Chapter 14
stacks and queues

reading: 14.1-14.4
Abstract data types (ADTs)

- **abstract data type (ADT):** A specification of a collection of data and the operations that can be performed on it.
  - Describes *what* a collection does, not *how* it does it.

- We don't know exactly how a the collections is implemented, and we don't need to.
  - We just need to understand the idea of the collection and what operations it can perform.
Stacks and queues

- Some collections are constrained so clients can only use optimized operations
  - **stack**: retrieves elements in reverse order as added
  - **queue**: retrieves elements in same order as added

```
top | 3  | 2  | 1  |
     |    |    |    |
bottom```

```
front | 1  | 2  | 3  |
      |    |    |    |
back  |    |    |    |
```
Stack Example

push

bottom

pop
top
Stacks

- **stack**: A collection based on the principle of adding elements and retrieving them in the opposite order.
  - Last-In, First-Out ("LIFO")
  - Elements are stored in order of insertion.
    - We do not think of them as having indexes.
  - Client can only add/remove/examine the last element added (the "top").

- basic stack operations:
  - **push**: Add an element to the top.
  - **pop**: Remove the top element.
  - **peek**: Examine the top element.
Stacks in computer science

- Programming languages and compilers:
  - method calls are placed onto a stack (call=push, return=pop)
  - compilers use stacks to evaluate expressions

- Matching up related pairs of things:
  - find out whether a string is a palindrome
  - examine a file to see if its braces `{ }` match
  - convert "infix" expressions to pre/postfix

- Sophisticated algorithms:
  - searching through a maze with "backtracking"
  - many programs use an "undo stack" of previous operations
## Class Stack

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stack&lt;E&gt;()</td>
<td>constructs a new stack with elements of type E</td>
</tr>
<tr>
<td>push(value)</td>
<td>places given value on top of stack</td>
</tr>
<tr>
<td>pop()</td>
<td>removes top value from stack and returns it; throws EmptyStackException if stack is empty</td>
</tr>
<tr>
<td>peek()</td>
<td>returns top value from stack without removing it; throws EmptyStackException if stack is empty</td>
</tr>
<tr>
<td>size()</td>
<td>returns number of elements in stack</td>
</tr>
<tr>
<td>isEmpty()</td>
<td>returns true if stack has no elements</td>
</tr>
</tbody>
</table>

```java
Stack<String> s = new Stack<String>();
s.push("a");
s.push("b");
s.push("c");     // bottom ["a", "b", "c"] top
System.out.println(s.pop()); // "c"
```

- Stack has other methods that are off-limits (not efficient)
Collections of primitives

- The type parameter specified when creating a collection (e.g. `ArrayList`, `Stack`, `Queue`) must be an object type.

```java
// illegal -- int cannot be a type parameter
Stack<int> s = new Stack<int>();
ArrayList<int> list = new ArrayList<int>();
```

- Primitive types need to be "wrapped" in objects.

```java
// creates a stack of ints
Stack<Integer> s = new Stack<Integer>();
```
Stack limitations/idioms

- You cannot loop over a stack in the usual way.

  ```java
  Stack<Integer> s = new Stack<Integer>();
  ...
  for (int i = 0; i < s.size(); i++) {
      do something with s.get(i);
  }
  ```

- Instead, you pull elements out of the stack one at a time.
  - common idiom: Pop each element until the stack is empty.

  ```java
  // process (and destroy) an entire stack
  while (!s.isEmpty()) {
      do something with s.pop();
  }
  ```
What happened to my stack?

Suppose we're asked to write a method `max` that accepts a Stack of integers and returns the largest integer in the stack:

```java
// Precondition: !s.isEmpty()
public static void max(Stack<Integer> s) {
    int maxValue = s.pop();
    while (!s.isEmpty()) {
        int next = s.pop();
        maxValue = Math.max(maxValue, next);
    }
    return maxValue;
}
```

The algorithm is correct, but what is wrong with the code?
What happened to my stack?

- The code destroys the stack in figuring out its answer.
- To fix this, you must save and restore the stack's contents:

```java
public static void max(Stack<Integer> s) {
    Stack<Integer> backup = new Stack<Integer>();
    int maxValue = s.pop();
    backup.push(maxValue);
    while (!s.isEmpty()) {
        int next = s.pop();
        backup.push(next);
        maxValue = Math.max(maxValue, next);
    }
    while (!backup.isEmpty()) { // restore
        s.push(backup.pop());
    }
    return maxValue;
}
```
Queue Example

add

remove

front

add

back
**Queues**

- **queue**: Retrieves elements in the order they were added.
  - First-In, First-Out ("FIFO")
  - Elements are stored in order of insertion but don't have indexes.
  - Client can only add to the end of the queue, and can only examine/remove the front of the queue.

- **basic queue operations**:  
  - **add** (enqueue): Add an element to the back.  
  - **remove** (dequeue): Remove the front element.  
  - **peek**: Examine the front element.
Queues in computer science

• Operating systems:
  • queue of print jobs to send to the printer
  • queue of programs / processes to be run
  • queue of network data packets to send

• Programming:
  • modeling a line of customers or clients
  • storing a queue of computations to be performed in order

• Real world examples:
  • people on an escalator or waiting in a line
  • cars at a gas station (or on an assembly line)
Programming with Queues

<table>
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<th>Method</th>
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<tr>
<td>add(value)</td>
<td>places given value at back of queue</td>
</tr>
<tr>
<td>remove()</td>
<td>removes value from front of queue and returns it; throws a NoSuchElementException if queue is empty</td>
</tr>
<tr>
<td>peek()</td>
<td>returns front value from queue without removing it; returns null if queue is empty</td>
</tr>
<tr>
<td>size()</td>
<td>returns number of elements in queue</td>
</tr>
<tr>
<td>isEmpty()</td>
<td>returns true if queue has no elements</td>
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</table>

Queue<Integer> q = new **LinkedList**<Integer>();
q.add(42);
q.add(-3);
q.add(17);  // front [42, -3, 17] back
System.out.println(q.remove());  // 42

• **IMPORTANT**: When constructing a queue you must use a new LinkedList object instead of a new Queue object.
• This is because Queue is an interface
Queue idioms

- As with stacks, must pull contents out of queue to view them.

```java
// process (and destroy) an entire queue
while (!q.isEmpty()) {
    do something with q.remove();
}
```

- another idiom: Examining each element exactly once.

```java
int size = q.size();
for (int i = 0; i < size; i++) {
    do something with q.remove();
    (including possibly re-adding it to the queue)
}
```

- Why do we need the `size` variable?
Mixing stacks and queues

- We often mix stacks and queues to achieve certain effects.
  - Example: Reverse the order of the elements of a queue.

```java
Queue<Integer> q = new LinkedList<Integer>();
q.add(1);
q.add(2);
q.add(3);  // [1, 2, 3]

Stack<Integer> s = new Stack<Integer>();
while (!q.isEmpty()) {  // Q -> S
    s.push(q.remove());
}
while (!s.isEmpty()) {  // S -> Q
    q.add(s.pop());
}
System.out.println(q);  // [3, 2, 1]
```
Exercises

• Write a method `repeat` that accepts a queue of integers as a parameter and replaces every element of the queue with two copies of that element.
  - front [1, 2, 3] back becomes front [1, 1, 2, 2, 3, 3] back

• Write a method `mirror` that accepts a queue of strings as a parameter and appends the queue's contents to itself in reverse order.
  - front [a, b, c] back becomes front [a, b, c, c, b, a] back