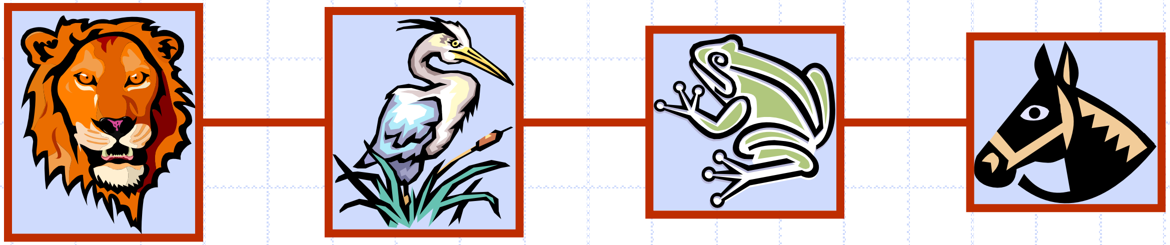
# Lists and Sequences

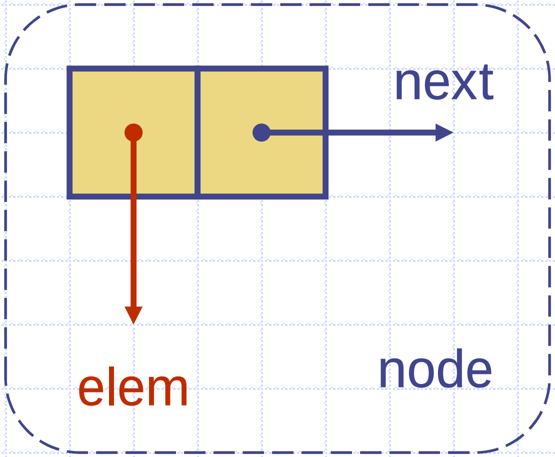


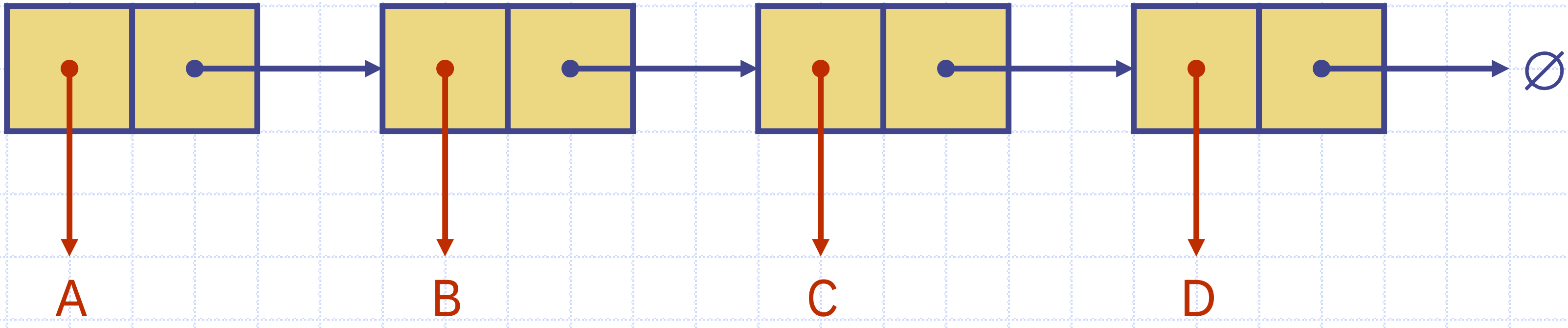
# Outline and Reading

- Singly linked list
- Position ADT and List ADT (§5.2.1)
- Doubly linked list (§ 5.2.3)
- Sequence ADT (§5.3.1)
- Implementations of the sequence ADT (§5.3.3)
- Iterators (§5.5)

# Singly Linked List

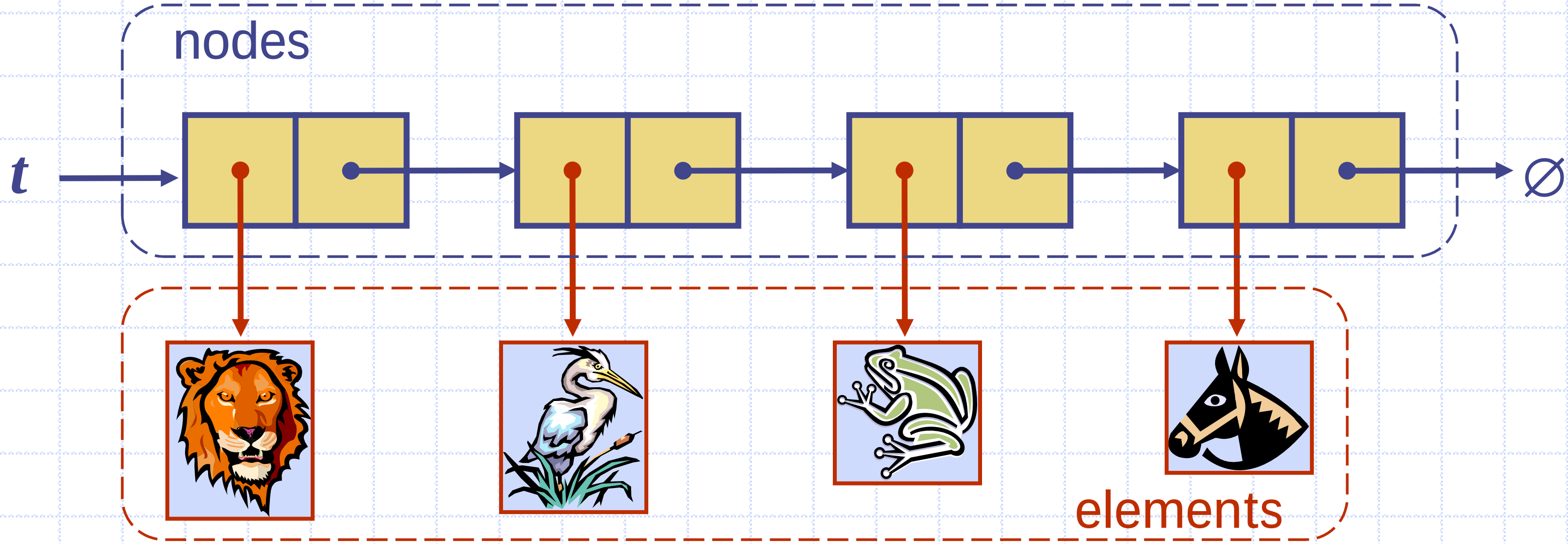
- A singly linked list is a concrete data structure consisting of a sequence of nodes
- Each node stores
  - element
  - link to the next node





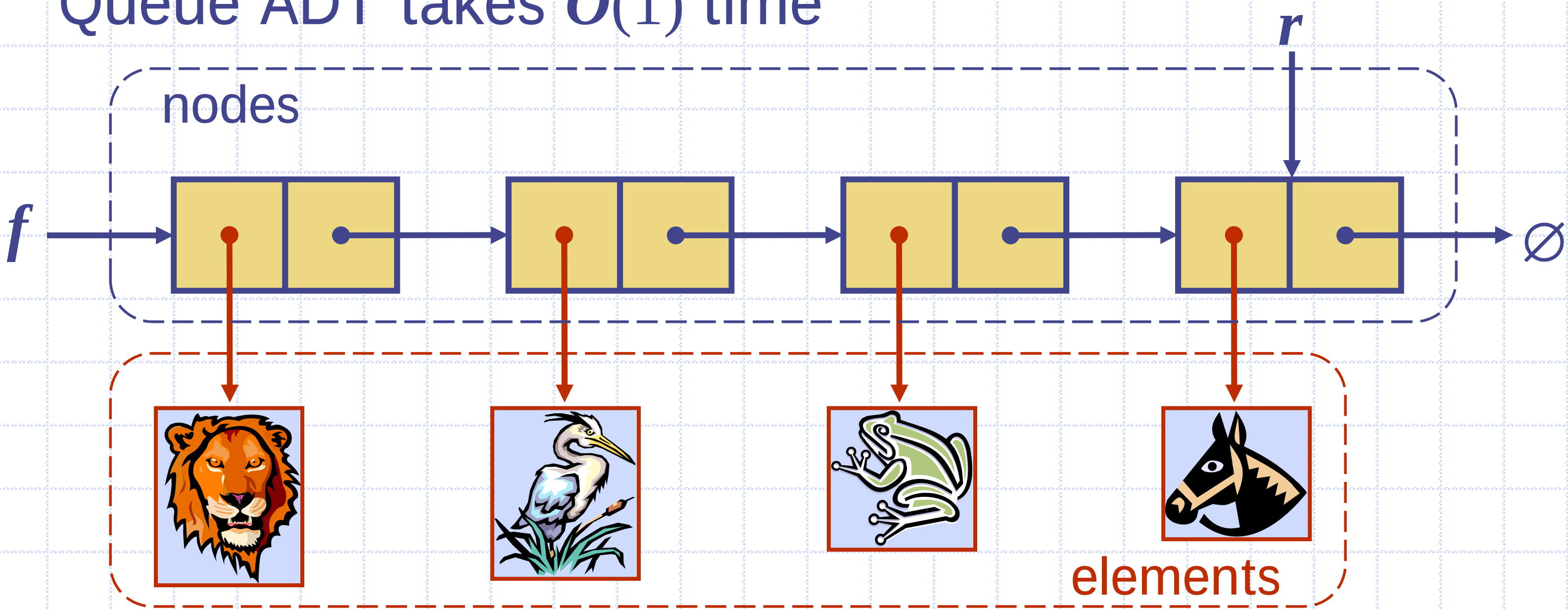
# Stack with a Singly Linked List

- We can implement a stack with a singly linked list
- The top element is stored at the first node of the list
- The space used is $O(n)$ and each operation of the Stack ADT takes $O(1)$ time



# Queue with a Singly Linked List

- We can implement a queue with a singly linked list
  - The front element is stored at the first node
  - The rear element is stored at the last node
- The space used is $O(n)$ and each operation of the Queue ADT takes $O(1)$ time



# Position ADT

- The Position ADT models the notion of place within a data structure where a single object is stored
- A special **null** position refers to no object.
- Positions provide a unified view of diverse ways of storing data, such as
  - a cell of an array
  - a node of a linked list
- Member functions:
  - Object& element(): returns the element stored at this position
  - bool isNull(): returns true if this is a null position

# List ADT

- The List ADT models a sequence of positions storing arbitrary objects
- It establishes a before/after relation between positions
- Generic methods:
  - size(), isEmpty()
- Query methods:
  - isFirst(p), isLast(p)

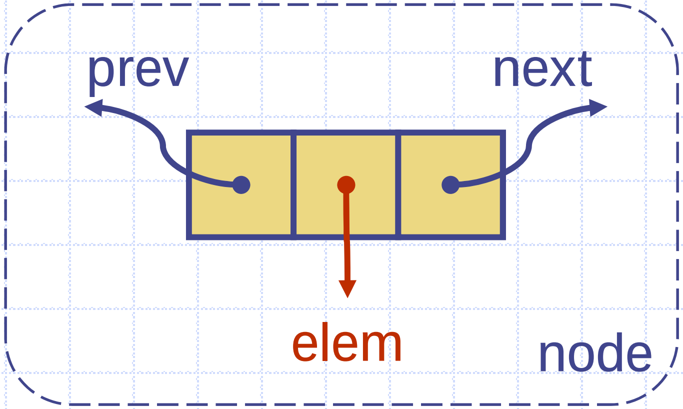
Accessor methods:

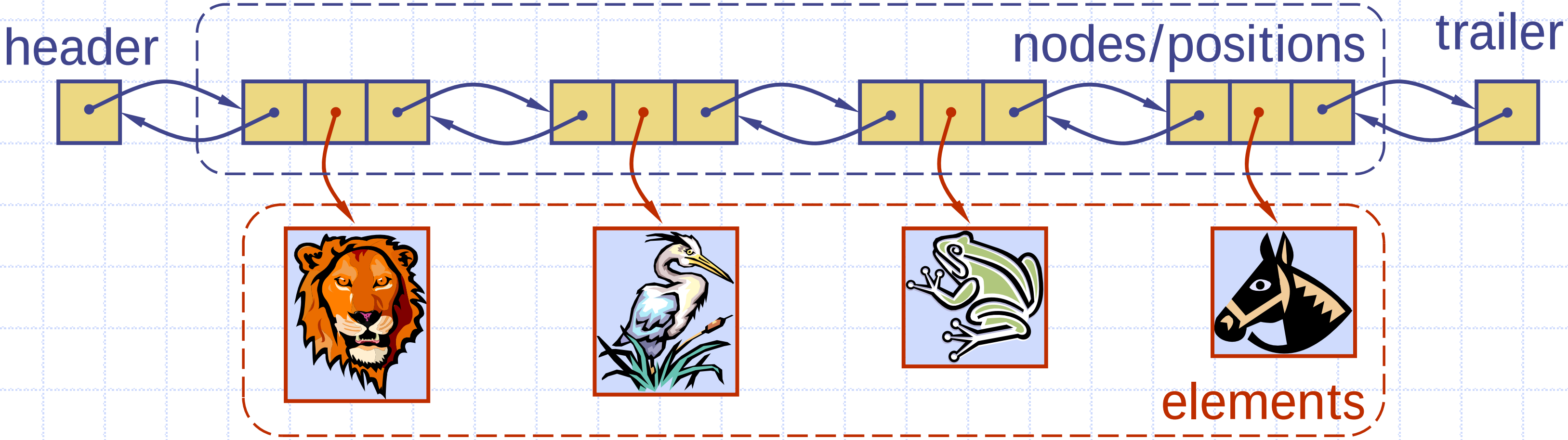
  - first(), last()
  - before(p), after(p)

- Update methods:
  - replaceElement(p, o), swapElements(p, q)
  - insertBefore(p, o), insertAfter(p, o),
  - insertFirst(o), insertLast(o)
  - remove(p)

# Doubly Linked List

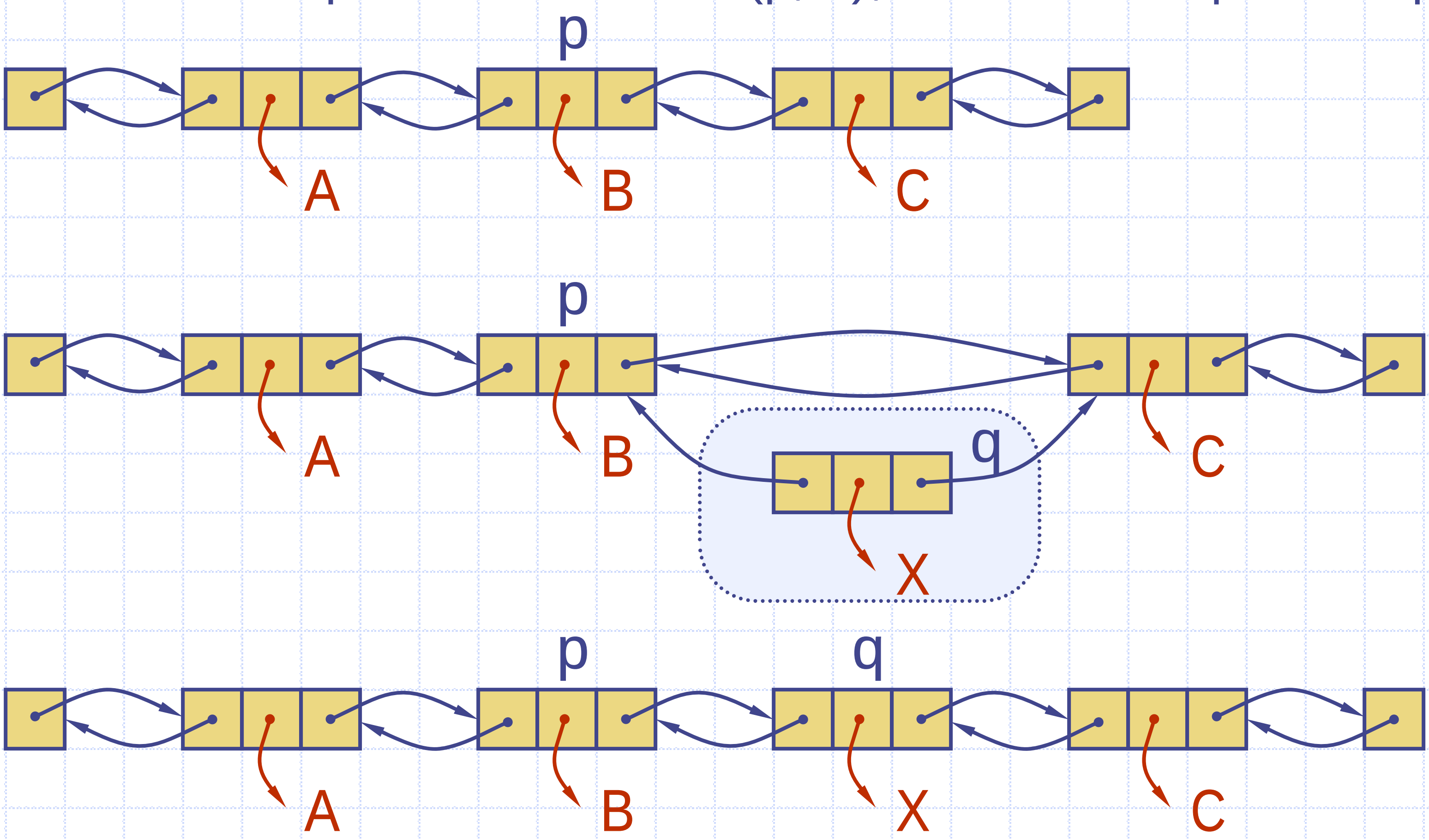
- A doubly linked list provides a natural implementation of the List ADT
- Nodes implement Position and store:
  - element
  - link to the previous node
  - link to the next node
- Special trailer and header nodes





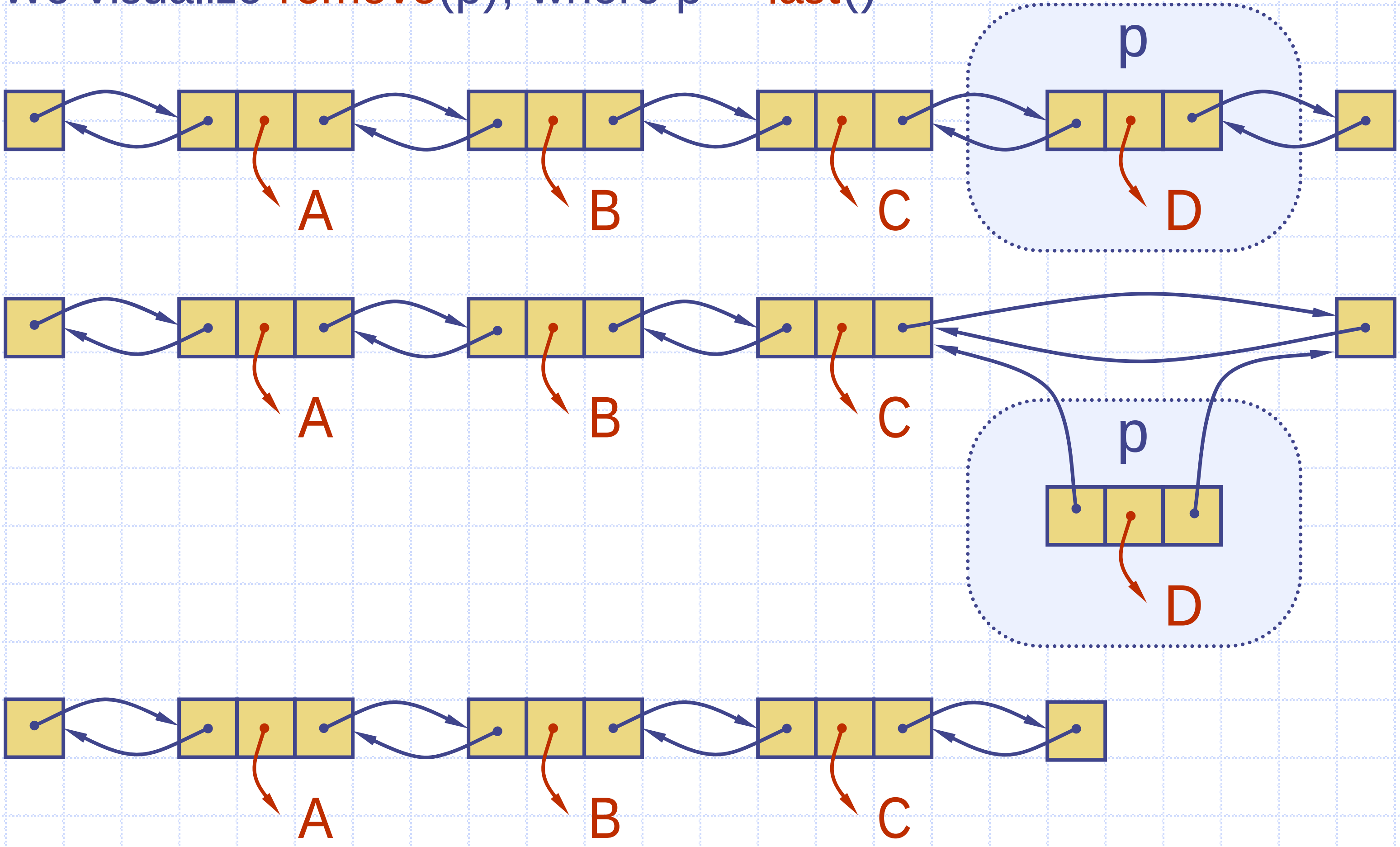
# Insertion

- We visualize operation insertAfter(p, X), which returns position q



# Deletion

- We visualize remove(p), where p = last()



# Performance

- In the implementation of the List ADT by means of a doubly linked list
  - The space used by a list with $n$ elements is $O(n)$
  - The space used by each position of the list is $O(1)$
  - All the operations of the List ADT run in $O(1)$ time
  - Operation element() of the Position ADT runs in $O(1)$ time

# Sequence ADT

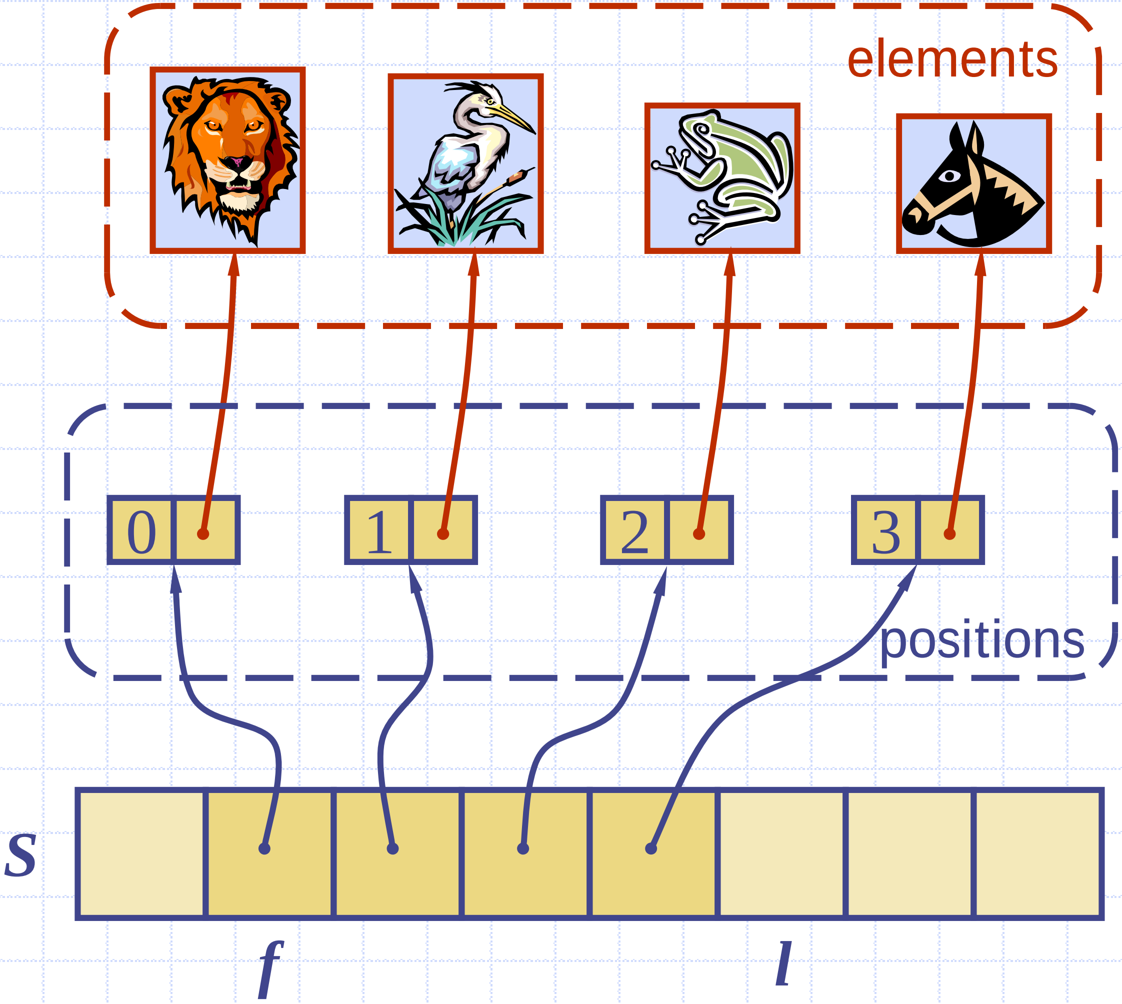
- The Sequence ADT is the union of the Vector and List ADTs
- Elements accessed by
  - Rank, or
  - Position
- Generic methods:
  - size(), isEmpty()
- Vector-based methods:
  - elemAtRank(r), replaceAtRank(r, o), insertAtRank(r, o), removeAtRank(r)
- List-based methods:
  - first(), last(), before(p), after(p), replaceElement(p, o), swapElements(p, q), insertBefore(p, o), insertAfter(p, o), insertFirst(o), insertLast(o), remove(p)
- Bridge methods:
  - atRank(r), rankOf(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

# Array-based Implementation

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



# Sequence Implementations

| Operation | Array | List |
|---|---|---|
| size, isEmpty | 1 | 1 |
| atRank, rankOf, elemAtRank | 1 | $n$ |
| first, last, before, after | 1 | 1 |
| replaceElement, swapElements | 1 | 1 |
| replaceAtRank | 1 | $n$ |
| insertAtRank, removeAtRank | $n$ | $n$ |
| insertFirst, insertLast | 1 | 1 |
| insertAfter, insertBefore | $n$ | 1 |
| remove | $n$ | 1 |

# Iterators

- An iterator abstracts the process of scanning through a collection of elements
- Methods of the ObjectIterator ADT:
  - boolean hasNext()
  - object next()
  - reset()
- Extends the concept of position by adding a traversal capability
- May be implemented with an array or singly linked list
- An iterator is typically associated with an another data structure
- We can augment the Stack, Queue, Vector, List and Sequence ADTs with method:
  - ObjectIterator elements()
- Two notions of iterator:
  - snapshot: freezes the contents of the data structure at a given time
  - dynamic: follows changes to the data structure