- Can't delete a node from an empty list
- A list is empty if **`head == null`**
- Could also throw an exception if deleting from an empty list (Savitch prints a message and exits)

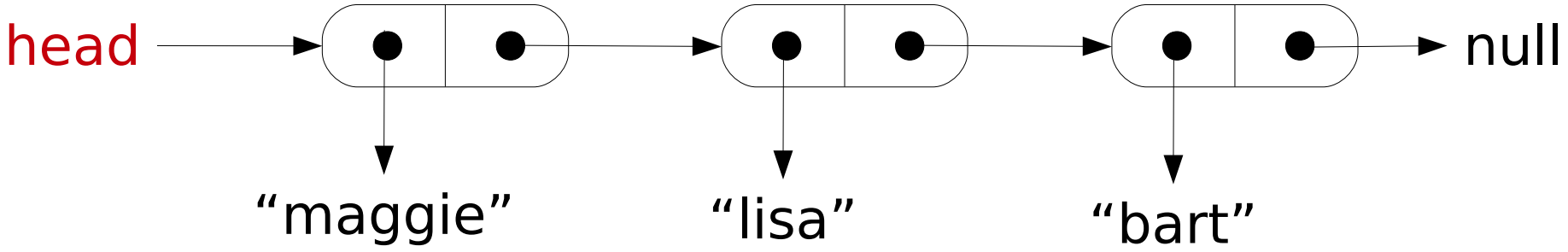
```
public void deleteHeadNode(){
  if (head == null)
    head = head.getlink();
  else {
    System.out.println("Deleting from an empty list.")
    System.exit(0);
```

# NullPointerException

- A **`NullPointerException`** indicates that access to an object has been attempted using a **`null`** reference.
- A **`null`** reference means that no object is referenced by the variable.
- A **`NullPointerException`** does not need to be caught or declared in a throws clause. It indicates that the code needs to be fixed.

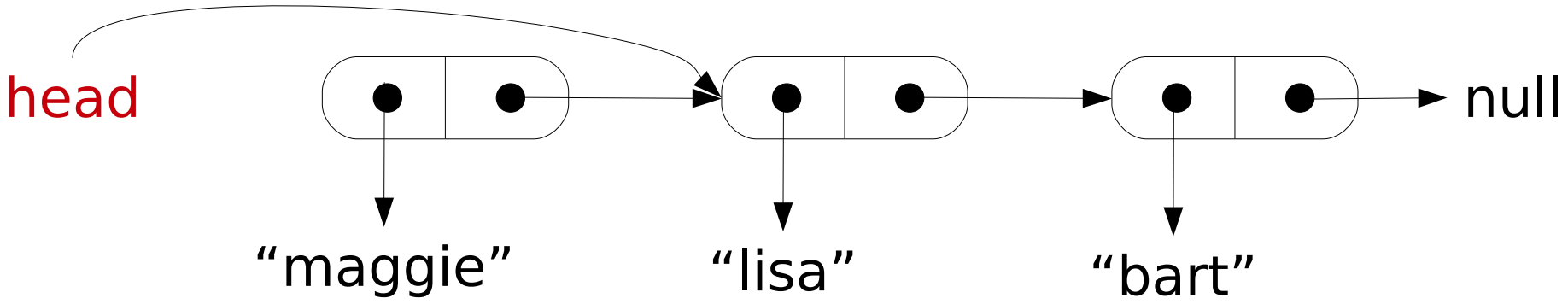
# StringLinkedList - deleteHeadNode

```
public void deleteHeadNode()  {
   if (head != null) {
      head = head.getLink();  public ListNode getLink(){return link;}
   } else {
      throw new NullPointerException("Deleting from empty list");
   }
}
```



# StringLinkedList - deleteHeadNode

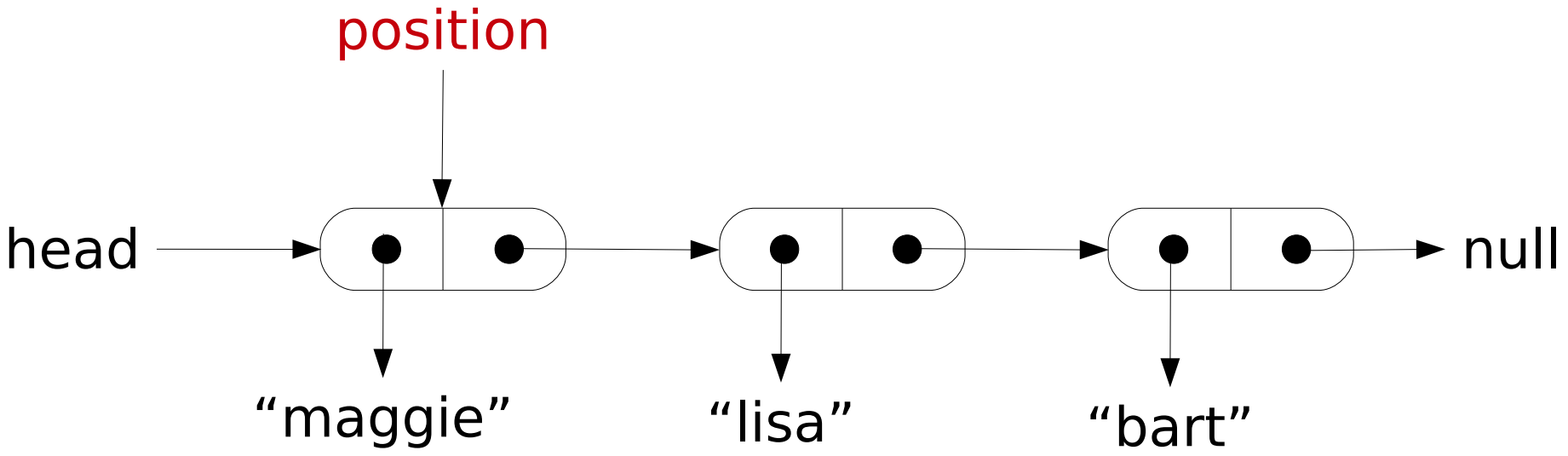
```
public void deleteHeadNode()  {
   if (head != null) {
      head = head.getLink();
   } else {
      throw new NullPointerException("Deleting from empty list");
   }
}
```




The "old" head node no longer has a reference to it and is lost.

# StringLinkedList - showList()

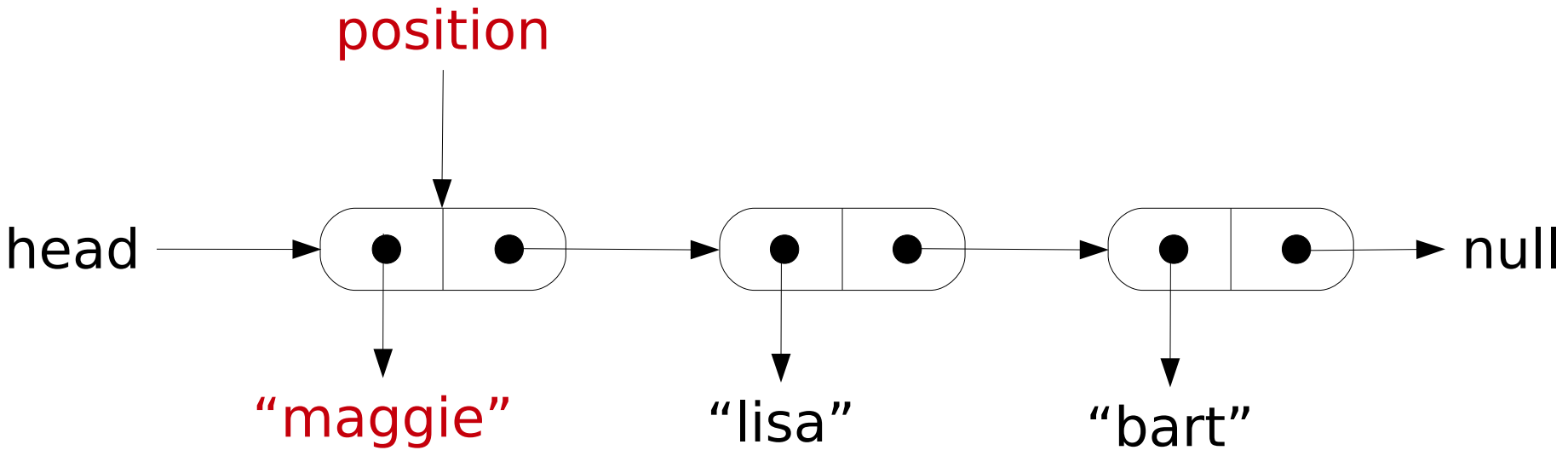
```
public void showList()  {
   ListNode position = head;
   while (position != null) {
      System.out.println(position.getData());
      position = position.getLink();
   }
}
```



# StringLinkedList - showList()

```
public void showList()  {
   ListNode position = head;
   while (position != null) {
      System.out.println(position.getData());
      position = position.getLink();
   }
}
```

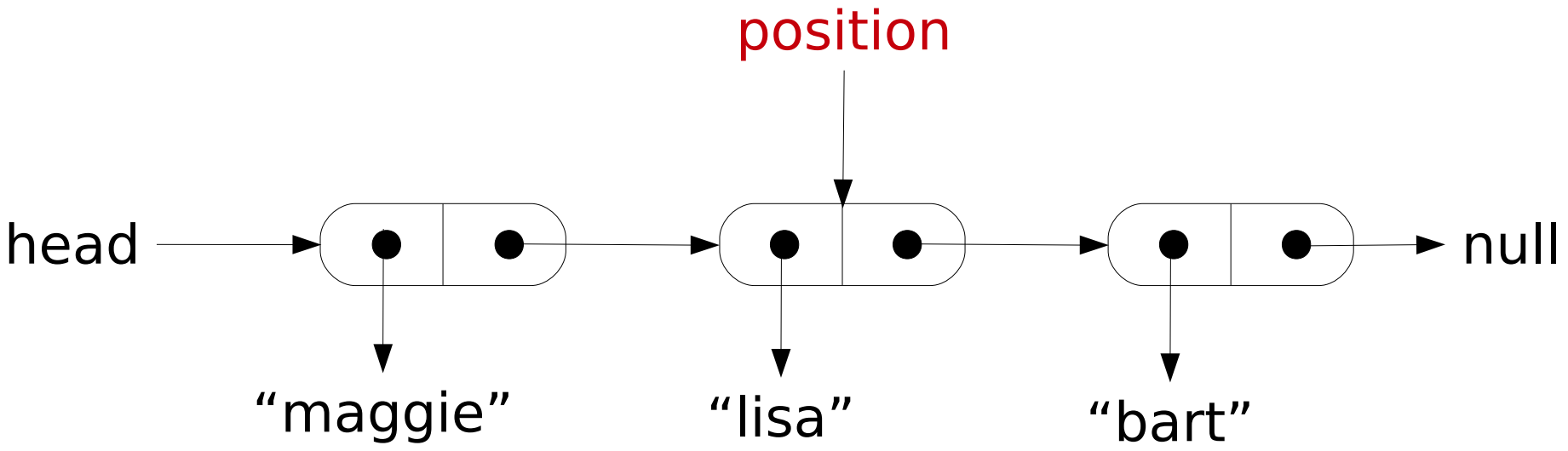
maggie



# StringLinkedList - showList()

```
public void showList()  {
   ListNode position = head;
   while (position != null) {
      System.out.println(position.getData());
      position = position.getLink();
   }
}
```

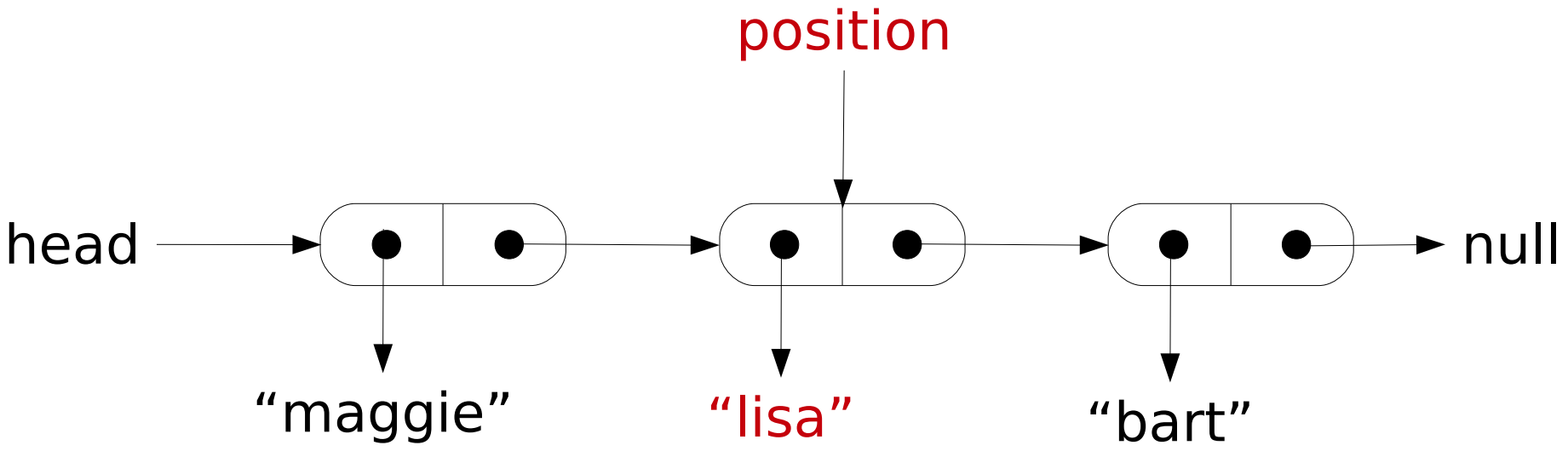
maggie



# StringLinkedList - showList()

```
public void showList()  {
   ListNode position = head;
   while (position != null) {
      System.out.println(position.getData());
      position = position.getLink();
   }
}
```

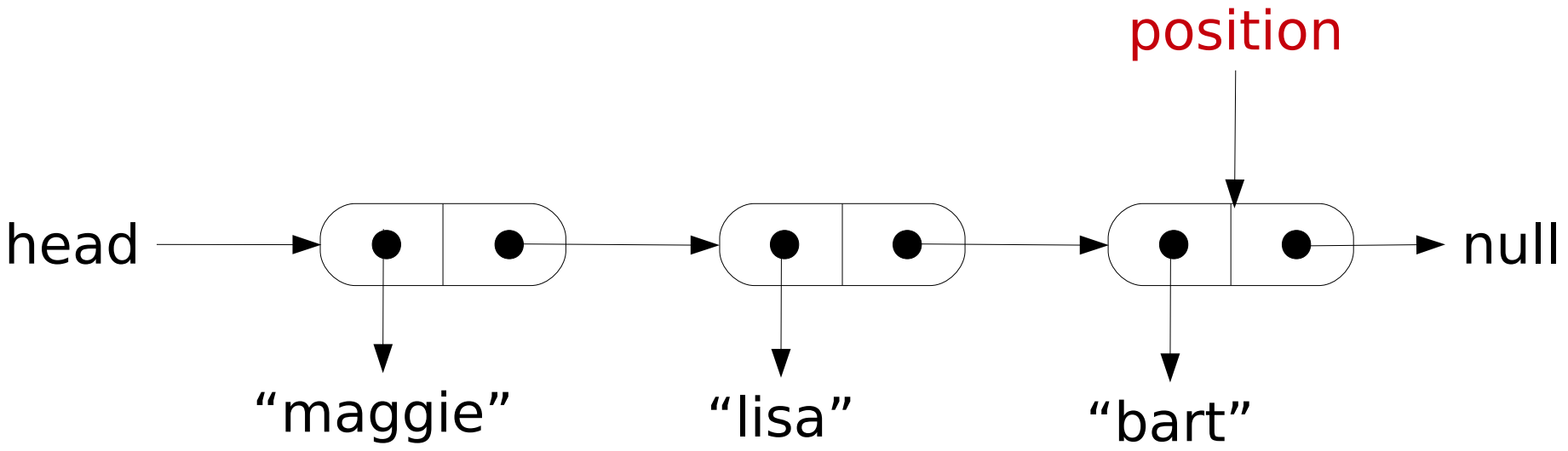
maggie
lisa



# StringLinkedList - showList()

```
public void showList()  {
   ListNode position = head;
   while (position != null) {
      System.out.println(position.getData());
      position = position.getLink();
   }
}
```

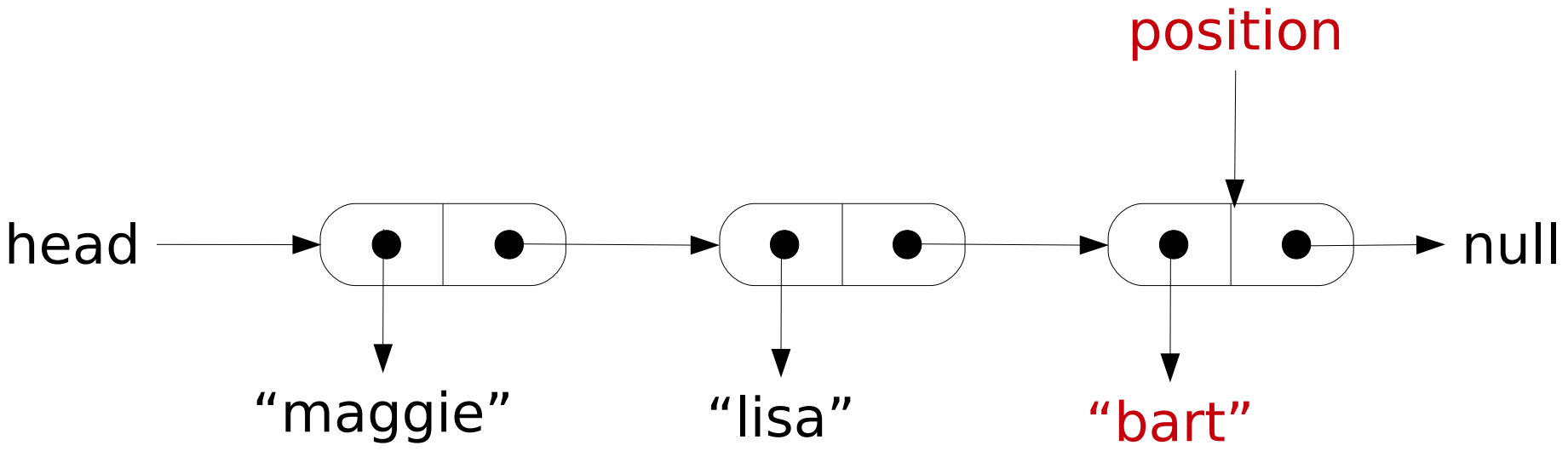
maggie
lisa



# StringLinkedList - showList()

```
public void showList()  {
   ListNode position = head;
   while (position != null) {
      System.out.println(position.getData());
      position = position.getLink();
   }
}
```

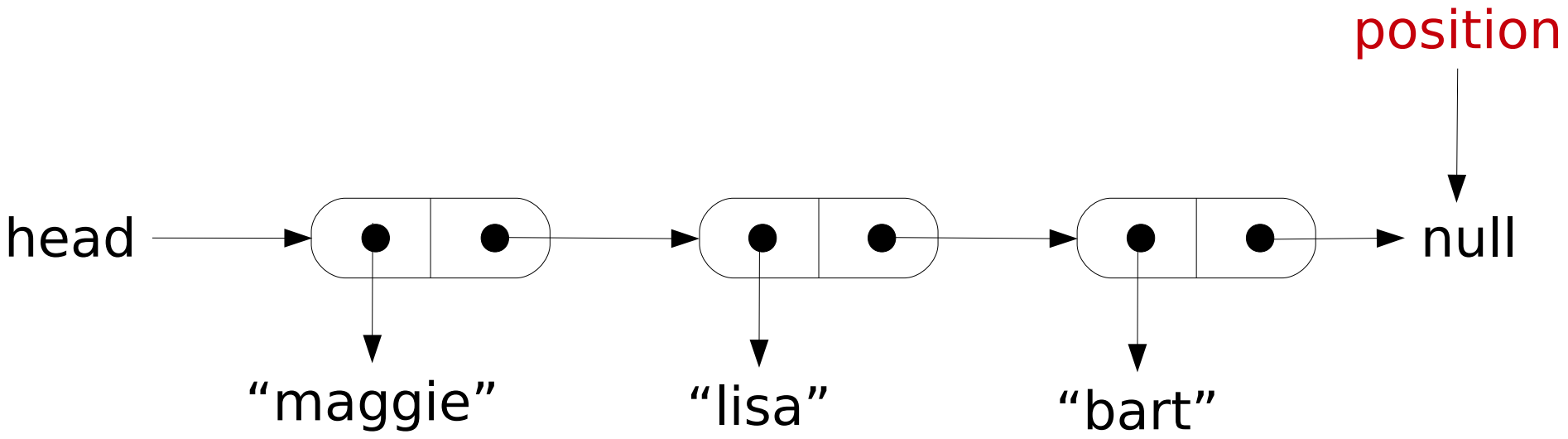
maggie
lisa
bart



# StringLinkedList - showList()

```
public void showList()  {
   ListNode position = head;
   while (position != null) {
      System.out.println(position.getData());
      position = position.getLink();
   }
}
```

maggie
lisa
bart



# Privacy Leaks

- The **`getLink`** method in class **`ListNode`** (page 837) returns an instance variable which is a reference to a node.
- A user could modify the data stored in that node, defeating the **`private`** restriction on the instance variable **`link`**.
- This problem can be fixed by making the class **`ListNode`** a private inner class of **`StringLinkedList`**.

# Inner Classes

- An *inner class* is a class defined within another class
- Defining an inner class:

```
public class OuterClass {

    // OuterClass instance variables
    // OuterClass methods

    private class InnerClass {
        // InnerClass instance variables
        // InnerClass methods
    }
}
```

# Inner Classes - Access

- The inner and outer classes have access to each other's methods and instance variables, even if they are declared **`private`**.

用途:
1. 封装和组织代码，增强安全性
2. 访问外部类(class)的私有成员，避免过多getter, setter（外部类无法直接访问内部类的私有成员）
3. 事件处理：常用于如GUI的按钮点击

# Node Inner Class

## `StringLinkedListSelfContained`

Savitch listing 12.5, p 849-851

- By making the node class in inner class of the linked list class, the linked list class becomes self-contained.

all the implementation details needed for the linked list, including the node structure, are encapsulated within a single class

- The accessor (get-) and mutator (set-) methods can be eliminated from the node class.
- They are no longer needed because the instance variables are directly accessible.

# List Iteration

- We often need to “step through” all the objects in a list and perform some operation on each object.
- An *iterator* allows us to “step through” a collection of objects (in this case a list of nodes).

逐个遍历

# List Iteration

- The loop control variable of a for-loop functions as an iterator for an array:

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

- We could place all the elements of a linked list into an array and “step through” the elements by iterating the array. This is called *external* iteration.

# List Iteration

- We will implement an *internal* iterator – one that uses an instance variable to step through the nodes.
- An instance variable in the linked list class capable of referencing a node can serve the same purpose as a loop control variable in a for loop.
- This allows us to “step through” the list and access or change data contained in the nodes or to insert and delete nodes.

# StringLinkedListWithIterator

Savitch listing 12.7, p 852-855

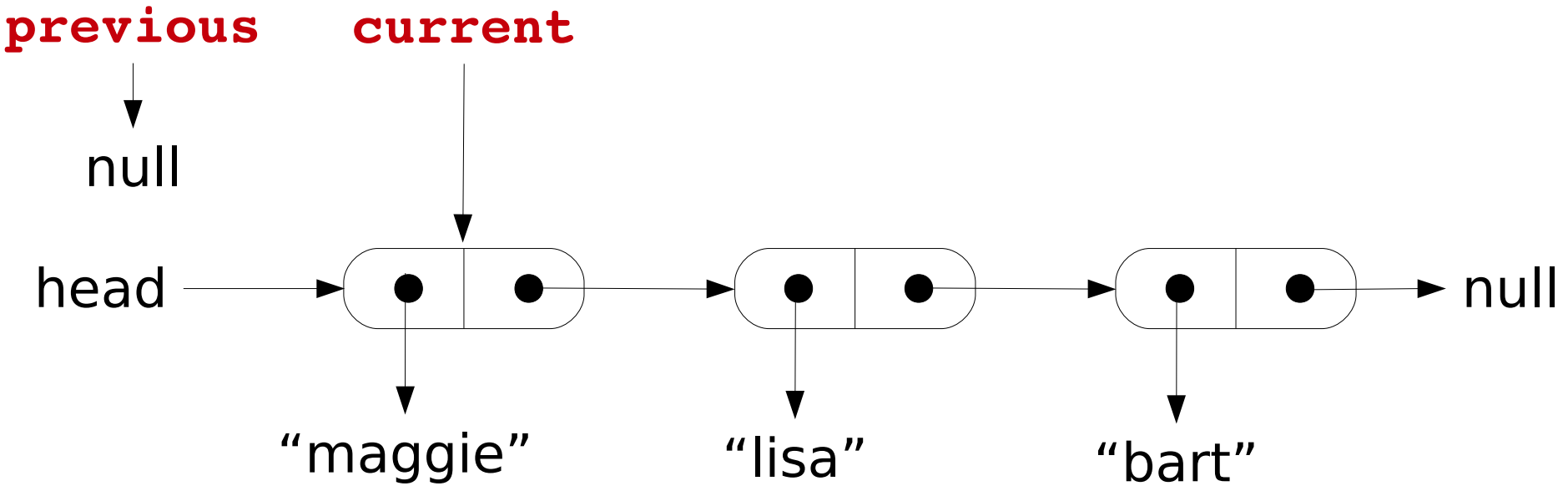
- Additional methods:
  - **resetIteration**
  - **goToNext**
  - **deleteCurrentNode**
  - **insertNodeAfterCurrent**
  - **moreToIterate**
  - **getDataAtCurrent**
  - **setDataAtCurrent**
- Must modify **addANodeToStart** method

# StringLinkedListWithIterator

- We need 2 more instance variables:
  - `private ListNode current;`
  - `private ListNode previous;`
- **`current`** should always reference the node currently being processed
- **`previous`** should always reference the node behind current and is needed if we want to delete the current node

# StringLinkedListWithIterator - resetIteration

```
public void resetIteration()  {
   // current, previous, head are all instance variables
   current = head;
   previous = null;
}
```



# Advancing to the next node

Possible situations:

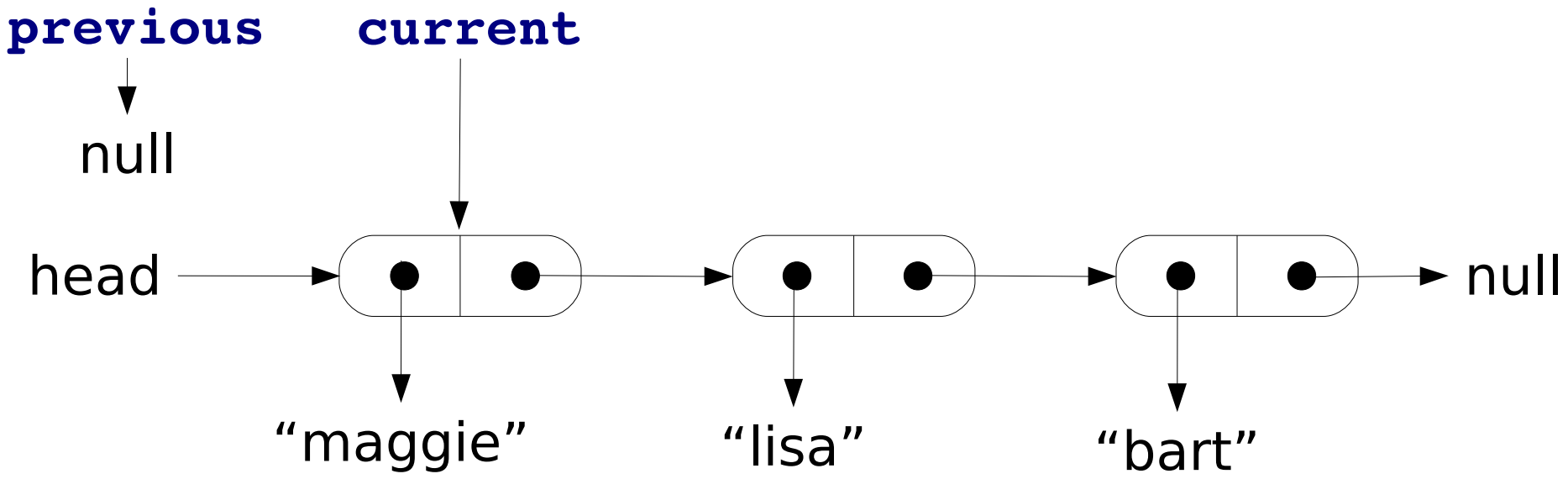
- There is a next node to advance to
- Errors: There is **not** a next node because:
  - the iteration was not initialized by calling **`resetIteration`**

    or
  - the iteration moved past end of list

    or
  - the list is empty

# StringLinkedListWithIterator - goToNext

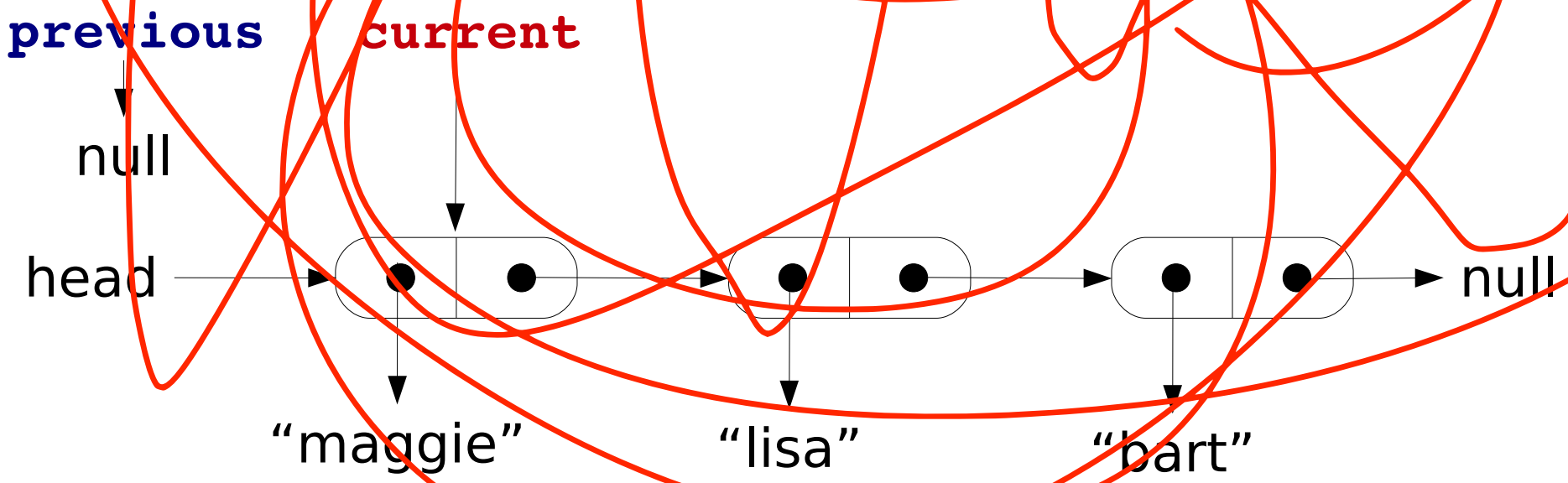
- The user must call **`resetIteration`** before the first call to **`goToNext`**
- If **`current != null`**, it is safe to go to the next node



# StringLinkedListWithIterator - goToNext

success

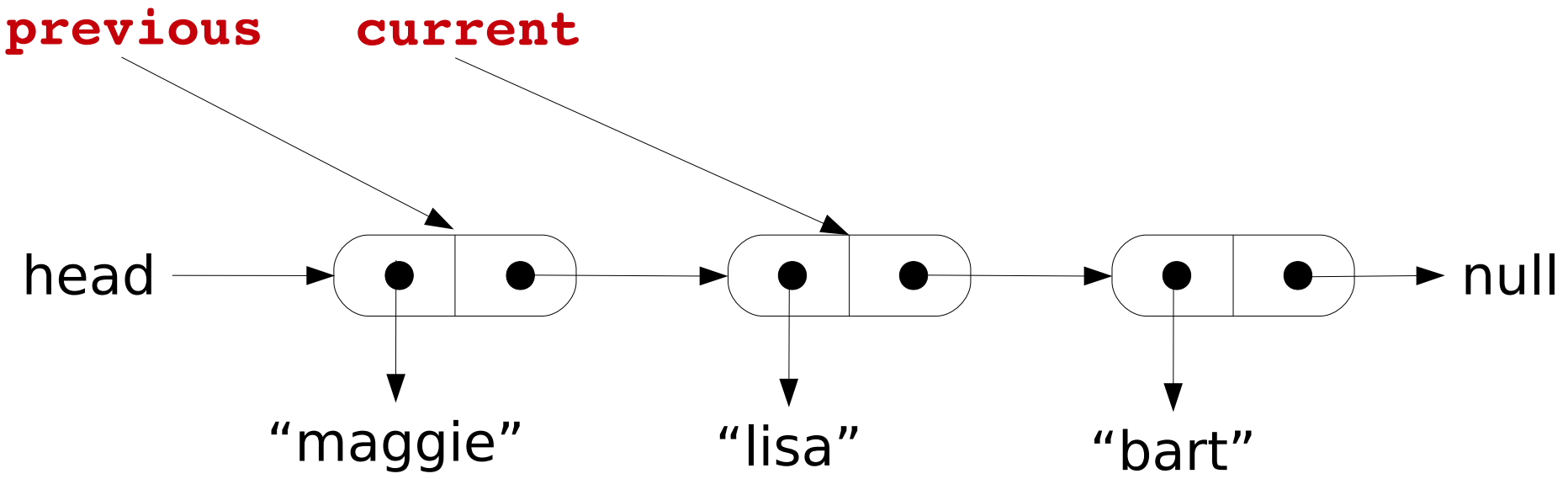
```
public void goToNext()  {
    if (current != null) {
        previous = current;
        current = current.link;
    } else if (head != null) {
        throw new LinkedListException("Iterated too many times " +
                                      "or uninitialized iteration");
    } else {
        throw new LinkedListException("Iterating empty list");
    }
}
```



# StringLinkedListWithIterator - goToNext

**success**

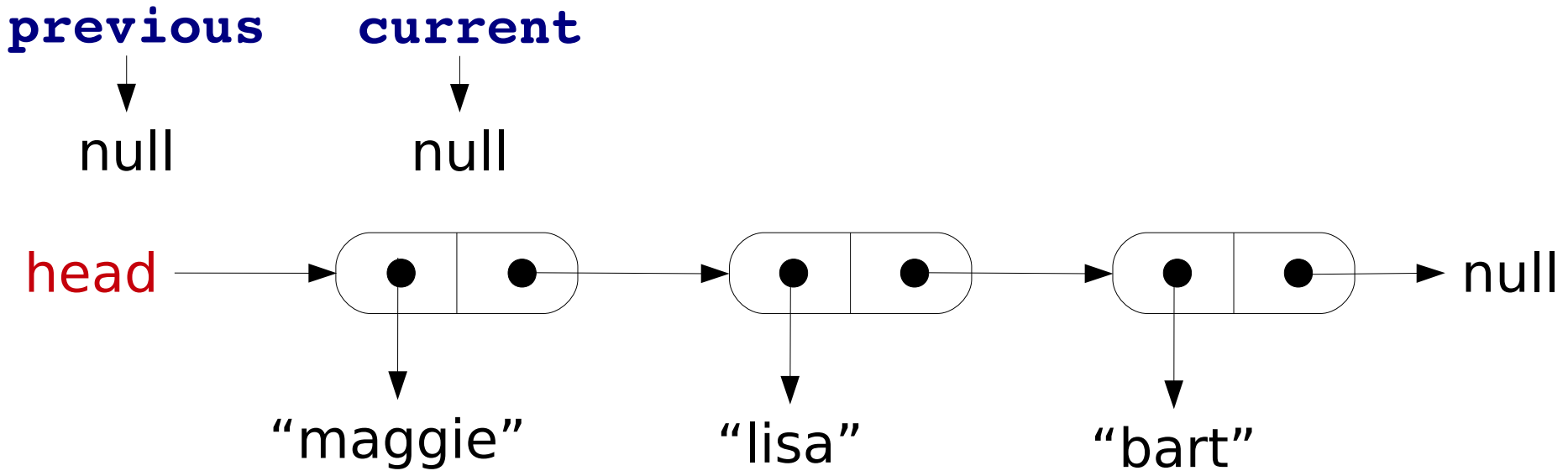
```
public void goToNext()  {
   if (current != null) {
      previous = current;
      current = current.link;
   } else if (head != null) {
      throw new LinkedListException("Iterated too many times " +
                                    "or uninitialized iteration");
   } else {
      throw new LinkedListException("Iterating empty list");
   }
}
```



# StringLinkedListWithIterator - goToNext

## uninitialized iteration

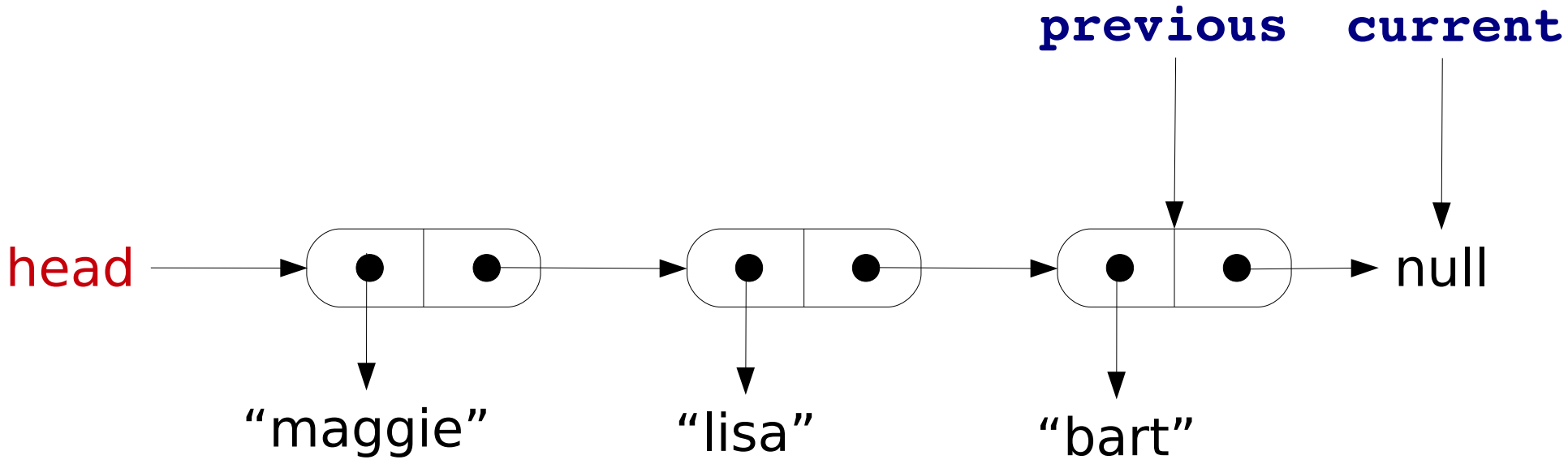
```
public void goToNext()  {
   if (current != null) {
      previous = current;
      current = current.link;
   } else if (head != null) {
      throw new LinkedListException("Iterated too many times " +
                                    "or uninitialized iteration");
   } else {
      throw new LinkedListException("Iterating empty list");
   }
}
```



# StringLinkedListWithIterator - goToNext

## done iterating

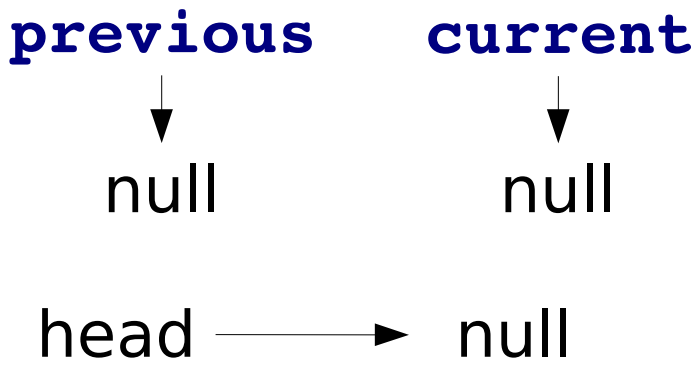
```
public void goToNext()  {
   if (current != null) {
      previous = current;
      current = current.link;
   } else if (head != null) {
      throw new LinkedListException("Iterated too many times " +
                                    "or uninitialized iteration");
   } else {
      throw new LinkedListException("Iterating empty list");
   }
}
```



# StringLinkedListWithIterator - goToNext

## empty list

```
public void goToNext()  {
   if (current != null) {
      previous = current;
      current = current.link;
   } else if (head != null) {
      throw new LinkedListException("Iterated too many times " +
                                    "or uninitialized iteration");
   } else {
      throw new LinkedListException("Iterating empty list");
   }
}
```



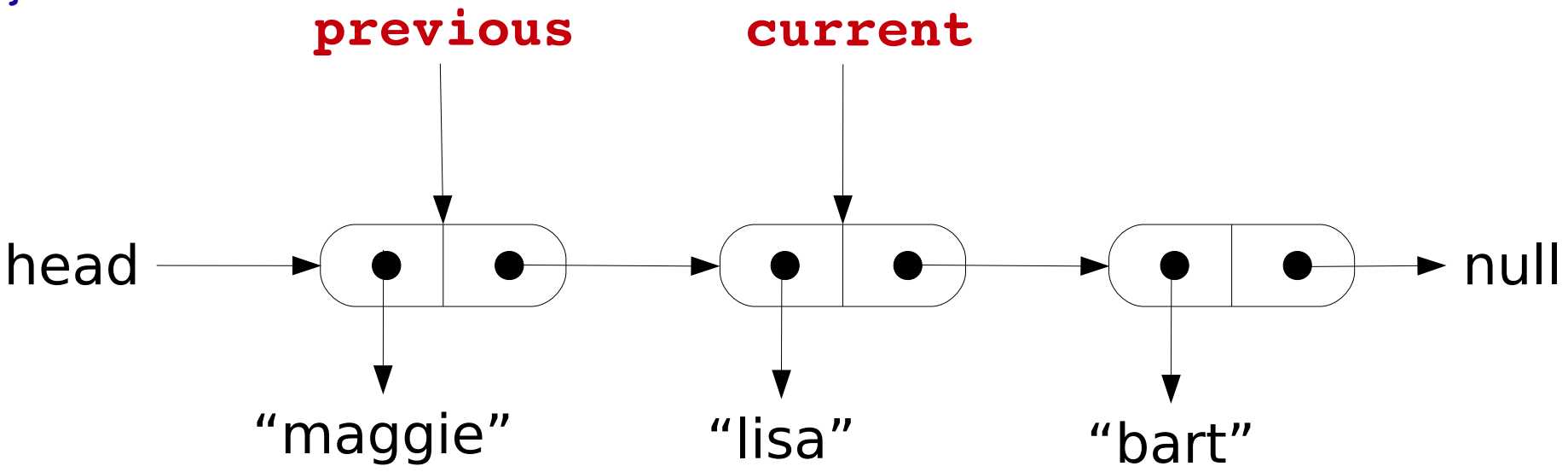
# StringLinkedListWithIterator - deleteCurrentNode

Possible situations:

- We are deleting a node from the middle of the list
- We are deleting the head node
- Error: there is no current node to delete

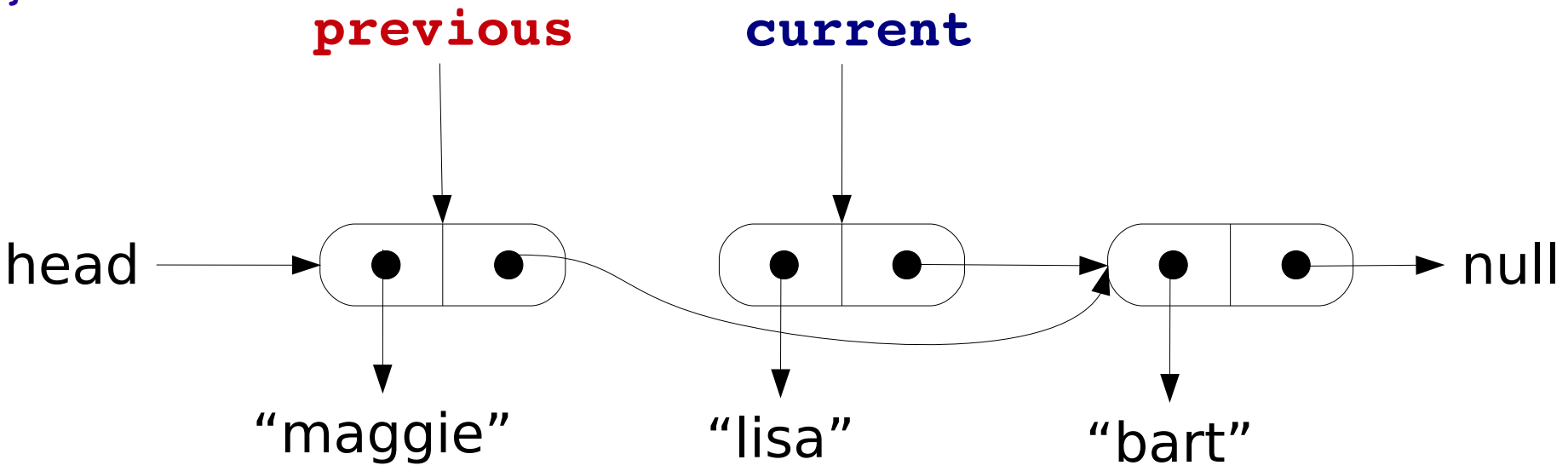
# StringLinkedListWithIterator - deleteCurrentNode from the middle

```
public void deleteCurrentNode()  {
  if ((current != null) && (previous != null)) {
      previous.link = current.link;
      current = current.link;
   } else if ((current != null) && (previous == null)) {
      head = current.link;
      current = head;
   } else {
      throw new LinkedListException("Deleting uninitialized " +
                                    "current or list is empty");
   }
}
```



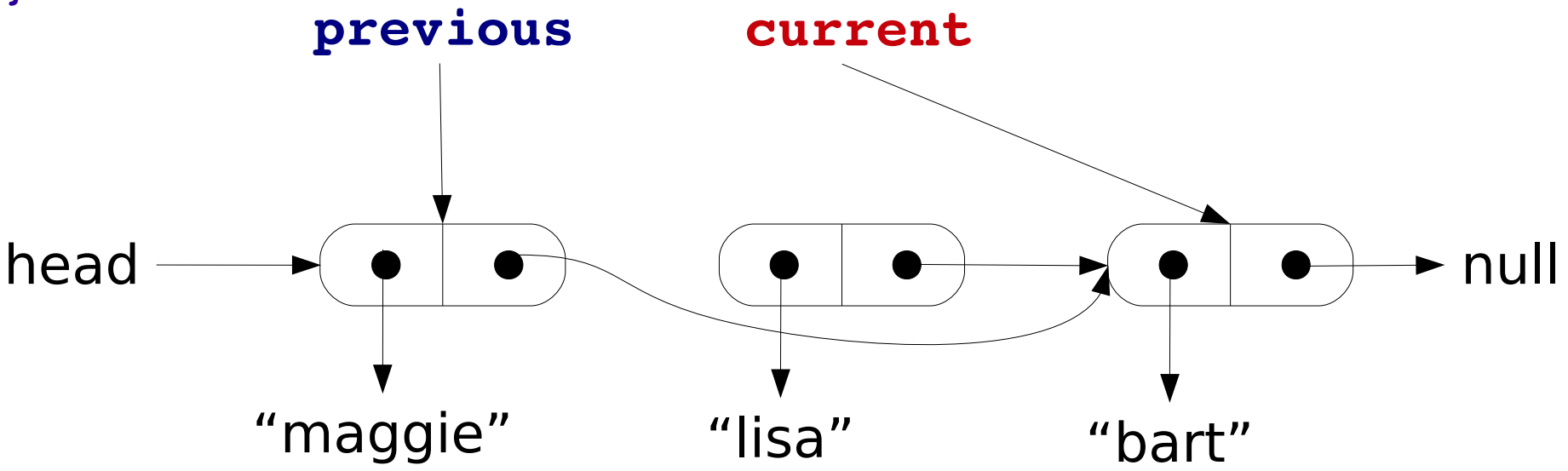
# StringLinkedListWithIterator - deleteCurrentNode from the middle

```
public void deleteCurrentNode()  {
  if ((current != null) && (previous != null)) {
      previous.link = current.link;
      current = current.link;
   } else if ((current != null) && (previous == null)) {
      head = current.link;
      current = head;
   } else {
      throw new LinkedListException("Deleting uninitialized " +
                                    "current or list is empty");
   }
}
```



# StringLinkedListWithIterator - deleteCurrentNode from the middle

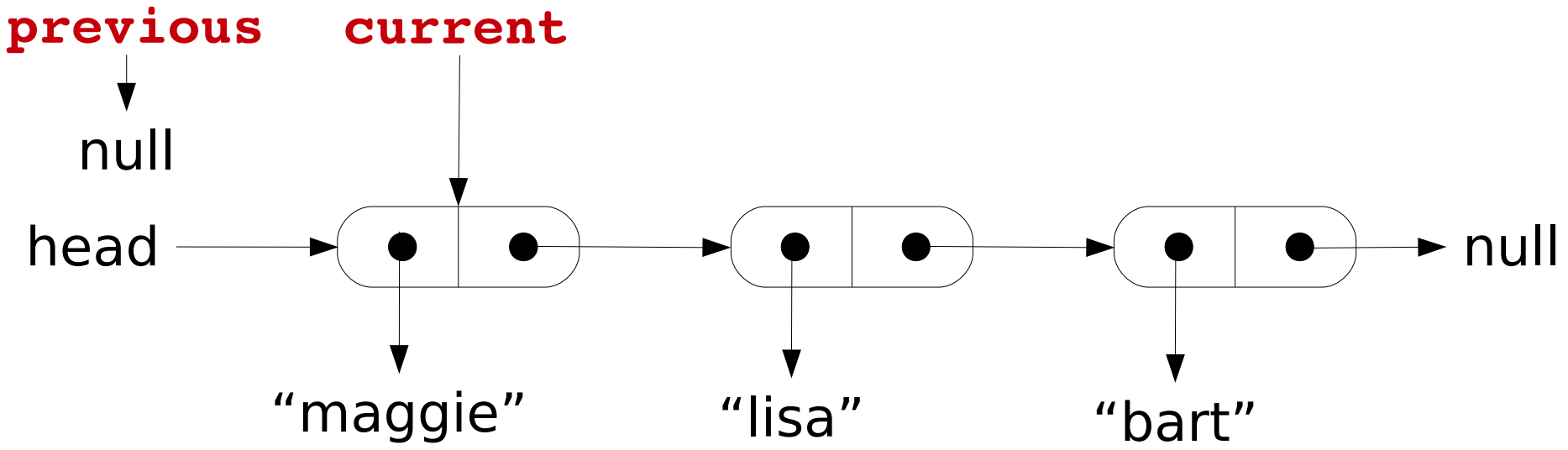
```
public void deleteCurrentNode()  {
  if ((current != null) && (previous != null)) {
      previous.link = current.link;
      current = current.link;
   } else if ((current != null) && (previous == null)) {
      head = current.link;
      current = head;
   } else {
      throw new LinkedListException("Deleting uninitialized " +
                                    "current or list is empty");
   }
}
```



# StringLinkedListWithIterator - deleteCurrentNode

## head node

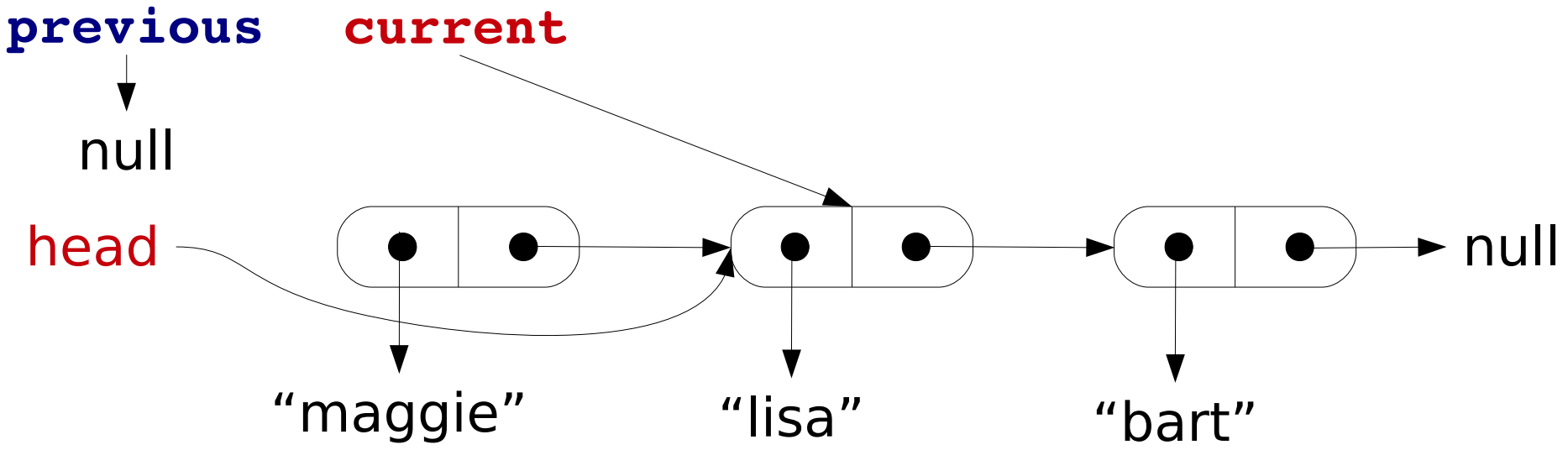
```
public void deleteCurrentNode()  {
  if ((current != null) && (previous != null)) {
      previous.link = current.link;
      current = current.link;
   } else if ((current != null) && (previous == null)) {
      head = current.link;
      current = head;
   } else {
      throw new LinkedListException("Deleting uninitialized " +
                                    "current or list is empty");
   }
}
```



# StringLinkedListWithIterator - deleteCurrentNode

## head node

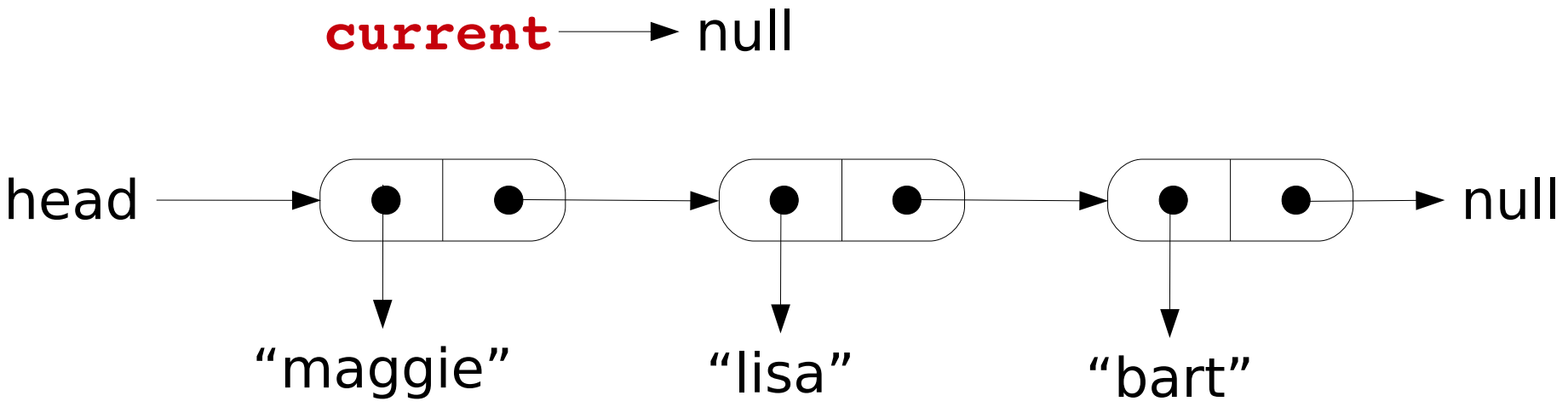
```
public void deleteCurrentNode()  {
  if ((current != null) && (previous != null)) {
      previous.link = current.link;
      current = current.link;
   } else if ((current != null) && (previous == null)) {
      head = current.link;
      current = head;
   } else {
      throw new LinkedListException("Deleting uninitialized " +
                                    "current or list is empty");
   }
}
```



# StringLinkedListWithIterator - deleteCurrentNode

## no current node

```
public void deleteCurrentNode()  {
  if ((current != null) && (previous != null)) {
      previous.link = current.link;
      current = current.link;
   } else if ((current != null) && (previous == null)) {
      head = current.link;
      current = head;
   } else {
      throw new LinkedListException("Deleting uninitialized " +
                                    "current or list is empty");
   }
}
```



# StringLinkedListWithIterator - insertNodeAfterCurrent

Possible situations:

- There is a current node to insert after
- Errors: There is **not** a current node because:
  - the iteration was not initialized by calling **`resetIteration`**

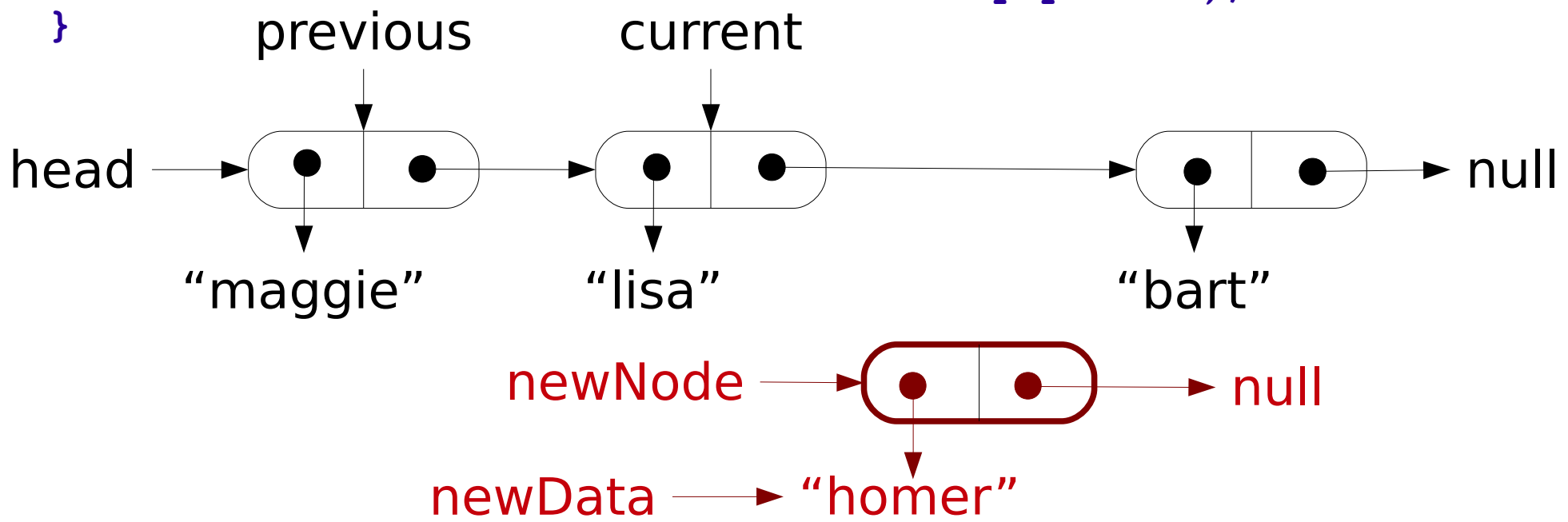
    or
  - the iteration moved past end of list

    or
  - the list is empty

# StringLinkedListWithIterator - insertNodeAfterCurrent

**success**

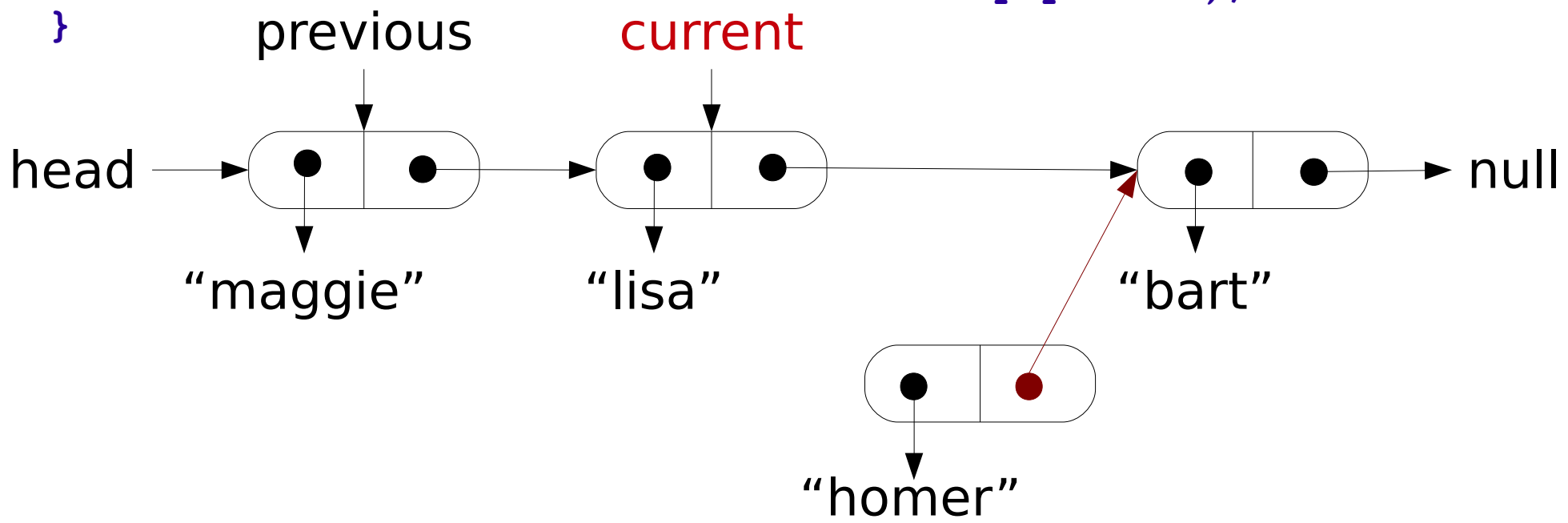
```
public void insertNodeAfterCurrent(String newData)  {
   ListNode newNode = new ListNode(newData, null);
   if (current != null) {
      newNode.link = current.link;
      current.link = newNode;
   } else if (head != null) {
      throw new LinkedListException("Inserting when iterator is " +
                          "past all nodes or uninitialized iterator");
   } else {
      throw new LinkedListException("Using insertNodeAfterCurrent " +
                                    "with empty list");
   }
}
```



# StringLinkedListWithIterator - insertNodeAfterCurrent

**success**

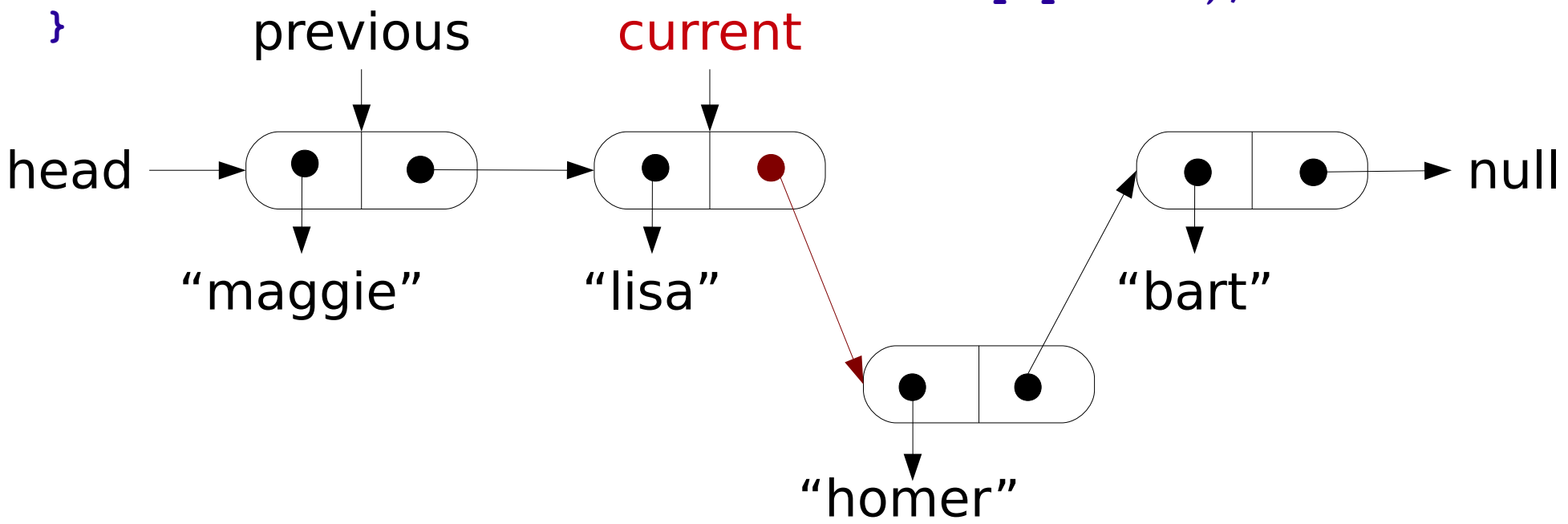
```
public void insertNodeAfterCurrent(String newData)  {
   ListNode newNode = new ListNode(newData, null);
   if (current != null) {
      newNode.link = current.link;
      current.link = newNode;
   } else if (head != null) {
      throw new LinkedListException("Inserting when iterator is " +
                          "past all nodes or uninitialized iterator");
   } else {
      throw new LinkedListException("Using insertNodeAfterCurrent " +
                                    "with empty list");
   }
}
```



# StringLinkedListWithIterator - insertNodeAfterCurrent

**success**

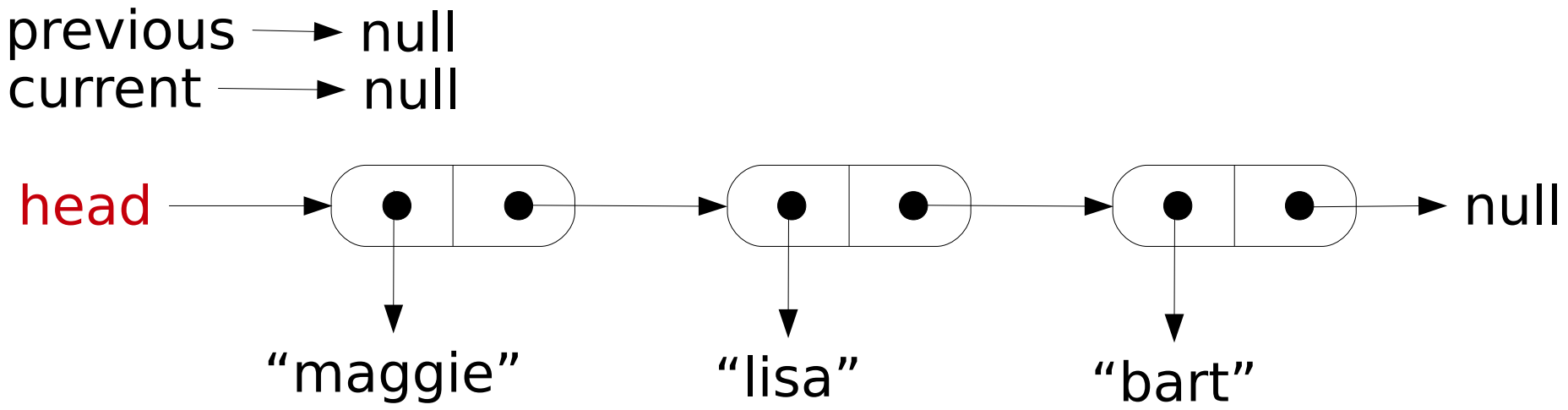
```
public void insertNodeAfterCurrent(String newData)  {
   ListNode newNode = new ListNode(newData, null);
   if (current != null) {
      newNode.link = current.link;
      current.link = newNode;
   } else if (head != null) {
      throw new LinkedListException("Inserting when iterator is " +
                        "past all nodes or uninitialized iterator");
   } else {
      throw new LinkedListException("Using insertNodeAfterCurrent " +
                                    "with empty list");
   }
}
```



# StringLinkedListWithIterator - insertNodeAfterCurrent

## uninitialized iteration

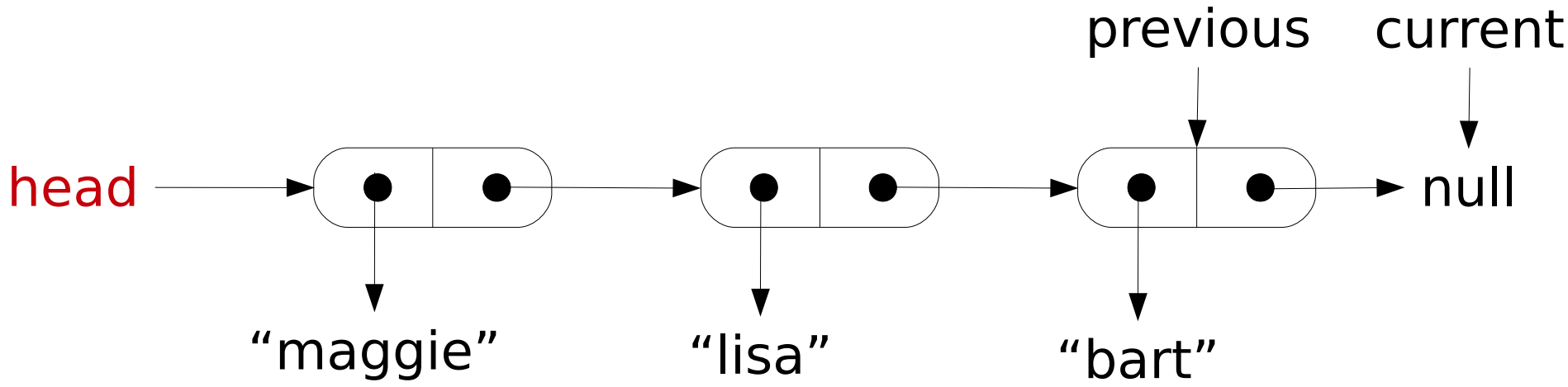
```
public void insertNodeAfterCurrent(String newData)  {
   ListNode newNode = new ListNode(newData, null);
   if (current != null) {
      newNode.link = current.link;
      current.link = newNode;
   } else if (head != null) {
      throw new LinkedListException("Inserting when iterator is " +
                        "past all nodes or uninitialized iterator");
   } else {
      throw new LinkedListException("Using insertNodeAfterCurrent " +
                                    "with empty list");
   }
}
```



# StringLinkedListWithIterator - insertNodeAfterCurrent

## done iterating

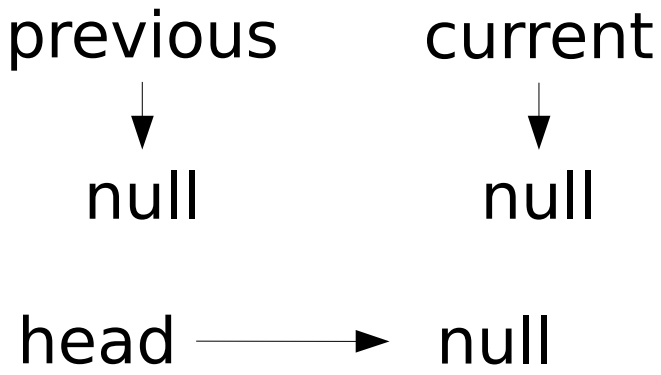
```
public void insertNodeAfterCurrent(String newData)  {
   ListNode newNode = new ListNode(newData, null);
   if (current != null) {
      newNode.link = current.link;
      current.link = newNode;
   } else if (head != null) {
      throw new LinkedListException("Inserting when iterator is " +
                        "past all nodes or uninitialized iterator");
   } else {
      throw new LinkedListException("Using insertNodeAfterCurrent " +
                                    "with empty list");
   }
}
```



# StringLinkedListWithIterator - insertNodeAfterCurrent

## empty list

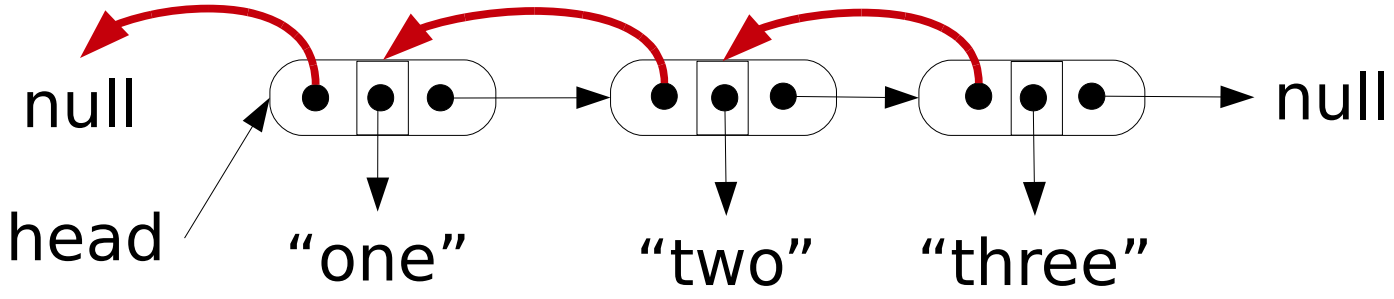
```
public void insertNodeAfterCurrent(String newData)  {
   ListNode newNode = new ListNode(newData, null);
   if (current != null) {
      newNode.link = current.link;
      current.link = newNode;
   } else if (head != null) {
      throw new LinkedListException("Inserting when iterator is " +
                        "past all nodes or uninitialized iterator");
   } else {
      throw new LinkedListException("Using insertNodeAfterCurrent " +
                                    "with empty list");
   }
}
```



# Doubly Linked Lists

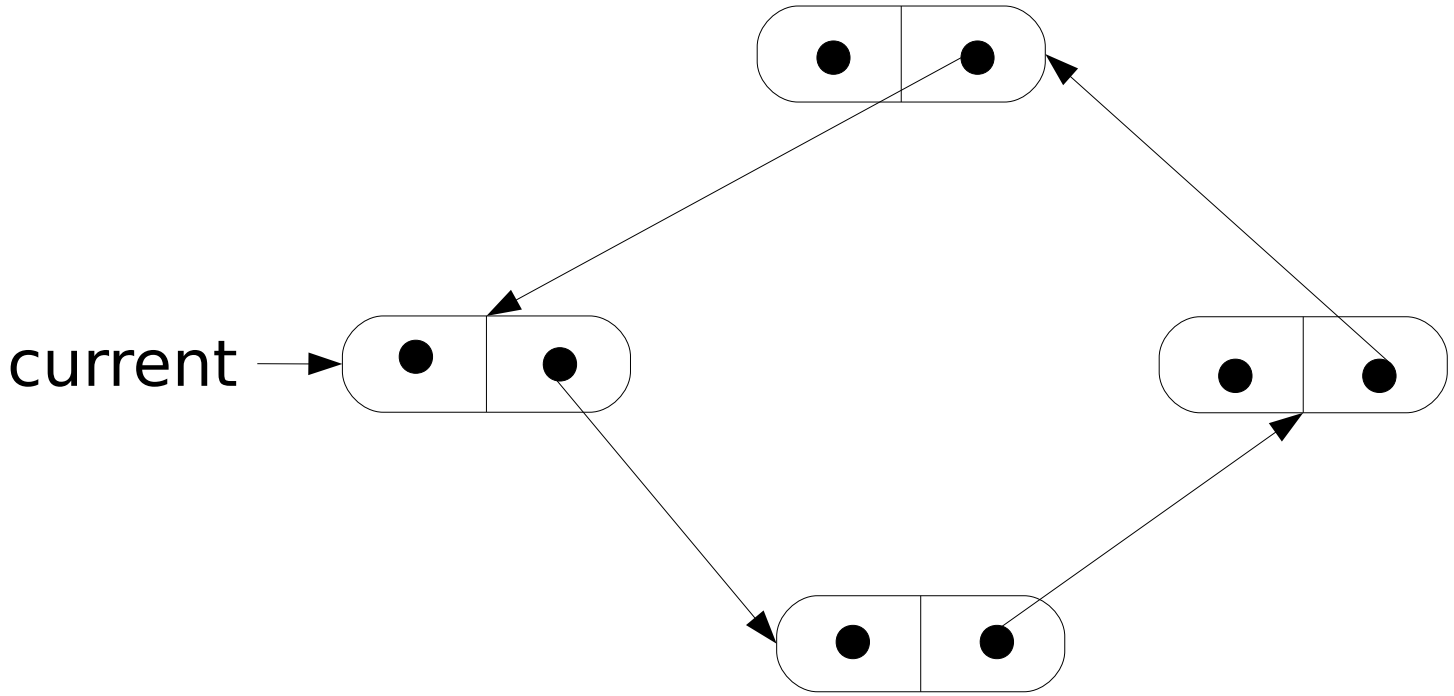
- An additional reference – to the previous node - can be added to the node class, producing a *doubly-linked list*.

```
private class ListNode {
    private String data;
    private ListNode next;
    private ListNode prev;
    ...
}
```



# Circularly Linked Lists

- The last node in a singly-linked list can reference the first node, producing a *circularly-linked list*.



# Generics

- Classes and methods can have a type parameter (like **`ArrayList<BaseType>`**)
- Any class type can be substituted for the **`BaseType`**

```
ArrayList<String> = new ArrayList<String>();
ArrayList<Integer> = new ArrayList<Integer>();
ArrayList<EnglishNoun> =
                        new ArrayList<EnglishNoun>();
```

- We can define our own generic classes.
- In the class definition, a *type parameter* **`T`** is used as a placeholder for the **`BaseType`**.

# Generics - Sample<T>

## Savitch listing 12.9, p 866

Using the **Sample<T>** class:

```
Sample<String> s1 = new Sample<String>();
s1.setData("Hello");
System.out.println(s1.getData());

Sample<Word> s2 = new Sample<Word>();
Word aWord = new Word("blah");
s2.setData(aWord);
```

# Generics - `LinkedList<E>`

## Savitch listing 12.10, p 870-871

- Use the type parameter **`E`** instead of a particular base type.
- By using a type parameter instead of a particular base type (**`String`**, for example), we can create a linked list with any type of data (**`Word`**, **`Car`**, **`BankAccount`**,...)

# Generics - LinkedList<E>

- The constructor heading does NOT include the type parameter in angle brackets.

```
// constructor
public LinkedList<E>() { //ILLEGAL
    // constructor code
}

// constructor
public LinkedList() {    //GOOD
    // constructor code
}
```

Limit use 1/3:
Constructor Heading

# Generics - `LinkedList<E>`

- The **`ListNode`** inner class heading also does NOT include the type parameter, but it can use the type parameter anyway.

```
// inner node class
private class ListNode {
    private E data;

    ...

}
```

Limit use 2/3:
Inner class heading

# Limited Use of a Type Parameter

- Within the definition of a parameterized class, there are places where a type name is allowed, but a type parameter is NOT allowed.
- Type parameters cannot be used in simple expressions that use **`new`** to create a new object.

```
Limit use 3/3:
`new` create new object
```

# Limited Use of a Type Parameter

- Examples:

```
T someObject;                 // LEGAL
someObject = new T();         // ILLEGAL

T[] someArray;                // LEGAL
someArray = new T[10];        // ILLEGAL
```

In both cases, the first **T** is legal, but the second **T** is illegal.

You cannot use type parameters directly with the `new` keyword to create new instances.
For example ❌ `T obj = new T();`
☑ `Factory<String> stringFactory = new Factory<String>() {}`

# Iteration

- The most common way to implement iteration of a collection of objects is by implementing **`Iterator<T>`**.
- Java provides an interface **`Iterator<T>`**
  - used by classes that represent a collection of objects
  - providing a way of moving through the collection one object at a time
  - defined in the java standard class library

# Iterator<T> Interface

这个iterface自带3个methods: next(), hasNext(), remove()

- The two primary methods of the interface **Iterator<T>** are:
  - **public T next();** (returns an object)
  - **public boolean hasNext();** (returns a boolean value)
- There is also an optional **remove** method. Even if you choose not to implement it, you must provide a **remove** method that simply throws an **UnsupportedOperationException**.
- The **Scanner** class implements this interface

# `Iterator<T>` Object

- The idea is to provide an **object** that iterates over the collection.
- This object can then call the **`hasNext`** and **`next`** methods to process the collection.

# Using an `Iterator<T>` Object

- Sample use of an **`Iterator<T>`** object:

```
LinkedList<String> list = new LinkedList<String>();
list.add(“Hello”);
list.add(“you”);
list.add(“there”);

Iterator<String> iter = list.iterator();
while (iter.hasNext()) {
    System.out.println(iter.next());
}
```

# Implementing `Iterator<T>`

- We need to provide a method (normally called **`iterator`**) that returns an object of type **`Iterator<T>`**.

```
public Iterator<T> iterator() {
    return new LinkedListIterator();
}
```

# Implementing `Iterator<T>`

- Where does the **`LinkedListIterator`** come from?
- **`LinkedListIterator`** is implemented as an **inner class** of the collection class (**`LinkedList`** in this case).
- **`LinkedListIterator`** implements the **`Iterator<T>`** interface and provides the required **`next`**, **`hasNext`**, and **`remove`** methods.

# Implementing `Iterator<T>`

- The **`LinkedListIterator`** inner class also needs:
  - an instance variable **`current`** that refers to the current node
  - A constructor that initializes **`current`** to the head of the list.

# Implementing `Iterator<T>`

```
import java.util.*;
public class LinkedList<T> {

    private ListNode head;

    // constructors and other methods...

    public Iterator<T> iterator() {
        return new LinkedListIterator();
    }
```

**Continued...**

# Implementing Iterator<T>

```
...Continued
    private class LinkedListIterator
                          implements Iterator<T> {
        private ListNode current;

        private LinkedListIterator() {
            current = head;
        }
        public boolean hasNext() { ... }
        public T next() { ... }
        public void remove() { ... }
    }

    private class ListNode {
        ...
    }
}
```

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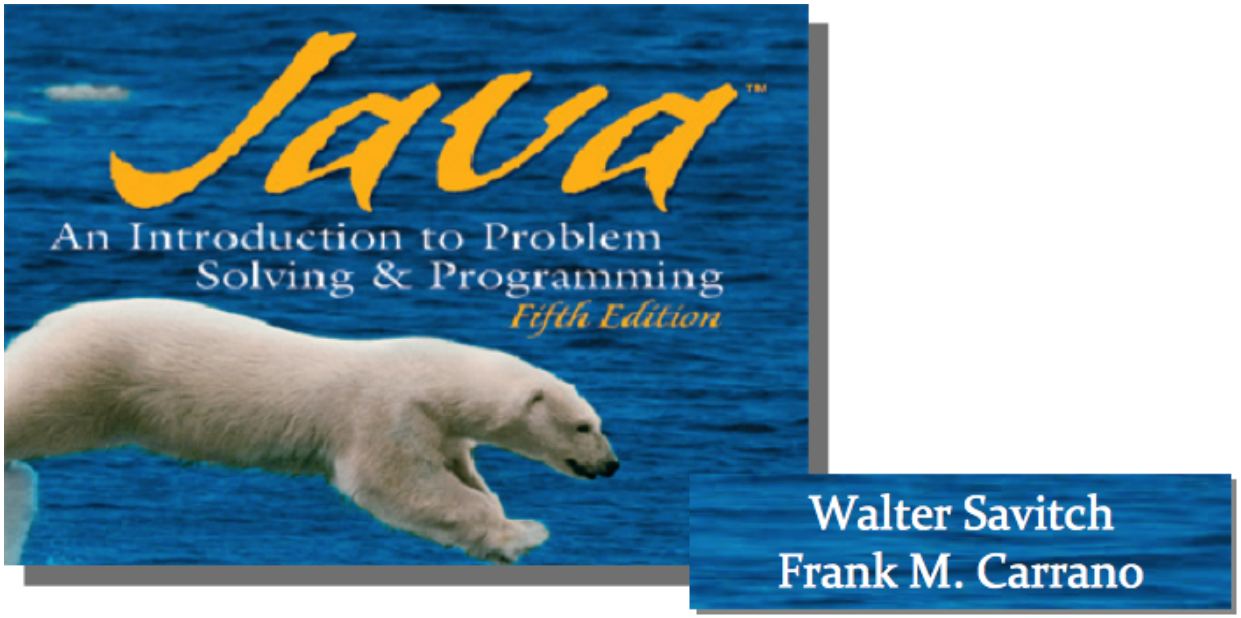


# Packages

**Reading: Savitch&Carrano chapter 6.7**
**Programming Course: Computational Linguistics – Verena Henrich**

# Packages and Importing

- A package is a named collection of related classes that can serve as a library of classes
- With packages you do not need to to place all classes in the same directory as your program
- In order to use classes from packages that have already been defined, such as **`Scanner`** or **`File`**, we need to import them:
  - Import a single class: **`import java.util.Scanner;`**
  - Import all classes from a package: **`import java.io.*;`**

# Defining your own Packages

- A package groups a set of classes together into a directory
- The name of the folder is the name of the package
- The classes in the package folder are each placed in a separate file (as usual)
- Each class in the package has **`package Package_Name;`** as the **first statement**, like this:

```
/** Description of the class */
package lib.helpers;
// rest of class definition...
```

# Package Names

- A package name tells the compiler the path (divided by dots) to the directory that contains the classes in the package
- For example: our package will be named **`lib.helpers`**, so we will store the package in the directory **`lib/helpers`**
- Put all Java files that should be included in the package in the package directory (**`lib/helpers`**)
- Our package has only one source file, **`ListHelper.java`** (from selftest 1), but we can add more later
- Don't put any source files that are not part of the package in this directory (no junit tests, for example)

# Setting the Classpath

- You need to tell Java where to find the **`lib`** directory by setting your classpath
- Setting the classpath in NetBeans:
  - Right-click on the project → select “Properties“
  - Choose the “Libraries“ tab → “Add Library” button
  - Navigate to the directory ABOVE the **`lib`** directory and single-click on the **`lib`** directory, so that it is selected, but you are not in it
  - Click “Choose”; you should see the path to the **`lib`** directory under “Libraries” now

# Using the Package

- Now you can use the package (in junit tests, demo programs, etc.) by importing it:
  - Either: `import lib.helpers.ListHelper;`
  - Or: `import lib.helpers.*;`

# Name Clashes

- Packages help in dealing with name clashes, i.e., when two classes have the same name
- Problem: different programmers writing different packages have used the same name for a class
- Solution: ambiguity can be resolved by using the package name before the class name ("fully qualified class name")

```
lib.helpers.ListHelper helper1 = new lib.helpers.ListHelper();
fantasy.ListHelper helper2 = new fantasy.ListHelper();
```

- Since fully qualified name includes the package name, there is no need to import the package

# Example

Package 1

public class Foo
public class Bar

Package 2

public class Foo2 extends Foo
public class Umu

Visibility of member of class Foo:

Access Level

| Modifier | Foo | Bar | Foo2 | Umu |
|---|---|---|---|---|
| `public` | y | y | y | y |
| `protected` | y | y | y | n |
| *`No modifier`* | y | y | n | n |
| `private` | y | n | n | n |

Concepts:

ADT
Dynamic Data Structure
LinkedList
Collection
NullExceptionPointer
Inner class
Iterator, interface
Package
Access Modifier