CSE 250 Recitation

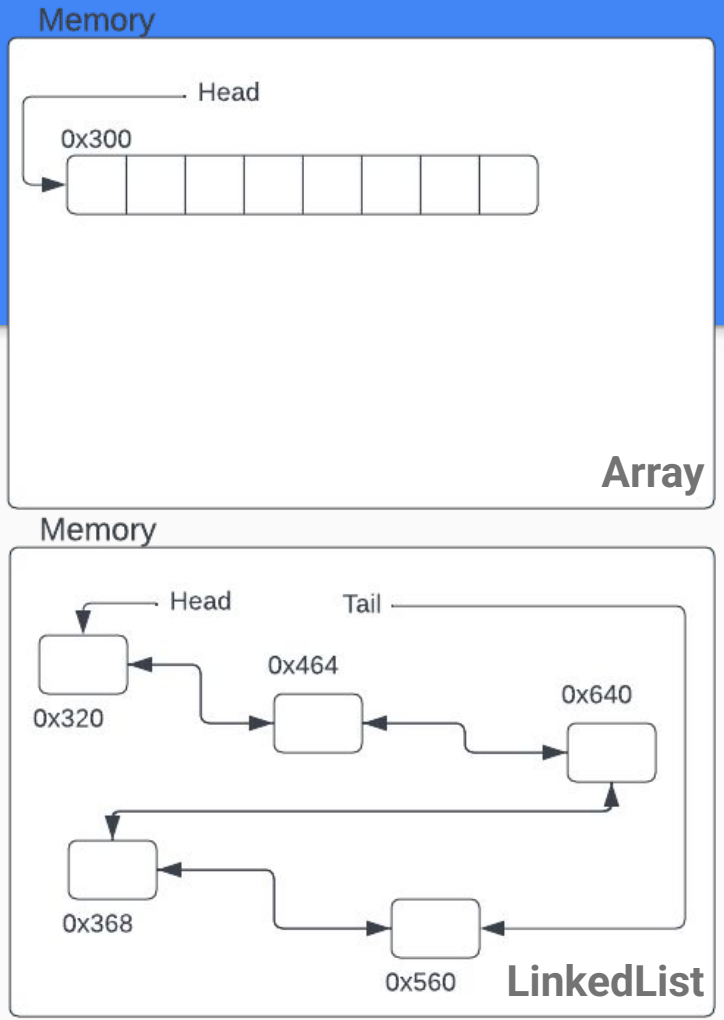
February 19 - 20: Lists, Sets, and Amortized Runtime

List ADT

Discussion: What is the runtime of `list.add(i, v)` when `List` is implemented using:

1. An `ArrayList`
2. A `LinkedList`
3. A `LinkedList` **and** you have a reference to the node representing index `i`

Breakdown the cost for each implementation



List ADT

An **`ArrayList`**

1. **If** out of space, create a new array and copy data	$O(n)$, Amortized $\Theta(1)$
2. Shift elements to the right to make space for new element	$O(n)$
3. Set element at index **`i`** to **`v`**	$\Theta(1)$
Total:	$O(n)$, Amortized $O(n)$

A **`LinkedList`**

1. Iterate from the head node to the insertion point	$O(n)$
2. Create a new node	$\Theta(1)$
3. Assign next/prev pointers accordingly	$\Theta(1)$
Total:	$O(n)$

A **`LinkedList`** w/relevant reference

1. Create a new node	$\Theta(1)$
2. Assign next/prev pointers accordingly	$\Theta(1)$
Total:	$\Theta(1)$

Amortized Runtime

If ***n*** calls to a function take **Θ(f(*n*))** steps

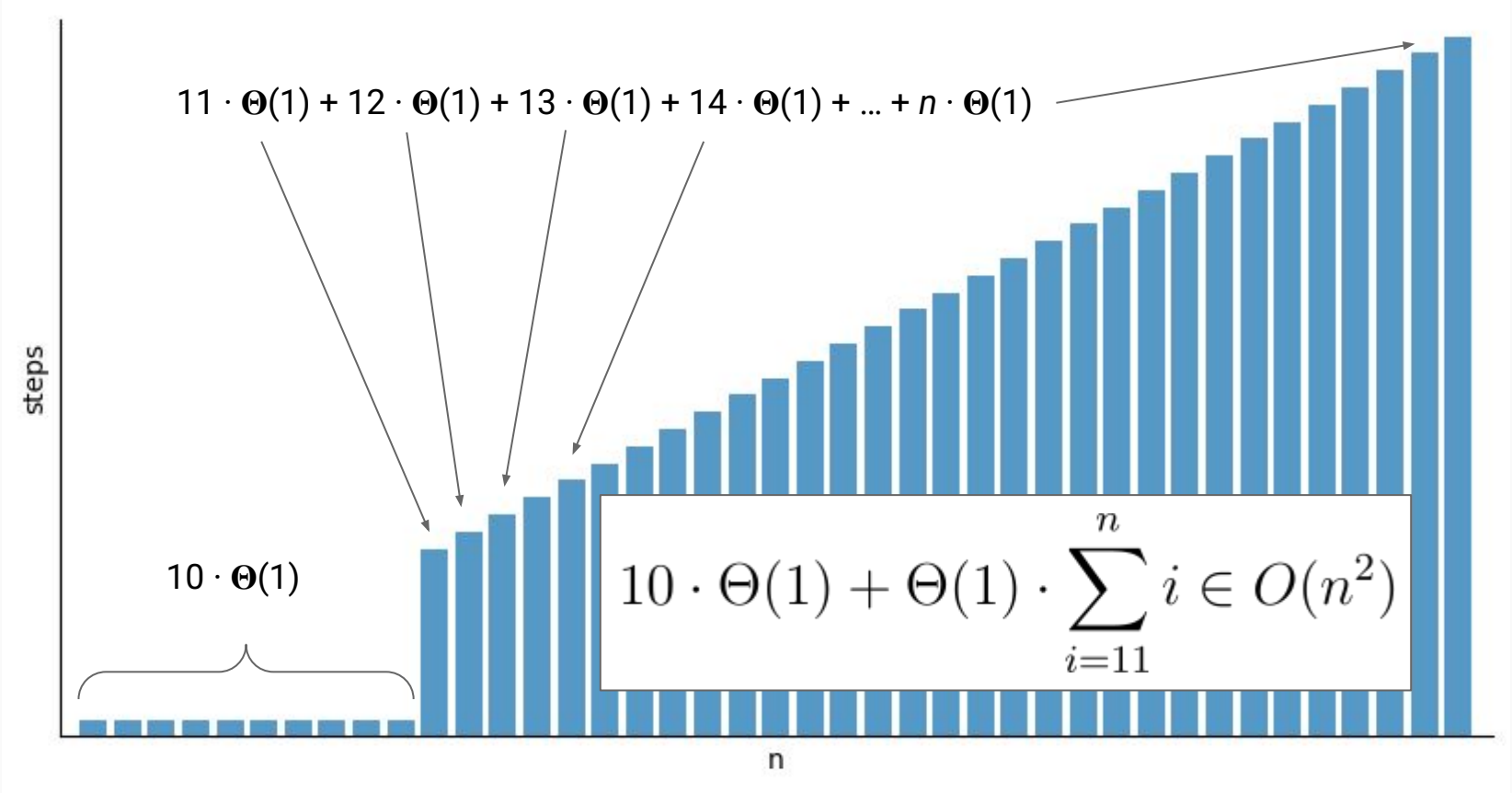
Then the **amortized runtime** of that function is **Θ(f(*n*)/*n*)**

To find the **unqualified runtime** of `foo()`, analyze this:

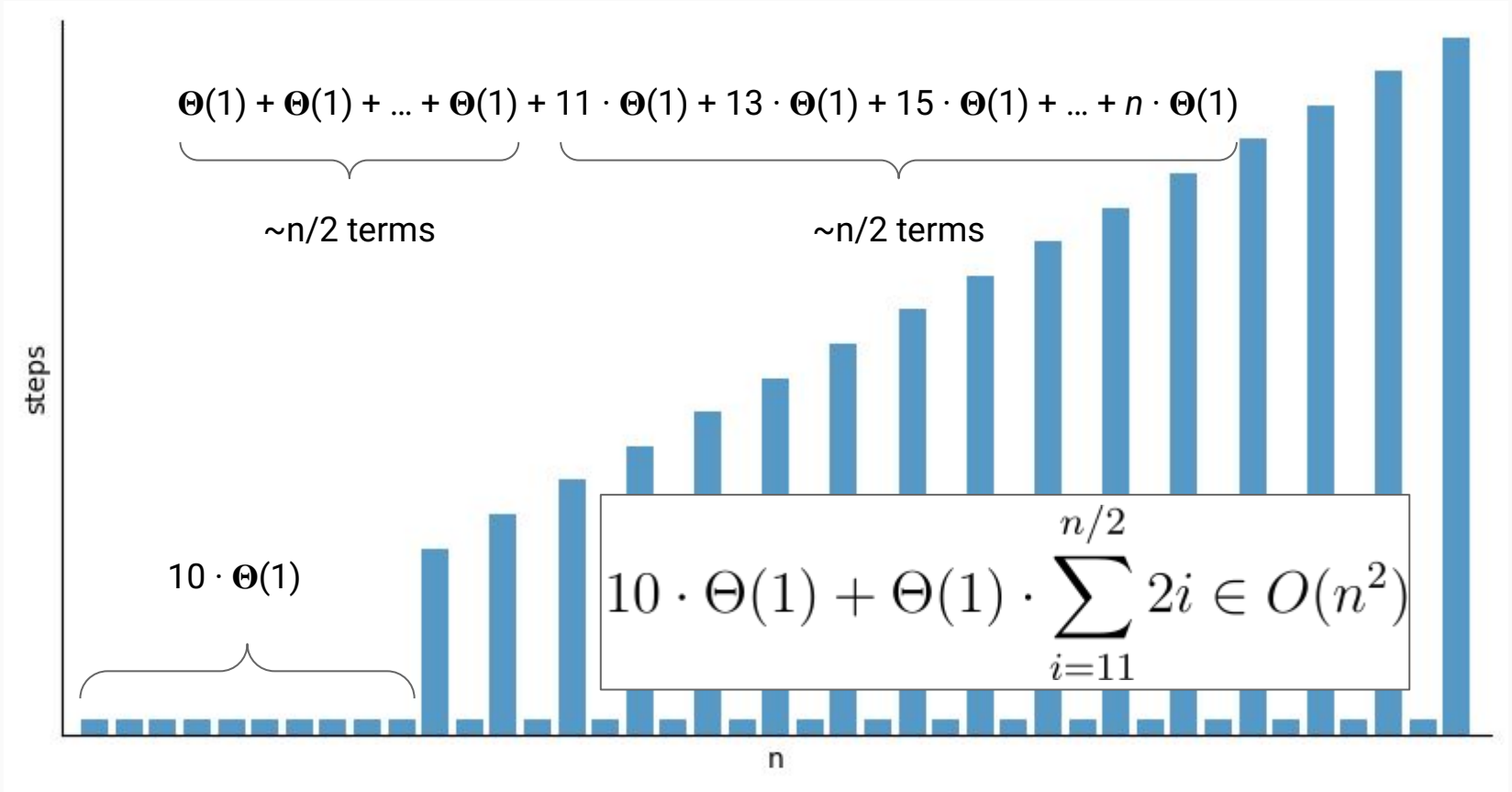
```
foo();
```

To find the **amortized runtime** of `foo()`, analyze this and divide by ***n***:

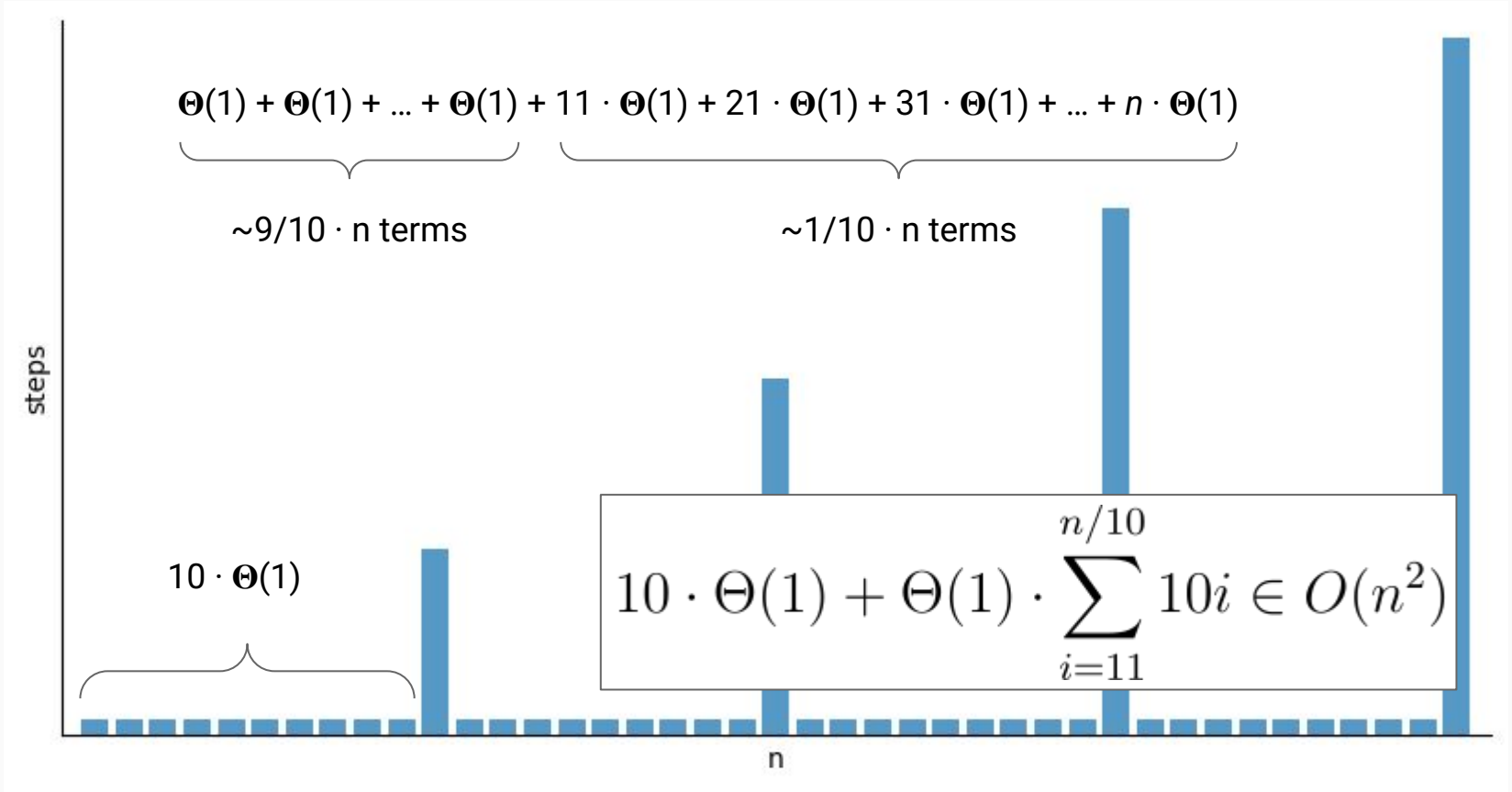
```
for i in 1..n:
    foo();
```



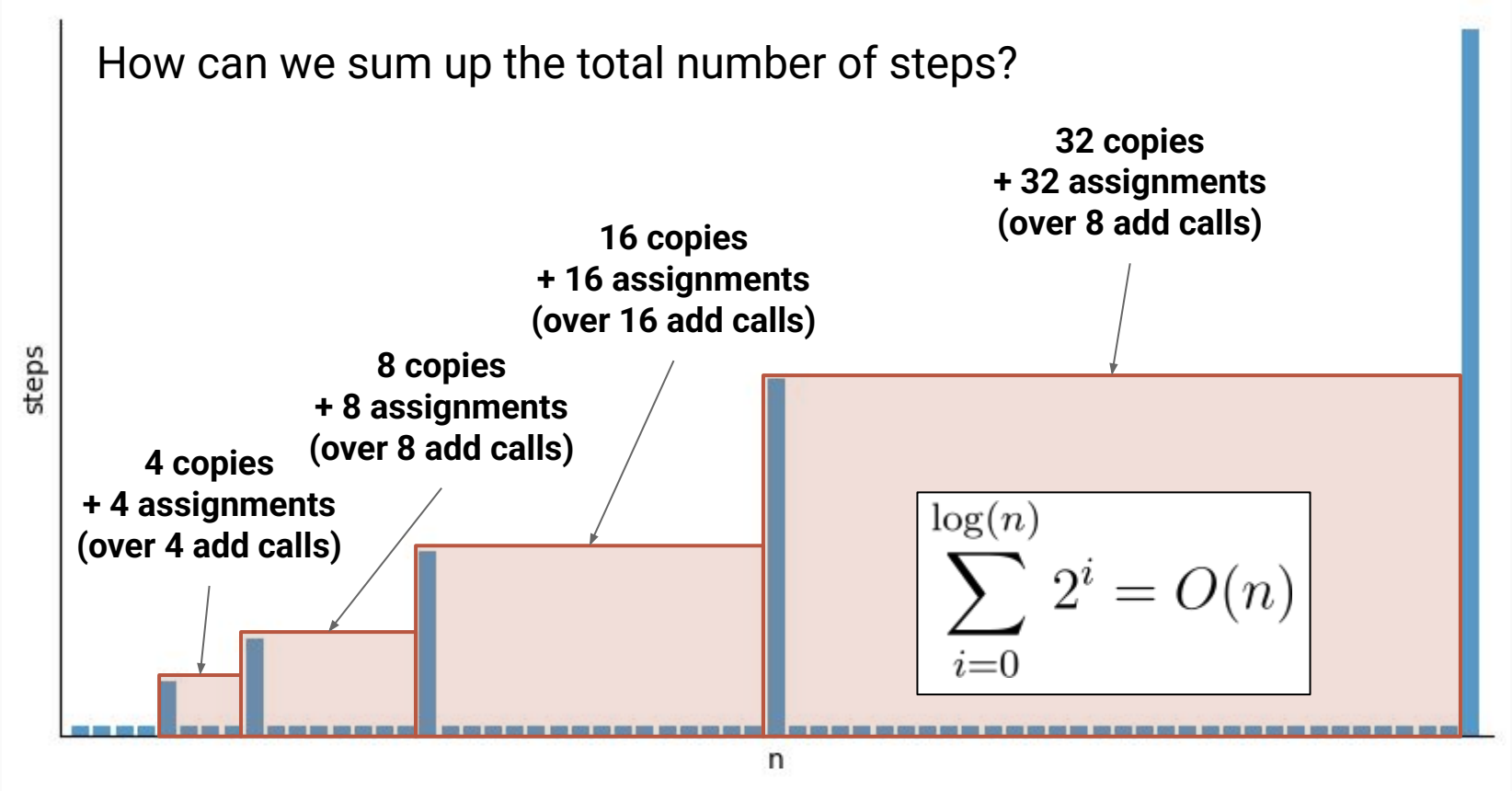
Cost of each call when the initial array size is 10, and newLength = data.length + 1



Cost of each call when the initial array size is 10, and newLength = data.length + 2



Cost of each call when the initial array size is 10, and newLength = data.length + 10



Cost of each call when the initial array size is 4, and newLength = data.length x 2

Amortized Runtime Analysis

```
1  public class Team {
2    private List<Player> players;
3
4    public void addPlayer(Player p) { /* ... */ }
5    public void importRoster(File f) { /* ... */ }
6    /* ... */
7  }
```

```
1  public void addPlayer(Player p) {
2    System.out.println("Welcome to the team " + p.name());
3    players.add(p);
4  }
```

Exercise: What are the unqualified and amortized runtime bounds of the **`addPlayer`** method when **`List`** is a **`LinkedList`**? an **`ArrayList`**?

Amortized Runtime Analysis

```
1  public class Team {
2    private List<Player> players;
3
4    public void addPlayer(Player p) { /*      */ }
5    public void importRoster(File
6    /* ... */
7  }
```

	players is LinkedList	players is ArrayList
addPlayer runtime	Unqualified $\Theta(1)$ Amortized $\Theta(1)$	Unqualified $O(n)$ Amortized $\Theta(1)$

```
1  public void addPlayer(Player p) {
2    System.out.println("Welcome to the team " + p.name());
3    players.add(p);
4  }
```

Exercise: What are the unqualified and amortized runtime bounds of the **`addPlayer`** method when **`List`** is a **`LinkedList`**? an **`ArrayList`**?

Amortized Runtime Analysis

```
1  public void importRoster(File f) {
2    BufferedReader br = new BufferedReader(new FileReader(f));
3    String line;
4    while (br.ready()) {
5      String line = br.readLine();
6      Player p = new Player(line);
7      addPlayer(p);
8    }
9  }
```

	`players` is `LinkedList`	`players` is `ArrayList`
`addPlayer` runtime	Unqualified $\Theta(1)$ Amortized $\Theta(1)$	Unqualified $O(n)$ Amortized $\Theta(1)$

Exercise: What are the unqualified and amortized runtime bounds of the **`importRoster`** method when **`List`** is a **`LinkedList`**? an **`ArrayList`**?

*(You can assume that opening the file, reading a line, and creating a **`Player`** are constant-time calls)*

Amortized Runtime Analysis

```
1  public void importRoster(File f) {
2    BufferedReader br = new BufferedReader(new FileReader(f));
3    String line;
4    while (br.ready()) {
5      String line = br.readLine();
6      Player p = new Player(line);
7      addPlayer(p);
8    }
9  }
```

	`players` is `LinkedList`	`players` is `ArrayList`
`addPlayer` runtime	Unqualified $\Theta(1)$ Amortized $\Theta(1)$	Unqualified $O(n)$ Amortized $\Theta(1)$
`importRoster` runtime	Unqualified $\Theta(n)$ Amortized $\Theta(n)$	Unqualified $\Theta(n)$ Amortized $\Theta(n)$

Exercise: What are
`importRoster` met

*(You can assume that opening the file, reading a line, and creating a **`Player`** are constant-time calls)*

Set ADT

Exercise: Describe an implementation of the Set ADT using your **`SortedList`** implementation from PA1.

Reminder: The methods of the Set ADT are **`add`**, **`contains`**, **`remove`**

`add(elem)`: Adds elem to the set if it is not already present in the set

`contains(elem)`: returns true if elem is in the set, false otherwise

`remove(elem)`: removes elem and returns true, otherwise returns false

Set ADT

Discussion:

Runtimes?

How does this implementation differ than the one from lecture?

What differs when we implement Bag?

```
Assume SortedList object is data

add(elem):
  if !data.findRef(elem).isPresent():
    data.insert(elem)

contains(elem):
  return data.findRef(elem).isPresent()

remove(elem):
  node = data.findRef(elem)
  if node.isPresent():
    data.remove(node)
    return true
  return false
```

Example Scenario

A company is developing three different applications for managing user data and wants you to design an efficient solution.

1. In the first application, the program frequently needs to retrieve user records at arbitrary positions (e.g., "get the 5000th element") as fast as possible, but the data set is fairly static. Insertions and deletions happen, but rarely.

2. In the second application, the program needs to support continuous appending of new user records as users sign up for the system. The total number of records is unbounded, and the company wants to avoid any delays during the user sign up process.

3. In the third application, admins need to frequently look users up based on their unique user ID. These searches should be as quick as possible

Discussion: What ADT and data structure would be best suited for each scenario?