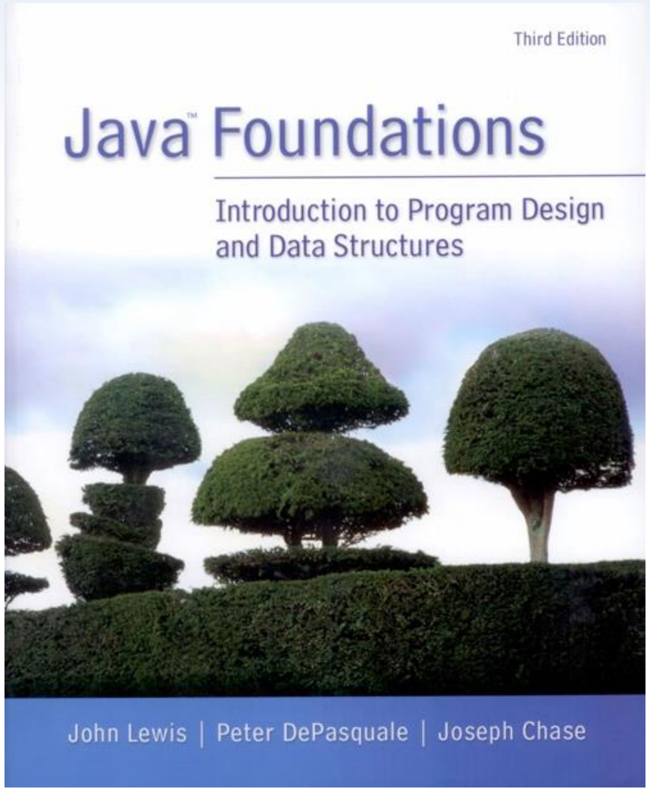

Third Edition
Java Foundations
Introduction to Program Design and Data Structures
John Lewis | Peter DePasquale | Joseph Chase

# Chapter 13

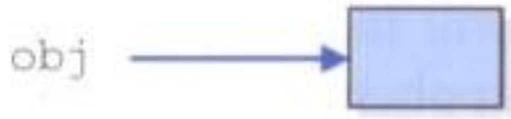
# Linked Structures - Stacks

## Chapter Scope

- Object references as links
- Linked vs. array-based structures
- Managing linked lists
- Linked implementation of a stack

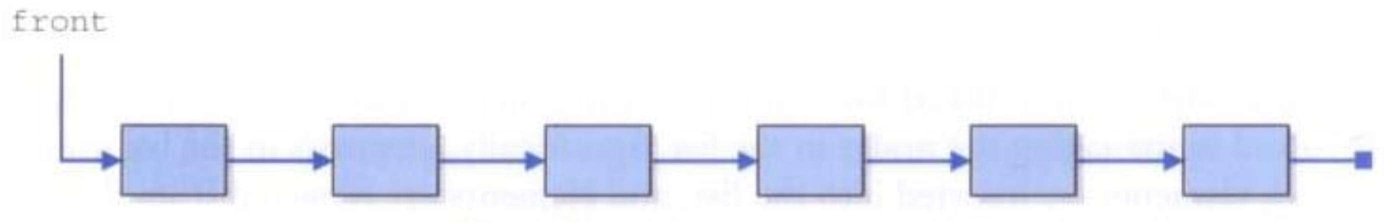
# Linked Structures

- An alternative to array-based implementations are *linked structures*
- A linked structure uses object references to create links between objects
- Recall that an object reference variable holds the address of an object



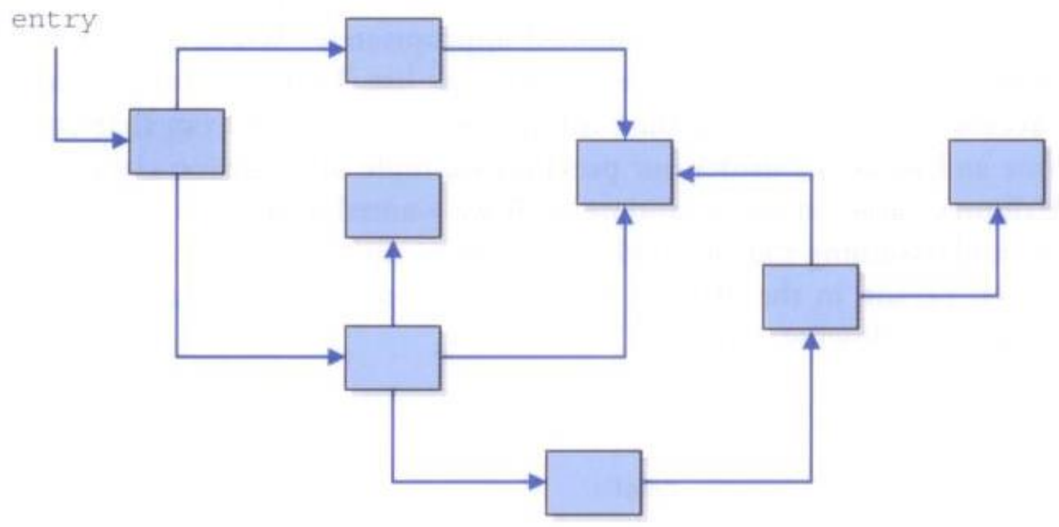
# Linked Structures

- A `Person` object, for instance, could contain a reference to another `Person` object
- A series of `Person` objects would make up a *linked list*:



# Linked Structures

- Links could also be used to form more complicated, non-linear structures



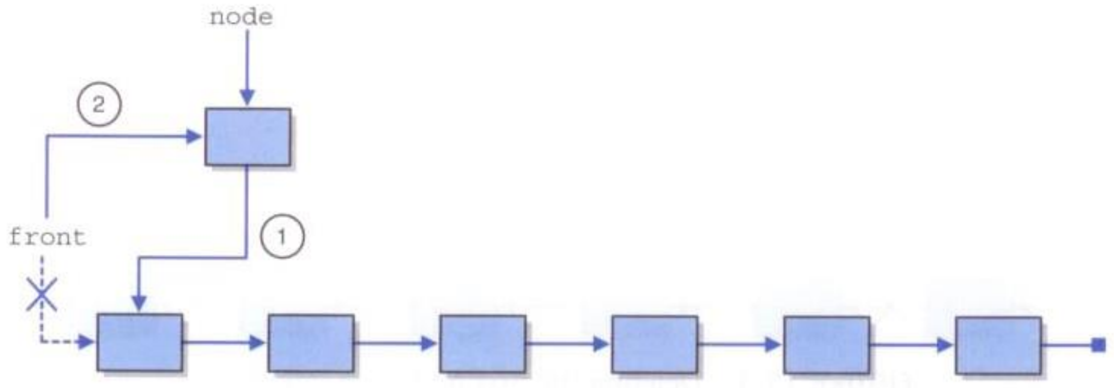
# Linked Lists

- There are no index values built into linked lists
- To access each node in the list you must follow the references from one node to the next

```
Person current = first;
while (current != null)
{
    System.out.println(current);
    current = current.next;
}
```

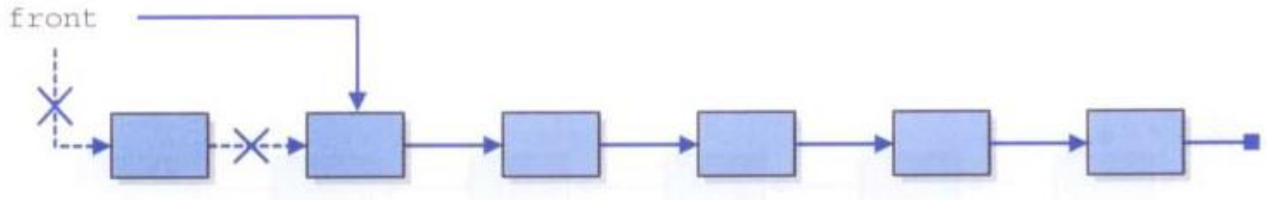
# Linked Lists

- Care must be taken to maintain the integrity of the links
- To insert a node at the front of the list, first point the new node to the front node, then reassign the `front` reference



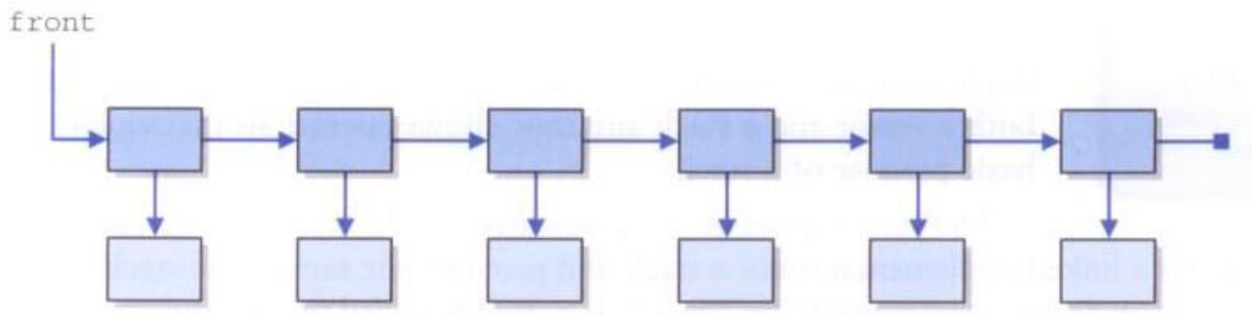
# Linked Lists

- To delete the first node, reassign the `front` reference accordingly
- If the deleted node is needed elsewhere, a reference to it must be established before reassigning the `front` pointer



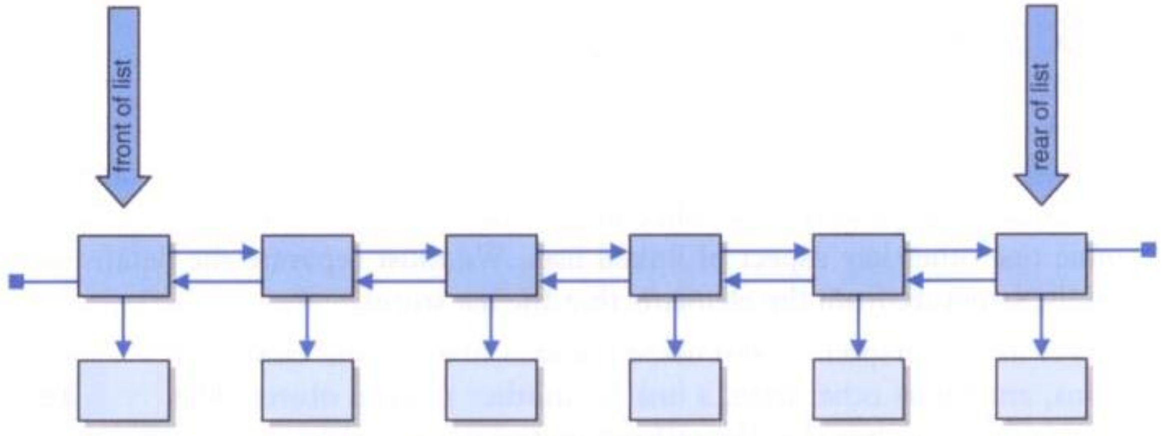
# Linked Lists

- So far we've assumed that the list contains nodes that are *self-referential* (`Person` points to a `Person`)
- But often we'll want to make lists of objects that don't contain such references
- Solution: have a separate `Node` class that forms the list and holds a reference to the objects being stored



# Linked Lists

- There are many variations on the basic linked list concept
- For example, we could create a *doubly-linked list* with `next` and `previous` references in each node and a separate pointer to the rear of the list



## Stacks Revisited

- In the previous chapter we developed our own array-based version of a stack, and we also used the `java.util.Stack` class from the Java API
- The API's stack class is derived from `Vector`, which has many non-stack abilities
- It is, therefore, not the best example of inheritance, because a stack is not a vector
- It's up to the user to use a `Stack` object only as intended

# Stacks Revisited

- Stack characteristics can also be found by using the `Deque` interface from the API
- The `LinkedList` class implements the `Deque` interface
- `Deque` stands for double-ended queue, and will be explored further later
- For now, we will use the stack characteristics of a `Deque` to solve the problem of traversing a maze

# Traversing a Maze

- Suppose a two-dimensional maze is represented as a grid of 1 (path) and 0 (wall)
- Goal: traverse from the upper left corner to the bottom right (no diagonal moves)

```
9 13
1 1 1 0 1 1 0 0 0 1 1 1 1
1 0 0 1 1 0 1 1 1 1 0 0 1
1 1 1 1 1 0 1 0 1 0 1 0 0
0 0 0 0 1 1 1 0 1 0 1 1 1
1 1 1 0 1 1 1 0 1 0 1 1 1
1 0 1 0 0 0 0 1 1 1 0 0 1
1 0 1 1 1 1 1 1 0 1 1 1 1
1 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 1 1 1 1 1 1 1 1 1 1
```

## Traversing a Maze

- Using a stack, we can perform a backtracking algorithm to find a solution to the maze
- An object representing a position in the maze is pushed onto the stack when trying a path
- If a dead end is encountered, the position is popped and another path is tried
- We'll change the integers in the maze grid to represent tried-but-failed paths (2) and the successful path (3)

```java
import java.util.*;
import java.io.*;

/**
 * Maze represents a maze of characters. The goal is to get from the
 * top left corner to the bottom right, following a path of 1's. Arbitrary
 * constants are used to represent locations in the maze that have been TRIED
 * and that are part of the solution PATH.
 *
 * @author Java Foundations
 * @version 4.0
 */
public class Maze
{
    private static final int TRIED = 2;
    private static final int PATH = 3;

    private int numberRows, numberColumns;
    private int[][] grid;
```

```
/**
 * Constructor for the Maze class. Loads a maze from the given file.
 * Throws a FileNotFoundException if the given file is not found.
 *
 * @param filename the name of the file to load
 * @throws FileNotFoundException if the given file is not found
 */
public Maze(String filename) throws FileNotFoundException
{
    Scanner scan = new Scanner(new File(filename));
    numberRows = scan.nextInt();
    numberColumns = scan.nextInt();

    grid = new int[numberRows][numberColumns];
    for (int i = 0; i < numberRows; i++)
        for (int j = 0; j < numberColumns; j++)
            grid[i][j] = scan.nextInt();
}
```

```
/**
 * Marks the specified position in the maze as TRIED
 *
 * @param row the index of the row to try
 * @param col the index of the column to try
 */
public void tryPosition(int row, int col)
{
    grid[row][col] = TRIED;
}

/**
 * Return the number of rows in this maze
 *
 * @return the number of rows in this maze
 */
public int getRows()
{
    return grid.length;
}

/**
 * Return the number of columns in this maze
 *
 * @return the number of columns in this maze
 */
public int getColumns()
{
    return grid[0].length;
}
```

```java
/**
 * Marks a given position in the maze as part of the PATH
 *
 * @param row the index of the row to mark as part of the PATH
 * @param col the index of the column to mark as part of the PATH
 */
public void markPath(int row, int col)
{
    grid[row][col] = PATH;
}

/**
 * Determines if a specific location is valid. A valid location
 * is one that is on the grid, is not blocked, and has not been TRIED.
 *
 * @param row the row to be checked
 * @param column the column to be checked
 * @return true if the location is valid
 */
public boolean validPosition(int row, int column)
{
    boolean result = false;

    // check if cell is in the bounds of the matrix
    if (row >= 0 && row < grid.length &&
        column >= 0 && column < grid[row].length)

        //  check if cell is not blocked and not previously tried
        if (grid[row][column] == 1)
            result = true;

    return result;
}
```

```
    /**
     * Returns the maze as a string.
     *
     * @return a string representation of the maze
     */
    public String toString()
    {
        String result = "\n";

        for (int row=0; row < grid.length; row++)
        {
            for (int column=0; column < grid[row].length; column++)
                result += grid[row][column] + "";
            result += "\n";
        }

        return result;
    }
}
```

```java
import java.util.*;

/**
 * MazeSolver attempts to traverse a Maze using a stack. The goal is to get from the
 * given starting position to the bottom right, following a path of 1's. Arbitrary
 * constants are used to represent locations in the maze that have been TRIED
 * and that are part of the solution PATH.
 *
 * @author Java Foundations
 * @version 4.0
 */
public class MazeSolver
{
    private Maze maze;

    /**
     * Constructor for the MazeSolver class.
     */
    public MazeSolver(Maze maze)
    {
        this.maze = maze;
    }
```

```
/**
 * Attempts to traverse the maze using a stack. Inserts special
 * characters indicating locations that have been TRIED and that
 * eventually become part of the solution PATH.
 *
 * @param row row index of current location
 * @param column column index of current location
 * @return true if the maze has been solved
 */
public boolean traverse()
{
    boolean done = false;
    int row, column;
    Position pos = new Position();
    Deque<Position> stack = new LinkedList<Position>();
    stack.push(pos);

    while (!(done) && !stack.isEmpty())
    {
        pos = stack.pop();
        maze.tryPosition(pos.getx(),pos.gety());  // this cell has been tried
        if (pos.getx() == maze.getRows()-1 && pos.gety() == maze.getColumns()-1)
            done = true;  // the maze is solved
        else
        {
            push_new_pos(pos.getx() - 1,pos.gety(), stack);
            push_new_pos(pos.getx() + 1,pos.gety(), stack);
            push_new_pos(pos.getx(),pos.gety() - 1, stack);
            push_new_pos(pos.getx(),pos.gety() + 1, stack);
        }
    }

    return done;
}
```

```
    /**
     * Push a new attempted move onto the stack
     * @param x represents x coordinate
     * @param y represents y coordinate
     * @param stack the working stack of moves within the grid
     * @return stack of moves within the grid
     */
    private void push_new_pos(int x, int y,
                                         Deque<Position> stack)
    {
        Position npos = new Position();
        npos.setx(x);
        npos.sety(y);
        if (maze.validPosition(x,y))
            stack.push(npos);
    }
}
```

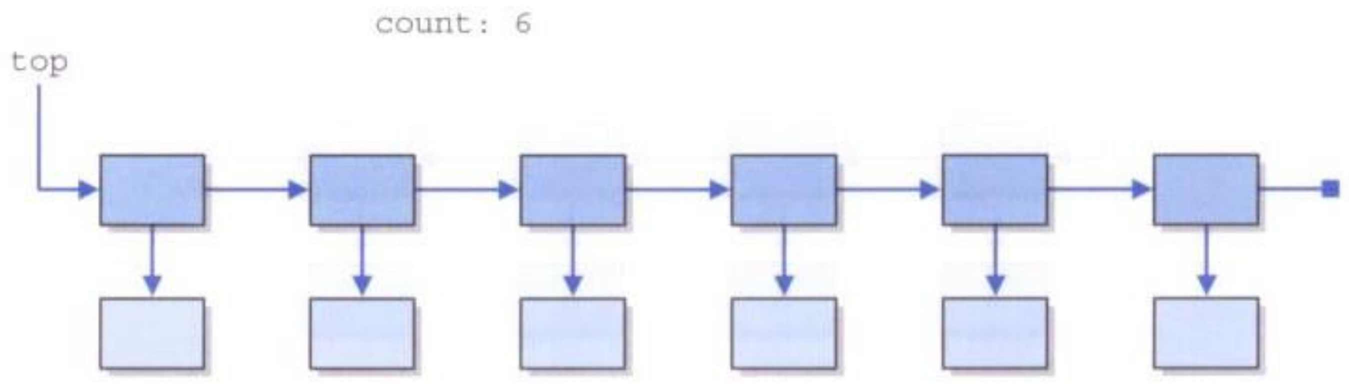
```java
import java.util.*;
import java.io.*;

/**
 * MazeTester determines if a maze can be traversed.
 *
 * @author Java Foundations
 * @version 4.0
 */
public class MazeTester
{
    /**
     * Creates a new maze, prints its original form, attempts to
     * solve it, and prints out its final form.
     */
    public static void main(String[] args) throws FileNotFoundException
    {
        Scanner scan = new Scanner(System.in);
        System.out.print("Enter the name of the file containing the maze: ");
        String filename = scan.nextLine();

        Maze labyrinth = new Maze(filename);

        System.out.println(labyrinth);

        MazeSolver solver = new MazeSolver(labyrinth);

        if (solver.traverse())
            System.out.println("The maze was successfully traversed!");
        else
            System.out.println("There is no possible path.");

        System.out.println(labyrinth);
    }
}
```

## Implementing a Stack using Links

- Let's now implement our own version of a stack that uses a linked list to hold the elements
- Our `LinkedStack<T>` class stores a generic type `T` and implements the same `StackADT<T>` interface used previously
- A separate `LinearNode<T>` class forms the list and hold a reference to the element stored
- An integer `count` will store how many elements are currently in the stack

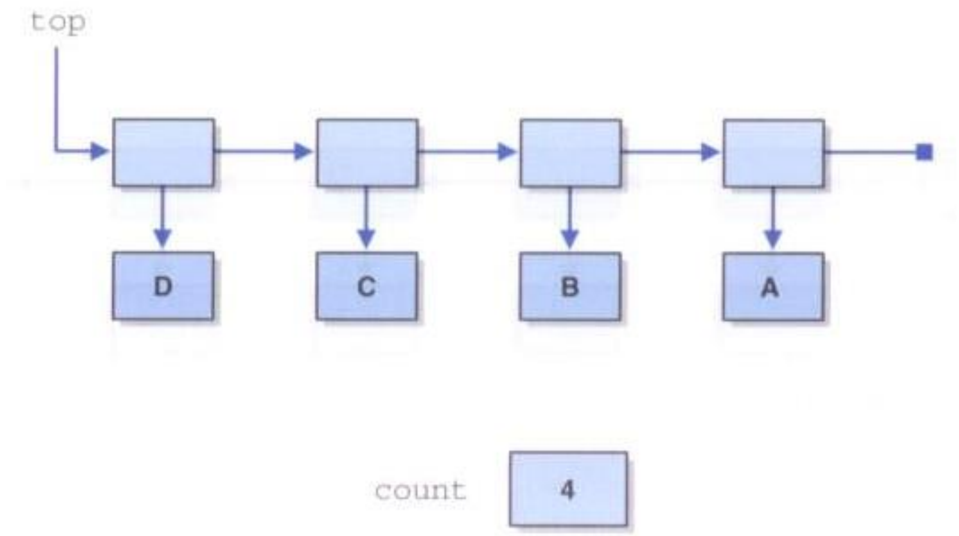
## Implementing a Stack using Links

- Since all activity on a stack happens on one end, a single reference to the front of the list will represent the top of the stack



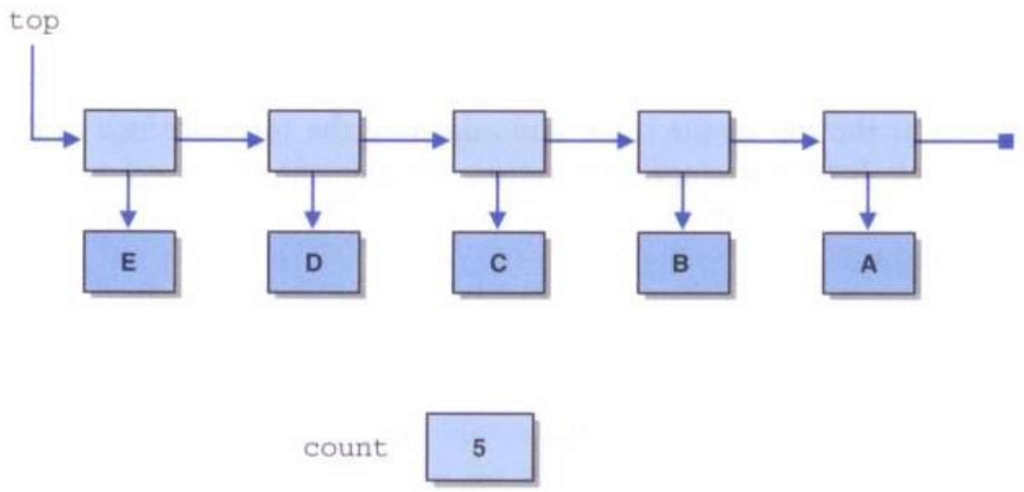
# Implementing a Stack using Links

- The stack after A, B, C, and D are pushed, in that order:



# Implementing a Stack using Links

- After E is pushed onto the stack:

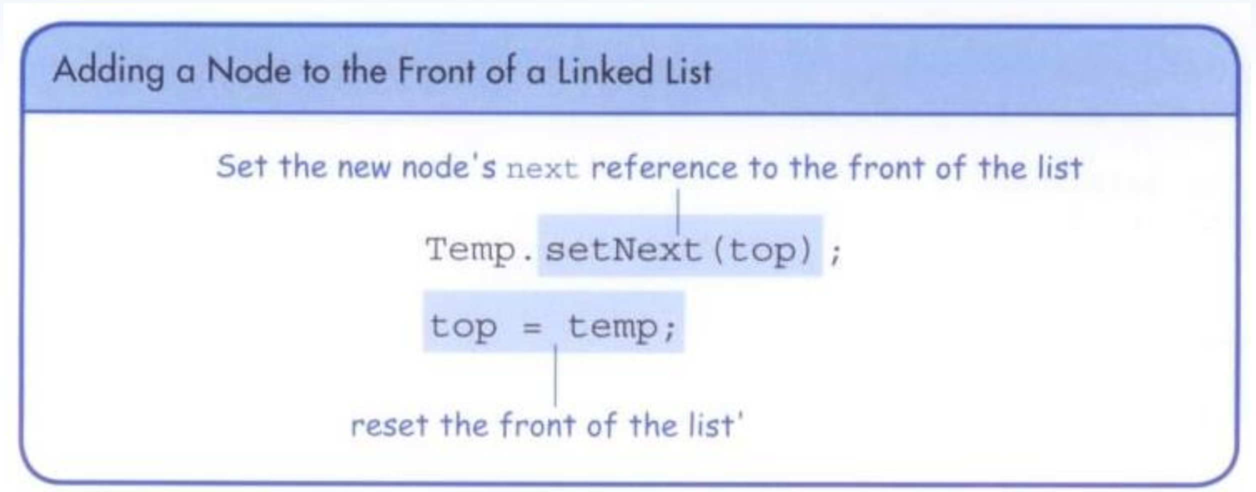


```java
package jsjf;

/**
 * Represents a node in a linked list.
 *
 * @author Java Foundations
 * @version 4.0
 */
public class LinearNode<T>
{
    private LinearNode<T> next;
    private T element;

    /**
     * Creates an empty node.
     */
    public LinearNode()
    {
        next = null;
        element = null;
    }

    /**
     * Creates a node storing the specified element.
     * @param elem element to be stored
     */
    public LinearNode(T elem)
    {
        next = null;
        element = elem;
    }
    /**
     * Returns the node that follows this one.
     * @return reference to next node
     */
    public LinearNode<T> getNext()
    {
        return next;
    }

    /**
     * Sets the node that follows this one.
     * @param node node to follow this one
     */
    public void setNext(LinearNode<T> node)
    {
        next = node;
    }

    /**
     * Returns the element stored in this node.
     * @return element stored at the node
     */
    public T getElement()
    {
        return element;
    }

    /**
     * Sets the element stored in this node.
     * @param elem element to be stored at this node
     */
    public void setElement(T elem)
    {
        element = elem;
    }
}
```

```
package jsjf;

import jsjf.exceptions.*;
import java.util.Iterator;

/**
 * Represents a linked implementation of a stack.
 *
 * @author Java Foundations
 * @version 4.0
 */
public class LinkedStack<T> implements StackADT<T>
{
    private int count;
    private LinearNode<T> top;

    /**
     * Creates an empty stack.
     */
    public LinkedStack()
    {
        count = 0;
        top = null;
    }
```

```
/**
 * Adds the specified element to the top of this stack.
 * @param element element to be pushed on stack
 */
public void push(T element)
{
    LinearNode<T> temp = new LinearNode<T>(element);

    temp.setNext(top);
    top = temp;
    count++;
}

/**
 * Removes the element at the top of this stack and returns a
 * reference to it.
 * @return element from top of stack
 * @throws EmptyCollectionException if the stack is empty
 */
public T pop() throws EmptyCollectionException
{
    if (isEmpty())
        throw new EmptyCollectionException("stack");

    T result = top.getElement();
    top = top.getNext();
    count--;

    return result;
}
```

# Implementing a Stack using Links


Adding a Node to the Front of a Linked List
Set the new node's next reference to the front of the list
reset the front of the list'

```
Temp.setNext(top);
top = temp;
```