CH7.
LIST AND ITERATOR ADTS

ACKNOWLEDGEMENT: THESE SLIDES ARE ADAPTED FROM SLIDES PROVIDED WITH DATA STRUCTURES AND ALGORITHMS IN JAVA, GOODRICH, TAMASSIA AND GOLDWASSER (WILEY 2016)

LIST ADT

size( ):	Returns the number of elements in the list.
isEmpty( ):	Returns a boolean indicating whether the list is empty.
get(i):	Returns the element of the list having index i; an error condition occurs if i is not in range $[0, \text{size}( ) - 1]$.
set(i, e):	Replaces the element at index i with e, and returns the old element that was replaced; an error condition occurs if i is not in range $[0, \text{size}( ) - 1]$.
add(i, e):	Inserts a new element e into the list so that it has index i, moving all subsequent elements one index later in the list; an error condition occurs if i is not in range $[0, \text{size}( )]$.
remove(i):	Removes and returns the element at index i, moving all subsequent elements one index earlier in the list; an error condition occurs if i is not in range $[0, \text{size}( ) - 1]$.

EXAMPLE

- A sequence of List operations:

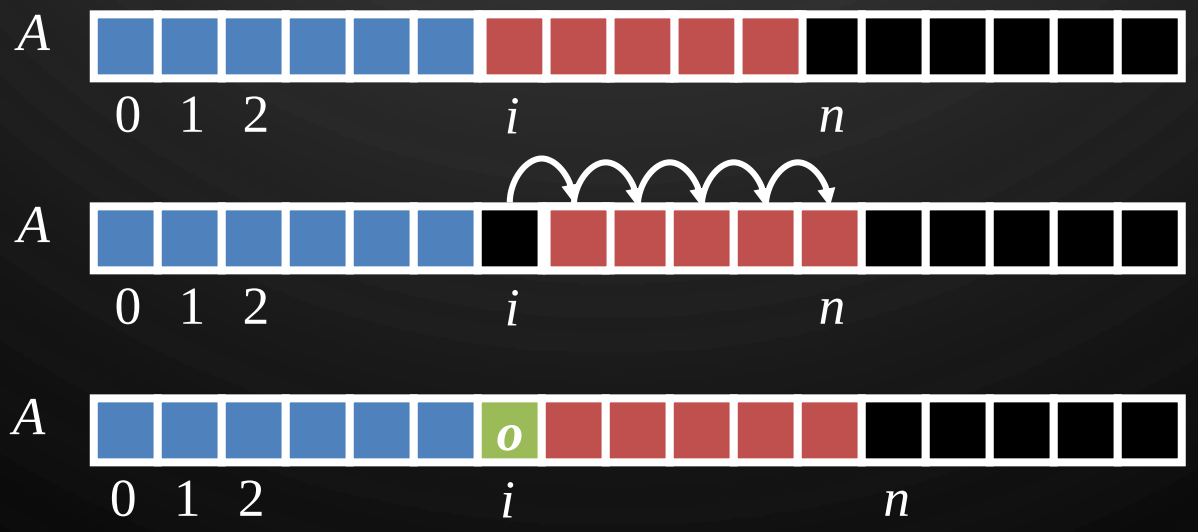
Method	Return Value	List Contents
add(0, A)	–	(A)
add(0, B)	–	(B, A)
get(1)	A	(B, A)
set(2, C)	"error"	(B, A)
add(2, C)	–	(B, A, C)
add(4, D)	"error"	(B, A, C)
remove(1)	A	(B, C)
add(1, D)	–	(B, D, C)
add(1, E)	–	(B, E, D, C)
get(4)	"error"	(B, E, D, C)
add(4, F)	–	(B, E, D, C, F)
set(2, G)	D	(B, E, G, C, F)
get(2)	G	(B, E, G, C, F)

ARRAY LISTS

- An obvious choice for implementing the list ADT is to use an array, A, where $A[i]$ stores (a reference to) the element with index i.
- With a representation based on an array A, the `get(`i`)` and `set(`i`,` e`)` methods are easy to implement by accessing $A[i]$ (assuming i is a legitimate index).

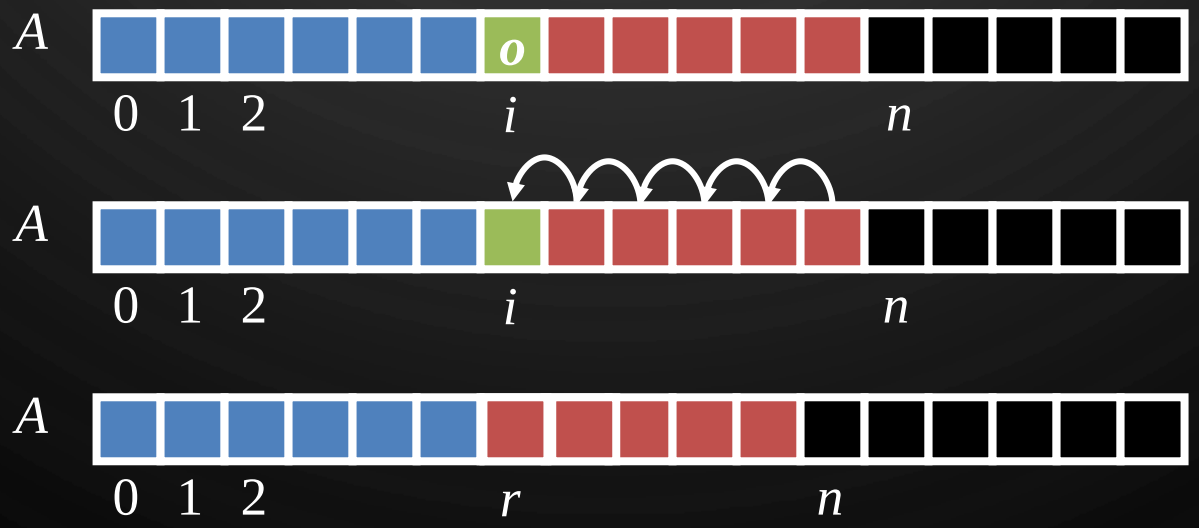
INSERTION

- In an operation `add(`i`, o)`, we need to make room for the new element by shifting forward the $n - i$ elements $A[i], \ldots, A[n-1]$
- In the worst case ($i = 0$), this takes $O(n)$ time



ELEMENT REMOVAL

- In an operation `remove`(i), we need to fill the hole left by the removed element by shifting backward the $n - i - 1$ elements $A[i + 1], \ldots, A[n - 1]$
- In the worst case ($i = 0$), this takes $O(n)$ time



PERFORMANCE

- In an array-based implementation of a dynamic list:
  - The space used by the data structure is $O(n)$
  - Indexing the element (`get`/`set`) at i takes $O(1)$ time
  - `add` and `remove` run in $O(n)$ time
- In an `add` operation, when the array is full, instead of throwing an exception, we can replace the array with a larger one …

EXERCISE:

- Implement the Deque ADT update functions using List functions
  - Deque update functions:
    - `first(), last(), addFirst(e), addLast(e), removeFirst(), removeLast(), size(), isEmpty()`
  - List functions:
    - `get(i), set(i, e), add(i, e), remove(i), size(), isEmpty()`

LIST SUMMARY

	Array Fixed-Size or Expandable	List Singly or Doubly Linked
`add(i, e)`, `remove(i)`	$O(1)$ Best Case ($i = n$) $O(n)$ Worst Case $O(n)$ Average Case	?
`get(i)`, `set(i, e)`	$O(1)$	?
`size()`, `isEmpty()`	$O(1)$	?

POSITIONAL LISTS

- To provide for a general abstraction of a sequence of elements with the ability to identify the location of an element, we define a positional list ADT.
- A **position** acts as a marker or token within the broader positional list.
- A position p is unaffected by changes elsewhere in a list; the only way in which a position becomes invalid is if an explicit command is issued to delete it.
- A position instance is a simple object, supporting only the following method:
  - `p.getElement()`: Return the element stored at position p.

POSITIONAL LIST ADT

- Accessor methods:

first( ):	Returns the position of the first element of L (or null if empty).
last( ):	Returns the position of the last element of L (or null if empty).
before(p):	Returns the position of L immediately before position p (or null if p is the first position).
after(p):	Returns the position of L immediately after position p (or null if p is the last position).
isEmpty( ):	Returns true if list L does not contain any elements.
size( ):	Returns the number of elements in list L.

POSITIONAL LIST ADT, 2

- Update methods:

addFirst(e):	Inserts a new element e at the front of the list, returning the position of the new element.
addLast(e):	Inserts a new element e at the back of the list, returning the position of the new element.
addBefore(p, e):	Inserts a new element e in the list, just before position p, returning the position of the new element.
addAfter(p, e):	Inserts a new element e in the list, just after position p, returning the position of the new element.
set(p, e):	Replaces the element at position p with element e, returning the element formerly at position p.
remove(p):	Removes and returns the element at position p in the list, invalidating the position.

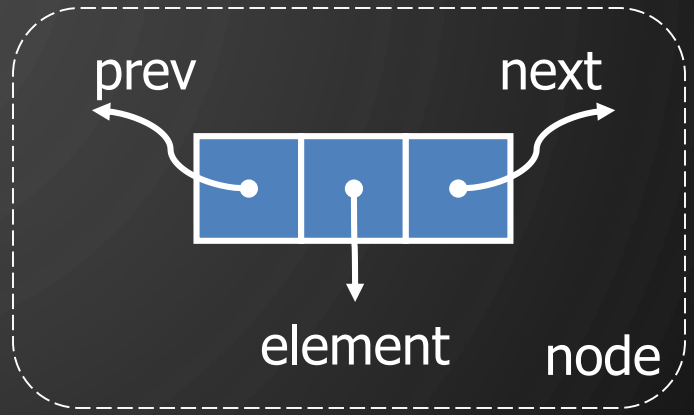
EXAMPLE

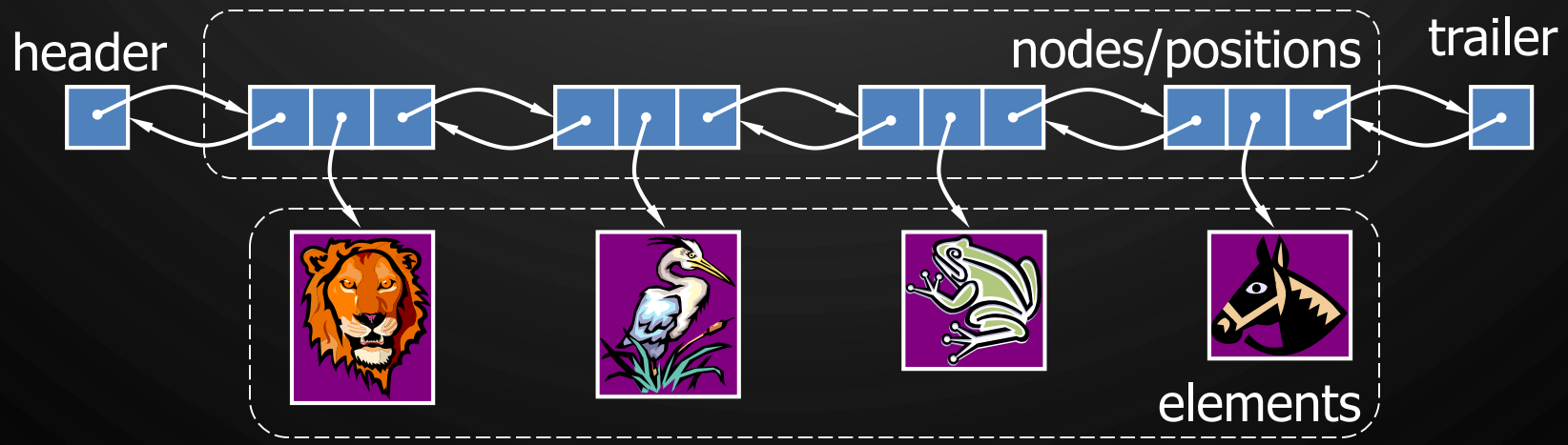
- A sequence of Positional List operations:

Method	Return Value	List Contents
addLast(8)	p	(8_p)
first( )	p	(8_p)
addAfter(p, 5)	q	$(8_p, 5_q)$
before(q)	p	$(8_p, 5_q)$
addBefore(q, 3)	r	$(8_p, 3_r, 5_q)$
r.getElement( )	3	$(8_p, 3_r, 5_q)$
after(p)	r	$(8_p, 3_r, 5_q)$
before(p)	null	$(8_p, 3_r, 5_q)$
addFirst(9)	s	$(9_s, 8_p, 3_r, 5_q)$
remove(last( ))	5	$(9_s, 8_p, 3_r)$
set(p, 7)	8	$(9_s, 7_p, 3_r)$
remove(q)	"error"	$(9_s, 7_p, 3_r)$

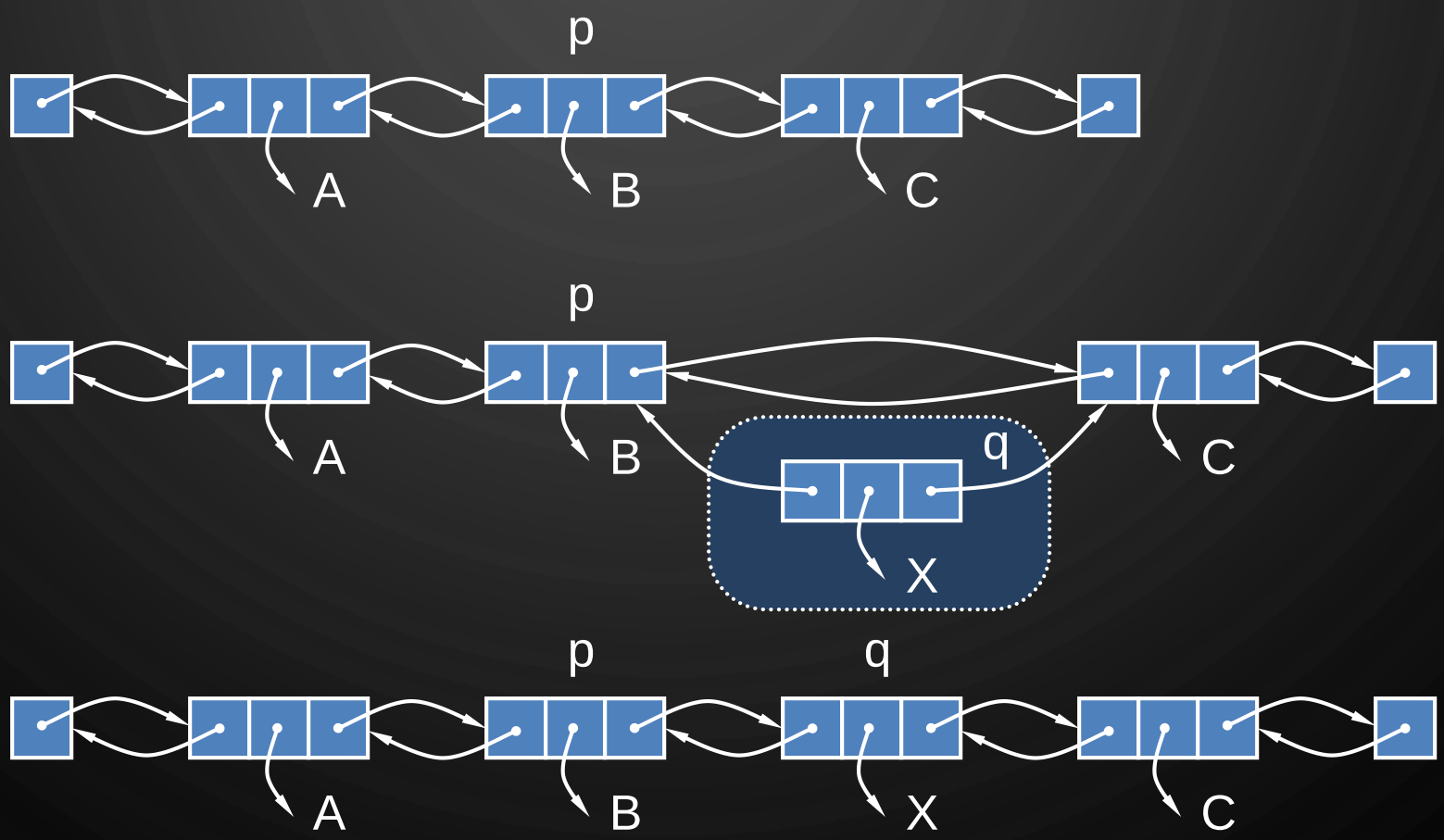
POSITIONAL LIST IMPLEMENTATION

- The most natural way to implement a positional list is with a doubly-linked list.

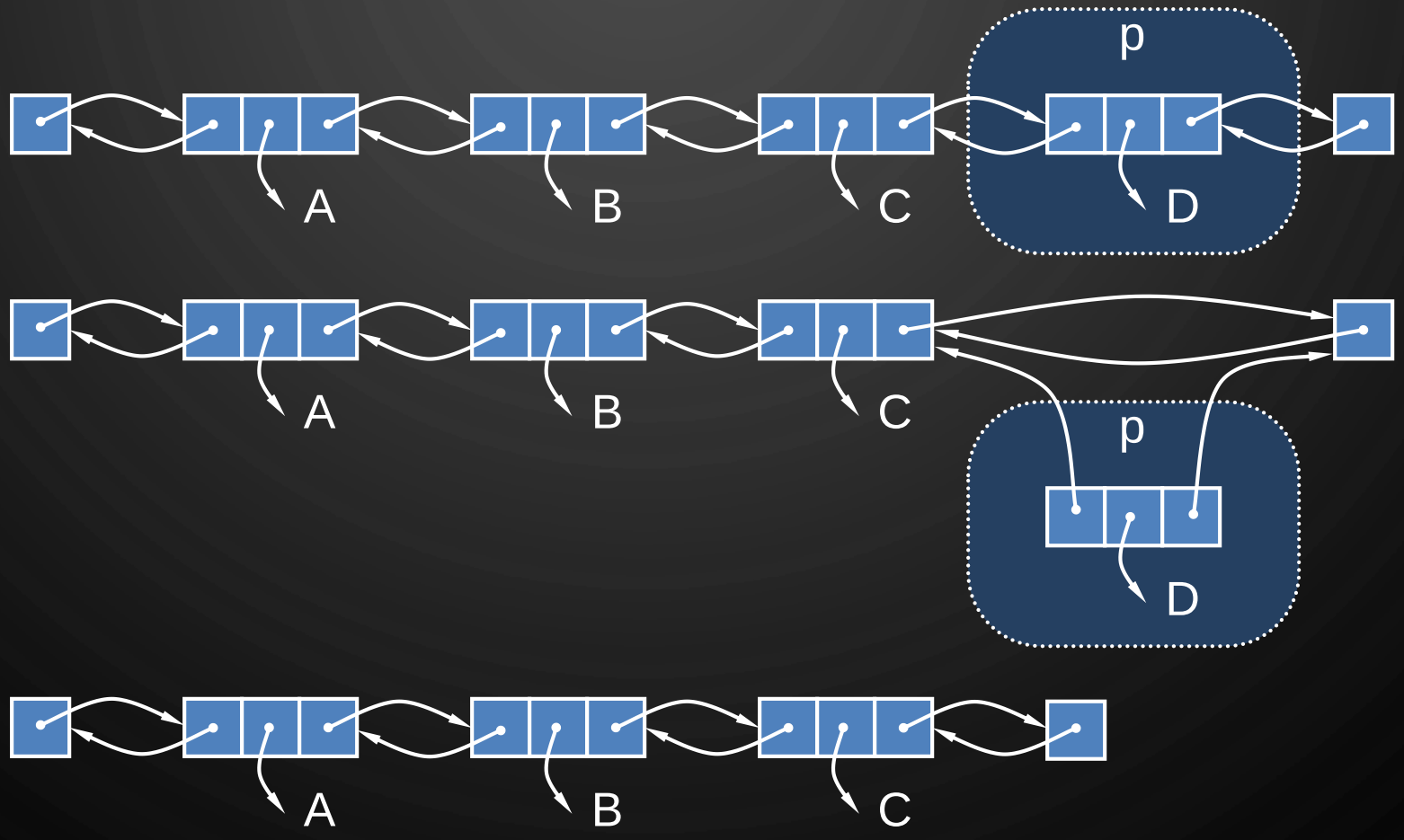




INSERTION, E.G., `ADDAFTER(P, E)`



REMOVE(P)



PERFORMANCE

- Assume doubly-linked list implementation of Positional List ADT
  - 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

POSITIONAL LIST SUMMARY

	List Singly-Linked	List Doubly- Linked
`first()`, `last()`, `addFirst()`, `addLast()`, `addAfter()`	$O(1)$	$O(1)$
`addBefore(p, e)`, `erase()`	$O(n)$ Worst and Average case $O(1)$ Best case	$O(1)$
`size( )`, `isEmpty()`	$O(1)$	$O(1)$

ITERATORS

- An **iterator** is a software design pattern that abstracts the process of scanning through a sequence of elements, one element at a time.

hasNext( ):	Returns true if there is at least one additional element in the sequence, and false otherwise.
next( ):	Returns the next element in the sequence.

THE ITERABLE INTERFACE

- Java defines a parameterized interface, named **Iterable**, that includes the following single method:
  - `iterator()`: Returns an iterator of the elements in the collection.
- An instance of a typical collection class in Java, such as an `ArrayList`, is `Iterable` (but not itself an iterator); it produces an iterator for its collection as the return value of the `iterator()` method.
- Each call to `iterator()` returns a new iterator instance, thereby allowing multiple (even simultaneous) traversals of a collection.

THE FOR-EACH LOOP

- Java's Iterable class also plays a fundamental role in support of the "for-each" loop syntax:

```
for (ElementType variable : collection) {
  loopBody                                    // may refer to "variable"
}
```

  - is equivalent to:

```
Iterator<ElementType> iter = collection.iterator();
while (iter.hasNext()) {
  ElementType variable = iter.next();
  loopBody                                    // may refer to "variable"
}
```

INTERVIEW QUESTION 1

- Write code to partition a list around a value x, such that all nodes less than x come before all nodes greater than or equal to x.

GAYLE LAAKMANN MCDOWELL, "CRACKING THE CODE INTERVIEW: 150 PROGRAMMING QUESTIONS AND SOLUTIONS", 5TH EDITION, CAREERCUP PUBLISHING, 2011.

INTERVIEW QUESTION 2

- Implement a function to check if a list is a palindrome.

GAYLE LAAKMANN MCDOWELL, "CRACKING THE CODE INTERVIEW: 150 PROGRAMMING QUESTIONS AND SOLUTIONS", 5TH EDITION, CAREERCUP PUBLISHING, 2011.