Data Structures

List

Ja-Hee Kim@seoultech

Contents

Data Structures . List

ADT: List

List

- a set of names, numbers etc, usually written one below the other, for example so that you can remember or check them

ADT List

List

Responsibilities

add: append element x

add: insert element x into i^{th} position

remove: delete element x

remove: delete i^{th} element

get: let the caller know what element is the ith element

indexOf: let the caller know what is the ith element

clear: remove all entries form the list

size: gets the number of entries currently in the list.

ADT List

List is the ordered collection of data, and it allows duplicate elements

- add(newEntry: T): Boolean
  Apend newEntry to the list
  - Input
    - newEntry is the object to be added.
  - Postcondition: the list contains newEntry
  - Return:
    - true if adding is success
    - false if adding is fail
- add(givenPosition: integer , newEntry: T): Boolean
  Adds newEntry into the givenPoistion of the list
  - Input
    - givenPosition: the index where the newEntry will be located
    - newEntry is the object to be added.
  - Postcondition: the list contains newEntry in givenPosition
  - Return:
    - true if adding is success
    - false if adding is fail

ADT List

- remove(anEntry: T): Boolean
  - Removes the first or only occurrence of anEntry from the list.
  - Input: anEntry is the object to be removed.
  - Postcondition: the first anEntry does not exist in the list
  - Return: Returns true if anEntry was located and removed, or false if not. In the latter case, the list remains unchanged.

- remove(givenPosition: integer): T
  - Removes and returns the entry at position givenPosition.
  - Input: givenPosition is an integer.
  - Postcondition: the element in the givenPosition does not exist in the list
  - Return: the object at the index givenPosition.

ADT List

- get(givenPosition: integer): T
  - Gets the element in the givenPosition
  - Input: givenPosition is an index.
  - Precondition: givenPosition has an element
  - Return: the object at the index givenPosition

- indexOf(anEntry: T): integer
  - Gets the position of the first or only occurrence of anEntry.
  - Input: anEntry is the object to be found.
  - Return: the position of anEntry if it occurs in the list. Otherwise, returns the position where anEntry would occur in the list, but as a negative integer

ADT List

- clear(): void
    - Removes all entries from the list.
    - Postcondition: the list does not have any element.

- size(): integer
    - Gets the number of entries currently in the list.
    - Return: the number of entries currently in the list.

Example

```java
 2  public class ListTest {
 3      public static void main(String[] args) {
 4          List<String> shoppingList = new Array_List<>();
 5          shoppingList.add("Brussels sprout");
 6          System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
 7          shoppingList.add("tofu");
 8          System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
 9          shoppingList.add("water");
10          System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
11          shoppingList.add(1, "yogurt");
12          System.out.println("The 0th item is "+ shoppingList.get(0));
13          System.out.println("tofu is located in "+ shoppingList.indexOf("tofu"));
14          System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
15          System.out.println("I got "+shoppingList.remove(1));
16          System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
17          if(shoppingList.remove("tofu")) System.out.println("I remove tofu.");
18          System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
19          shoppingList.clear();
20          System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
21      }
22  }
```

🖳 Console ✕   🧑 Problems   🗾 Debug Shell   ▣ ✖ ✖✖ 📄 🔒

```
<terminated> ListTest [Java Application] C:\Program Files\Java\jdk-15.0.1\bin\javaw.exe  (2022. 8. 22. 오후 10:22:03 – 오후 10:22:09)
What I should buy are 1 items:[Brussels sprout]
What I should buy are 2 items:[Brussels sprout,tofu]
What I should buy are 3 items:[Brussels sprout,tofu,water]
The 0th item is Brussels sprout
tofu is located in 2
What I should buy are 4 items:[Brussels sprout,yogurt,tofu,water]
I got yogurt
What I should buy are 3 items:[Brussels sprout,tofu,water]
I remove tofu.
What I should buy are 2 items:[Brussels sprout,water]
What I should buy are 0 items:[]
```

Data Structures . List

Array List

Concept

```java
public class ListTest {
    public static void main(String[] args) {
        List<String> shoppingList = new Array_List<>(5);
        shoppingList.add("Brussels sprout");
        shoppingList.add("tofu");
        shoppingList.add("water");
        System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
        shoppingList.add(1, "yogurt");
        System.out.println("The 0th item is "+ shoppingList.get(0));
        System.out.println("tofu is located in "+ shoppingList.indexOf("tofu"));
        System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
        System.out.println("I got "+shoppingList.remove(1));
        if(shoppingList.remove("tofu")) System.out.println("I remove tofu.");
        shoppingList.clear();
        System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
    }
}
```

```
What I should buy are 3 items:[Brussels sprout,tofu,water]
```

Concept

```java
public class ListTest {
    public static void main(String[] args) {
        List<String> shoppingList = new Array_List<>(5);
        shoppingList.add(0, "Brussels sprout");
        shoppingList.add(1, "tofu");
        shoppingList.add(2, "water");
        System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
        shoppingList.add(1, "yogurt");
        System.out.println("The 0th item is "+ shoppingList.get(0));
        System.out.println("tofu is located in "+ shoppingList.indexOf("tofu"));
        System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
        System.out.println("I got "+shoppingList.remove(1));
        if(shoppingList.remove("tofu")) System.out.println("I remove tofu.");
        shoppingList.clear();
        System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
    }
}
```

```
The 0th item is Brussels sprout
tofu is located in 2
What I should buy are 4 items:[Brussels sprout,yogurt,tofu,water]
```

```
I got yogurt
I remove tofu.
```

Concept

```java
public class ListTest {

    public static void main(String[] args) {

        List<String> shoppingList = new Array_List<>(5);
        shoppingList.add(0, "Brussels sprout");
        shoppingList.add(1, "tofu");
        shoppingList.add(2, "water");
        System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
        shoppingList.add(1, "yogurt");
        System.out.println("The 0th item is "+ shoppingList.get(0));
        System.out.println("tofu is located in "+ shoppingList.indexOf("tofu"));
        System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
        System.out.println("I got "+shoppingList.remove(1));
        if(shoppingList.remove("tofu")) System.out.println("I remove tofu.");

        shoppingList.clear();

        System.out.println("What I should buy are "+ shoppingList.size() + " items:"+shoppingList);
    }

}
```

```
What I should buy are 0 items:[]
```

🥬	🍶			

Design Issue 1

- How to declare data field
- Array_List will hold a collection of objects
    one field can be an array of these object
- Capacity:
    - the length of array vs. the number of element
    - user defined vs. default number

```java
private final T list[];
private int numberOfEntries;
private static final int DEFAULT_CAPACITY=25;
```

Design Issue 2

- initializing the array of parameter T

- What is the current initializing
  - Syntax error
    - list = new T[capacity]
    - list = new Object[capacity]
  - Missing type checking
    - list = (T[])new Object[capacity];
  - Suggestion

    @SuppressWarnings("unchecked")

    T[] tempList = (T[])new Object[desiredCapacity];

    list = tempList;

ArrayBag.java:24: warning: [unchecked] unchecked cast
found   : java.lang.Object[]
required: T[]
  bag = (T[])new Object[capacity];

Suppressing compiler warnings

To suppress an unchecked-cast warning from the compiler, you precede the flagged statements with the instruction

    @SuppressWarnings("unchecked")

Note that this instruction can precede only a method definition or a variable declaration.

Design Issue 3

- Fail-safe programming:
  - What happens if a client tries to create a List whose capacity exceeds a given limit?
  - What happens if a constructor does not execute completely?

```java
private boolean integrityOK;
private static final int MAX_CAPACITY = 1000;

public Array_List(int desiredCapacity) {
    integrityOK= false;
    if(desiredCapacity <= MAX_CAPACITY) {
        @SuppressWarnings("unchecked")
        T[] tempList = (T[])new Object[desiredCapacity];
        list = tempList;
        numberOfEntries=0;
        integrityOK=true;
    } else {
        throw new IllegalStateException("Attemp to create a list whose "+
                "capacity exceeds allowed maximum");
    }
}
```

Design Issue 4

```
public T[] toArray(){
    return list;
}
```

```
public T[] toArray() {
    checkIntegrity();
    @SuppressWarnings("unchecked")
    T[] result = (T[])new Object[numberOfEntries];
    for(int i = O ; i < numberOfEntries ; i++)
        result[i] = list[i];
     return result;
}
```

A private data field should be changed only by the method.
However, if a client know the reference of a private data field, it can change freely without method of the ADT.

Ex:
list=shoppingList.toArray();
list[O] = null;

Design Issue 5

Some code may be duplicated.
1. Integrity checking
2. Finding a certain entry:
   indexOf (T anEntry)
   remove(T anEntry)
3. Remove an item in a certain location
   remove(int givenPosition): boolean
   remove(T anEntry): anEntry
   clear()

- checkIntegrity() : void
- indexOf (T anEntry)
- removeEntry(int index): T

Array_List

```java
public class Array_List<T> implements List<T> {
    private final T list[];
    private int numberOfEntries;
    private static final int DEFAULT_CAPACITY=25;
    private boolean integrityOK;
    private static final int MAX_CAPACITY = 1000;

    public Array_List(int desiredCapacity) {...}
    public Array_List() {...}
    public boolean add(T newEntry) {...}
    public boolean add(int givenPosition, T newEntry) {...}
    public boolean remove(T anEntry) {...}
    public T remove(int givenPosition) {...}
    public T get(int givenPosition) {...}
    public int indexOf(T anEntry) {...}
    public void clear() {...}
    public int size() {...}
    public String toString() {...}
    public T[] toArray() {...}
    private void checkIntegrity() {...}
    private boolean isFull() {...}
}
```

Data Structures . List

Linked List

Analogy-Train

list:Node⟨T⟩ → | data | next |

Analogy

- Network of Emergency Contacts

data   next
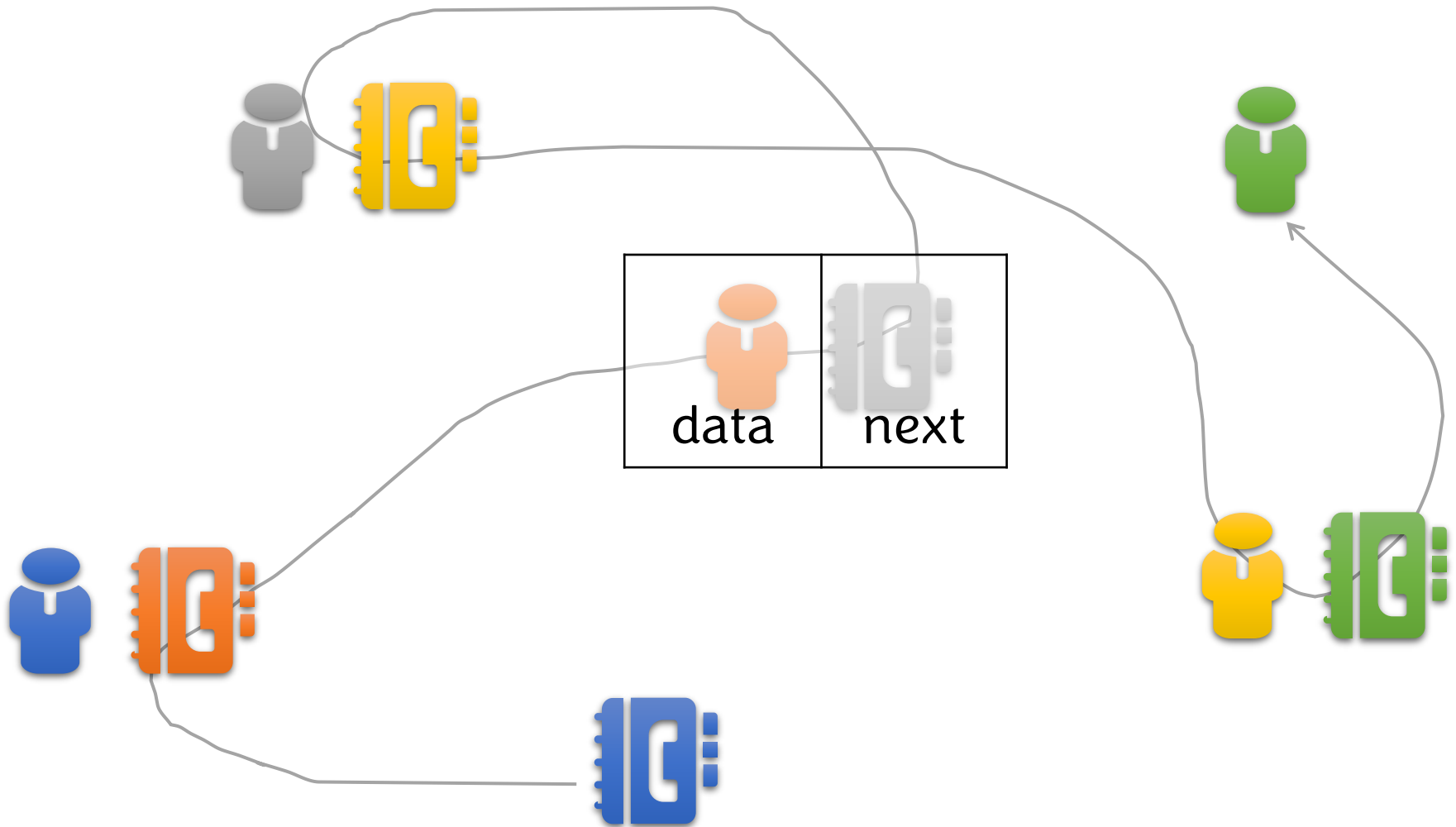
Node

```
private class Node<T> {
    private T data;
    private Node<T> next;
    private Node(T x) {…}
    private Node(T x, Node<T> n) {…}
} // end of inner class Node
```
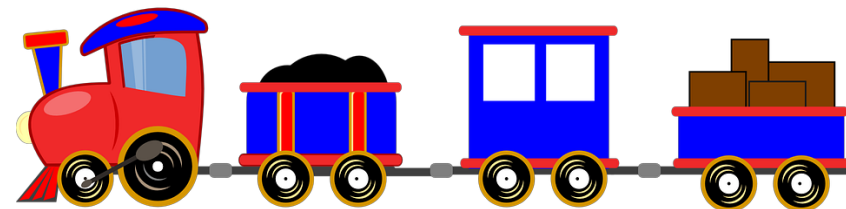
Node

- Nested class:
  - defined in another class definition
- Inner class:
  - a nested class that is not static
- Outer class = enclosing class:
  - embeds a nested class
- Top-level class = outermost class:
  - outer class that is not a nest class

```java
public class Linked_List<T> implements List<T>{
    class Node<T> {
        private T data;
        private Node<T> next;
        Node(T dataPortion) {  // the constructor's name is Node, not Node<T>
            this(dataPortion, null);
        } // end constructor
        Node(T dataPortion, Node<T> nextNode){
            data = dataPortion;
            next = nextNode;
        } // end constructor
        T getData(){
            return data;
        } // end getData
        Node<T> getNextNode(){
            return next;
        } // end getNextNode
        void setData(T newData){
            data = newData;
        } // end setData
        void setNextNode(Node<T> nextNode){
            next = nextNode;
        } // end setNextNode
    }
    private Node<T> list; // Entry in list
    private int numberOfEntries;
    public Linked_List() {…
    public boolean add( T newEntry) { // OutOfMemoryError possible…
    public boolean add(int givenPosition, T newEntry) { // OutOfMemoryError possible…
    public boolean remove(T anEntry) {…
    public T remove(int givenPosition) {…
    public T get(int givenPosition) {…
    public int indexOf(T anEntry) {…
    public void clear() {…
    public int size() {…
    public String toString() {…
}
```

Concept: add

- Add

```
List<String> shoppingList = new Linked_List<>();
shoppingList.add("Brussels sprout");
```

Increase number of entries
if the list is empty
    shoppingList points the new node

shoppingList
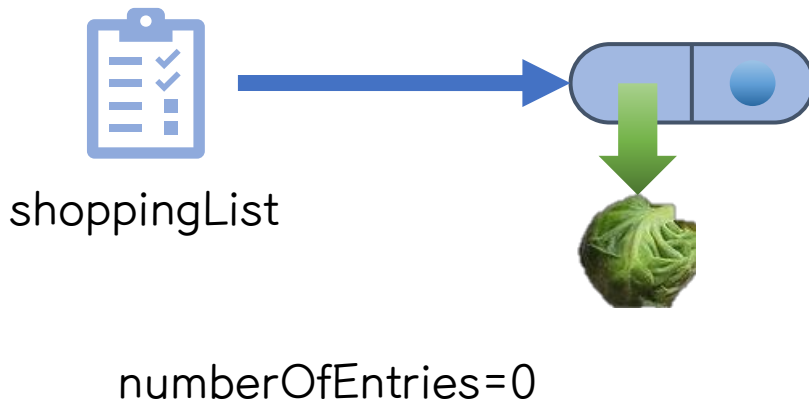
numberOfEntries=0

```
Node(T dataPortion, Node<T> nextNode){
    data = dataPortion;
    next = nextNode;
} // end constructor
```

Concept: add

- Add

```
shoppingList.add("tofu");
```

if the list is not empty
    find the last node
    the last node points the new node

How can we know the last node?

shoppingList   shoppingList.next

shoppingList

numberOfEntries=1

Concept: add

- Add

shoppingList.add("water");

if the list is not empty
    find the last node
    the last node points the new node

shoppingList   shoppingList.next

shoppingList

numberOfEntries

Concept: add

• Add
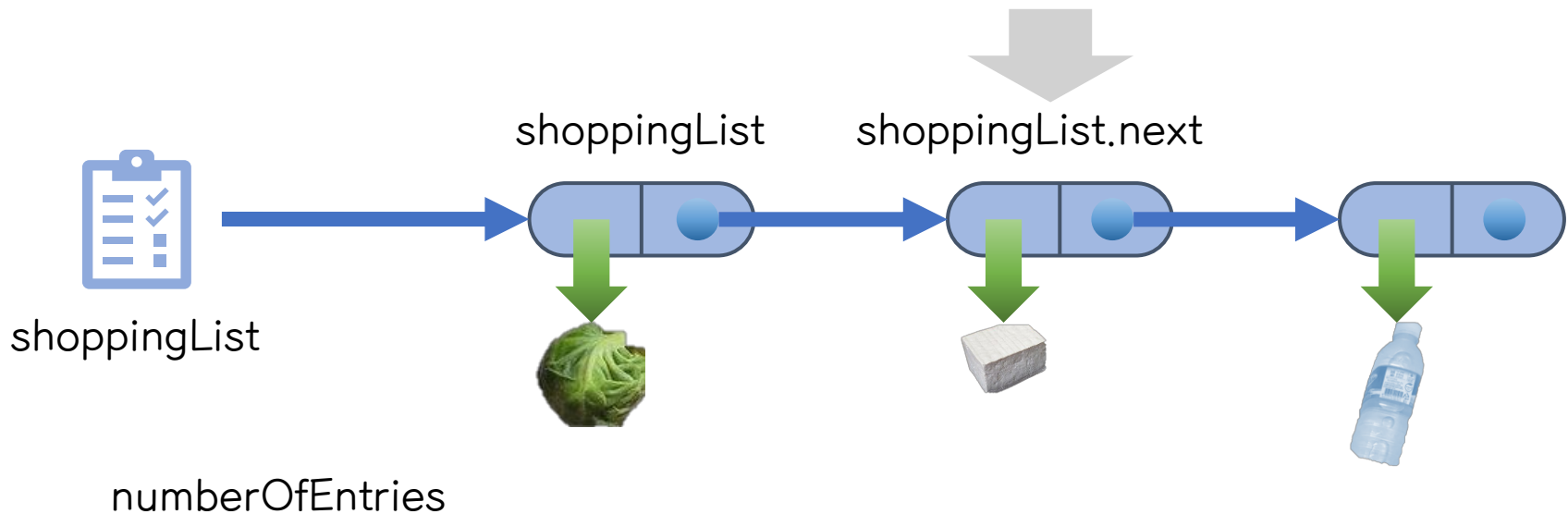
```
shoppingList.add(1, "yogurt");
```

Q: How can we find the location with the given index?

A: temporary point

shoppingList

shoppingList.next.next

shoppingList

numberOfEntries

shoppingList.next

shoppingList.next.next.next
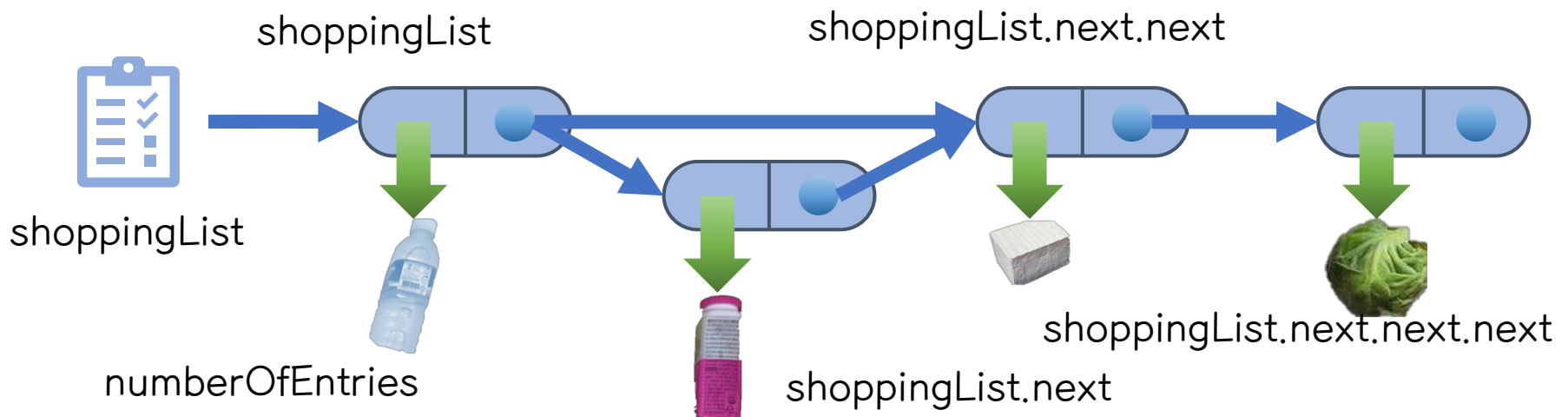
Current point p

- Counting with integer variable: i
- Pointing the current node: p

i =   0

          1

p

shoppingList

numberOfEntries
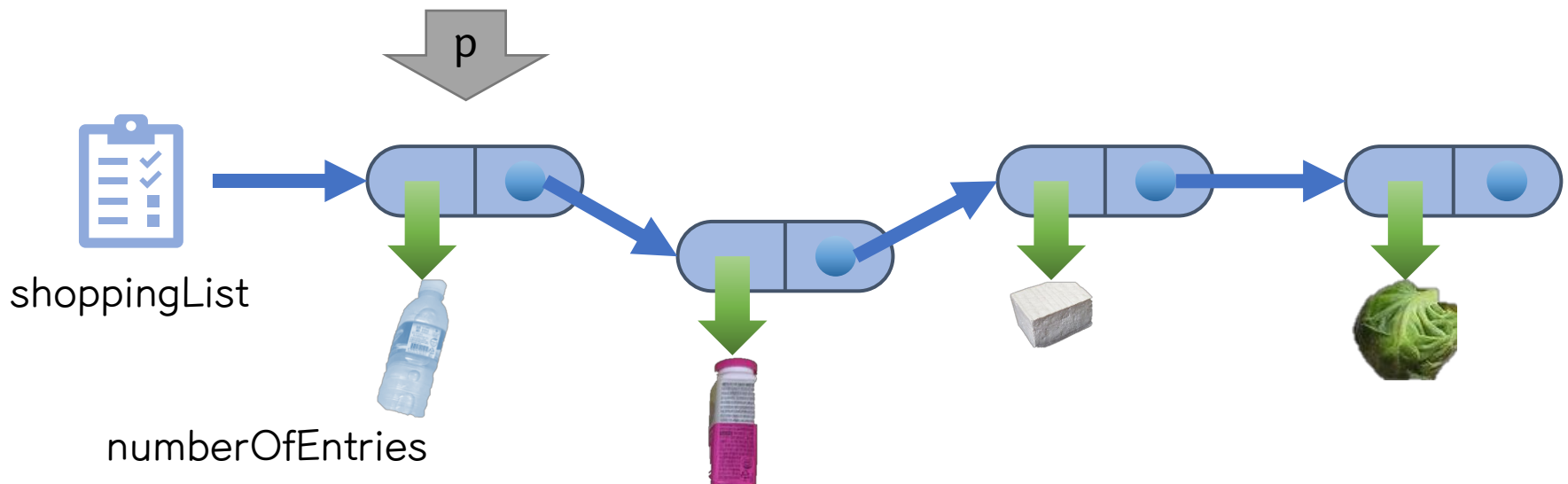
size, toString

```
System.out.println(
        "What I should buy are "
        + shoppingList.size() + " items:"+shoppingList);
```


p

shoppingList

numberOfEntries=3
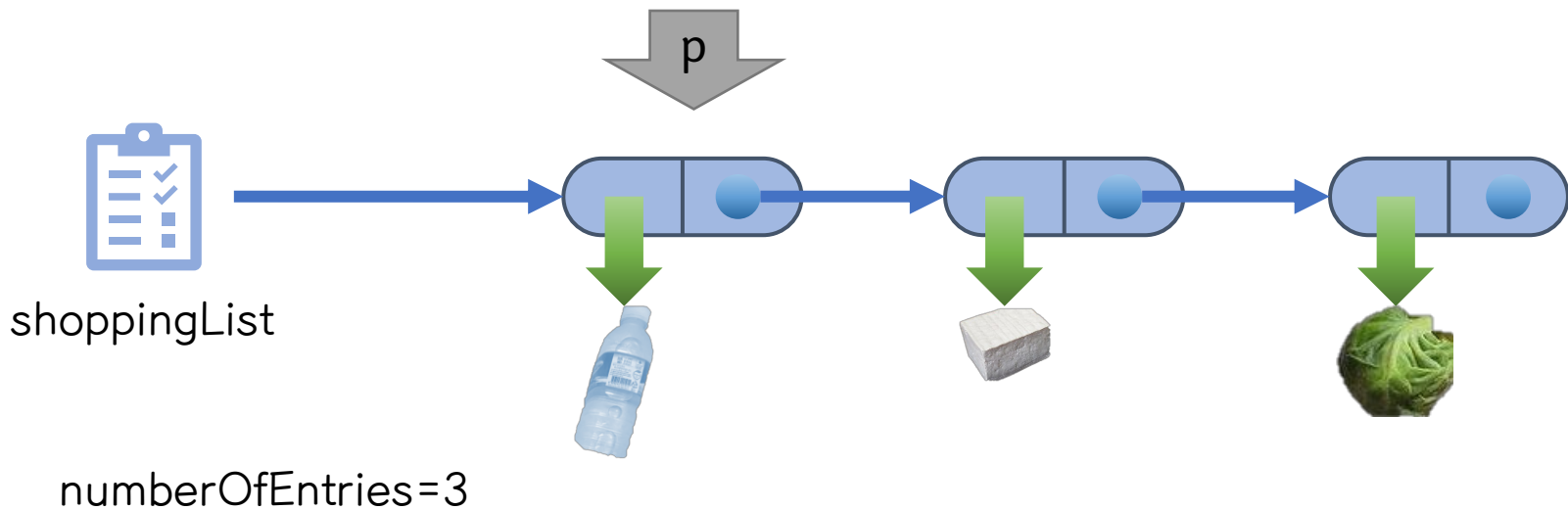
indexOf

```
System.out.println(
        "tofu is located in "+ shoppingList.indexOf("tofu"));
```

Index= 1
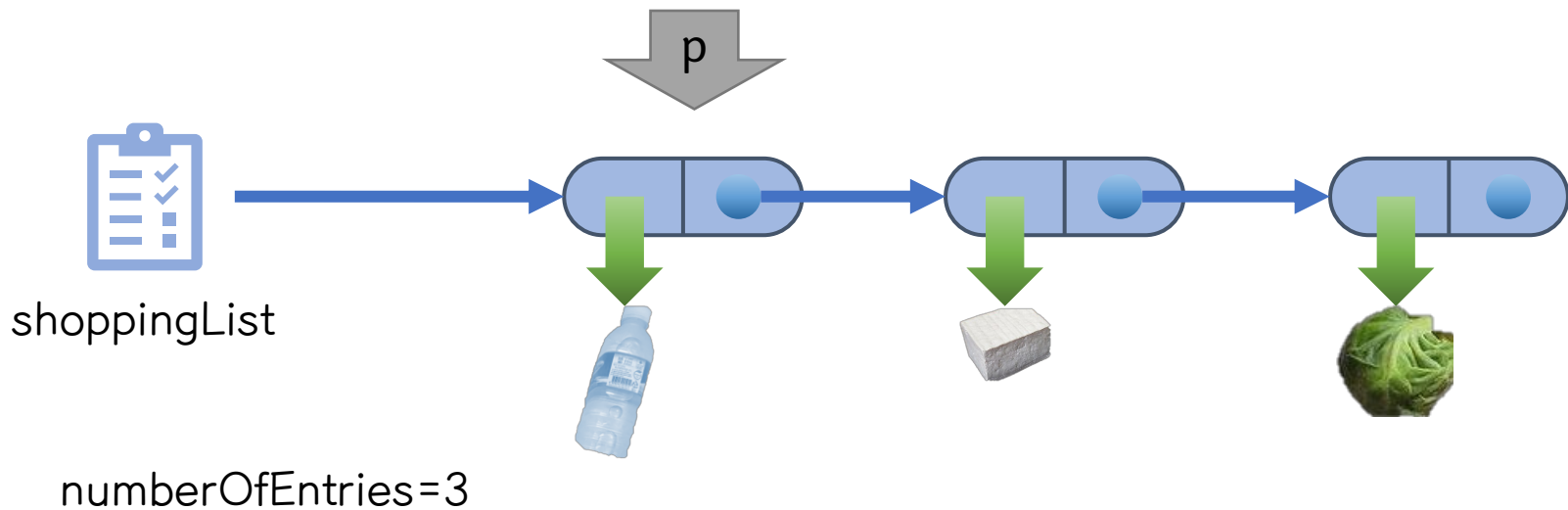
Remove with index

```
System.out.println("I got "+shoppingList.remove(1));
```

How to know who's next is me?

p

shoppingList

numberOfEntries= 2
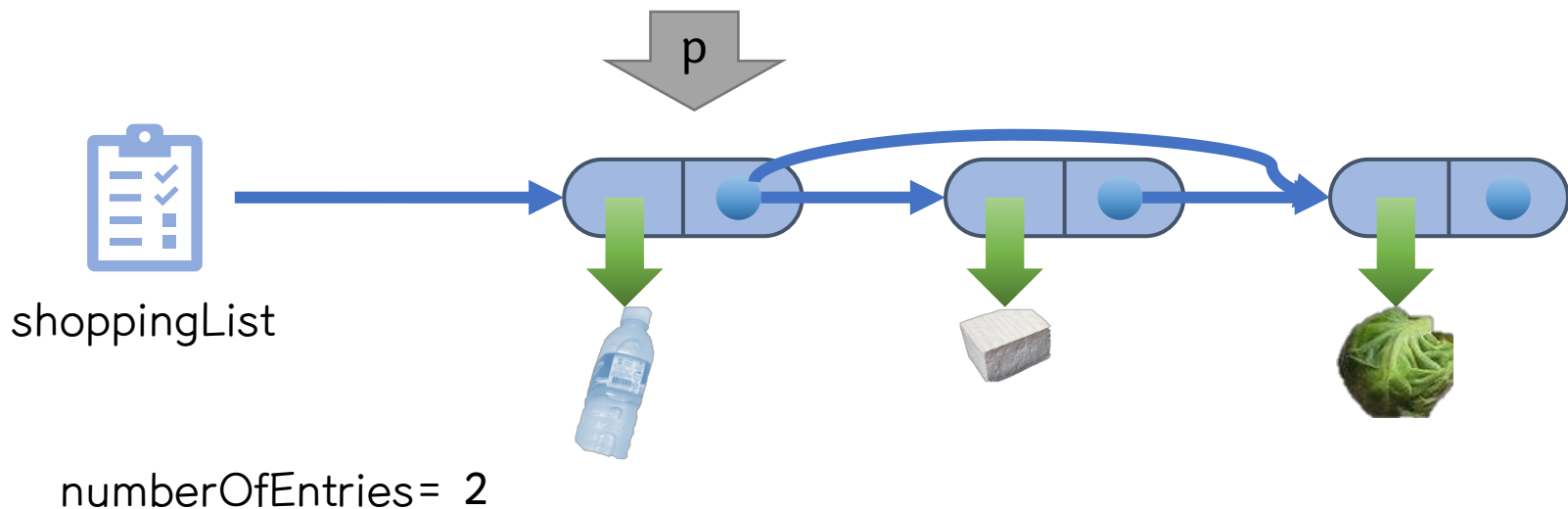
Removing case

- Removing a givenPosition
  - Case 1: the list is empty–return false
  - Case 2: index 0

shoppingList
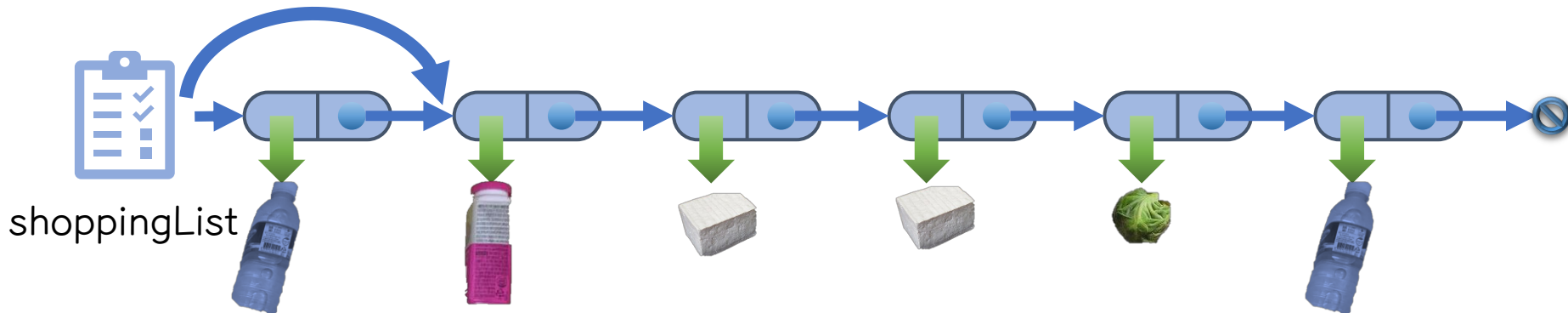
  - Case 3: index is bigger than the size
  - Case 4: other case

Removing

- Case 4

    check the data of p.next not p

```java
for(Node<T> p = list; p.getNextNode() != null  && i < givenPosition;p=p.getNextNode(),i++) {
    if (i+1==givenPosition) {
        T temp = p.getNextNode().getData();
        p.setNextNode(p.getNextNode().getNextNode());//delete it
        numberOfEntries--;
        return temp;
    }
}
```
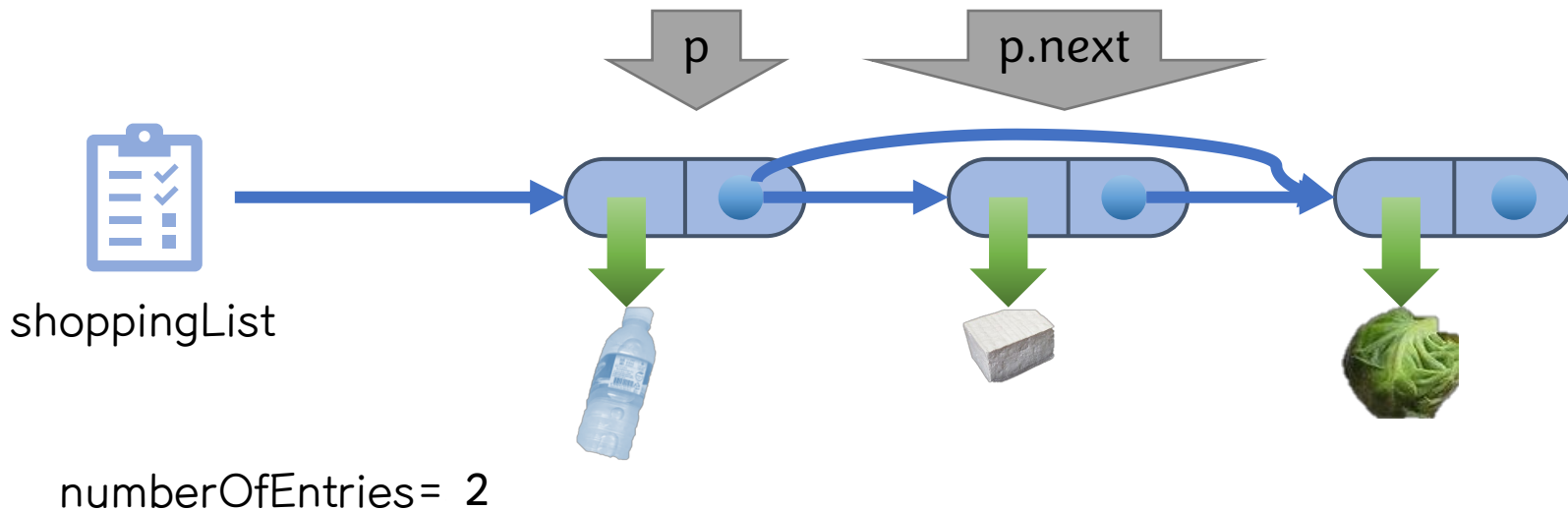

p

p.next

shoppingList

numberOfEntries= 2

Remove with data

```java
if(shoppingList.remove("tofu"))
        System.out.println("I remove tofu.");
```


p

shoppingList

numberOfEntries=2
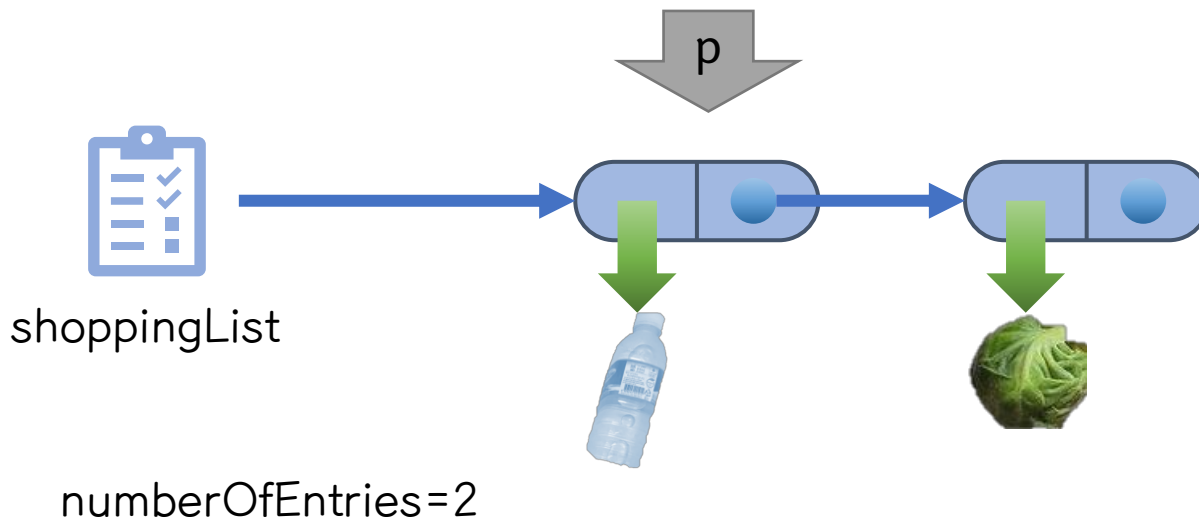
Design issue

- Inner class vs package
  - We need getter and setter methods if you define Node outside of Linked_List.

```java
class Node<T> {
    private T data;
    private Node<T> next;
    Node(T dataPortion) {  // the constructor's name is Node, not Node<T>
        this(dataPortion, null);
    } // end constructor
    Node(T dataPortion, Node<T> nextNode){
        data = dataPortion;
        next = nextNode;
    } // end constructor
    T getData(){
        return data;
    } // end getData
    Node<T> getNextNode(){
        return next;
    } // end getNextNode        getter
    void setData(T newData){
        data = newData;
    } // end setData
    void setNextNode(Node<T> nextNode){      setter
        next = nextNode;
    } // end setNextNode
}
```

Comparing to Array_List

Resizable

Pros

Cons

More memory

Time complexity

ADT operations	Array	Linked
add	O(n)	O(n)
remove	O(n)	O(n)
indexOf	O(n)	O(n)
clear	O(1)	O(1)
size, toArray	O(n)	O(n)

Data Structures . List

Variations

Agenda

- Sorted List

- Singly linked list

- Doubly linked list

- Circular linked list
  - The last node points to the first node instead of null.

ADT List

Sorted List

Responsibilities

add: Adds newEntry to the sorted list so that the list remains sorted

remove: delete element x

remove: delete i^{th} element

get: let the caller know what element is the ith element

indexOf: let the caller know what is the ith element

clear: remove all entries form the list

size: gets the number of entries currently in the list.

add

- precondition: the list is in ascending order;
- postcondition: the list is in ascending order, and it contains x
- Cases
  - Case 1: empty sorted list
  - Case 2: insertion at the front of the list
  - Case 3: attach after the last node
  - Case 4: between two nodes

```java
public void add (T x){
    if (start == null|| start.data.compareTo(x)>0) {
        start=new Node<T>(x,start);
        return;
    }
    Node<T> p = start;
    while (p.next != null ){
        if(p.next.data.compareTo(x)>0) break;
        p=p.next;
    }
    p.next = new Node<T>(x,p.next);
}
```
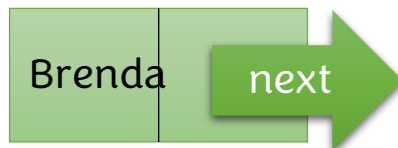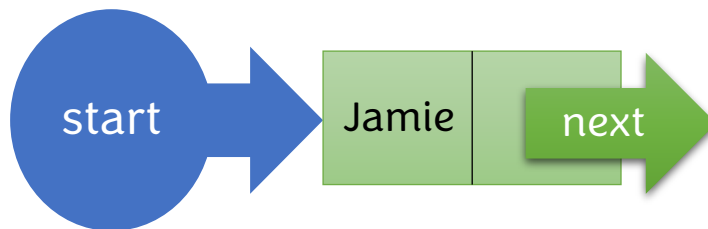
Case 1: empty sorted list

- Client program:

    list.add("Jamie");

```java
public void add (T x){
    if (start == null|| start.data.compareTo(x)>0) {
        start=new Node<T>(x,start);
        return;
    }
    Node<T> p = start;
    while (p.next != null ){
        if(p.next.data.compareTo(x)>0) break;
        p=p.next;
    }
    p.next = new Node<T>(x,p.next);
}
```
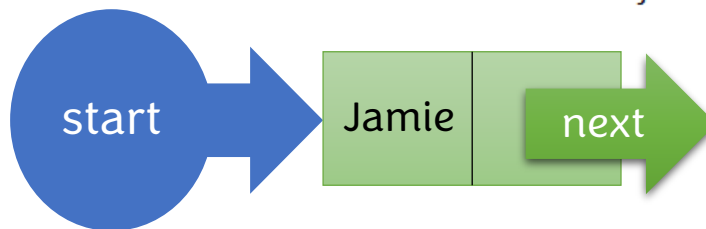
Case 2: insertion at the front of the list
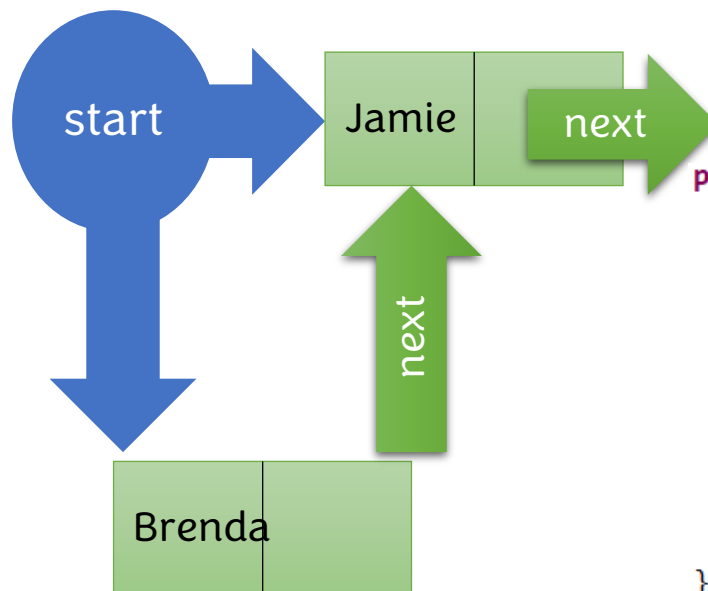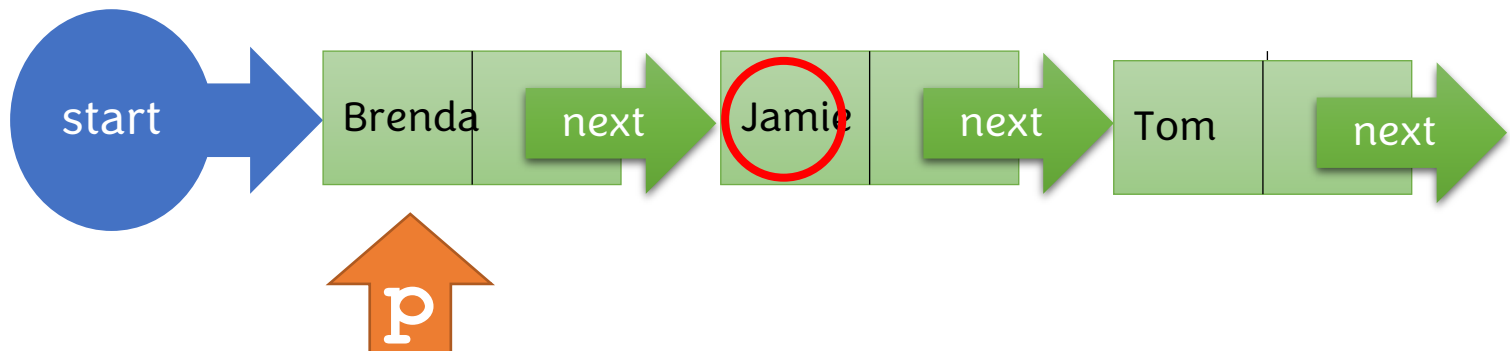
- Client program:

    list.add("Jamie");

    list.add("Brenda");

```
public void add (T x){
    if (start == null|| start.data.compareTo(x)>0) {
        start=new Node<T>(x,start);
        return;
    }
    Node<T> p = start;
    while (p.next != null ){
        if(p.next.data.compareTo(x)>0) break;
        p=p.next;
    }
    p.next = new Node<T>(x,p.next);
}
```

- Case 2: insertion at the front of the list
  - the next of the new node to start.next
  - start.next points the new node

start → Jamie → next

next ↑

Brenda

```java
public void add (T x){
    if (start == null|| start.data.compareTo(x)>0) {
        start=new Node<T>(x,start);
        return;
    }
    Node<T> p = start;
    while (p.next != null ){
        if(p.next.data.compareTo(x)>0) break;
        p=p.next;
    }
    p.next = new Node<T>(x,p.next);
}
```

Case 3: attach after the last node

- Client program:

  list.add("Jamie");

  list.add("Brenda");

  list.add("Tom");

```
public void add (T x){
    if (start == null|| start.data.compareTo(x)>0) {
        start=new Node<T>(x,start);
        return;
    }
    Node<T> p = start;
    while (p.next != null ){
        if(p.next.data.compareTo(x)>0) break;
        p=p.next;
    }
    p.next = new Node<T>(x,p.next);
}
```

Case 4: between two nodes

- Client program:

  list.add("Jamie");

  list.add("Brenda")

  list.add("Tom");

  list.add("Carlos");

```java
public void add (T x){
    if (start == null|| start.data.compareTo(x)>0) {
        start=new Node<T>(x,start);
        return;
    }
    Node<T> p = start;
    while (p.next != null ){
        if(p.next.data.compareTo(x)>0) break;
        p=p.next;
    }
    p.next = new Node<T>(x,p.next);
}
```
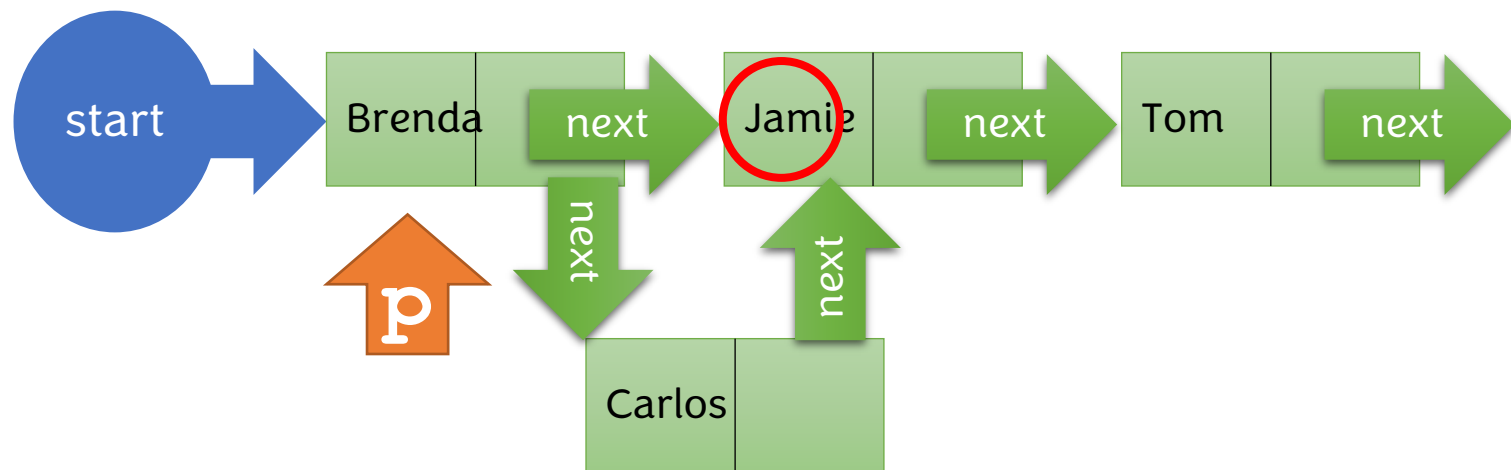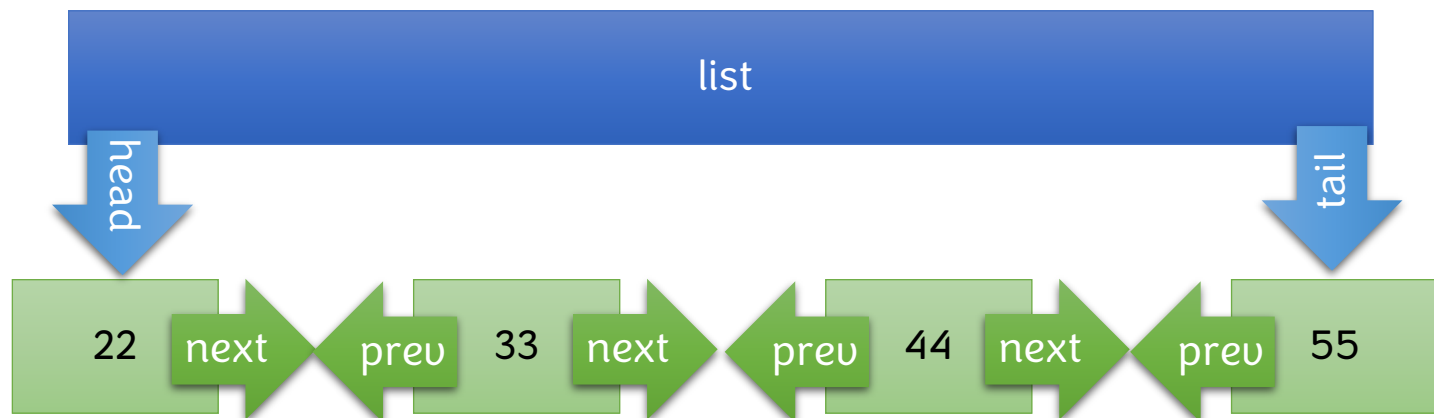
doubly linked list

- A node of a doubly linked list
- a node = data + previous point + next point
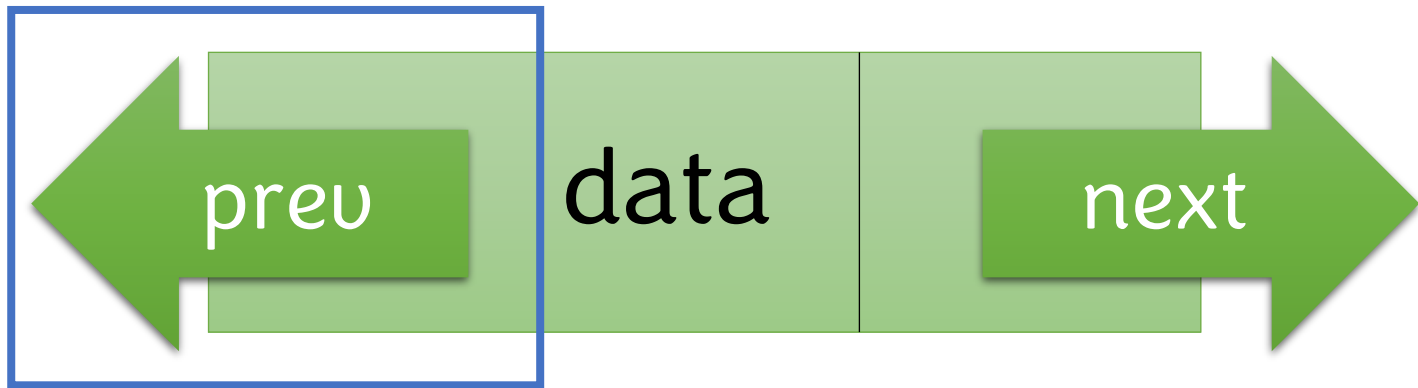

```
Class Node<T> {

    T data; // for data field

    Node prev; // for the previous node

    Node next; // for the next node

}
```
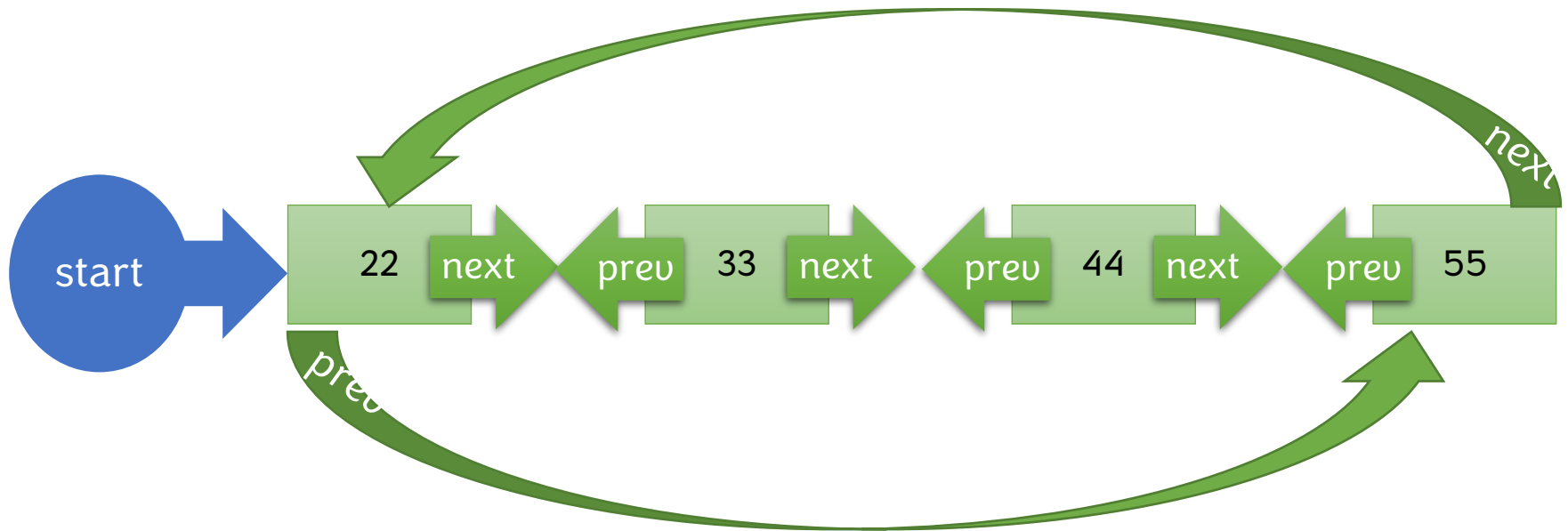
doubly linked list

- Structure of a doubly linked list
- The first and last nodes of a doubly linked list are immediately accessible
- Advantage
  - Allows traversal of nodes in both direction
  - Deque can be implemented using a doubly linked list easily

Circular Linked List

- The last node points to the first node instead of null.

- It can be a singly linked list or a doubly linked list

Thank you!

Questions?   Exit