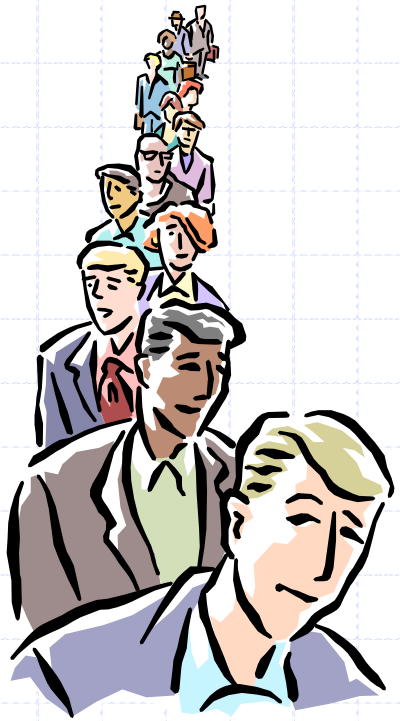
Iterators and Sequences



Iterators

- An iterator abstracts the process of scanning through a collection of elements
- It maintains a cursor that sits between elements in the list, or before the first or after the last element
- Methods of the Iterator ADT:
  - hasNext(): returns true so long as the list is not empty and the cursor is not after the last element
  - next(): returns the next element
- Extends the concept of position by adding a traversal capability
- Implementation with an array or singly linked list

Iterable Classes

- An iterator is typically associated with an another data structure, which can implement the Iterable ADT
- We can augment the Stack, Queue, Vector, List and Sequence ADTs with method:
  - Iterator<E> iterator(): returns an iterator over the elements
  - In Java, classes with this method extend Iterable<E>
- Two notions of iterator:
  - snapshot: freezes the contents of the data structure at a given time
  - dynamic: follows changes to the data structure
  - In Java: an iterator will fail (and throw an exception) if the underlying collection changes unexpectedly (thus snapshot type)

The For-Each Loop

- Java provides a simple way of looping through the elements of an Iterable class:
  - for (type name: expression)
    loop_body
  - For example:

```
List<Integer> values;
int sum=0
for (Integer i : values)
  sum += i;   // boxing/unboxing allows this
```

Implementing Iterators

- Array based
  - array A of the elements
  - index i that keeps track of the cursor
- Linked list based
  - doubly-linked list L storing the elements, with sentinels for header and trailer
  - pointer p to node containing the last element returned (or the header if this is a new iterator).
- We can add methods to our ADTs that return iterable objects, so that we can use the for-each loop on their contents

List Iterators in Java

- Java uses a the ListIterator ADT for node-based lists.
- This iterator includes the following methods:
  - add(e): add e at the current cursor position
  - hasNext(): true if there is an element after the cursor
  - hasPrevious(): true if there is an element before the cursor
  - previous(): return the element e before the cursor and move cursor to before e
  - next(): return the element e after the cursor and move cursor to after e
  - set(e): replace the element returned by last next or previous operation with e
  - remove(): remove the element returned by the last next or previous method

Sequence ADT

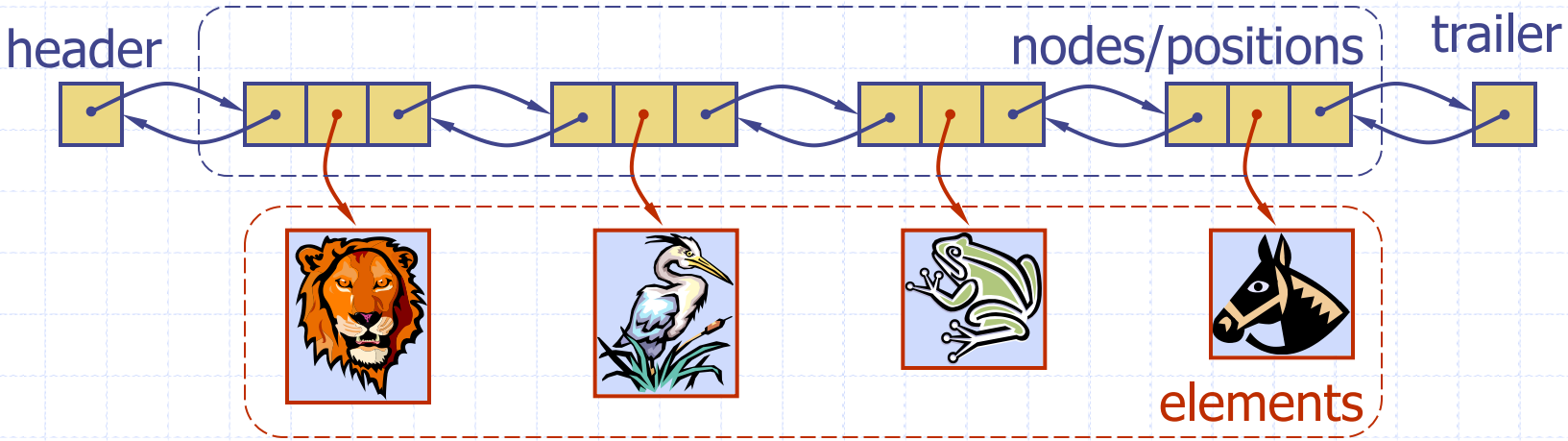
- The Sequence ADT is the union of the Array List and Node List ADTs
- Elements accessed by
  - **Index, or**
  - **Position**
- Generic methods:
  - size(), isEmpty()
- ArrayList-based methods:
  - get(i), set(i, o), add(i, o), remove(i)
- List-based methods:
  - first(), last(), prev(p), next(p), replace(p, o), addBefore(p, o), addAfter(p, o), addFirst(o), addLast(o), remove(p)
- Bridge methods:
  - atIndex(i), indexOf(p)

Applications of Sequences

- The Sequence ADT is a basic, general-purpose, data structure for storing an ordered collection of elements
- Direct applications:
  - Generic replacement for stack, queue, vector, or list
  - small database (e.g., address book)
- Indirect applications:
  - Building block of more complex data structures

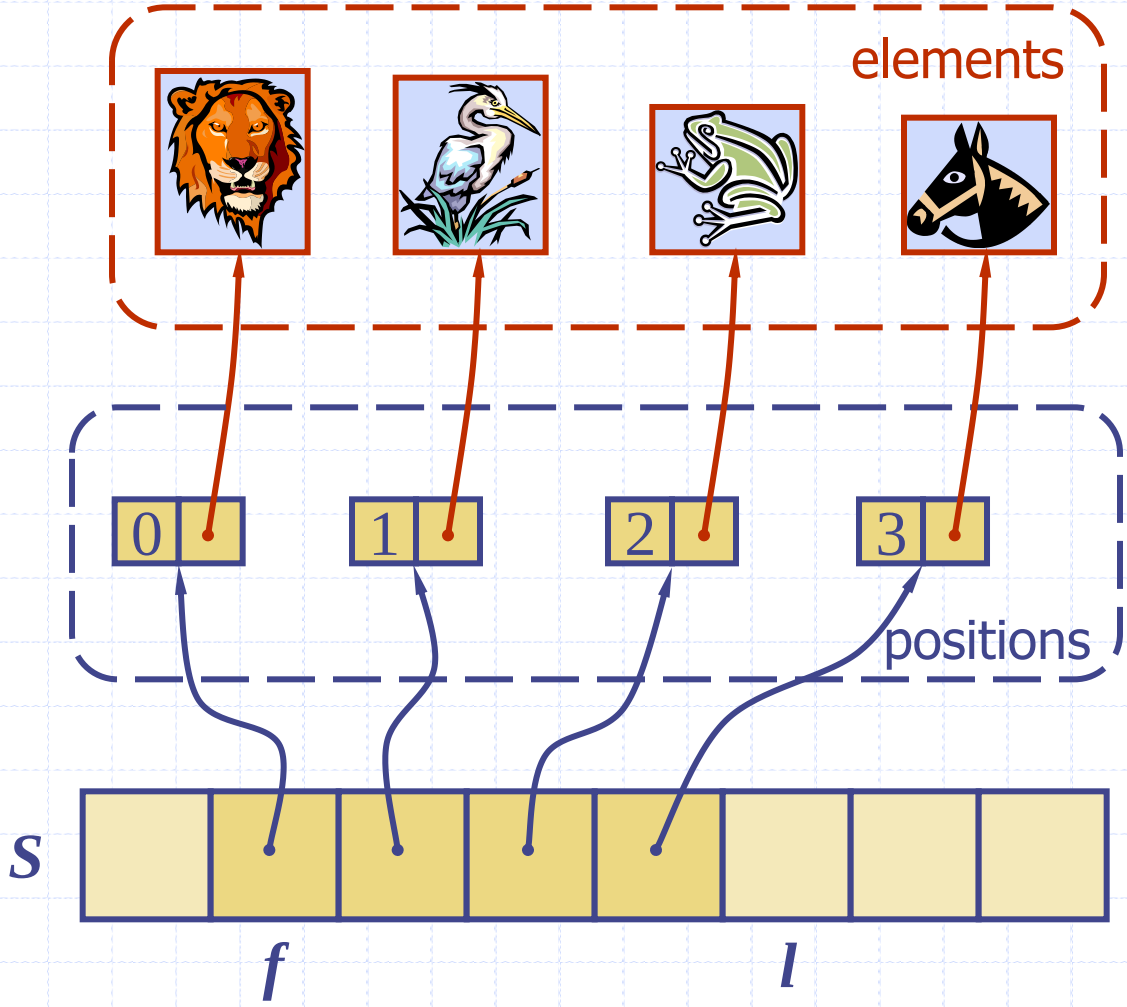
Linked List Implementation

- A doubly linked list provides a reasonable implementation of the Sequence ADT
- Nodes implement Position and store:
  - element
  - link to the previous node
  - link to the next node
- Special trailer and header nodes
- Position-based methods run in **constant time**
- Index-based methods require searching from header or trailer while keeping track of indices; hence, run in **linear time**



Array-based Implementation

- We use a circular array storing positions
- A position object stores:
  - Element
  - Index
- Indices *f* and *l* keep track of first and last positions



Comparing Sequence Implementations

Operation	Array	List
size, isEmpty	1	1
atIndex, indexOf, get	1	n
first, last, prev, next	1	1
set(p,e)	1	1
set(i,e)	1	n
add(i,e), remove(i)	n	n
addFirst, addLast	1	1
addAfter, addBefore	n	1
remove(p)	n	1