```
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

ADT is defined in contrast to **concrete data types** or **implementation details**.
An ADT focuses on the logical behaviour of data structures, rather than the specific details of how they are implemented.

In essence:

Abstract Data Type (ADT): Refers to the what — what operations a data structure supports and what its behavior is.

ADTs define the interface (e.g., what operations can be performed, like adding, removing, or accessing elements), but not how these operations are carried out.

Concrete Data Type/Implementation: Refers to the how — how the ADT is actually implemented in memory or through algorithms. This includes data structures like arrays, linked lists, hash tables, etc., that physically realize an ADT.

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

  * No implement details.

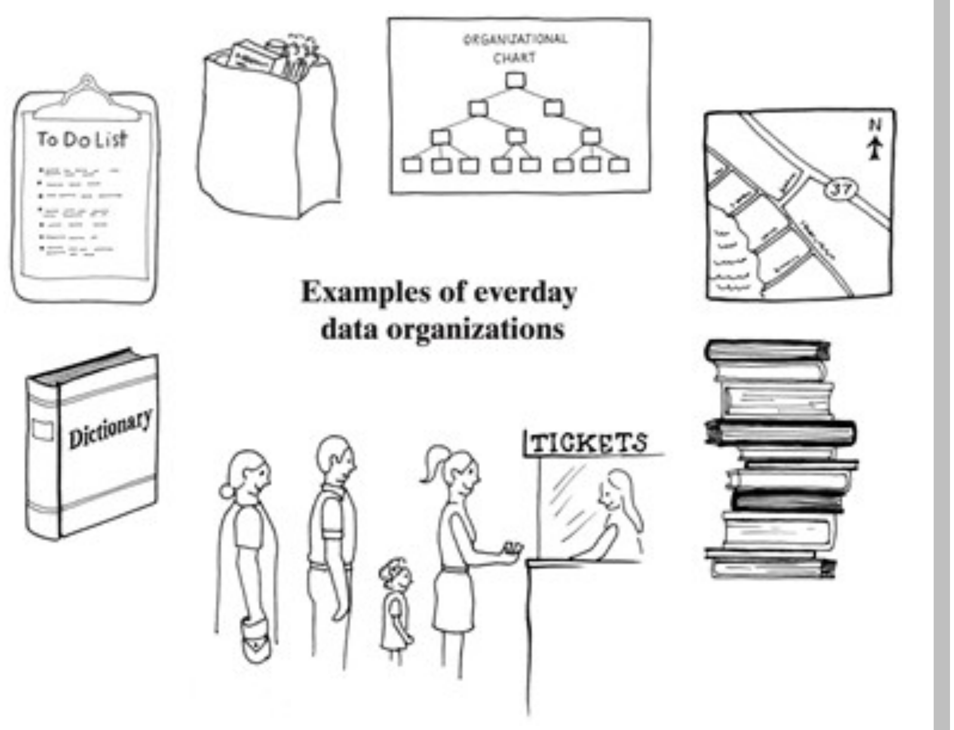
  - data that is stored – No how data being represented
  - operations that can be done on the data

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

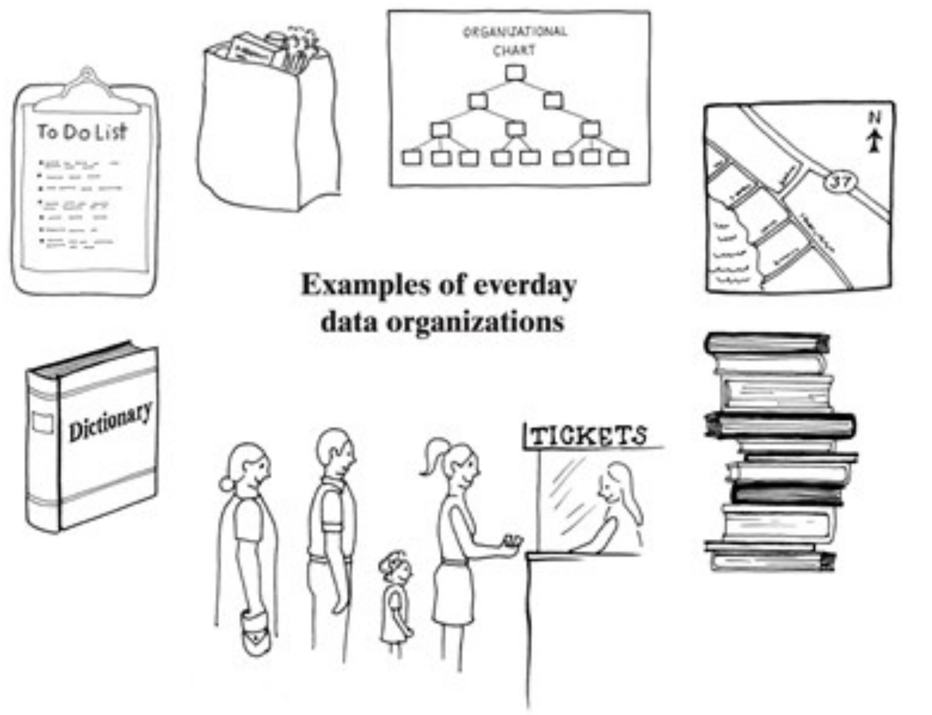
7个:
Bag, List, Stack, Queue,
Dictionary, Tree, Graph



- Bag
  - Unordered collection, may contain duplicates
- List ArrayList here
  - 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

```
**ADT** is ways of organising data,
its implementation is **Data Structure**.
In Java, ADT is represented as an **Interface**,
which implements by **classes**
```

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 (abstract) 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.

vs Array: can change in length,
but less efficient +
base type cant be primitive type
(wrapper class needed)

ArrayLists

- **ArrayLists** perform the resizing operation that we implemented ourselves up to now
- **ArrayLists** serve the same purposes as arrays, but can [redacted] 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`

1. Import,
2. Create with object type + (optional) capacity (it'll grow autoly)

- 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`

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

- Syntax:

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

or:

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

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

byte – Byte
short – Short
int – Integer
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

`.get(index)` : 0 <= index < size

Create an ArrayList of type `Word` objects and add **Words**:

```
   ArrayList<Word> list = new ArrayList<Word>();
index:
0  list.add(new Word("the"));
1  list.add(new Word("dog"));
2  list.add(new Word("bites"));
```

Get the second element:

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

The reason why you need to use `new Word("xxx")` instead of directly writing `list.add("the")` is because `ArrayList<Word>` is a list of Word objects, not a list of String objects.
[Type mismatch] `list.add("the")` tries to add a String to the list. However, the list is declared as `ArrayList<Word>`, meaning it can only hold objects of the class Word, not String objects.

Adding and Getting Elements

Inserting into the middle:

insert “vicious” at index 1

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

- The **`Word`** “vicious” is now at index 1
- The other **`Words`** get moved down

before:

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

after:

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

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**
3 bites	**3 children**
4 children	

the rest move up

`remove(index)`:

$0 <= index < size()$

Removing an Element

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1/3: 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2/3：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3/3：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

String[]

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

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,
以前都是Array時，直接res[i] = s[i]即可

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`.

```
T stands for **generic type**, -
 a generic class/interface that is parameterised over types.

It is replaced by actual datatypes when instances created.

`className<T>`
```

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);
}
```

`element`是自定义用户名，可换成`item`等任何java中合法的命名

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

String element 只是表明每次迭代时，
list 中的一个元素会被赋值给 element，
然后你可以在循环体内使用这个变量来访问该元素。

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

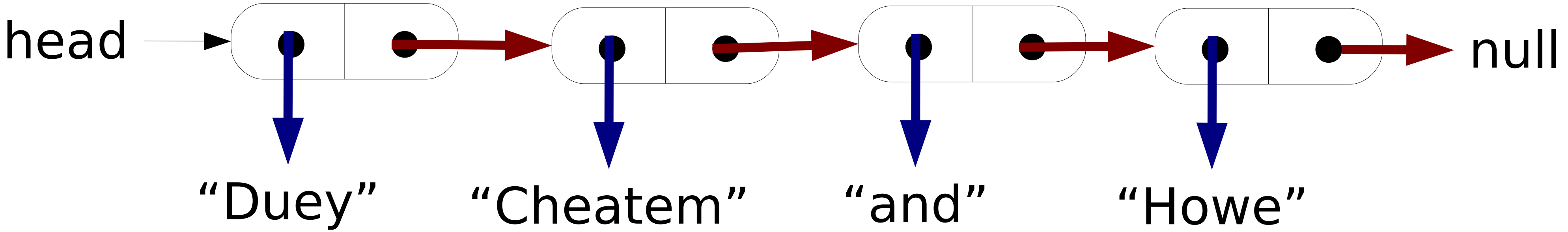
- Java has a predefined **`LinkedList`** class, which is part of the **`java.util`** package

- In order to learn how linked data structures work, we will construct our own linked list class.

String Linked List

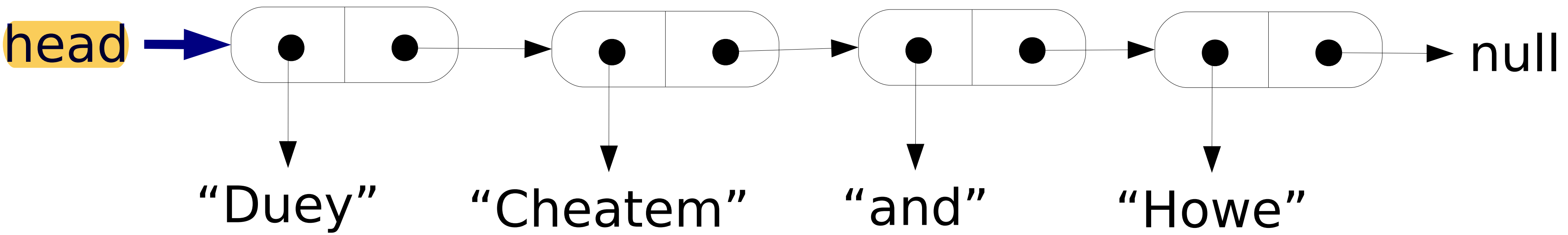
- We will call our linked list class **`StringLinkedList`**.
- **`StringLinkedList`** *has-a* reference to the first node in the list – also called the **`head`** of the list.
- We will define a separate class called **`ListNode`** to represent a node.
- A **`ListNode`** *has* data and a link to the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

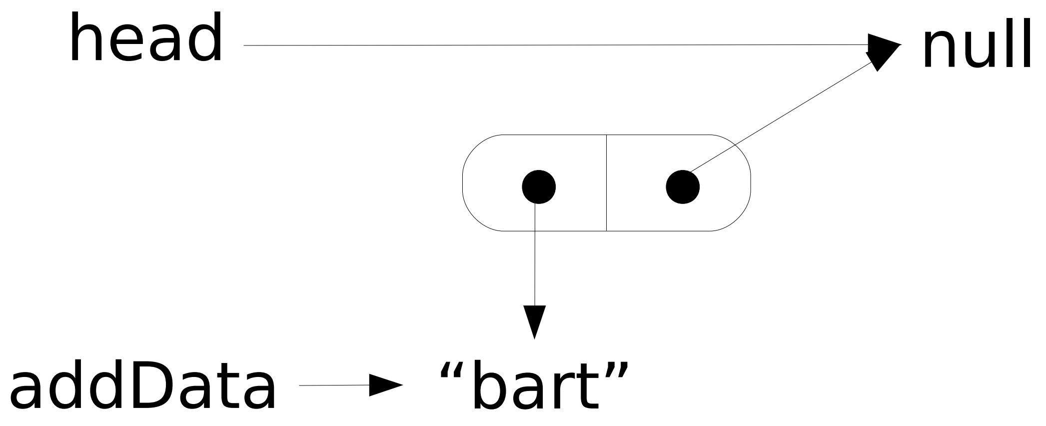
head → null

StringLinkedList - addANodeToStart

add the first node

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

Create new node:

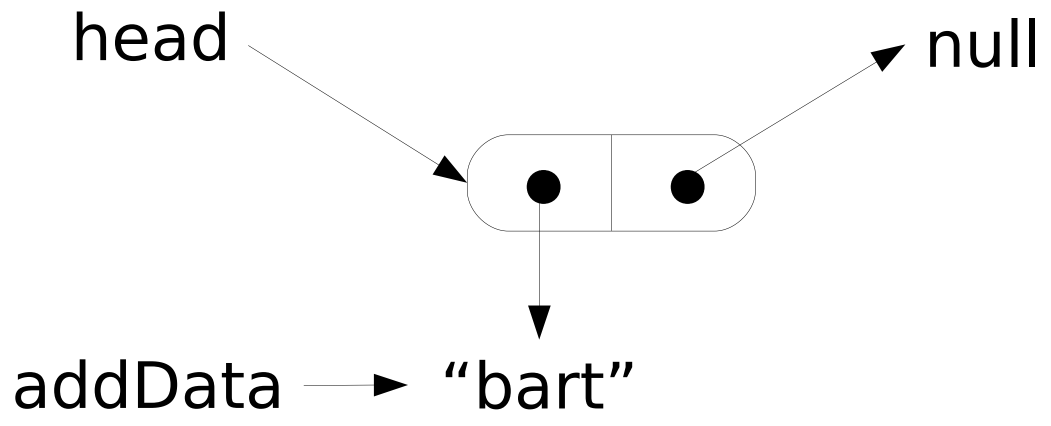


StringLinkedList - addANodeToStart

add the first node

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

After:

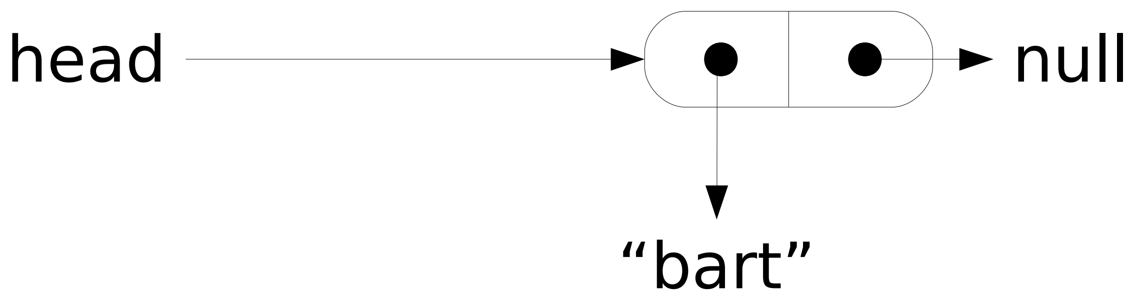


StringLinkedList - addANodeToStart

add a second node

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

Before:



StringLinkedList - addANodeToStart

add a second node

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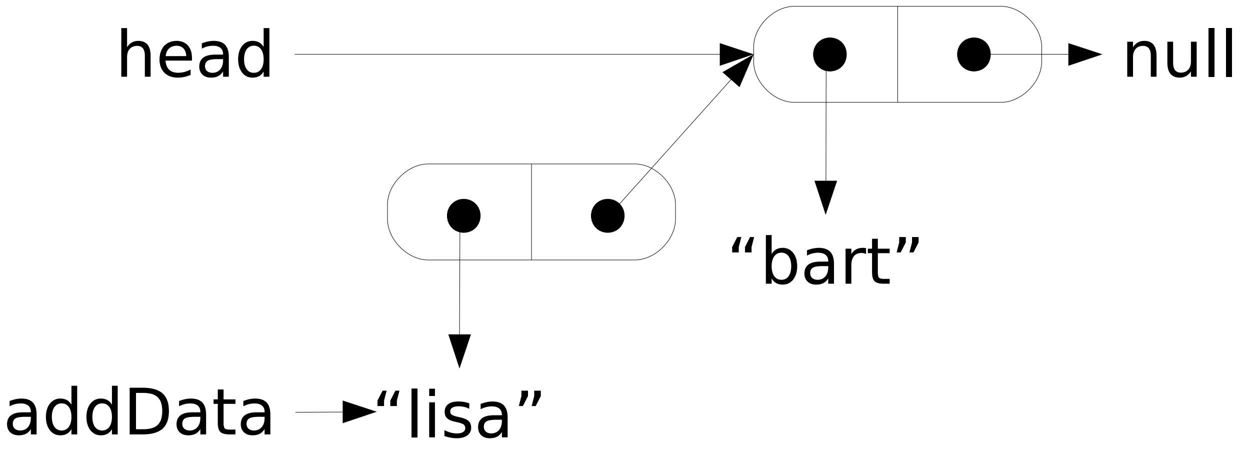
    head = new ListNode(addData, head);
}
```

Create new node:

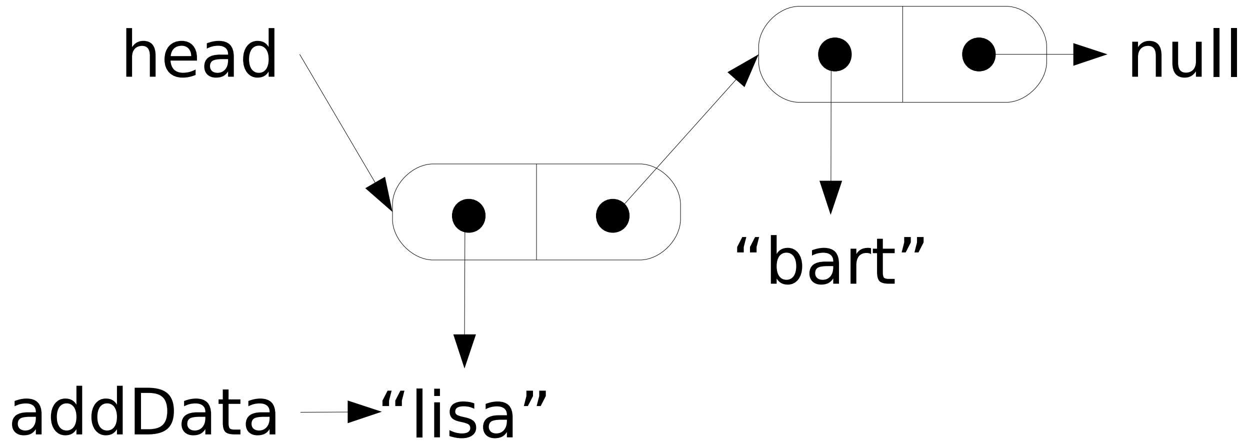


StringLinkedList - addANodeToStart

add a second node

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

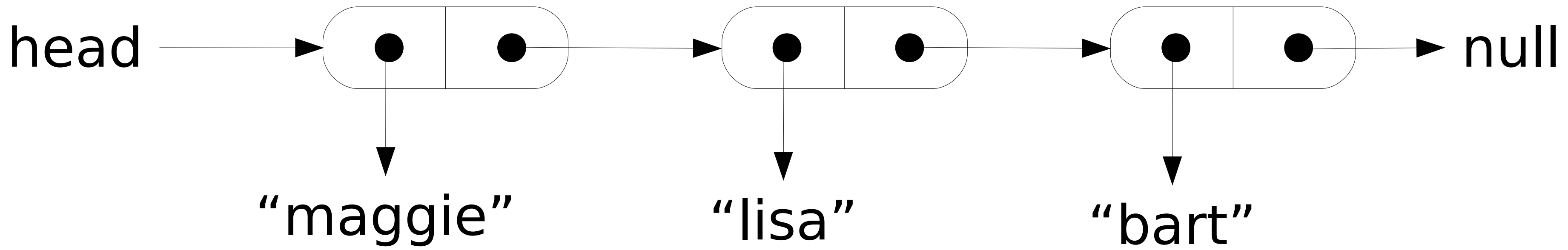
After:



StringLinkedList - length

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

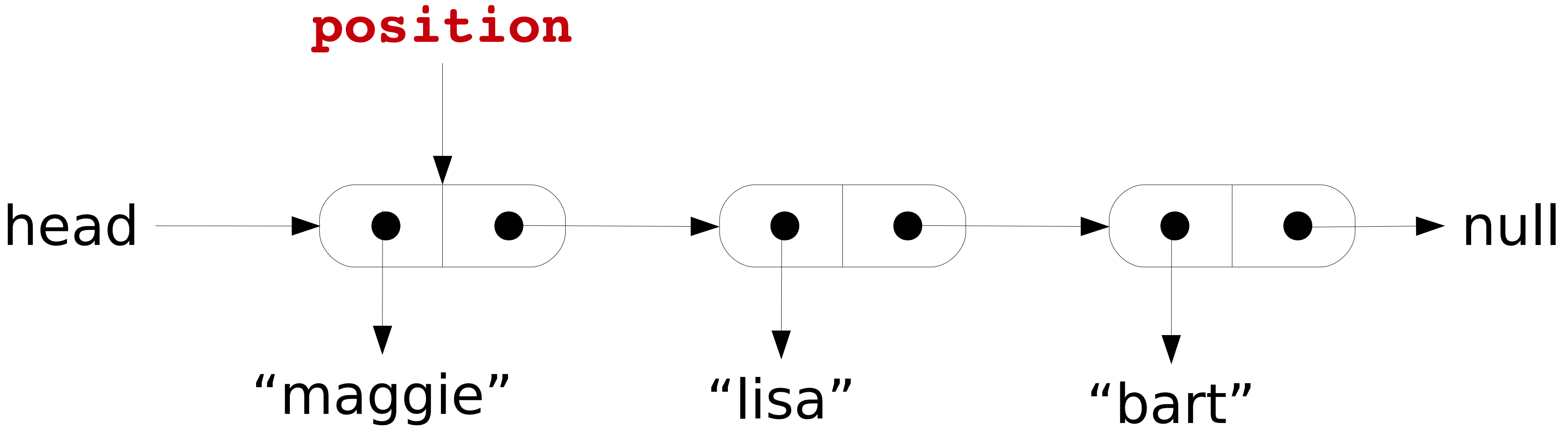
count: 0



StringLinkedList - length

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

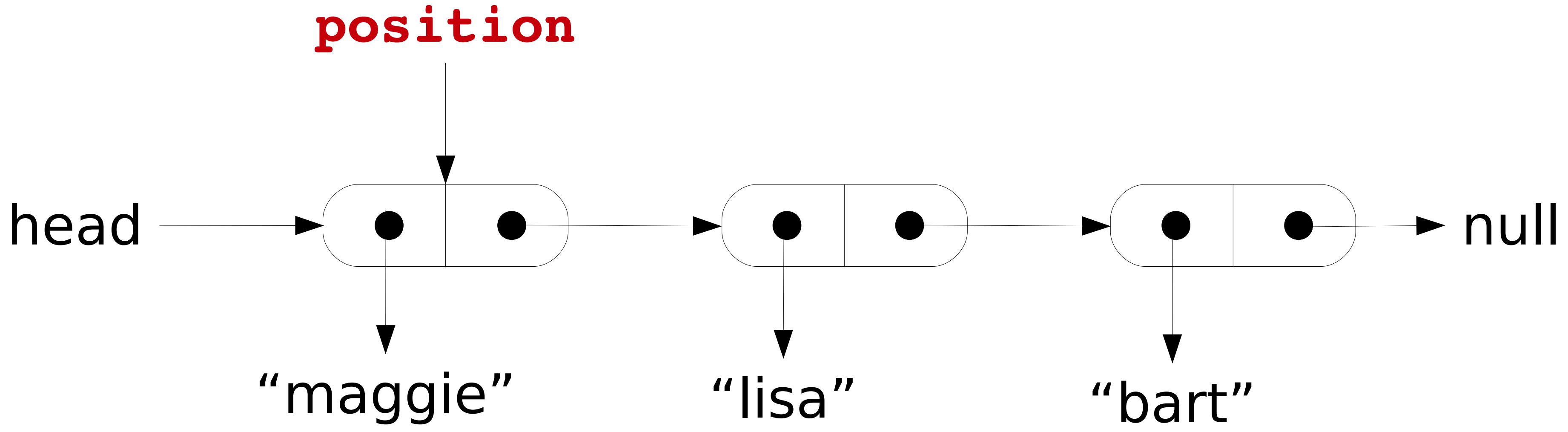
count: 0



StringLinkedList - length

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

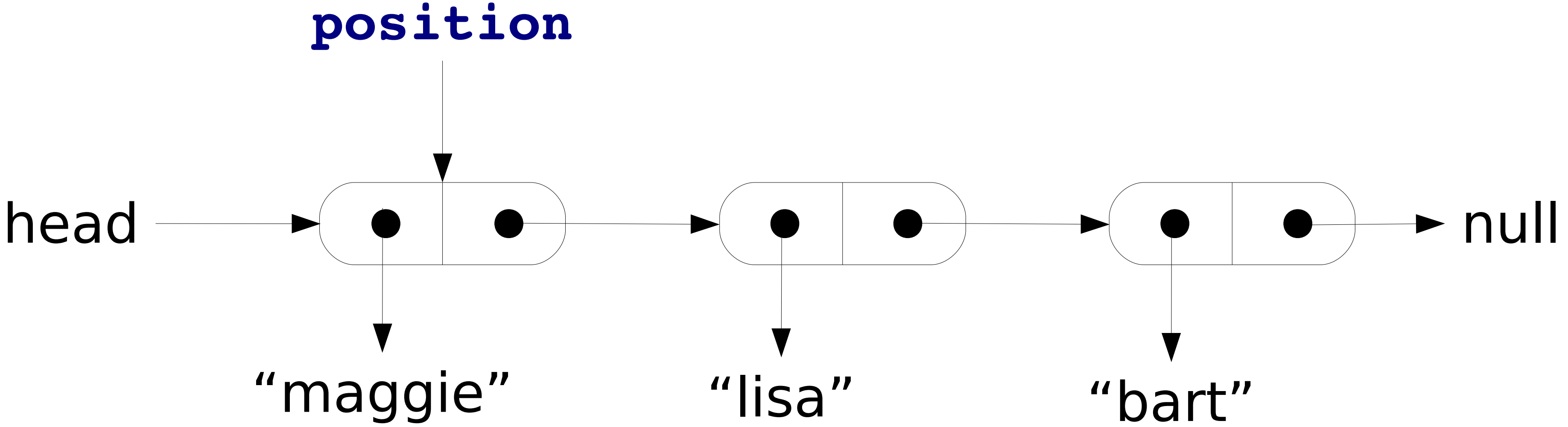
count: 0



StringLinkedList - length

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

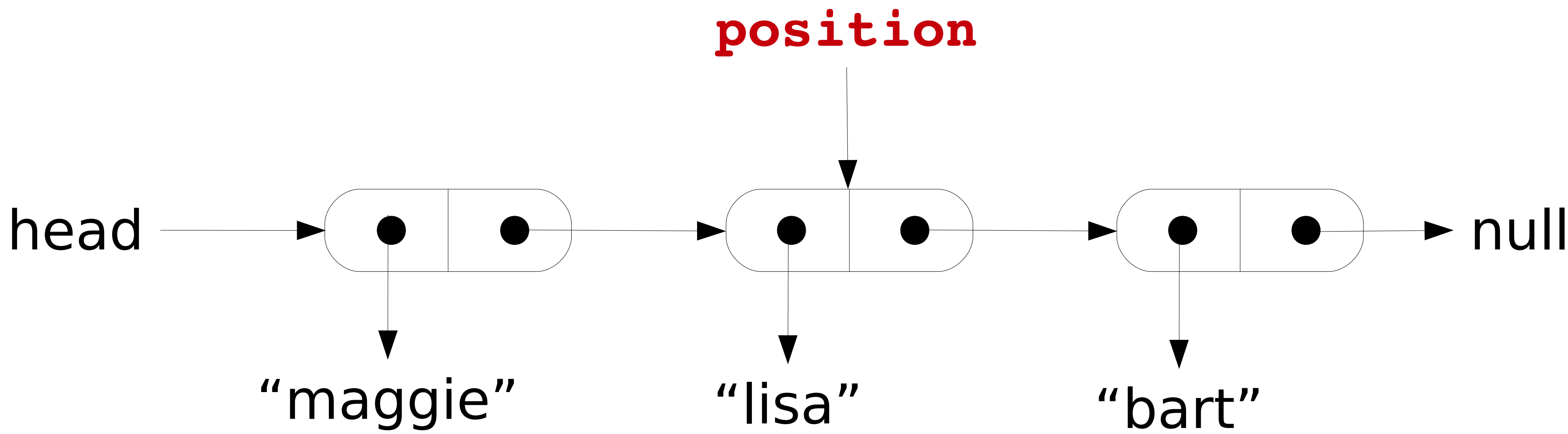
count: 1



StringLinkedList - length

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

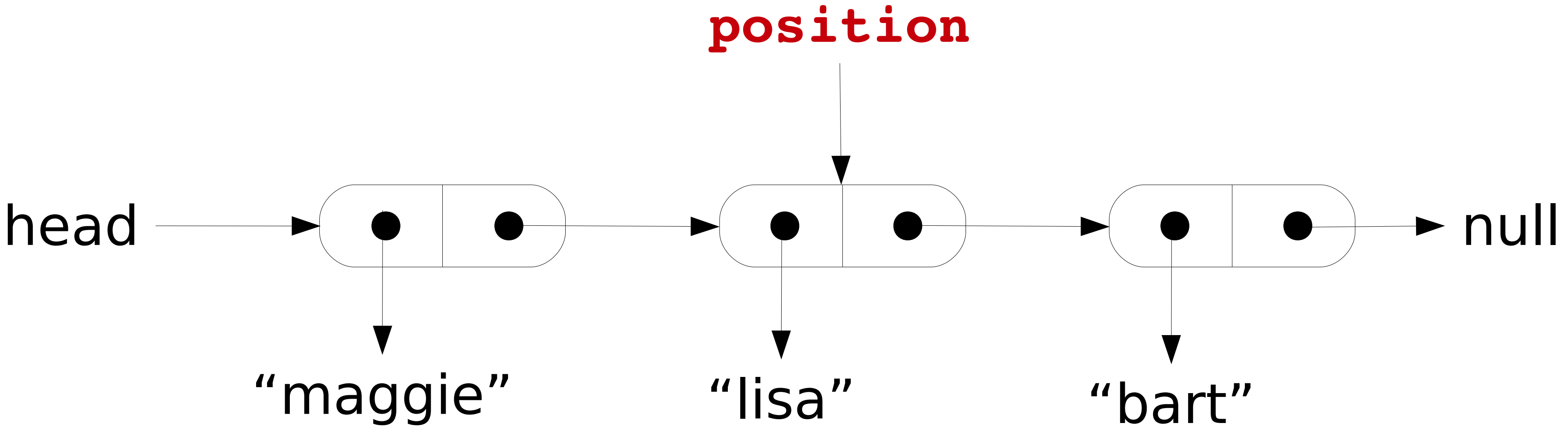
count: 1



StringLinkedList - length

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

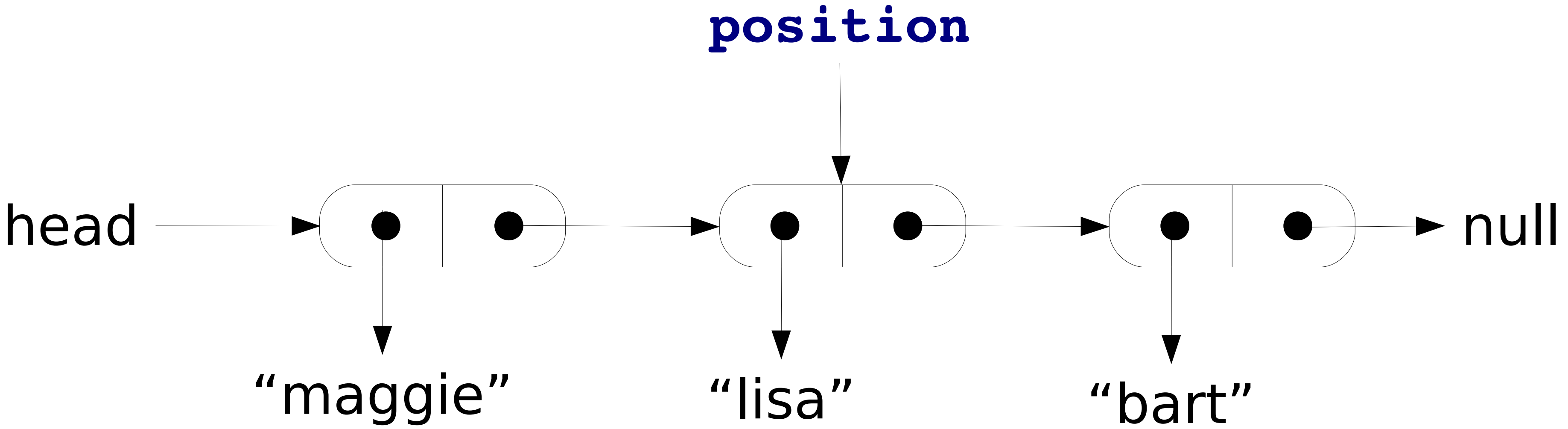
count: 1



StringLinkedList - length

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

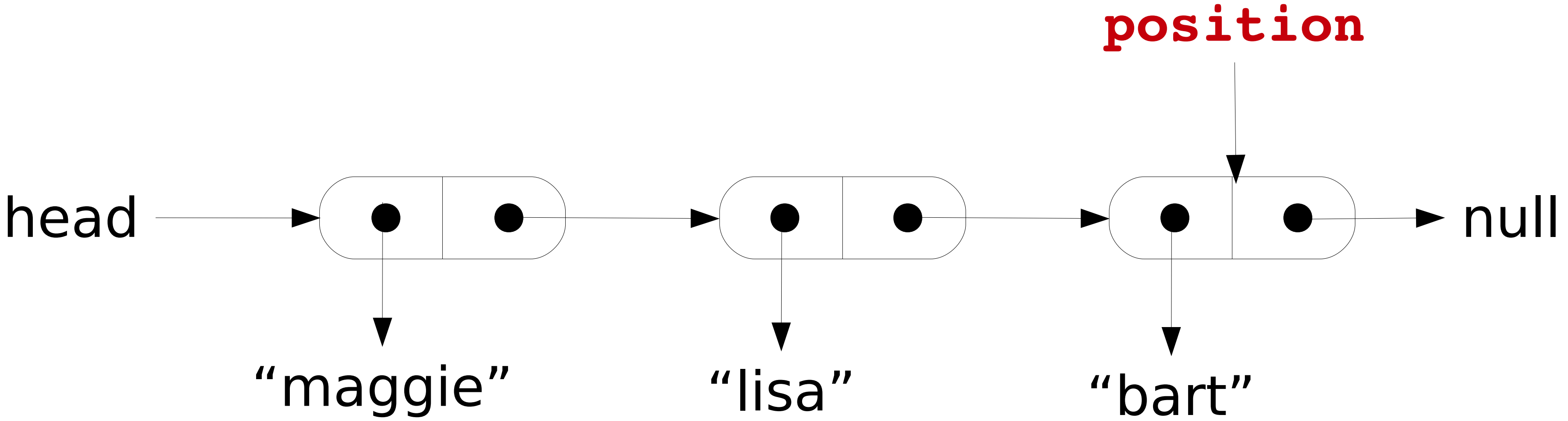
count: 2



StringLinkedList - length

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

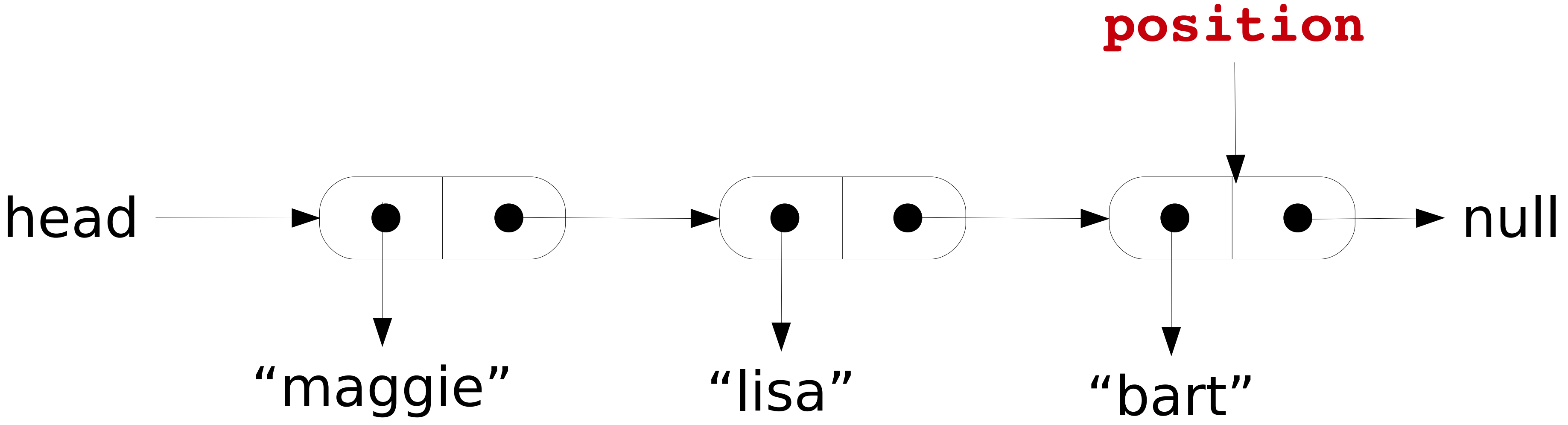
count: 2



StringLinkedList - length

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

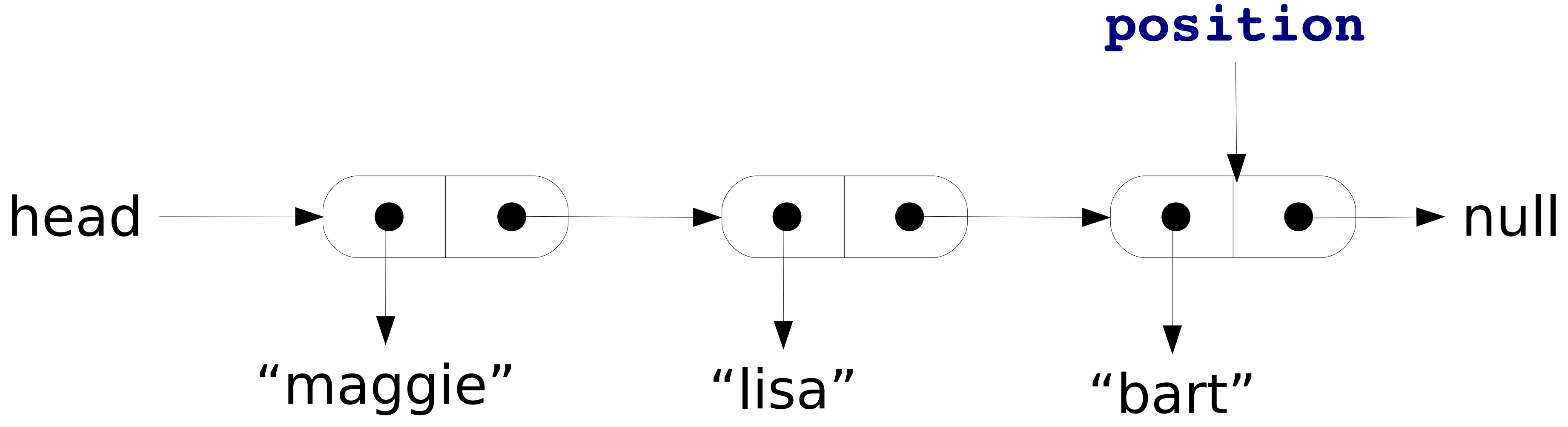
count: 2



StringLinkedList - length

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

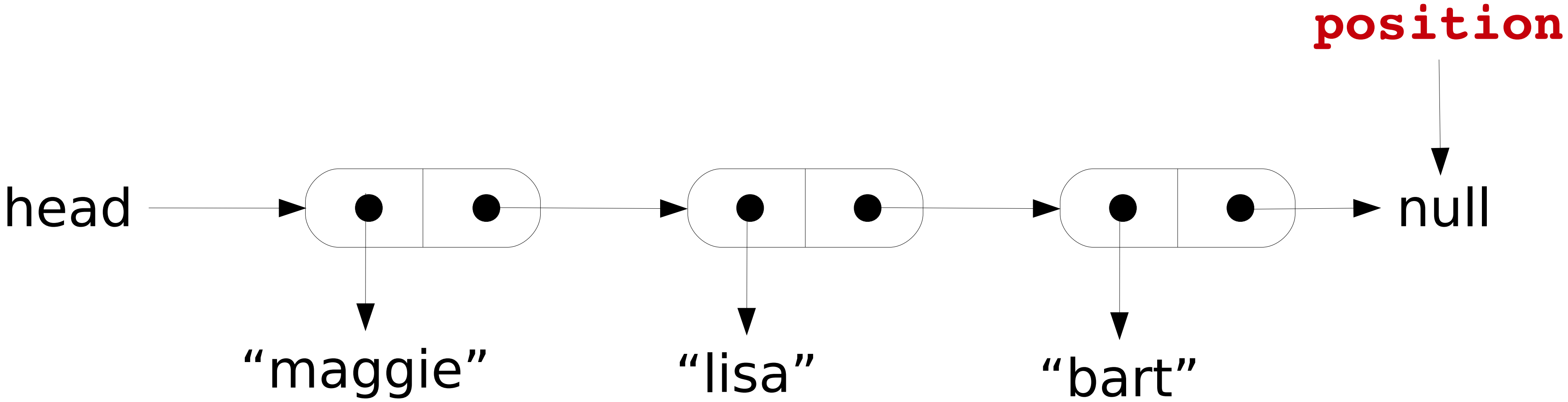
count: 3



StringLinkedList - length

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

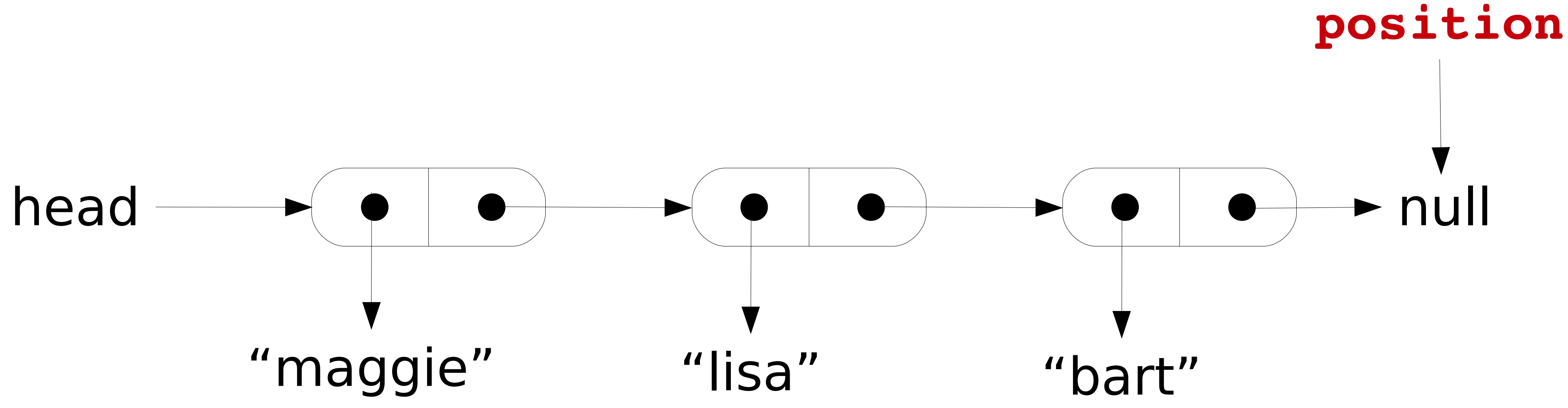
count: 3



StringLinkedList - length

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

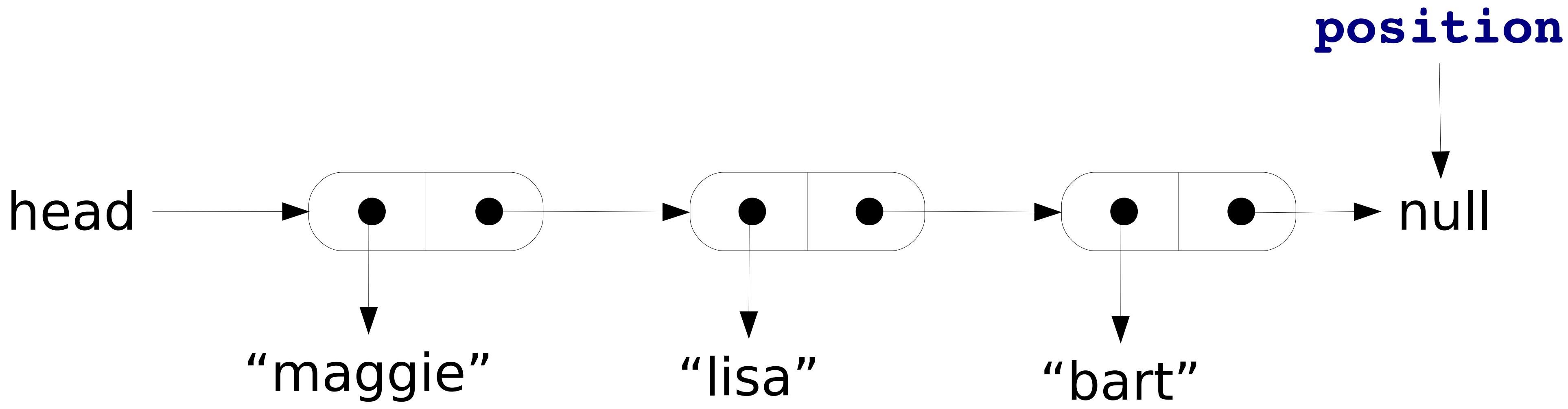
count: 3



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)
    System.out.println(“Deleting from an empty list.”)
    System.exit(0);
  else {
    head = head.getlink();
```

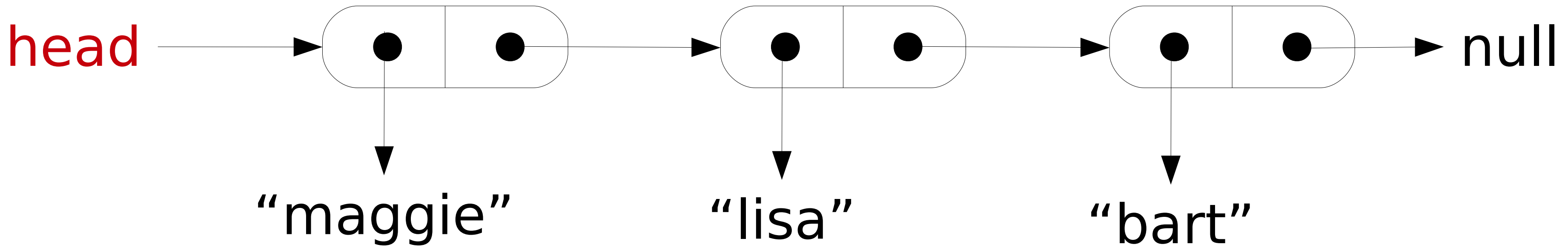
NullPointerException

- 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.

use null reference to access an object;
variable refers to no object

StringLinkedList - deleteHeadNode

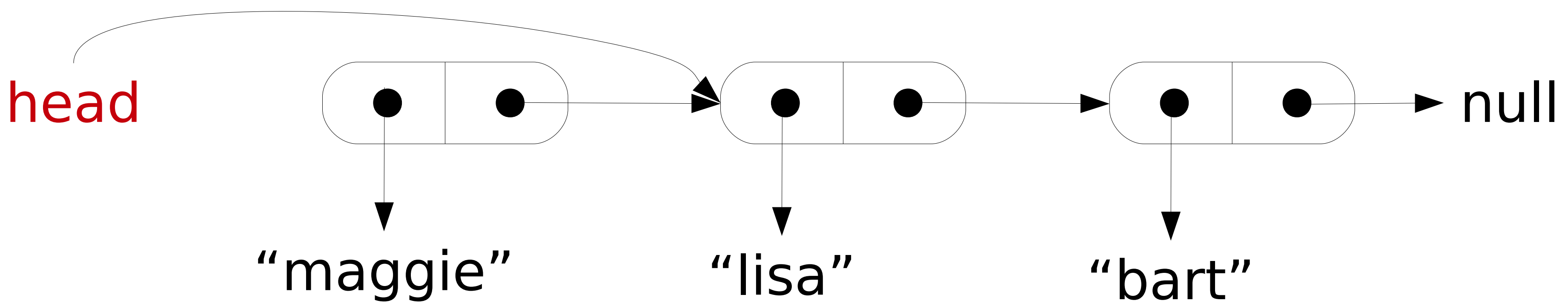
```
public void deleteHeadNode()  {
   if (head != null) {
      head = head.getLink();  public ListNode getLink(){return link;}
   } else {
      throw new NullPointerException("Deleting from empty list");
   }
}
```



StringLinkedList - deleteHeadNode

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

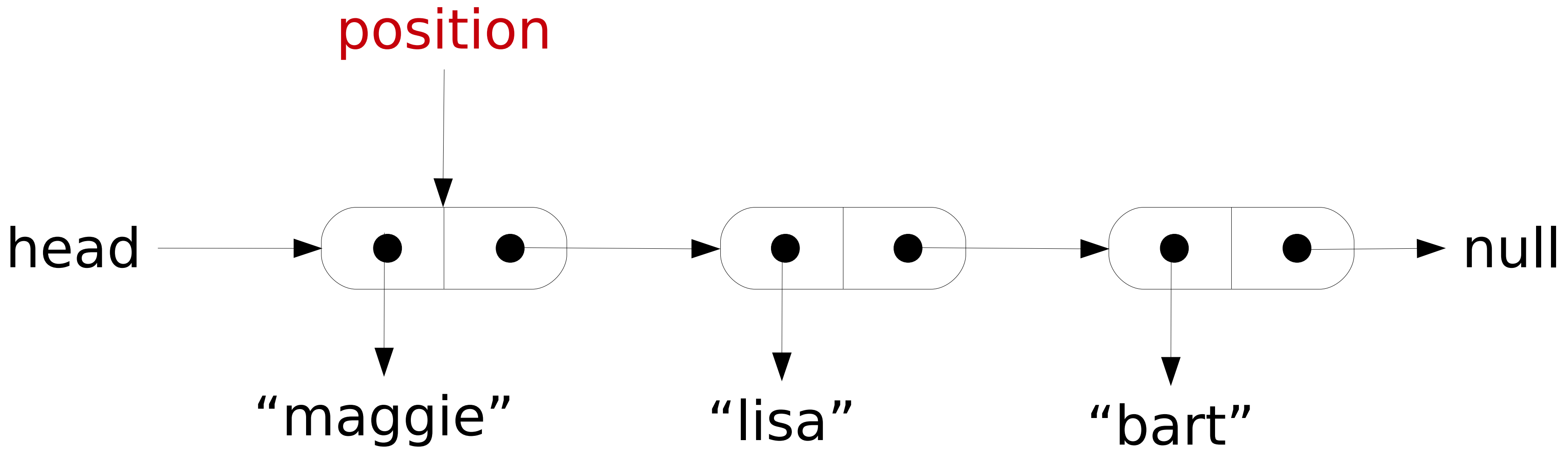
getLink(),
用于获取当前节点的“链接部分”,
即指向下一个节点的引用。
head本来指向链表的第一个节点node1,
现在head = 原head指向的下一个节点 (即node2



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

StringLinkedList - showList()

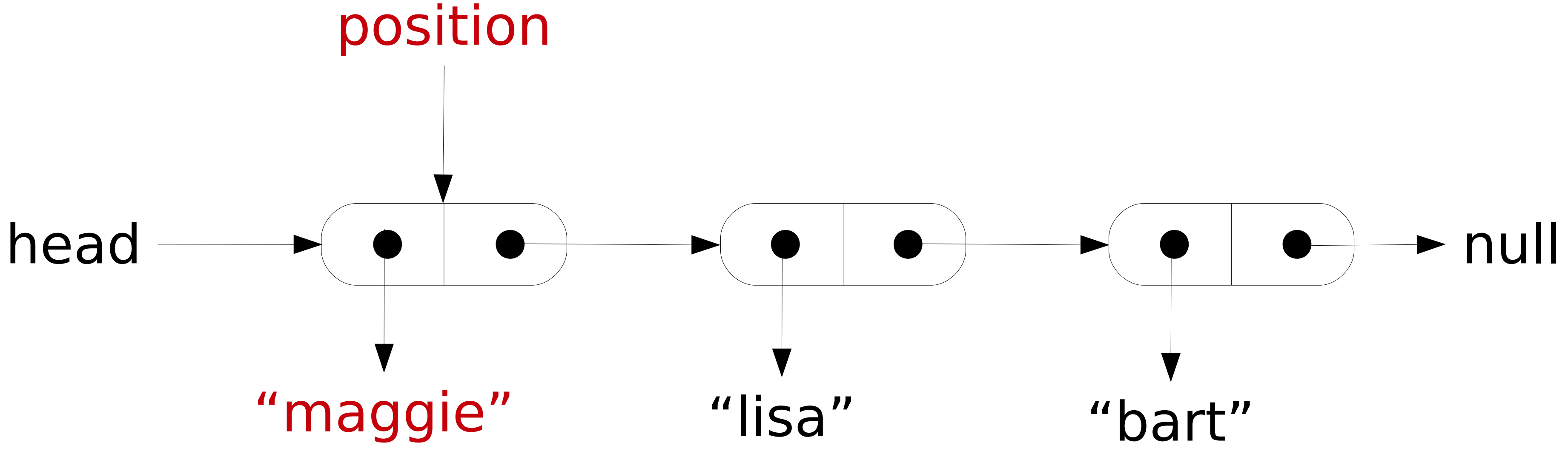
```
public void showList()  {
   ListNode position = head;
   while (position != null) {
      System.out.println(position.getData());
      position = position.getLink();
   }
}
```



StringLinkedList - showList()

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

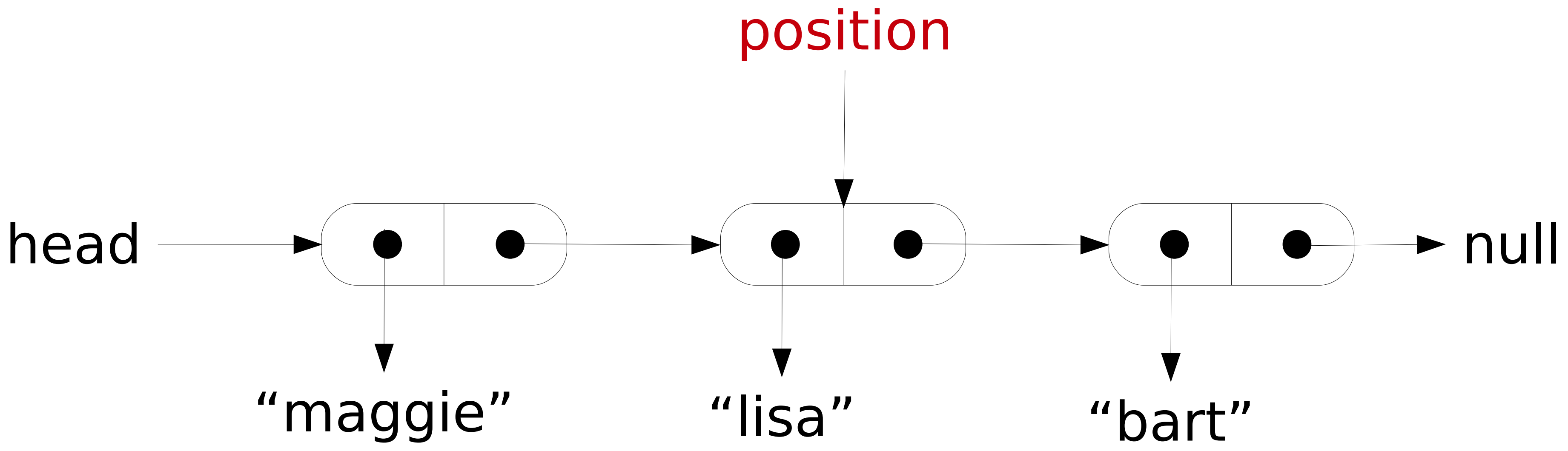
maggie



StringLinkedList - showList()

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

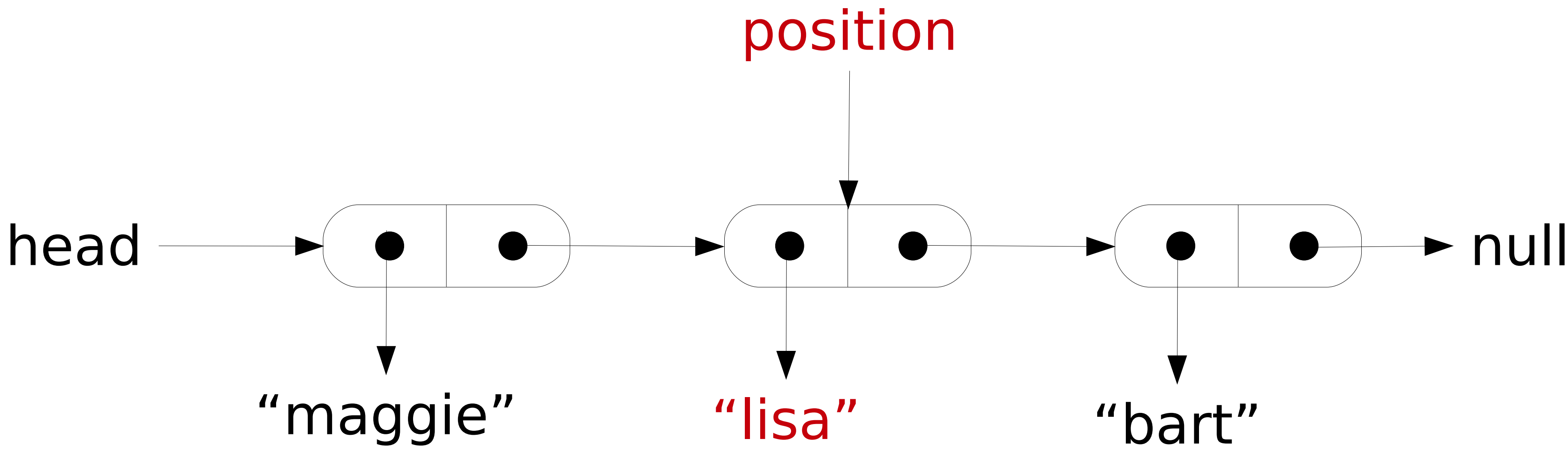
maggie



StringLinkedList - showList()

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

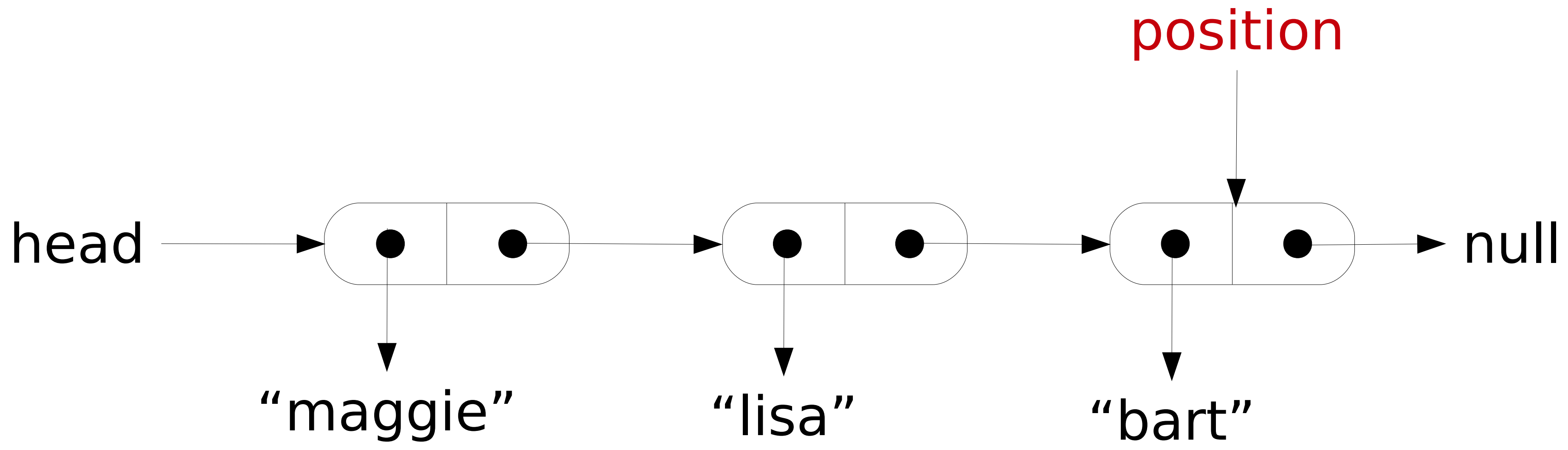
maggie
lisa



StringLinkedList - showList()

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

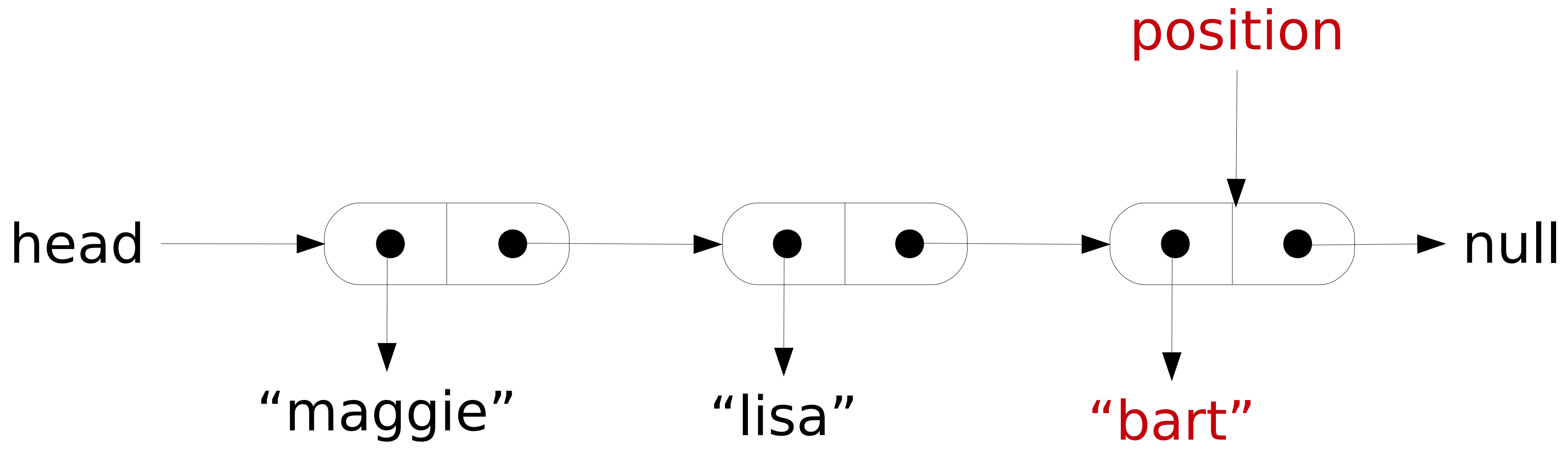
maggie
lisa



StringLinkedList - showList()

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

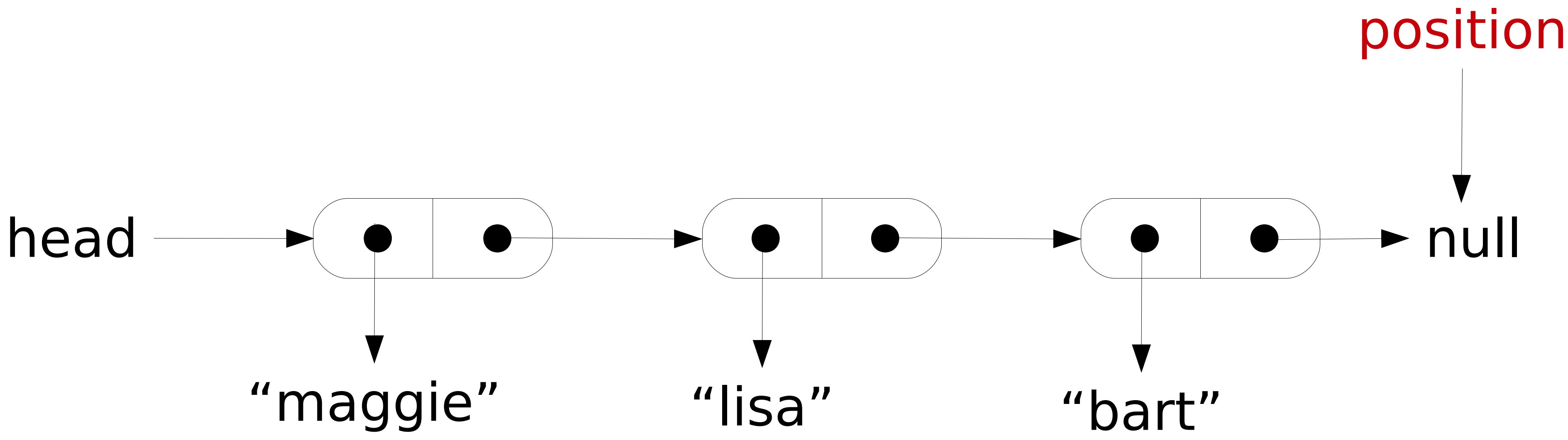
maggie
lisa
bart



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(outer 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.

逐个遍历

- An *iterator* allows us to “step through” a collection of objects (in this case a list of nodes).

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

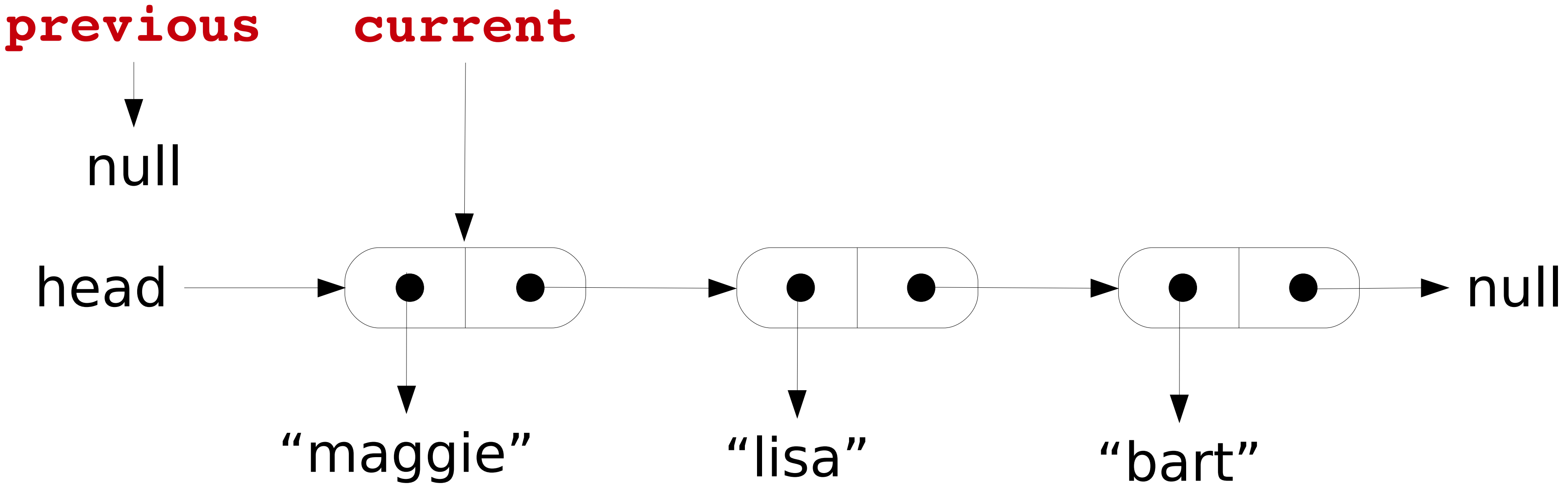
- Additional methods:
  - **`resetIteration`**
  - **`goToNext`**
  - **`deleteCurrentNode`**
  - **`insertNodeAfterCurrent`**
  - **`moreToIterate`**
  - **`getDataAtCurrent`**
  - **`setDataAtCurrent`**
- Must modify **`addANodeToStart`** method

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

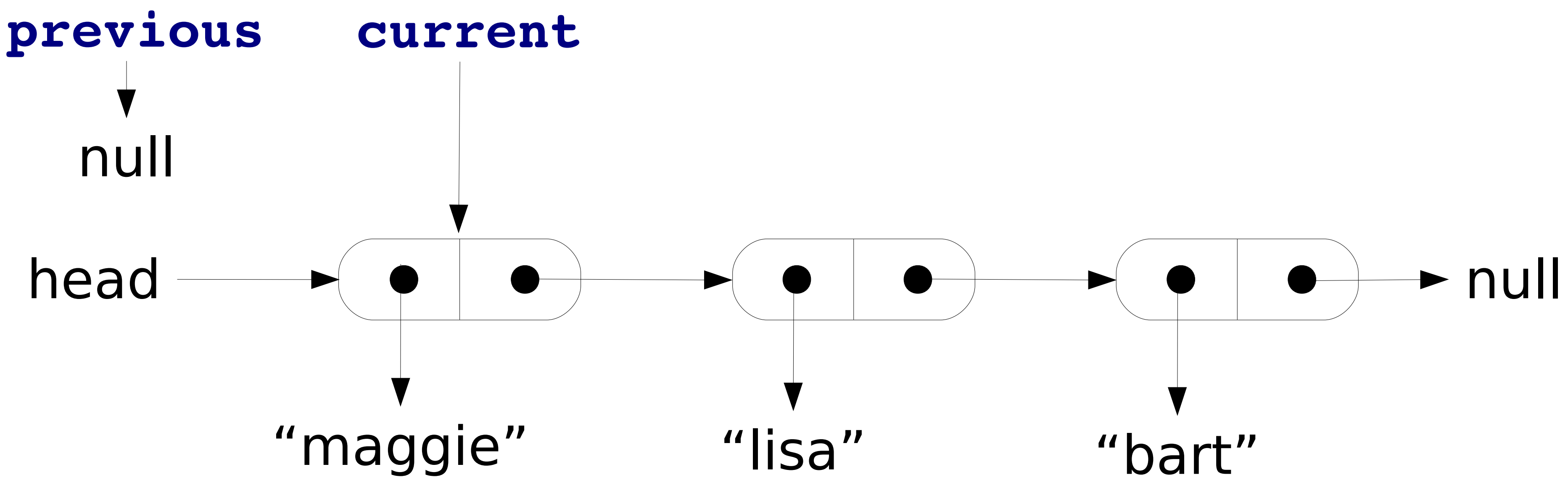
  - the iteration moved past end of list

    or

  - the list is empty

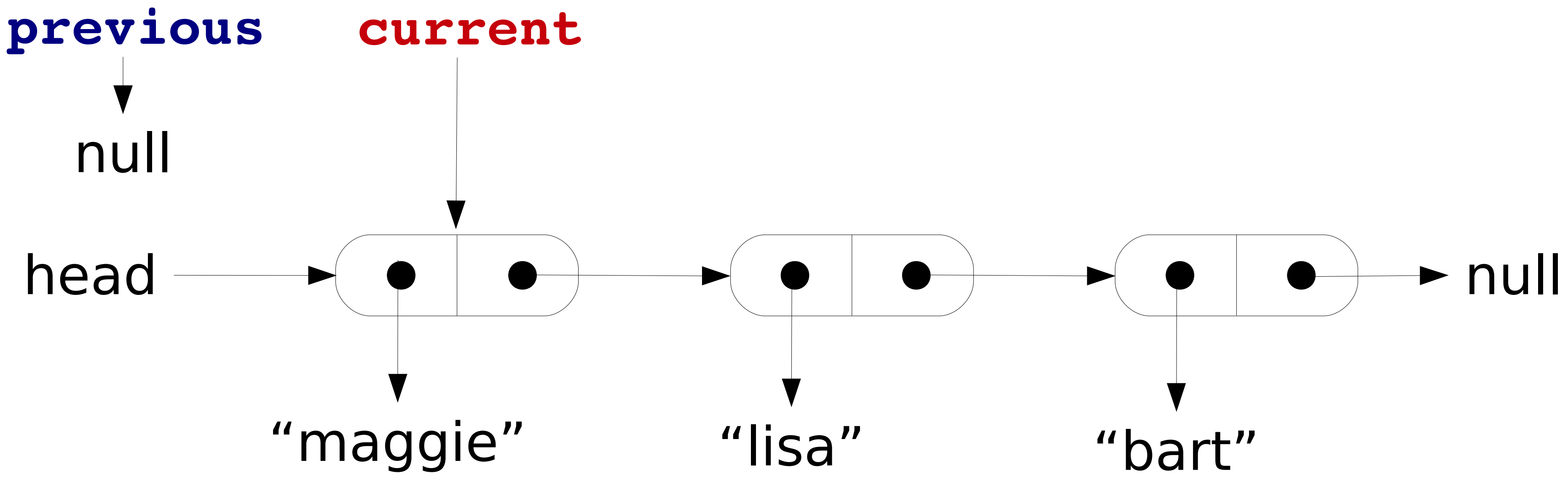
StringLinkedListWithIterator - goToNext

- 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

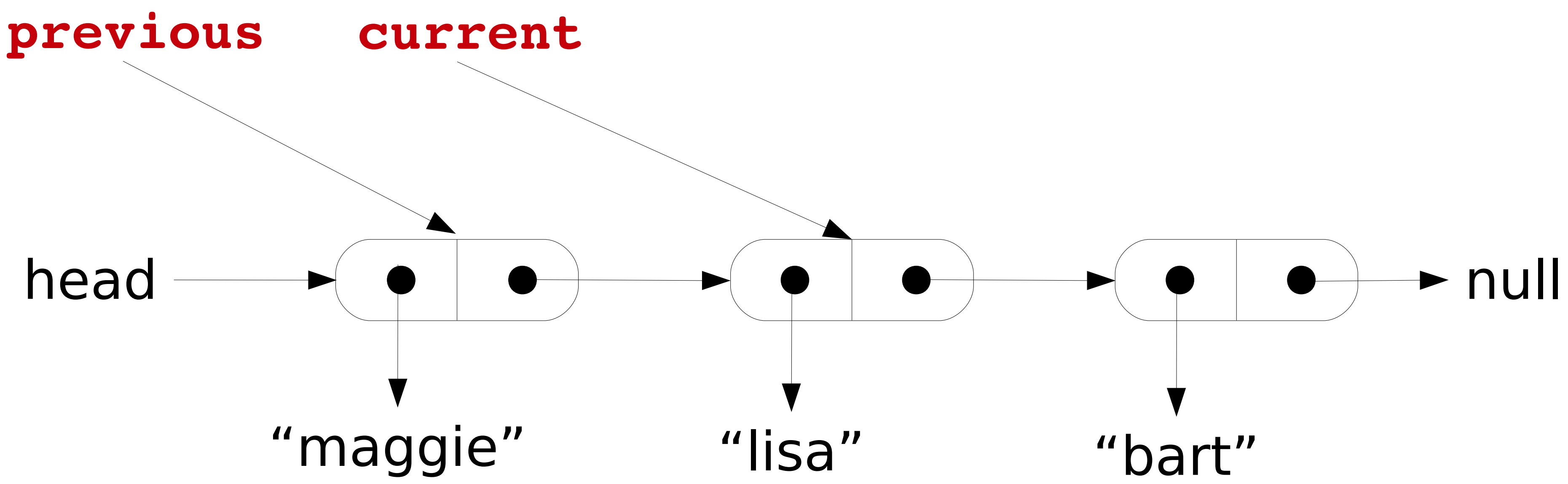
```
public void goToNext()  {
   if (current != null) {
      previous = current;
      current = current.link;
   } else if (head != null) {
      throw new LinkedListException("Iterated too many times " +
                                    "or uninitialized iteration");
   } else {
      throw new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

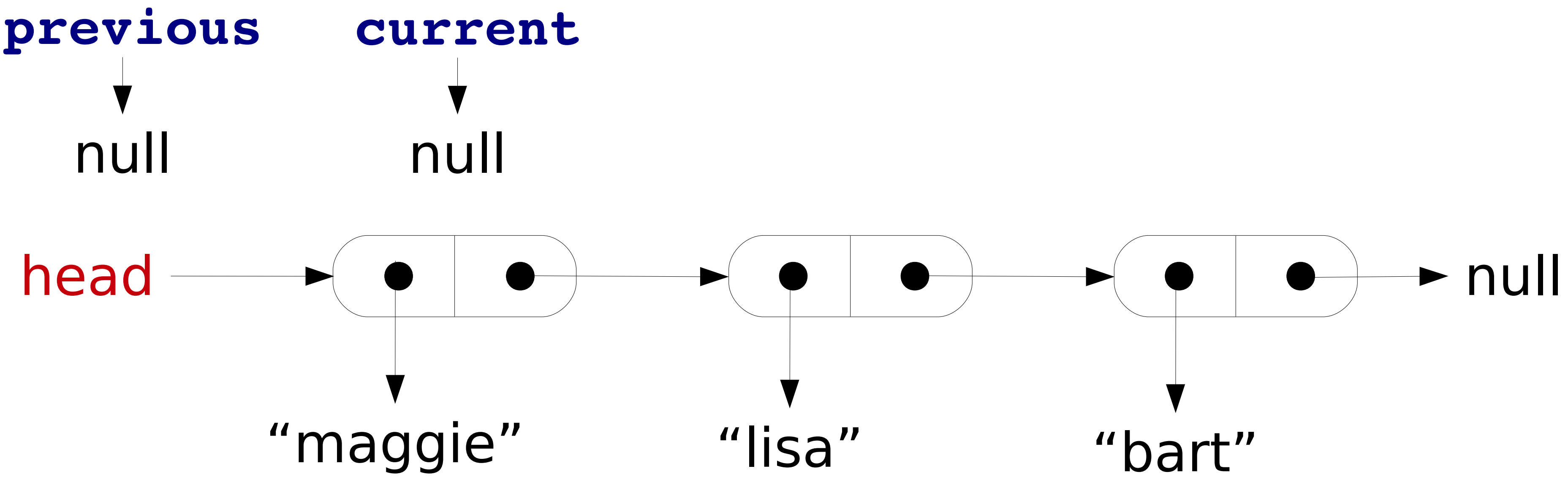
现current赋值给previous,
更新现current为原current下一个



StringLinkedListWithIterator - goToNext

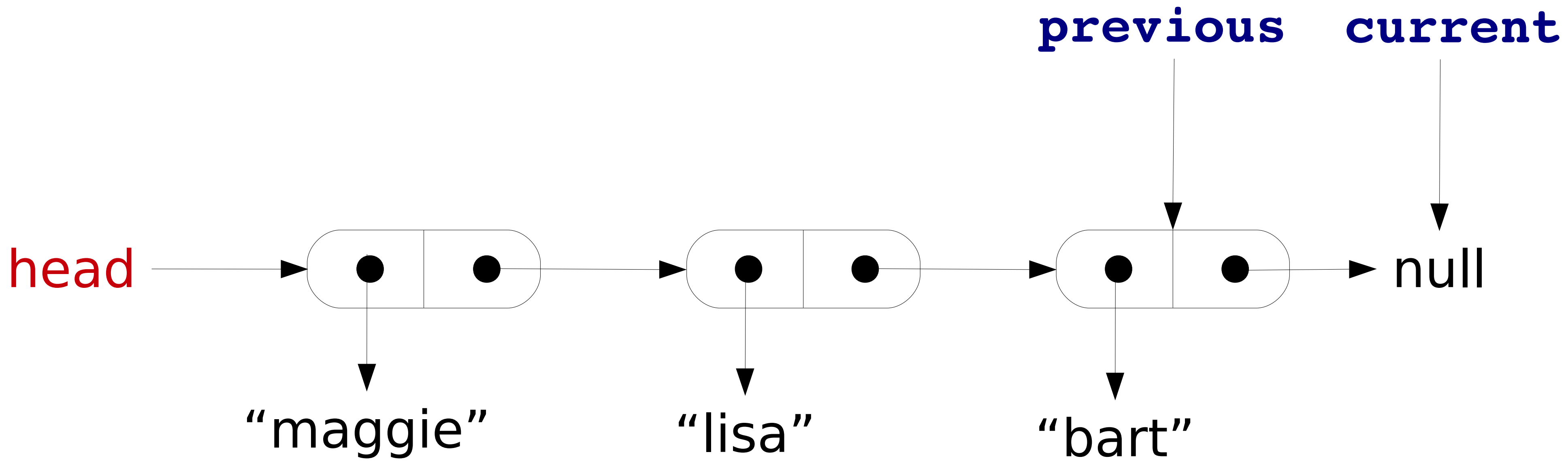
uninitialized iteration

```
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");
   }
}
```



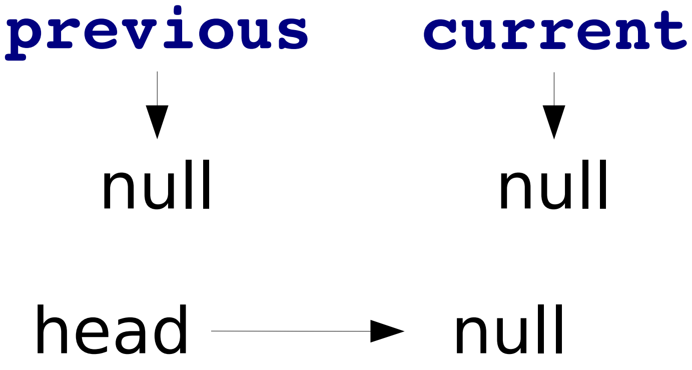
StringLinkedListWithIterator - goToNext done iterating

```
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");
   }
}
```



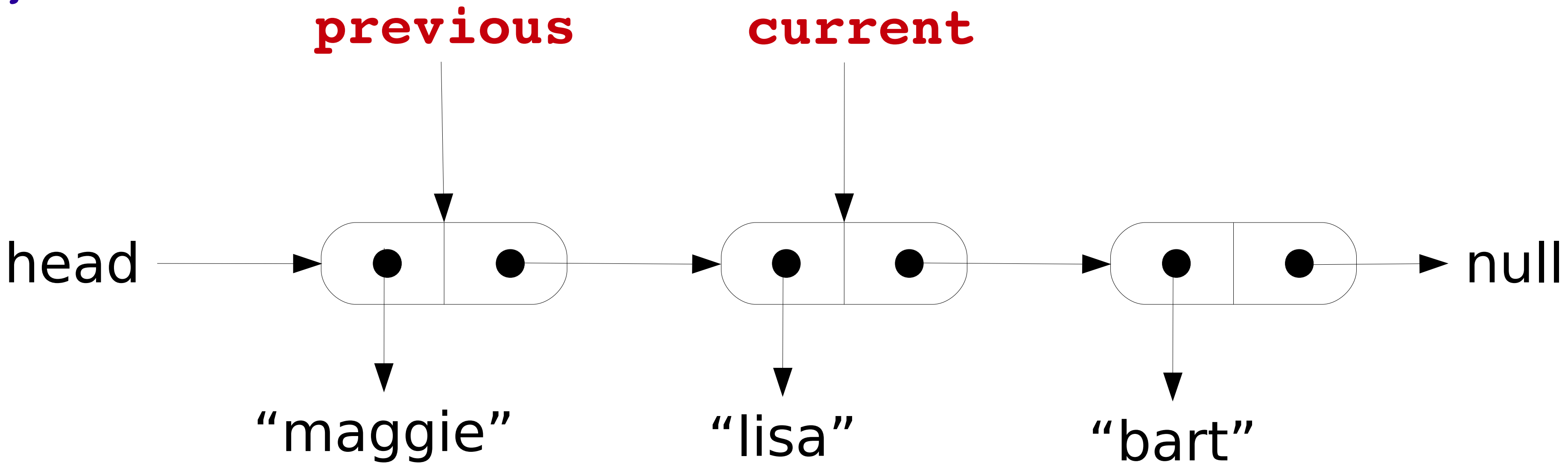
`StringLinkedListWithIterator` – `deleteCurrentNode`

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

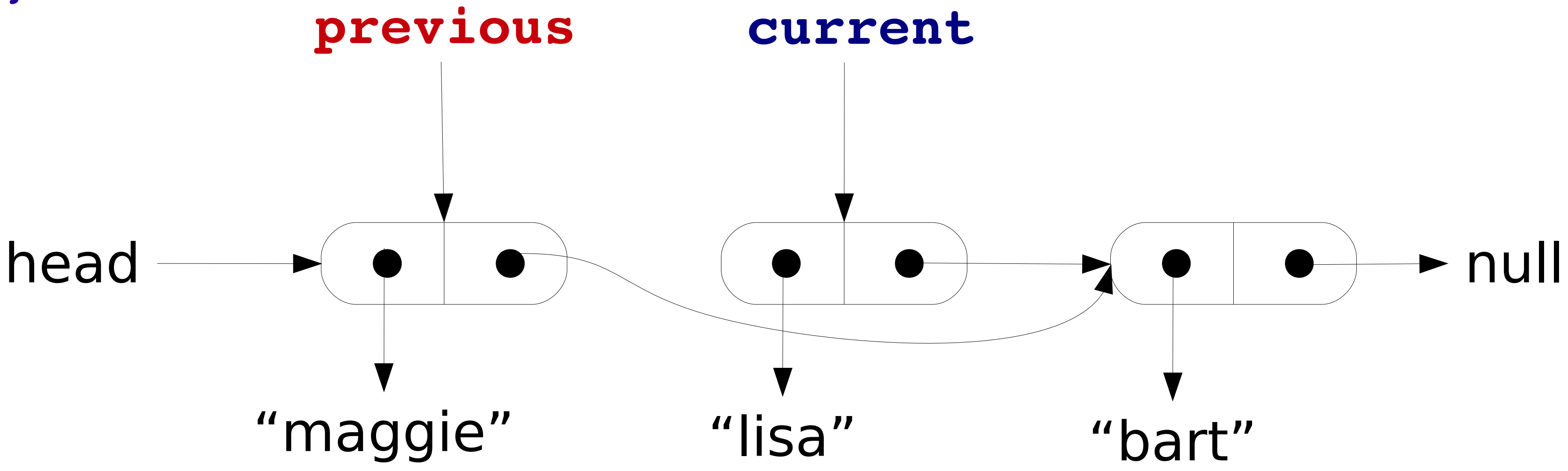
StringLinkedListWithIterator - deleteCurrentNode from the middle

```
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");
   }
}
```



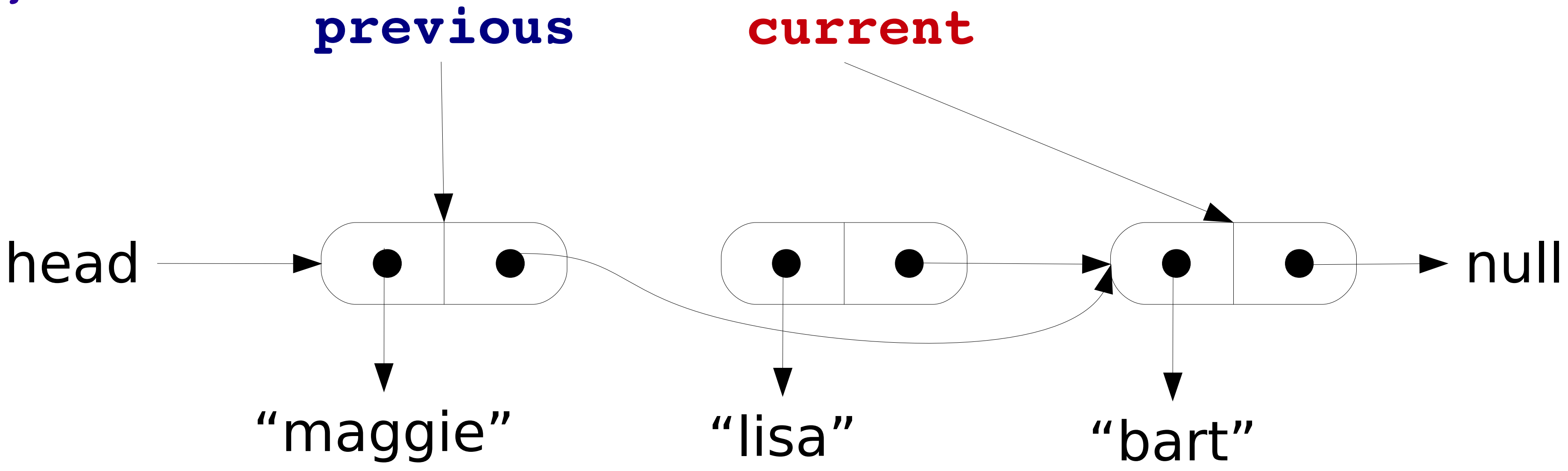
StringLinkedListWithIterator - deleteCurrentNode from the middle

```
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

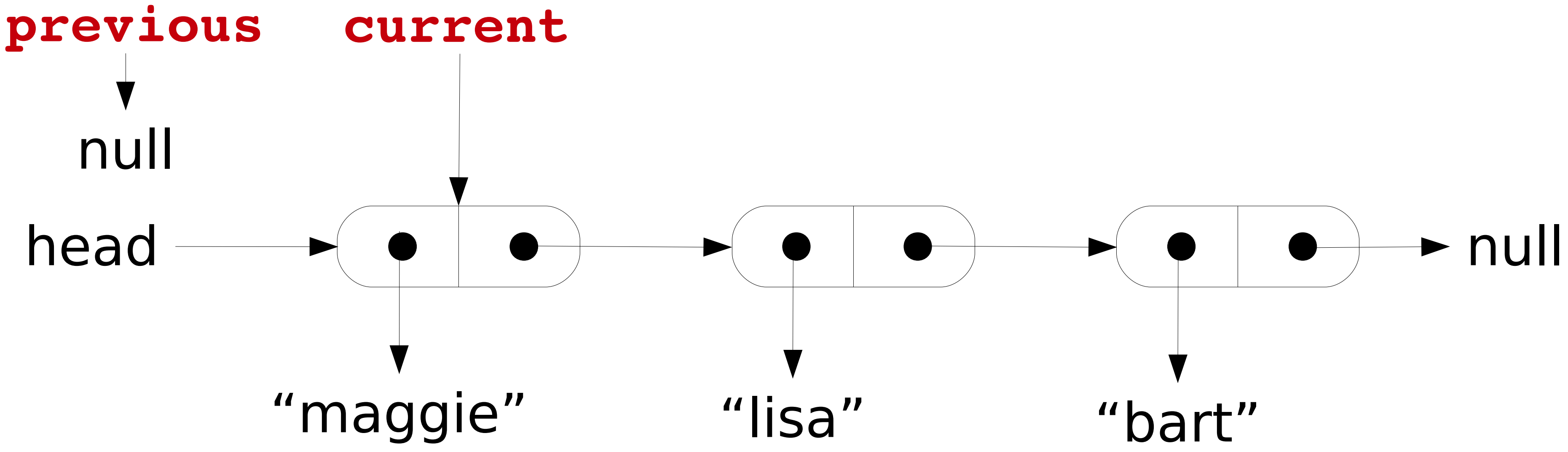
```
public void deleteCurrentNode()  {
  if ((current != null) && (previous != null)) {
      previous.link = current.link;
      current = current.link;
   } else if ((current != null) && (previous == null)) {
      head = current.link;
      current = head;
   } else {
      throw new LinkedListException("Deleting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



StringLinkedListWithIterator - deleteCurrentNode

head node

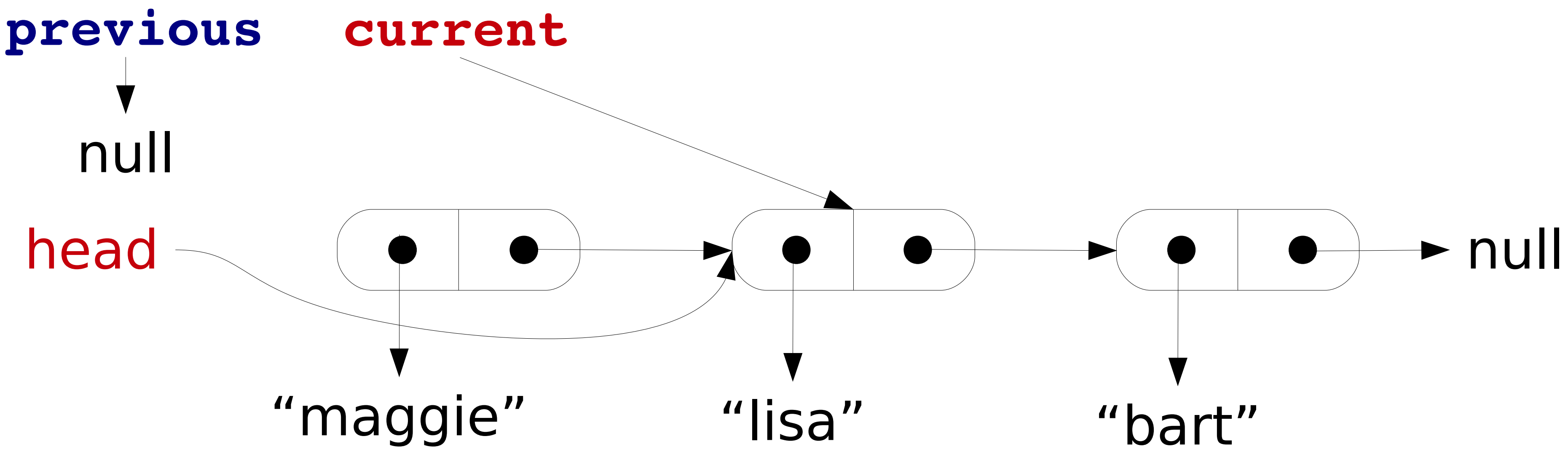
```
public void deleteCurrentNode()  {
  if ((current != null) && (previous != null)) {
      previous.link = current.link;
      current = current.link;
   } else if ((current != null) && (previous == null)) {
      head = current.link;
      current = head;
   } else {
      throw new LinkedListException("Deleting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



StringLinkedListWithIterator - deleteCurrentNode

head node

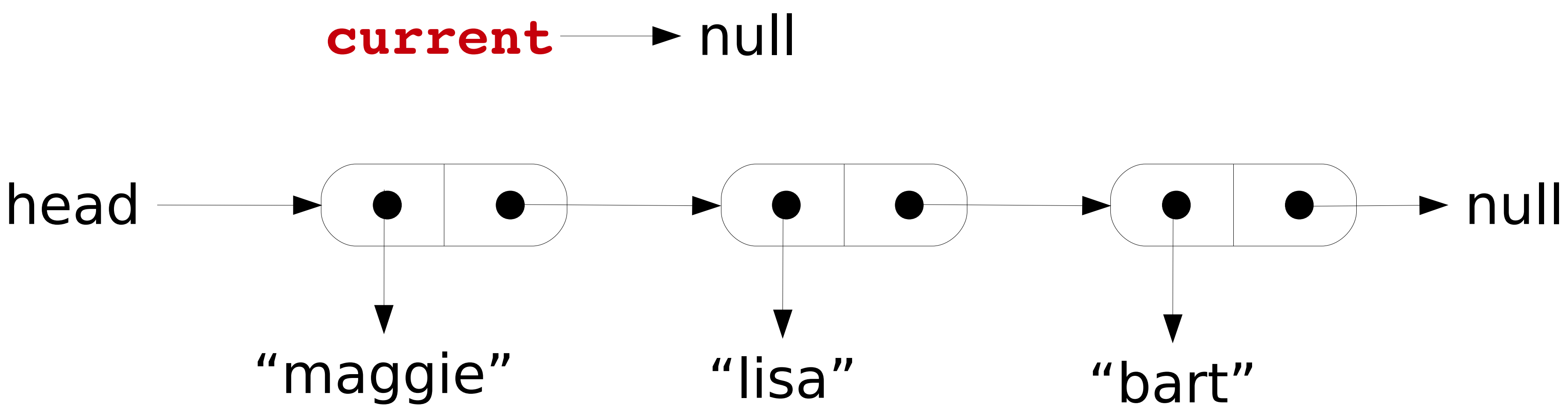
```
public void deleteCurrentNode()  {
   if ((current != null) && (previous != null)) {
        previous.link = current.link;
        current = current.link;
    } else if ((current != null) && (previous == null)) {
        head = current.link;
        current = head;
    } else {
        throw new 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`**

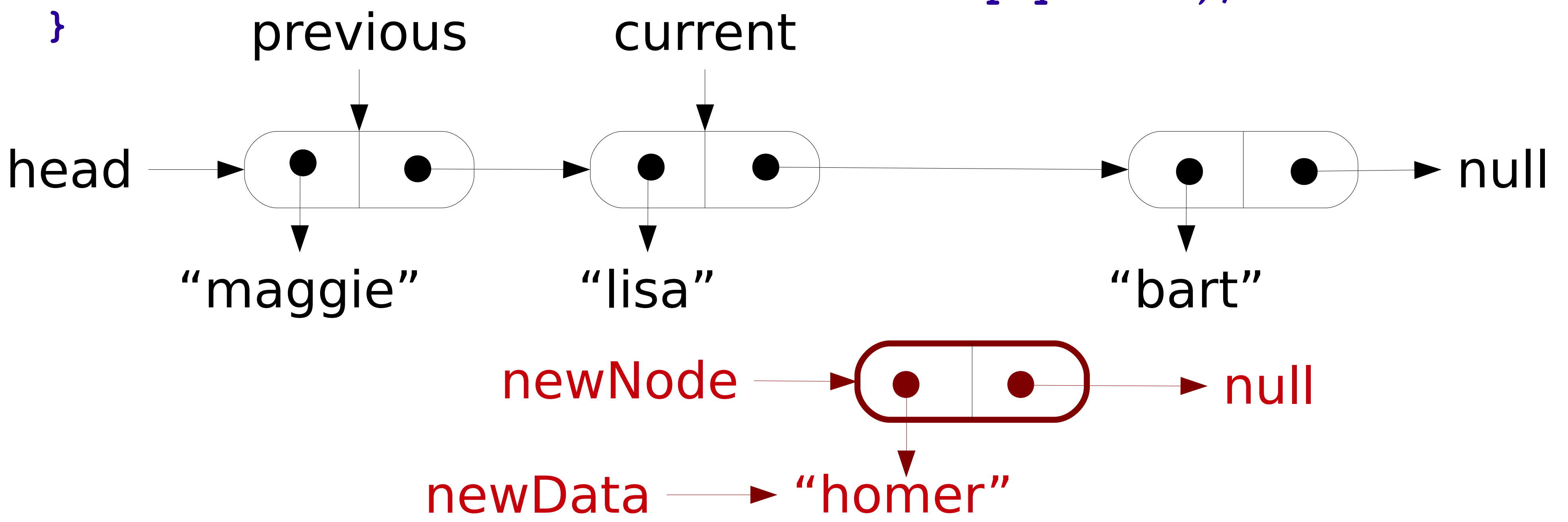
    or
  - the iteration moved past end of list

    or
  - the list is empty

StringLinkedListWithIterator - insertNodeAfterCurrent

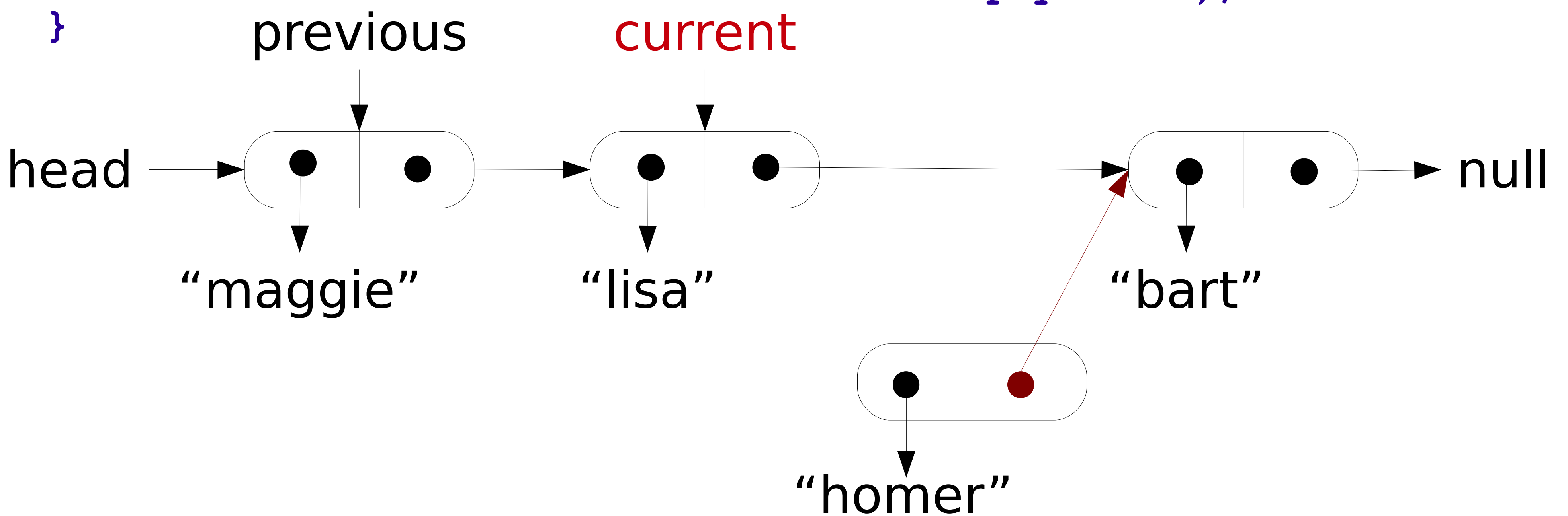
success

```
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");
   }
}
```

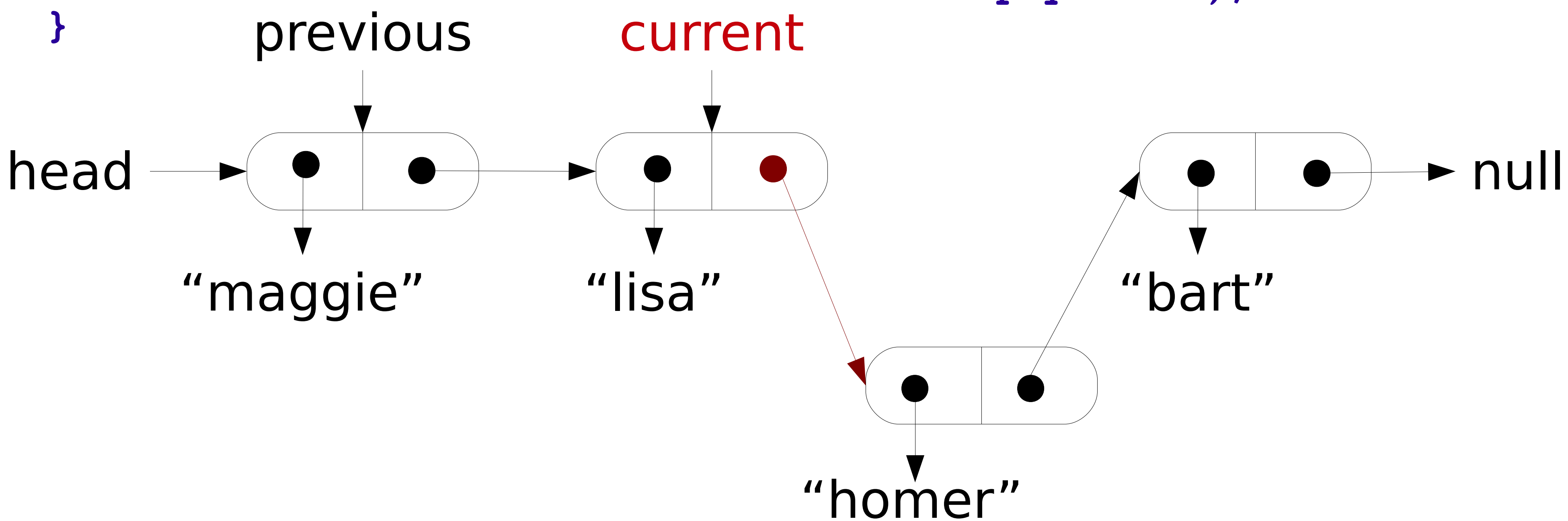


StringLinkedListWithIterator - insertNodeAfterCurrent

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");
   }
}
```

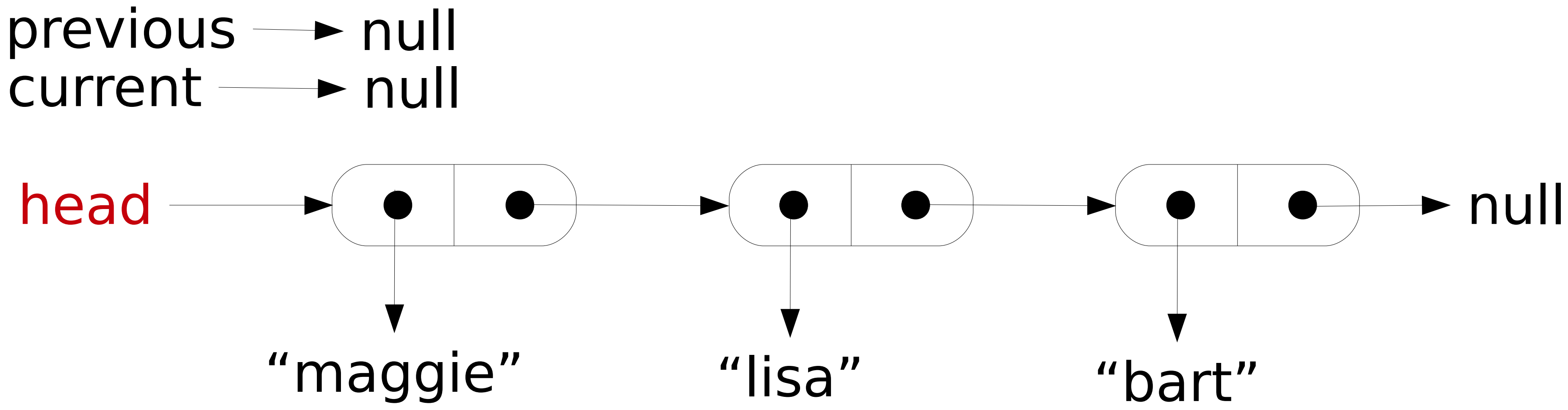
先动指针



StringLinkedListWithIterator - insertNodeAfterCurrent

uninitialized iteration

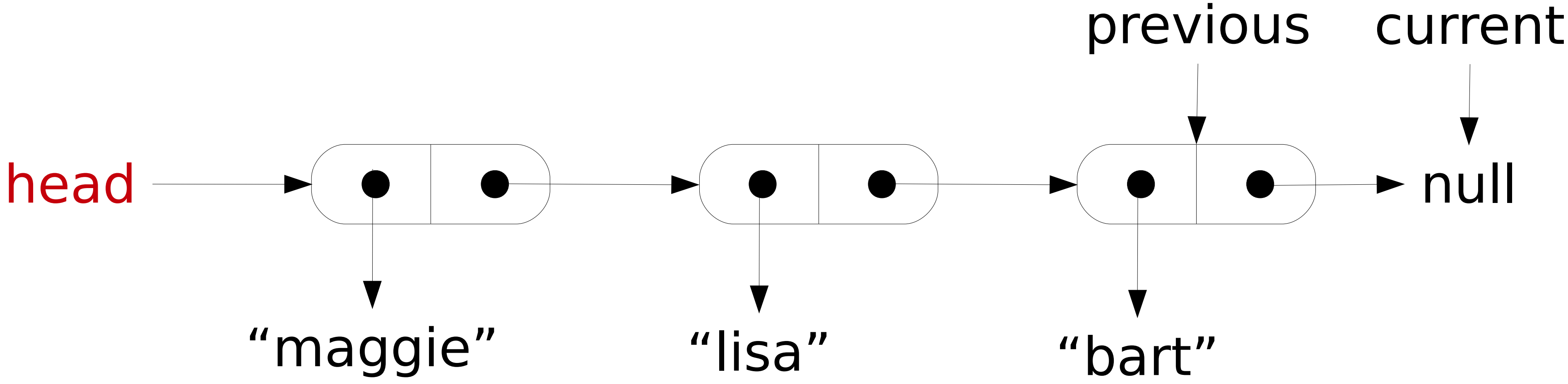
```
public void insertNodeAfterCurrent(String newData)  {
   ListNode newNode = new ListNode(newData, null);
   if (current != null) {
      newNode.link = current.link;
      current.link = newNode;
   } else if (head != null) {
      throw new LinkedListException("Inserting when iterator is " +
  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



StringLinkedListWithIterator - insertNodeAfterCurrent

done iterating

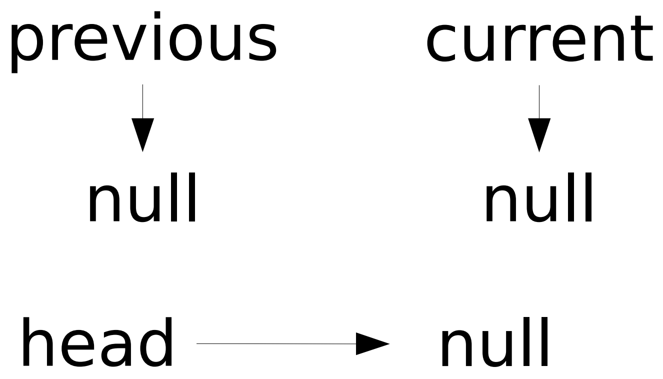
```
public void insertNodeAfterCurrent(String newData)  {
   ListNode newNode = new ListNode(newData, null);
   if (current != null) {
      newNode.link = current.link;
      current.link = newNode;
   } else if (head != null) {
      throw new LinkedListException("Inserting when iterator is " +
  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



StringLinkedListWithIterator - insertNodeAfterCurrent

empty list

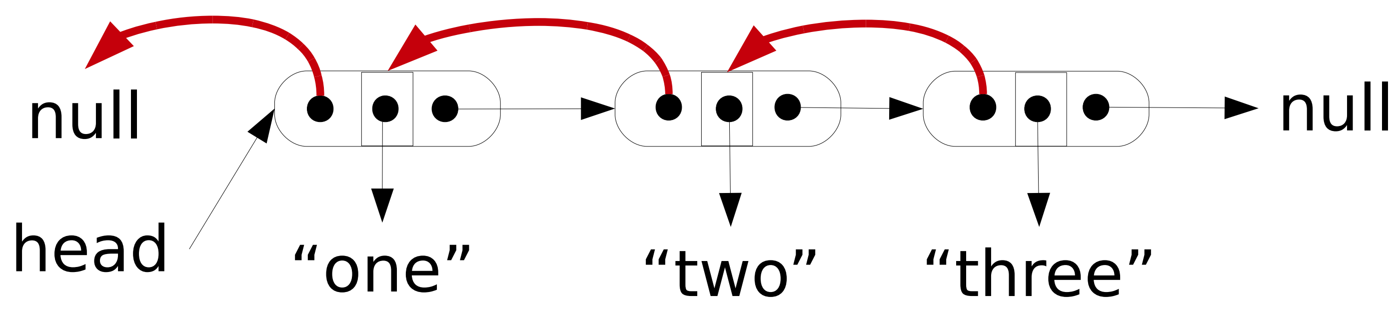
```
public void insertNodeAfterCurrent(String newData)  {
   ListNode newNode = new ListNode(newData, null);
   if (current != null) {
      newNode.link = current.link;
      current.link = newNode;
   } else if (head != null) {
      throw new LinkedListException("Inserting when iterator is " +
                       "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*.

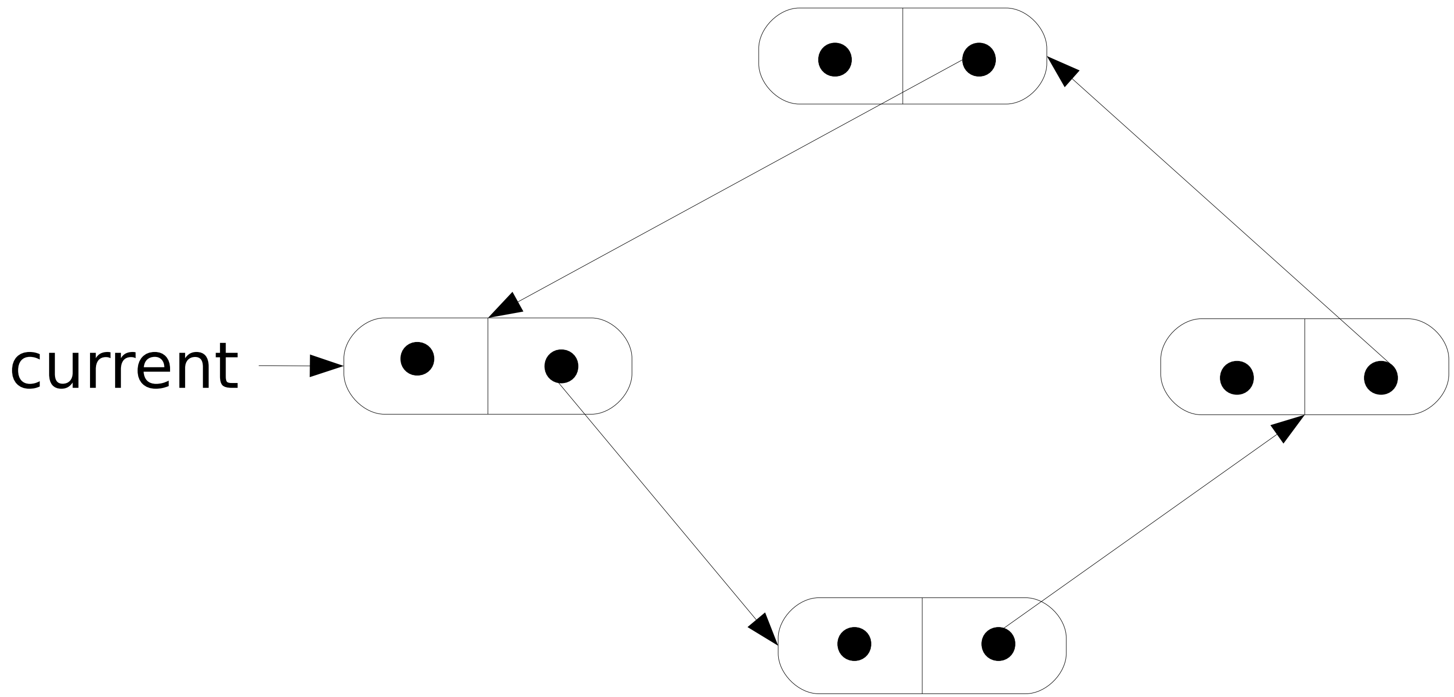
```
private class ListNode {
    private String data;
    private ListNode next;
    private ListNode prev;
    ...
}
```



Circularly Linked Lists

last to first

- 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();
    }
```

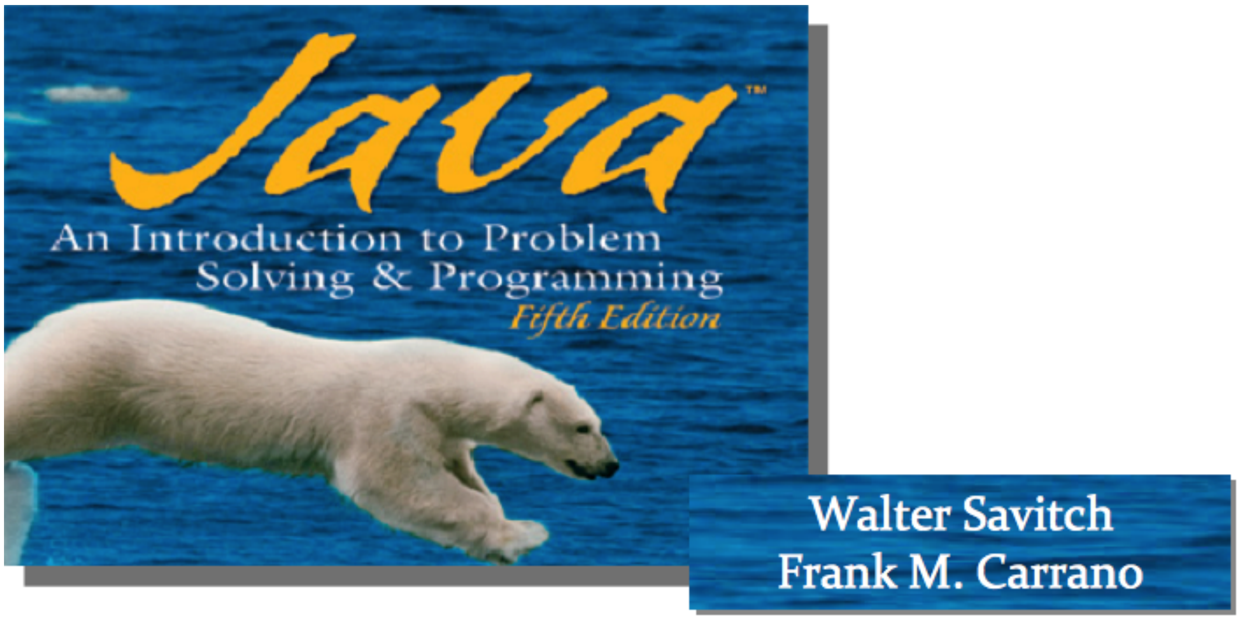
Continued...

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 {
        ...
    }
}
```



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