COMP 250

Lecture 16

interface examples:
Comparable, Iterable & Iterator

Feb. 11, 2022

Recall: Java `interface`

`interface` is a reserved word in the Java language.

A Java is interface like a class, but the methods have no bodies.

e.g. `List<T>`

`ArrayList<T>` and `LinkedList<T>` implement `List<T>`.

Java `Comparable` interface

Suppose you want to define an *ordering* on objects of some class.

Sorted lists and other data structures we'll see later (binary search trees, priority queues) all *require* that an ordering exists.

You cannot use the "<" operator to compare objects.

`Comparable` interface

```
interface  Comparable<T> {
        int   compareTo( T   t );
}
```

It is part of the java.lang package (see API)

It has a generic type, like `List<T>`.

e.g. `String implements Comparable<T>`

https://docs.oracle.com/javase/7/docs/api/java/lang/String.html

The natural ordering on strings is called the lexigraphic ordering (like in a dictionary).

compareTo

```
public int compareTo(String anotherString)
```

Compares two strings lexicographically. The comparison is based on the Unicode value of each character in the strings. The character sequence represented by this `String` object is compared lexicographically to the character sequence represented by the argument string. The result is a negative integer if this `String` object lexicographically precedes the argument string. The result is a positive integer if this `String` object lexicographically follows the argument string. The result is zero if the strings are equal; `compareTo` returns `0` exactly when the `equals(Object)` method would return `true`.

This is the definition of lexicographic ordering. If two strings are different, then either they have different characters at some index that is a valid index for both strings, or their lengths are different, or both. If they have different characters at one or more index positions, let *k* be the smallest such index; then the string whose character at position *k* has the smaller value, as determined by using the < operator, lexicographically precedes the other string. In this case, `compareTo` returns the difference of the two character values at position `k` in the two string -- that is, the value:

```
this.charAt(k)-anotherString.charAt(k)
```

If there is no index position at which they differ, then the shorter string lexicographically precedes the longer string. In this case, `compareTo` returns the difference of the lengths of the strings -- that is, the value:

```
this.length()-anotherString.length()
```

`Comparable` recommendation

Suppose `class T implements Comparable<T>`

```
T   e1,   e2;
```

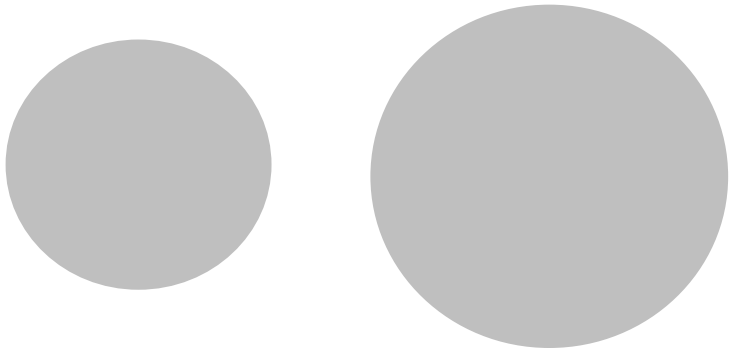
Java API *recommends* `e1.compareTo(e2)` returns:

negative number,	if e1 < e2
0,	if `e1.equals(e2)` is true
positive number,	if e1 > e2

Note “>” and “<“ here do not refer to a Java operation, but rather to our model (in our heads) of the ordering.

Example: Circle

Q: How can we define a `compareTo( Circle )` and `equals( … )` method for ordering `Circle` objects ?



A: Compare their radii.

```
public class Circle extends Shape implements
                                        Comparable<Circle>{
      private double radius;

      public Circle(double radius){
            this.radius = radius; }

      public int compareTo(Circle c) {
            if (this.radius > c.radius)
                  return 1;
            else if (this.radius == c.radius)
                  return 0;
            else
                  return -1;
      }

      public boolean equals(Object obj) {
            return (obj instanceof Circle) &&
                this.radius ==((Circle) obj).radius;
      }
}
```

equivalent to **this.equals(c)**

Example: Rectangle

Q: When are two Rectangle objects equal ?

A: Their heights are equal and their widths are equal.

However, there is no unique and natural way to define a `compareTo()` method for ordering Rectangle objects.
(e.g. compare areas? or perimeters? or heights? etc).

e.g. the left one has a larger width but smaller height

Example : `Ork`

Suppose we have created a new data type `Ork`.

How should we compare elements of this type?

Based on their weapon? height? name?

`Ork.compareTo()` -- based on height only ?

```
public class Ork implements Comparable<Ork> {
        private Weapon w;
        private Integer height;
        private String name;

        public int compareTo(Ork o) {
                if  (this.height > o.height) {
                        return 1;
                } else if  (this.height == o.height) {
                        return 0;
                } else {  return -1;        }
        }
}
```

But we let's say we want to consider two Orcs to be "equal" only if they have the same weapon, height, and name. Then, the above `compareTo()` method would violate the Java API recommendation that **`e1.compareTo(e2)`** is 0 if and only if **`e1.equals(e2)`** is true.

`Orc.compareTo()` – based on all attributes

```
public class Ork implements Comparable<Ork> {
        private Weapon w;       // implements Comparable
        private Integer height;
        private String name;

        public int compareTo(Ork o) {
             int result = this.w.compareTo( o.w );
             if (result==0) {
                   result = this.height.compareTo( o.height );
             }
             if (result == 0) {
                  result = this.name.compareTo( o.name );
             }
             return result;
        }
}
```

Note this definition uses overloaded methods for `compareTo()`, namely for classes Weapon, Integer, String.

How is `Comparable` used?

```
interface  Comparable<T> {
        int   compareTo( T   e );
}
```

This interface will be used later when we wish to *sort and/or search a collection* of (comparable) elements.

ASIDE: the Java Collections class is used for this.

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interface examples:

Comparable, Iterable & Iterator

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Recall: Java enhanced for loop

```
double dArray = {1.0,  7.5,  -2.67,  5.999};

for (double   d   :   dArray)  {
      System.out.println( d );
}
```

```
LinkedList<String>   list =  new LinkedList<String>();
          ....

for (String   s   :   list)  {
      System.out.println( s );
}
```

More generally....

We often want to visit (or "iterate through") *all* the objects in some collection of objects.

- arraylist
- linked list
- hash map entries (later in course)
- binary search tree (later in course)
- vertices in a graph (later in course)
- .....

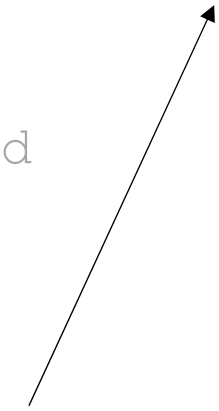
`Iterator` and `Iterable`

- The enhanced for loop (*for-each)* makes use of two interfaces: `Iterator` and `Iterable`.

- We can implement these interfaces for our own classes, and iterate through a collection using the enhanced for loop, or in other ways.

`Iterator` interface

```
interface  Iterator<T> {

      boolean   hasNext();
      T         next();       // returns current element
                              // and advances to the next

      void      remove();     // optional;   ignore it
}
```



`next()` is a method, rather than a field.

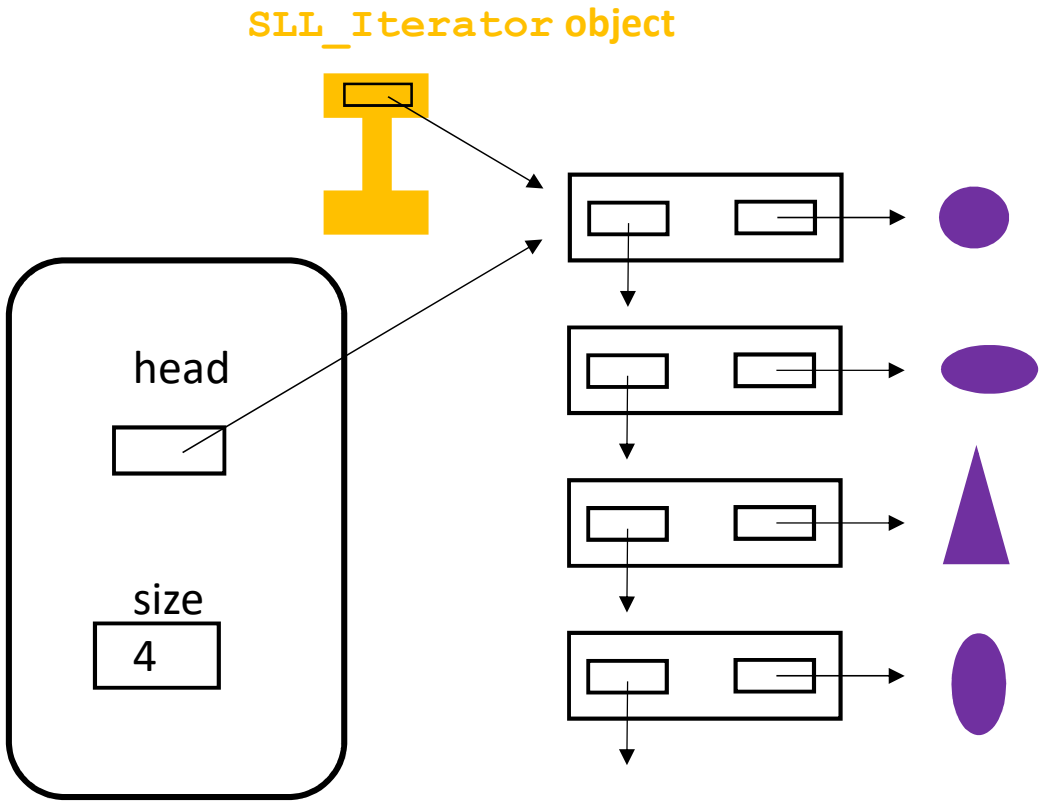
Example: Singly Linked Lists

```
class   SLinkedList<E>  implements Iterable<E>{
    SNode<E>   head;
          :
    class   SNode<E> {
          SNode<E>    next;
          E           element;
               //  etc
    }
    class SLL_Iterator<E> implements Iterator<E>{
          //  implements the hasNext() and next() methods
    }
}
```

explained soon...

This a second inner class.

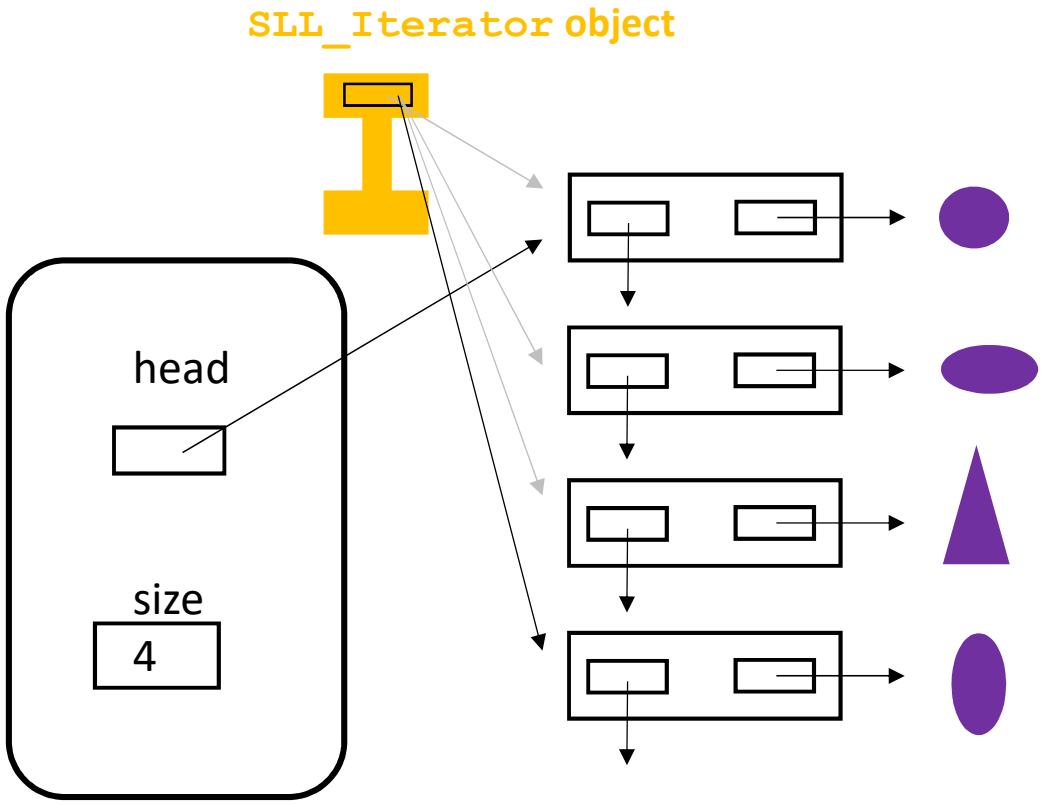
An `SLL_Iterator` object will reference a node in the singly linked list.



Q: How many objects do we have here ?

A: 1 + 1 + 4 + 4 = 10

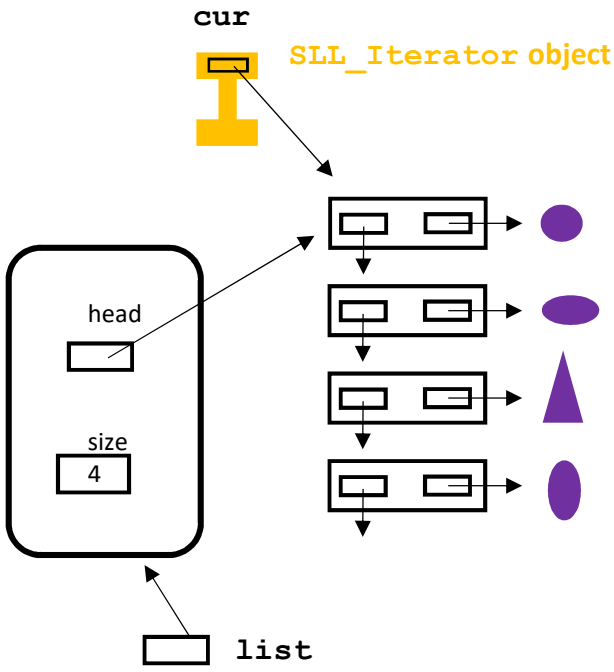
The `SLL_Iterator` object will reference a node in the singly linked list.



The `SLL_Iterator` object will iterate through the nodes and return the element referenced by each node.

SLL_Iterator implementation

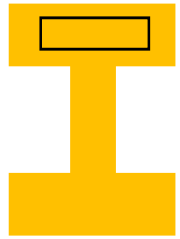
```
class  SLL_Iterator<E>  implements  Iterator<E>{

    SNode<E>   cur;

    SLL_Iterator( SLinkedList<E>  list){
       cur = list.getHead();
    }

    public boolean hasNext() {
       return (cur != null);
    }

    public  E  next() {
       E   element  =  cur.getElement;
       cur = cur.getNext();
       return element;
    }
}
```



Don't confuse use of "next()" and "hasNext()" above with how "next" is used in linked lists.

`SLL_Iterator` constructor

`SLL_Iterator` object



Q: Who constructs an `SLL_Iterator` object ?

A: A `SLinkedList` object does this, similar to how it constructs a new `SNode` when it adds a new element to the list.
See next slide.

(Recall from several slides ago that `SLL_Iterator` is an inner class of `SLinkedList`, just like `SNode` is an inner class.)

Java `Iterable` interface

```
interface  Iterable<T> {
      Iterator<T>    iterator();
}
```

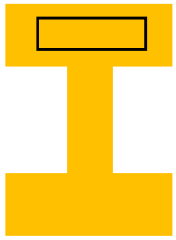
We say "a class is iterable" if it can make/construct an `Iterator` object that can iterate over its elements.

So, if a class implements `Iterable`, then this class has an `iterator()` method, which constructs an `Iterator` object.

ASIDE: I think `iterator()` should have been called `makeIterator()`, since it is easy to confuse the method `iterator()` with the interface `Iterator`.

Let's add the `iterator()` method to the singly linked list class.

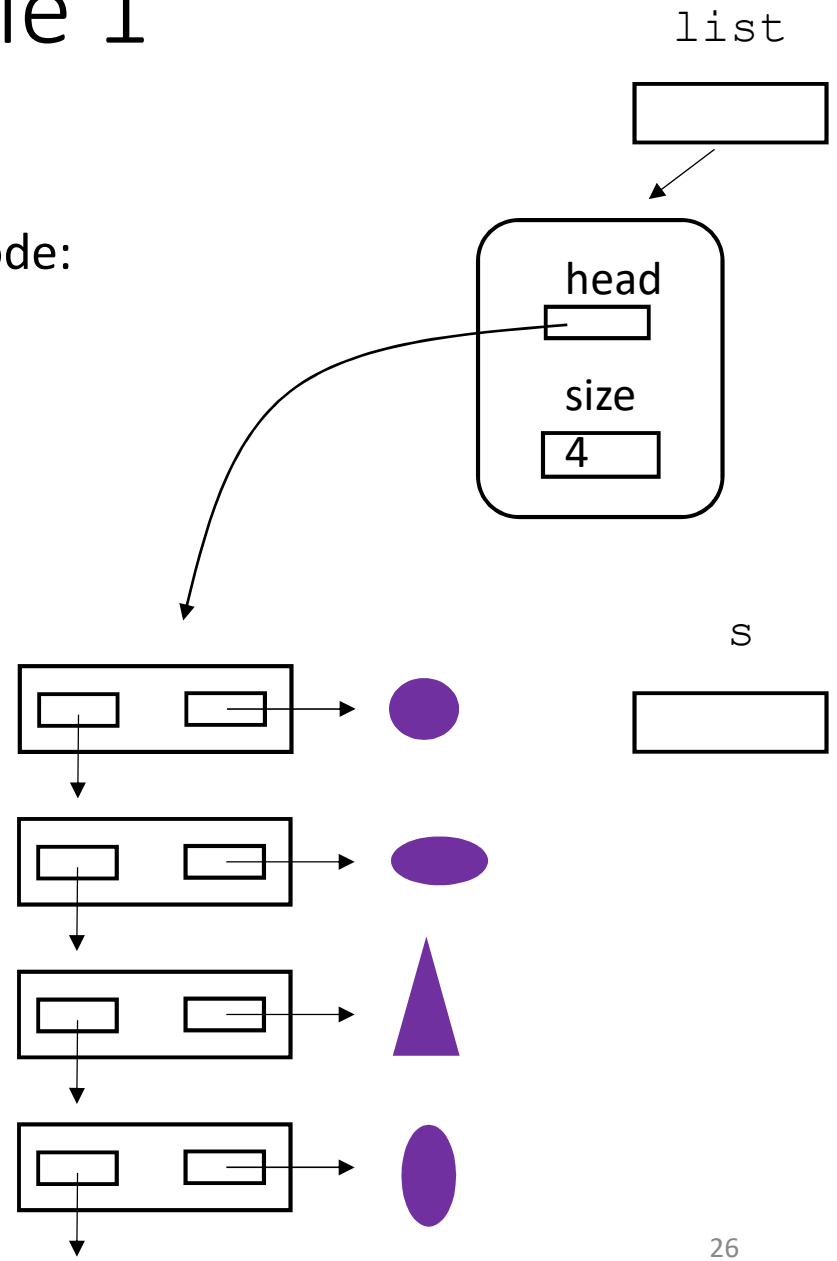
```
class   SLinkedList<E> implements Iterable<E> {

    SNode<E>   head;


    class   SNode<E> {
              SNode<E>   next;
              E          element;
                      //  etc
         }

    class SLL_Iterator<E>  implements Iterator<E>{
           //  implements the hasNext() and next() methods
           //  (see earlier slides)
    }

    SLL_Iterator<E>   iterator()   {
         return  new  SLL_Iterator( this );
    } ;


}
```



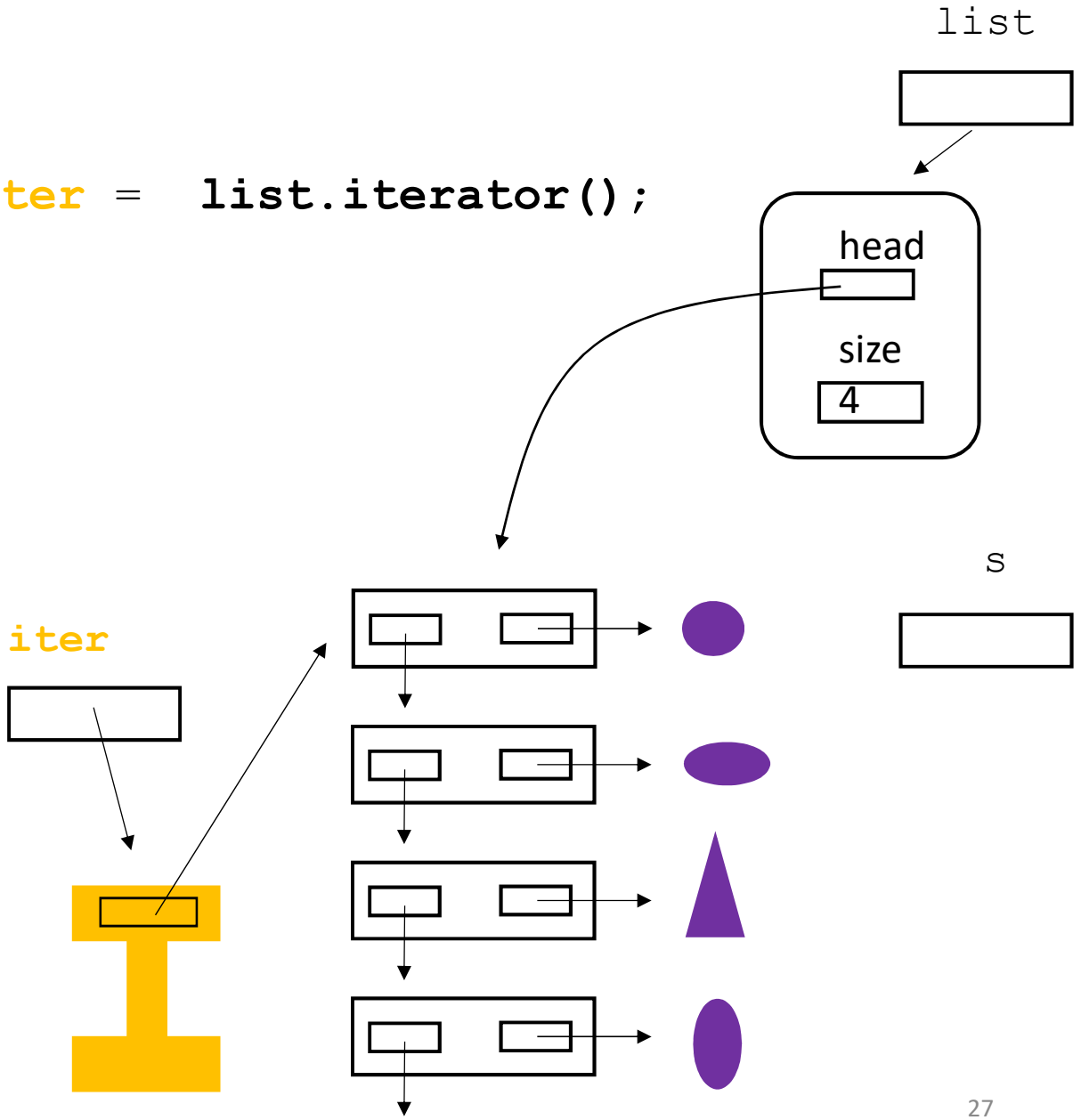
Example 1

Suppose a method in some class has this code:

```
SLinkedList<Shape>   list;
Shape    s;

// make a list
```

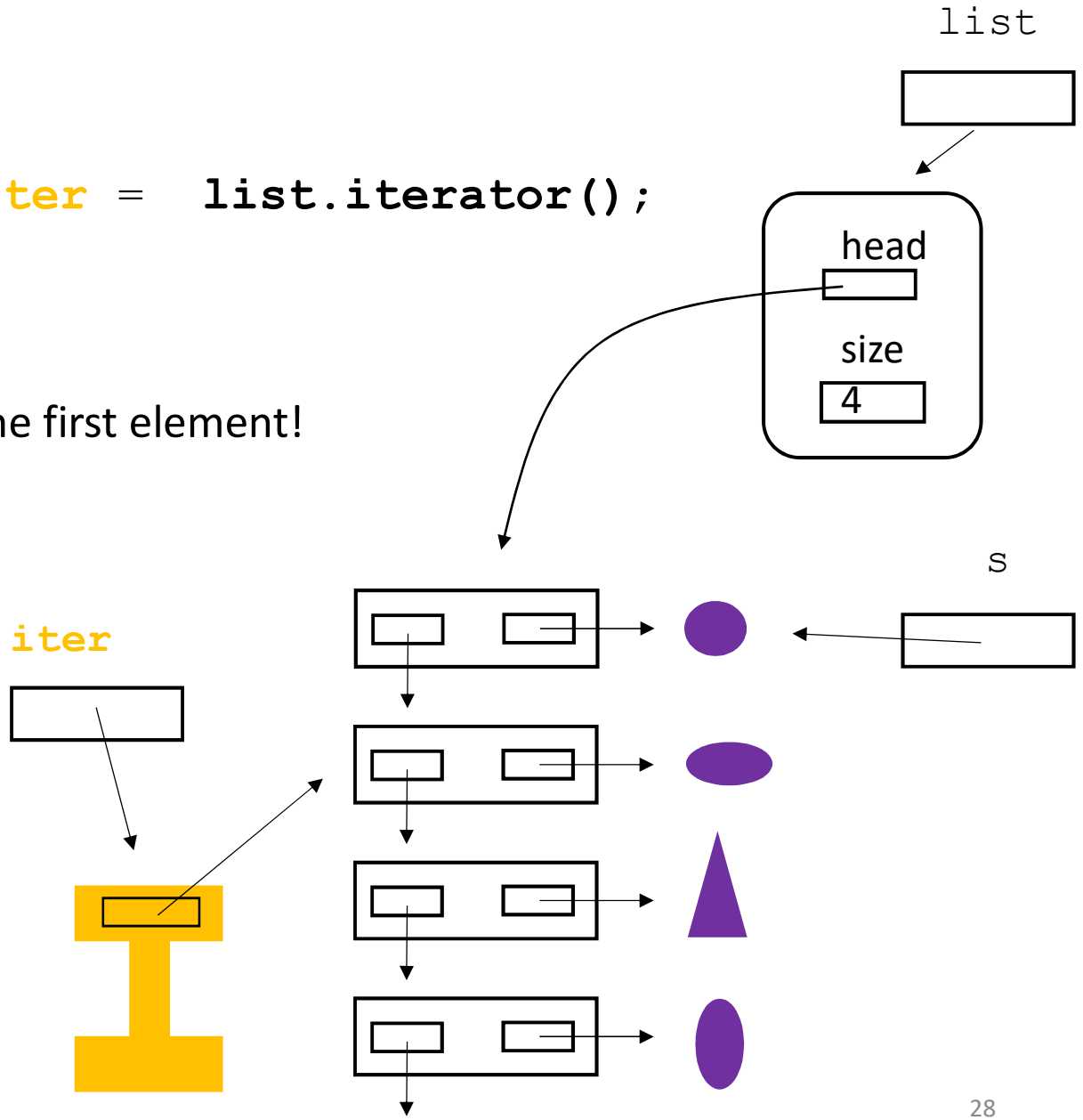


```
SLinkedList<Shape>   list;
Shape    s;
//  make a list

Iterator<Shape> iter =  list.iterator();
```



```
SLinkedList<Shape>   list;
Shape    s;
//  make a list

Iterator<Shape> iter =  list.iterator();

s = iter.next()
```

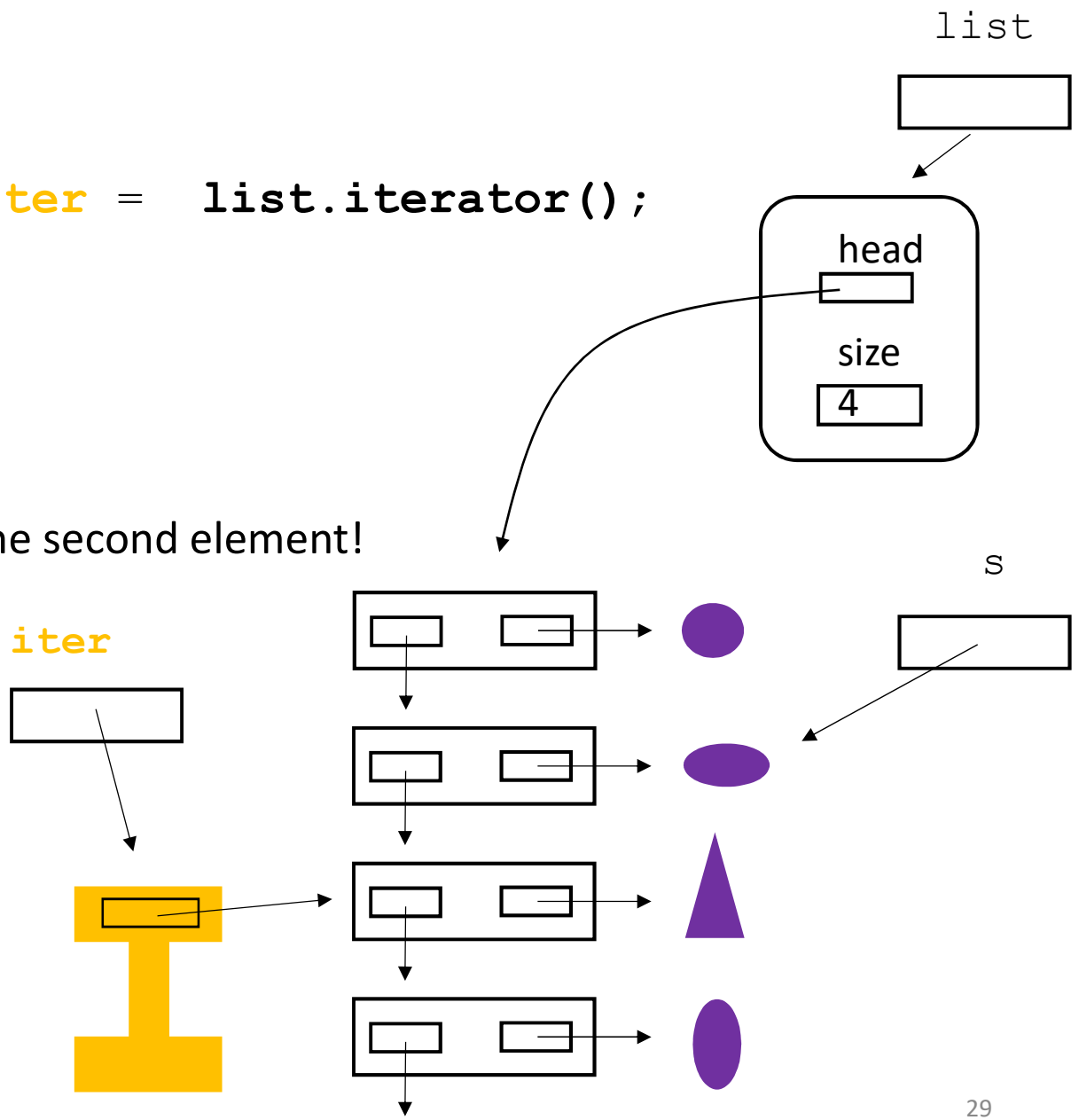
Note that s references the first element!



The iterators iterate over LinkedList nodes, not Shapes. The next() method returns Shapes.

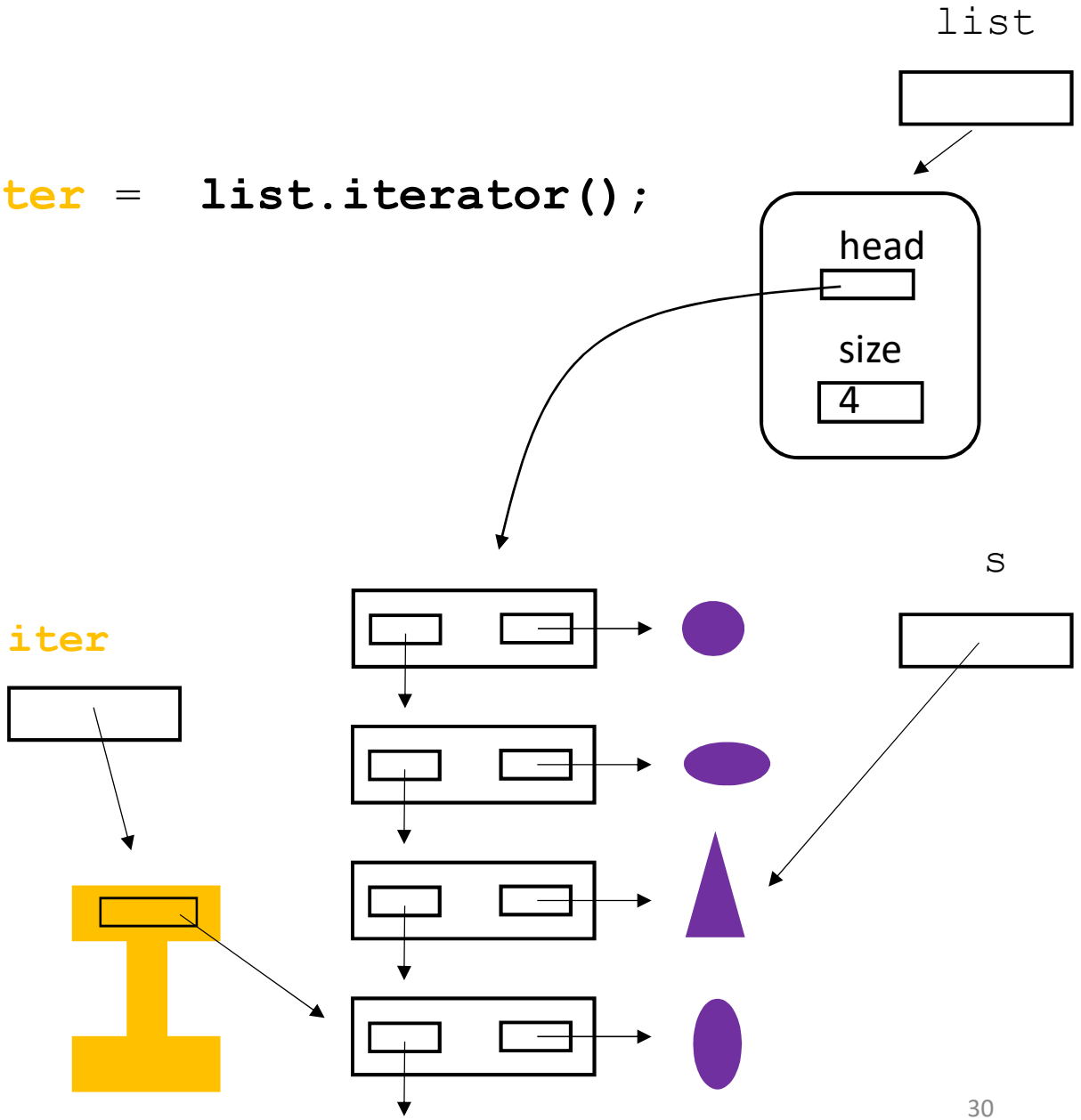
```
SLinkedList<Shape>   list;
Shape    s;
//  make a list

Iterator<Shape> iter =  list.iterator();

s = iter.next()

s = iter.next()
```

Note that s references the second element!



The iterators iterate over LinkedList nodes, not Shapes. The next() method returns Shapes.

```
SLinkedList<Shape>   list;
Shape    s;
//  make a list

Iterator<Shape> iter =  list.iterator();

s = iter.next()

s = iter.next()

s = iter.next()
```



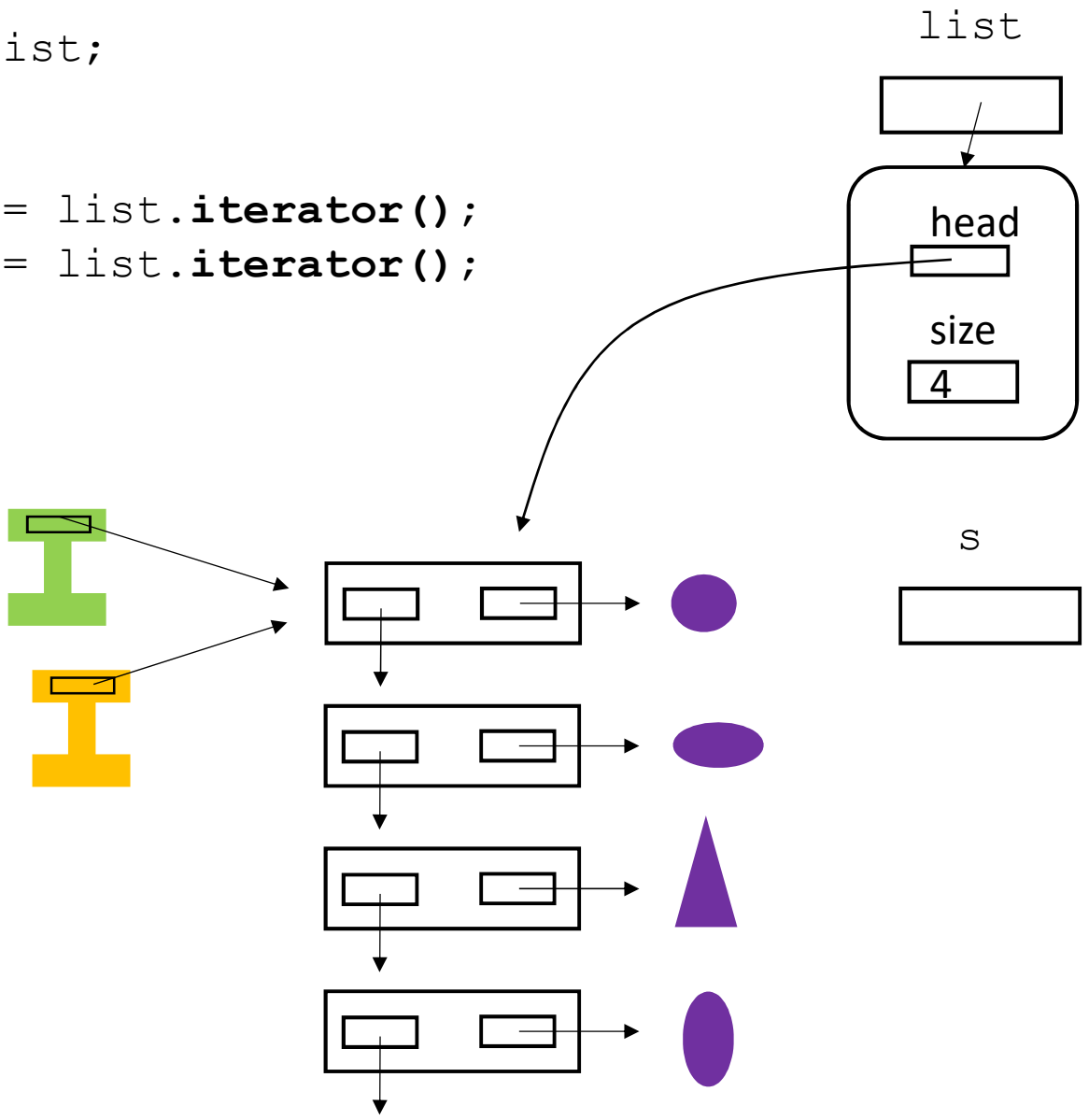
The iterators iterate over LinkedList nodes, not Shapes. The next() method returns Shapes.

Example 2

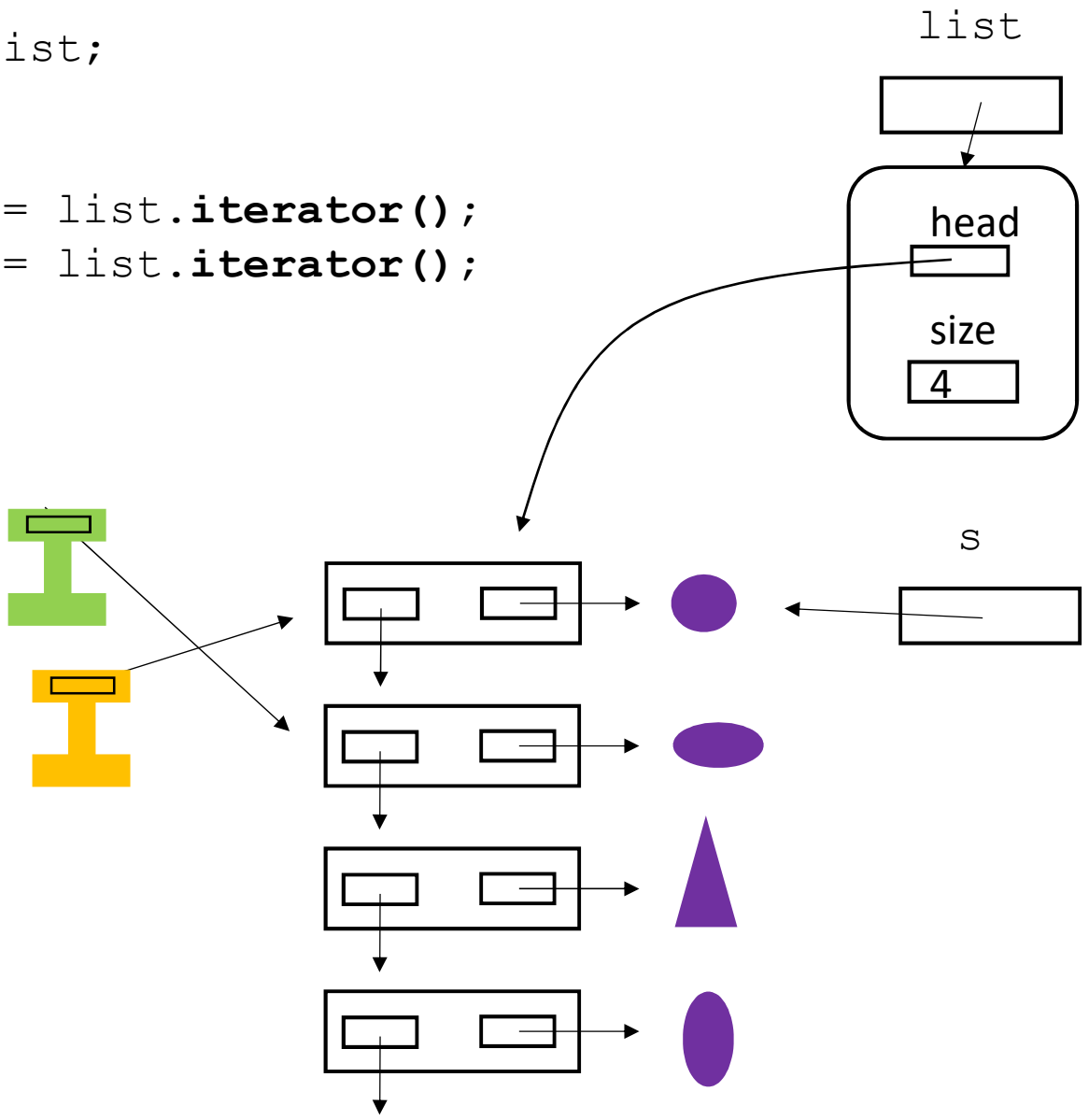
What if we want to have multiple “iterators” ?

Analogy: Multiple TA’s grading a collection of exams.

```
SLinkedList<Shape>   list;
Shape    s;
          :
Iterator<Shape> iter1 = list.iterator();
Iterator<Shape> iter2 = list.iterator();
```

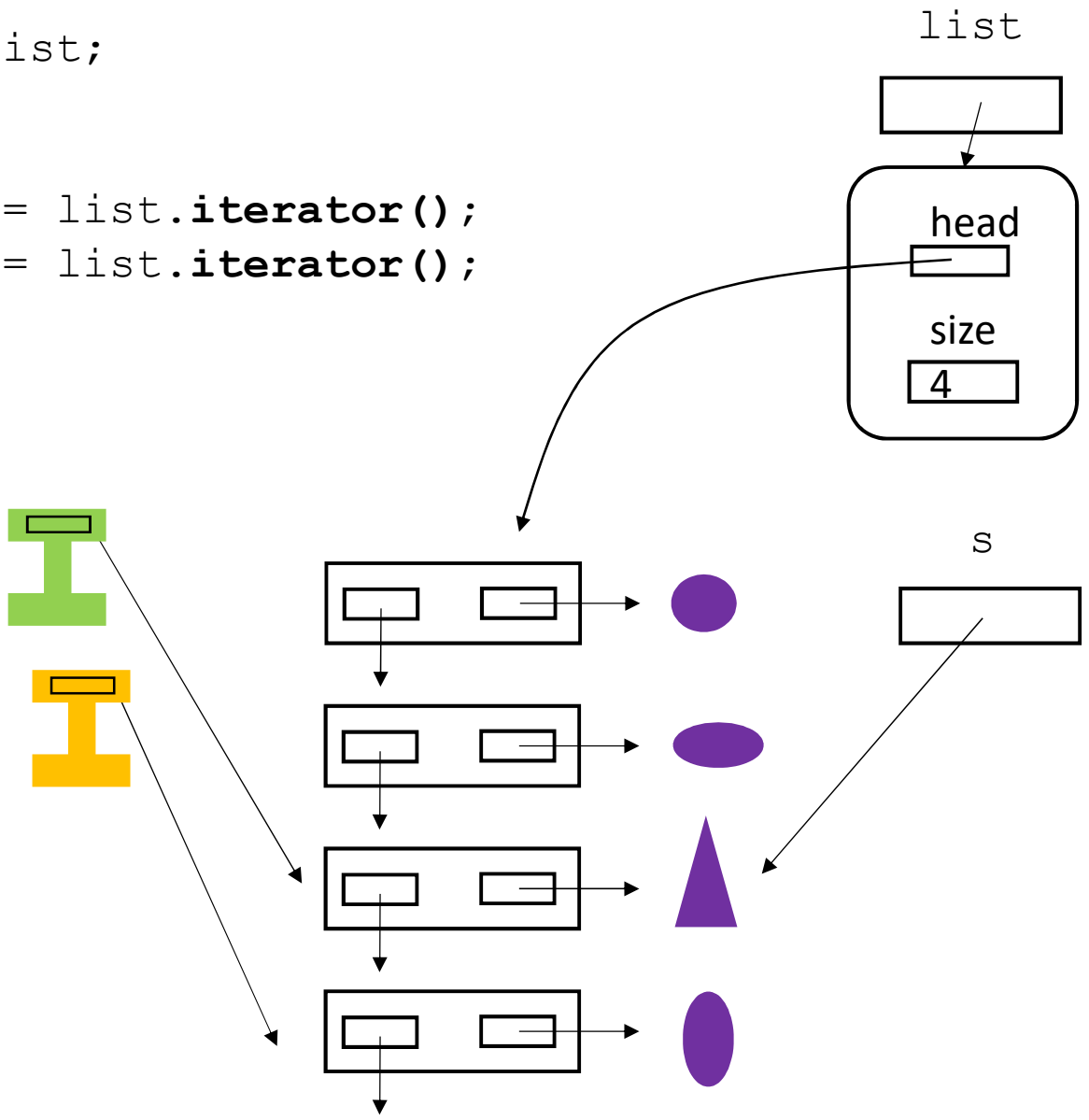


```
SLinkedList<Shape>   list;
Shape    s;
          :
Iterator<Shape> iter1 = list.iterator();
Iterator<Shape> iter2 = list.iterator();

s = iter1.next()
```



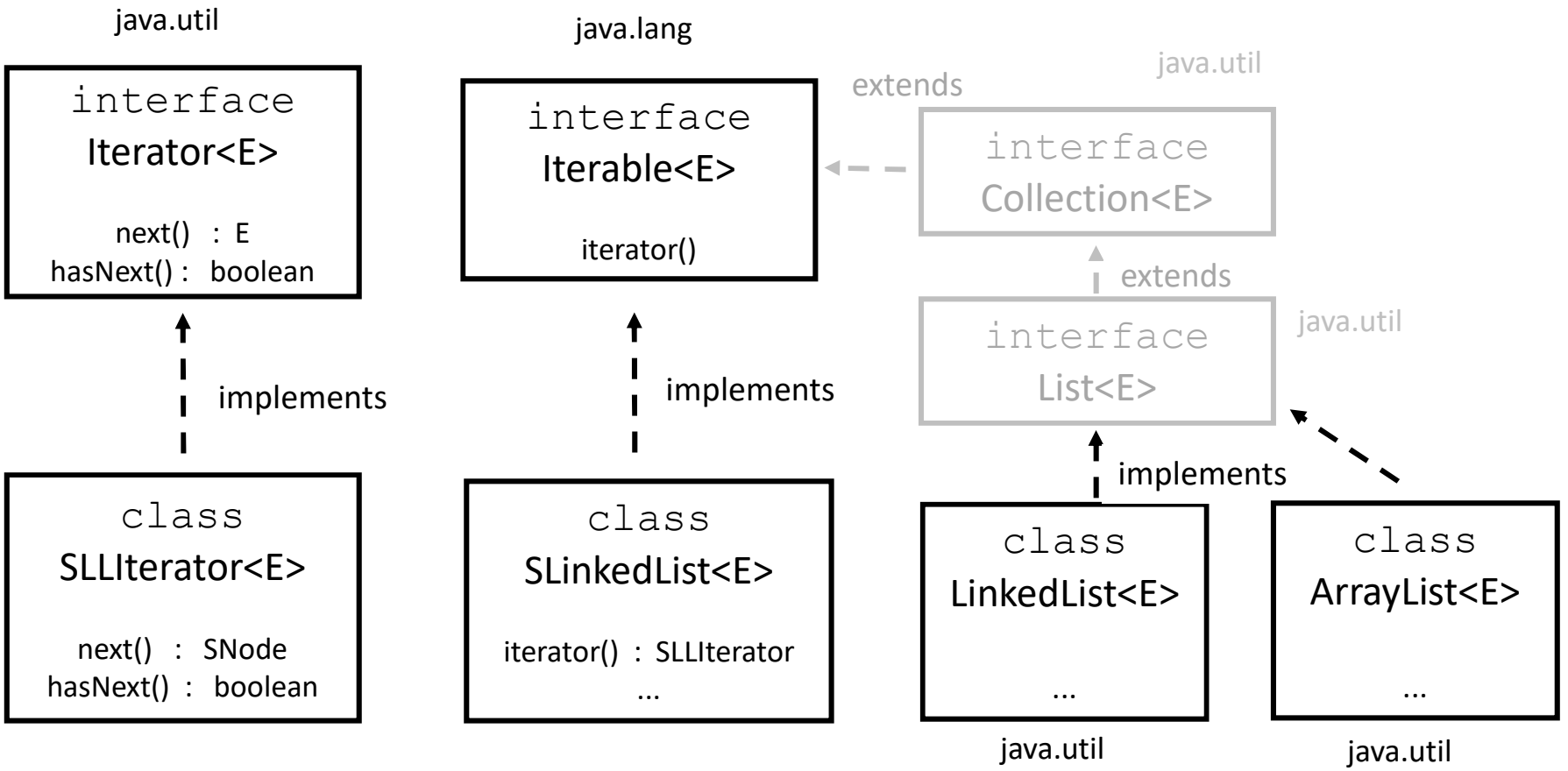
The iterators iterate over SNodes, not Shapes.
The `next()` method returns a reference to a Shape.

```
SLinkedList<Shape>   list;
Shape    s;
          :
Iterator<Shape> iter1 = list.iterator();
Iterator<Shape> iter2 = list.iterator();

s = iter1.next()
s = iter1.next()

s = iter2.next()
s = iter2.next()
s = iter2.next()
```



The iterators iterate over SNodes, not Shapes.
The `next()` method returns a reference to a Shape.

A Big Picture



Coming up…

Lectures

Mon. Feb. 14 Stacks

Wed. Feb. 16 Queues

Fri. Feb. 18 Mathematical Induction

(The following week we start recursion.)

Assessments

Assignment 1

- due today

Quiz 2 closes at 8 pm (finish by then)

Assignment 2 will be posted today