4.3 Stacks, Queues, and Linked Lists
Data Types and Data Structures

Data types: Set of values and operations on those values.

• Some are built into the Java language: `int`, `double[]`, `String`, ...
• Most are not: `Complex`, `Picture`, `Stack`, `Queue`, `ST`, `Graph`, ...

Data structures:

• Represent data or relationships among data.
• Some are built into Java language: arrays.
• Most are not: linked list, circular list, tree, sparse array, graph, ...

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Collections

Fundamental data types:
• Set of operations (add, remove, test if empty) on generic data.
• Intent is clear when we insert.
• Which item do we remove?

Stack:  [LIFO = last in first out]
• Remove the item most recently added.
• Ex:  Pez, cafeteria trays, Web surfing.

Queue:  [FIFO = first in, first out]
• Remove the item least recently added.
• Ex:  Line for help in TA office hours.

Symbol table:
• Remove the item with a given key.
• Ex:  Phone book.
Stack API

```java
class StackOfStrings {
    StackOfStrings() {
        // create an empty stack
    }
    boolean isEmpty() {
        // is the stack empty?
    }
    void push(String item) {
        // push a string onto the stack
    }
    String pop() {
        // pop the stack
    }
}
```

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public class Reverse {
    public static void main(String[] args) {
        StackOfStrings stack = new StackOfStrings();
        while (!StdIn.isEmpty()) {
            String s = StdIn.readString();
            stack.push(s);
        }
        while (!stack.isEmpty()) {
            String s = stack.pop();
            StdOut.println(s);
        }
    }
}

% more tiny.txt
it was the best of times

% java Reverse < tiny.txt
times of best the was it

stack contents when standard input is empty
Array implementation of a stack.

- Use array \(a[\ldots]\) to store \(N\) items on stack.
- \texttt{push()} add new item at \(a[N]\).
- \texttt{pop()} remove item from \(a[N-1]\).

```
public class ArrayStackOfStrings {
  private String[] a;
  private int N = 0;

  public ArrayStackOfStrings(int max) { a = new String[max]; }
  public boolean isEmpty() { return (N == 0); }
  public void push(String item) { a[N] = item; N++; }
  public String pop() { N--; return a[N]; }
}
```

Temporary solution: make client provide capacity.
Linked Lists

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Official Florida Presidential Ballot
Follow the arrow and Punch the appropriate dot.

Bush

Buchanan

Gore

Nader

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Sequential vs. Linked Allocation

Sequential allocation: Put items one after another.
- TOY: consecutive memory cells.
- Java: array of objects.

Linked allocation: Include in each object a link to the next one.
- TOY: link is memory address of next item.
- Java: link is reference to next item.

Key distinctions:
- Array: random access, fixed size.
- Linked list: sequential access, variable size.
Singly-Linked Data Structures

From the point of view of a particular object:
all of these structures look the same!

Multiply-linked data structures: Many more possibilities.

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Linked Lists

Linked list:
• A recursive data structure.
• An item plus a pointer to another linked list (or empty list).
  — Unwind recursion: linked list is a sequence of items.

Node data type:
• A reference to a `String`.
• A reference to another `Node`.

```java
public class Node {
    public String item;
    public Node next;
}
```

First item next special pointer value `null` terminates list
Building a Linked List

Node third = new Node();
third.item = "Carol";
third.next = null;

Node second = new Node();
second.item = "Bob";
second.next = third;

Node first = new Node();
first.item = "Alice";
first.next = second;

addr | Value
--- | ---
C0 | "Carol"
C1 | null
C2 | -
C3 | -
C4 | "Alice"
C5 | CA
C6 | -
C7 | -
C8 | -
C9 | -
CA | "Bob"
CB | C0
CC | -
CD | -
CE | -
CF | -
Stack Push: Linked List Implementation

Node second = first;

first = new Node();

first.item = "of";
f first.next = second;
Stack Pop: Linked List Implementation

first

of → best → the → was → it

String item = first.item;

"of"

garbage-collected

first

of

best → the → was → it

first = first.next;

return item;

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public class LinkedStackOfStrings {
    private Node first = null;

    private class Node {
        private String item;
        private Node next;
    }

    public boolean isEmpty() { return first == null; }

    public void push(String item) {
        Node second = first;
        first = new Node();
        first.item = item;
        first.next = second;
    }

    public String pop() {
        String item = first.item;
        first = first.next;
        return item;
    }
}
Linked List Stack: Test Client Trace

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Stack Data Structures: Tradeoffs

Two data structures to implement Stack data type.

Array:
• Every push/pop operation take constant time.
• But... must fix maximum capacity of stack ahead of time.

Linked list:
• Every push/pop operation takes constant time.
• Memory is proportional to number of items on stack.
• But... uses extra space and time to deal with references.
List Processing Challenge 1

What does the following code fragment do?

```java
for (Node x = first; x != null; x = x.next) {
    System.out.println(x.item);
}
```
List Processing Challenge 2

What does the following code fragment do?

```java
Node last = new Node();
last.item = 5;
last.next = null;
Node first = last;
for (int i = 1; i < 6; i++) {
    last.next = new Node();
    last = last.next;
    last.item = i;
    last.next = null;
}
```