CSE373: Data Structures and Algorithms

Lecture 1: Introduction; ADTs; Stacks/Queues

Catie Baker

Spring 2015

Registration

- We have 150 students registered and many on the wait list!
- If you're thinking of dropping the course please decide *soon!*

Wait listed students

- Please sign up on the paper waiting list after class, so I know who you are.
- If you think you absolutely have to take the course this quarter, speak to the CSE undergraduate advisors.
- The CSE advisors and I will decide by end of Friday who gets in.

Welcome!

We have 10 weeks to learn *fundamental data structures and algorithms for organizing and processing information*

- "Classic" data structures / algorithms
- How to rigorously analyze their efficiency
- How to decide when to use them
- Queues, dictionaries, graphs, sorting, etc.

Today in class:

- Introductions and course mechanics
- What this course is about
- Start *abstract data types* (ADTs), *stacks*, and *queues*
  - Largely review

To-do list

In next 24-48 hours:

- Read the web page
- Read all course policies
- Read Chapters 3.1 (lists), 3.6 (stacks) and 3.7 (queues) of the Weiss book
  - Relevant to Homework 1, due next week
- Set up your Java environment for Homework 1

http://courses.cs.washington.edu/courses/cse373/15sp/

Course staff

Catie Baker
3rd Year CSE Ph.D. Grad Student
Works with Richard Ladner in Accessibility


Conrad Nied


Yunyi Song


Andy Li


Rama Gokhale

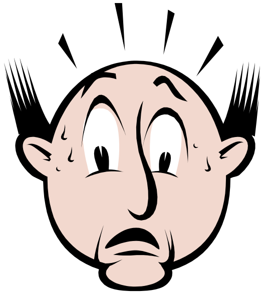

Luyi Lu


Cyndi Ai

Office hours, email, etc. on course web-page

Communication

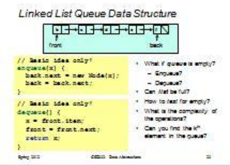
- Course email list: **`cse373a_15sp@u.washington.edu`**
  - Students and staff already subscribed
  - You must get announcements sent there
  - Fairly low traffic
- Course staff: **`cse373-staff@cs.washington.edu`**
- Discussion board
  - For appropriate discussions; TAs will monitor
  - Encouraged, but won't use for important announcements
- Anonymous feedback link
  - For good and bad, but please be gentle.



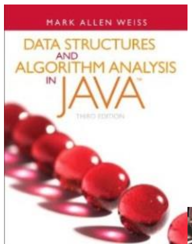
Course meetings

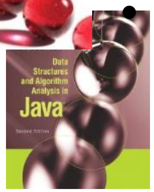
- Lecture
  - Materials posted, but take notes
  - Ask questions, focus on key ideas (rarely coding details)
- Optional help sessions
  - Help on programming/tool background
  - Helpful math review and example problems
  - Again, optional but helpful
  - May cancel some later in course (experimental)
- Office hours
  - Use them: *please visit me for talking about course concepts or just CSE in general.*

Course materials



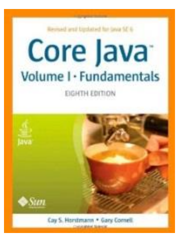
- All lecture will be posted
  - But they are visual aids, not always a complete description!
  - If you have to miss, find out what you missed





- Textbook: Weiss 3rd Edition in Java

- A good Java reference of your choosing
  - Don’t struggle Googling for features you don’t understand



Computer Lab

- College of Arts & Sciences Instructional Computing Lab
  - http://depts.washington.edu/aslab/
  - Or your own machine
- Will use Java for the programming assignments
- Eclipse is recommended programming environment

Course Work

- 6 homeworks (60%)
  - Most involve programming, but also written questions
  - Higher-level concepts than “just code it up”
  - First programming assignment due next week

- Midterm: May 6, in class (15%)
- Final exam: Tuesday June 9, 2:30-4:20PM (25%)

Collaboration and Academic Integrity

- Read the course policy very carefully
  - Explains quite clearly how you can and cannot get/provide help on homework and projects

- Always explain any unconventional action on your part
  - When it happens, when you submit, not when asked

- The CSE Department and I take academic integrity extremely seriously.

Some details

- You are expected to do your own work
  - Exceptions (group work), if any, will be clearly announced
- Sharing solutions, doing work for, or accepting work from others is cheating
- Referring to solutions from this or other courses from previous quarters is cheating
- But you can learn from each other: see the policy

What this course will cover

- Introduction to Algorithm Analysis
- Lists, Stacks, Queues
- Trees, Hashing, Dictionaries
- Heaps, Priority Queues
- Sorting
- Disjoint Sets
- Graph Algorithms
- Introduction to Parallelism and Concurrency

Goals

- Be able to make good design choices as a developer, project manager, etc.
  - Reason in terms of the general abstractions that come up in all non-trivial software (and many non-software) systems
- Be able to justify and communicate your design decisions

You will learn the key abstractions used almost every day in just about anything related to computing and software.

- This is not a course about Java! We use Java as a tool, but the data structures you learn about can be implemented in any language.

Data structures

A data structure is a (often *non-obvious*) way to organize information to enable *efficient* computation over that information

A data structure supports certain *operations*, each with a:

- Meaning: what does the operation do/return
- Performance: how efficient is the operation

Examples:

- ***List*** with operations **`insert`** and **`delete`**
- ***Stack*** with operations **`push`** and **`pop`**

Trade-offs

A data structure strives to provide many useful, efficient operations

But there are unavoidable trade-offs:

- Time vs. space
- One operation more efficient if another less efficient
- Generality vs. simplicity vs. performance

We ask ourselves questions like:

- Does this support the operations I need efficiently?
- Will it be easy to use (and reuse), implement, and debug?
- What assumptions am I making about how my software will be used? (E.g., more lookups or more inserts?)

Terminology

- Abstract Data Type (ADT)
  - Mathematical description of a “thing” with set of operations
  - Not concerned with implementation details
- Algorithm
  - A high level, language-independent description of a step-by-step process
- Data structure
  - A specific organization of data and family of algorithms for implementing an ADT
- Implementation of a data structure
  - A specific implementation in a specific language

Example: Stacks

- The ***Stack*** ADT supports operations:
  - **`isEmpty`**: have there been same number of pops as pushes
  - **`push`**: adds an item to the top of the stack
  - **`pop`**: raises an error if empty, else removes and returns most-recently pushed item not yet returned by a pop
  - What else?

- A Stack data structure could use a linked-list or an array and associated algorithms for the operations

- One implementation is in the library **`java.util.Stack`**

Why useful

The Stack ADT is a useful abstraction because:

- It arises all the time in programming (e.g., see Weiss 3.6.3)
  - Recursive function calls
  - Balancing symbols in programming (parentheses)
  - Evaluating postfix notation: 3 4 + 5 *
  - Clever: Infix ((3+4) * 5) to postfix conversion (see text)

- We can code up a reusable library

- We can communicate in high-level terms
  - "Use a stack and push numbers, popping for operators…"
  - Rather than, "create an array and keep indices to the…"

Stack Implementations

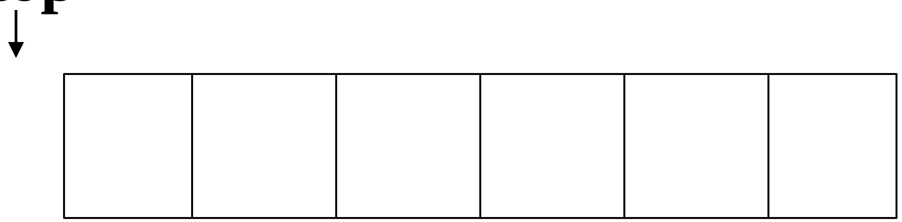
- stack as a linked list

top

NULL

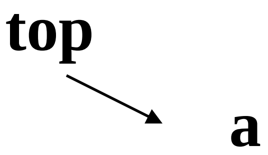
- stack as an array

top

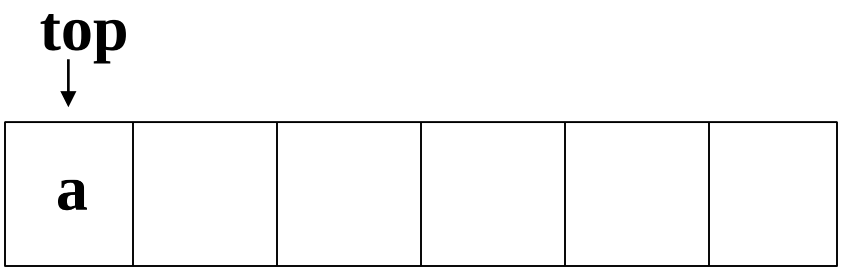


Stack Implementations

- stack as a linked list

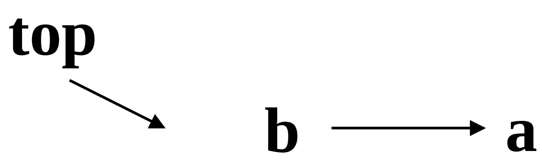


- stack as an array

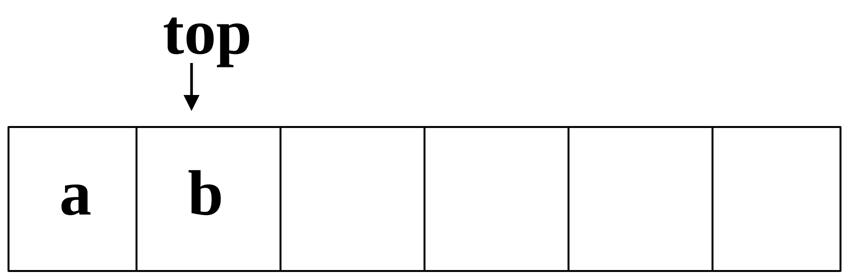


Stack Implementations

- stack as a linked list



- stack as an array



The Queue ADT

- Operations

  `create`

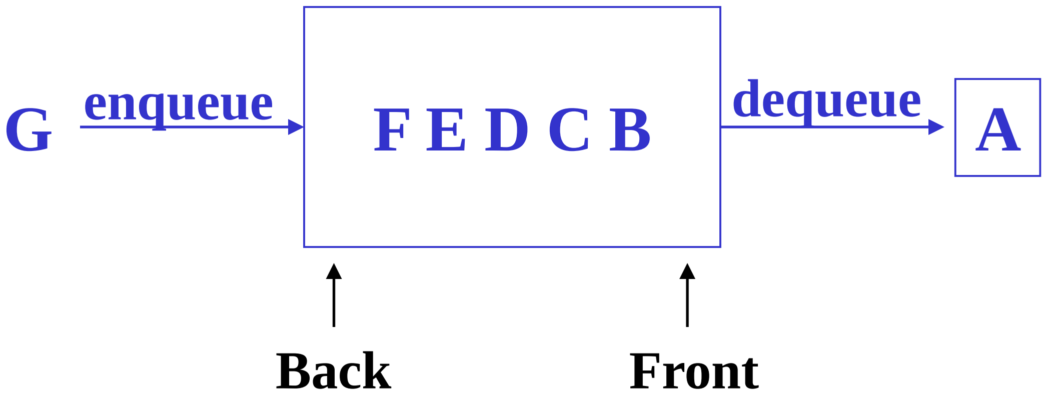
  `destroy`

  `enqueue`

  `dequeue`

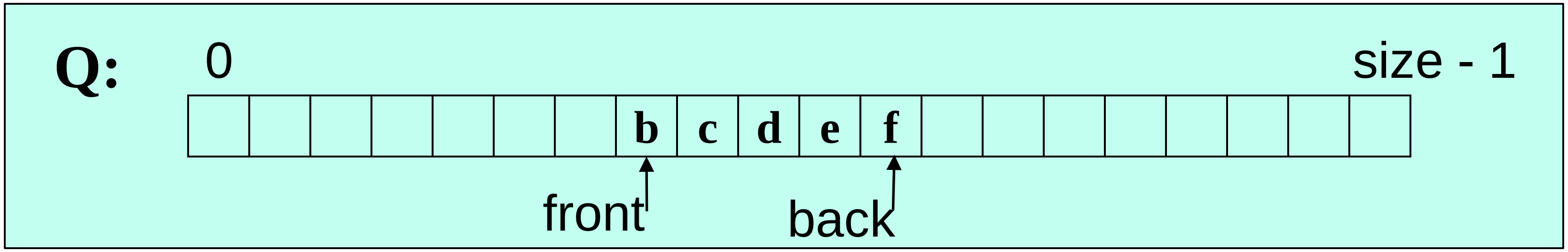
  `is_empty`

`What else?`



- Just like a stack except:
  - Stack: LIFO (last-in-first-out)
  - Queue: FIFO (first-in-first-out)

Circular Array Queue Data Structure

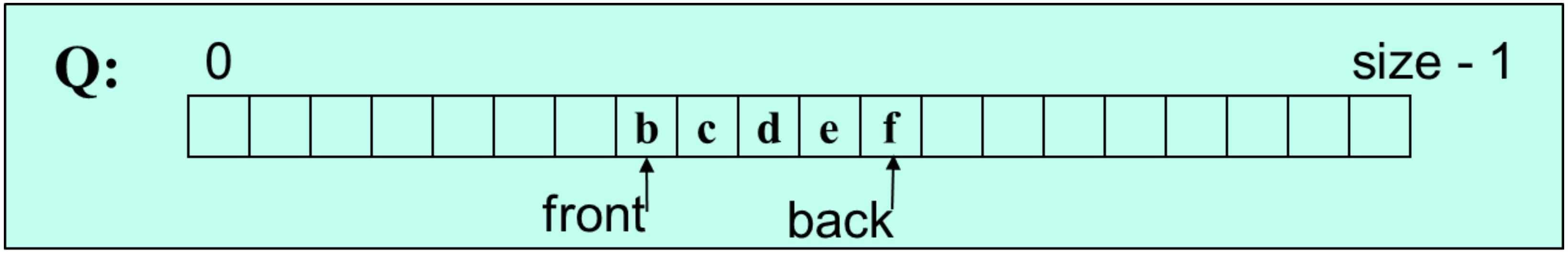



```
// Basic idea only!
enqueue(x) {
  next = (back + 1) % size
  Q[next] = x;
  back = next
}
```

```
// Basic idea only!
dequeue() {
  x = Q[front];
  front = (front + 1) % size;
  return x;
}
```

- What if ***queue*** is empty?
  - Enqueue?
  - Dequeue?
- What if ***array*** is full?
- How to *test* for empty?
- What is the *complexity* of the operations?
- Can you find the k^{th} element in the queue?

Circular Array Example *(text p 94 has another one)*



enqueue('g')

o1 = dequeue( )

o2 = dequeue( )

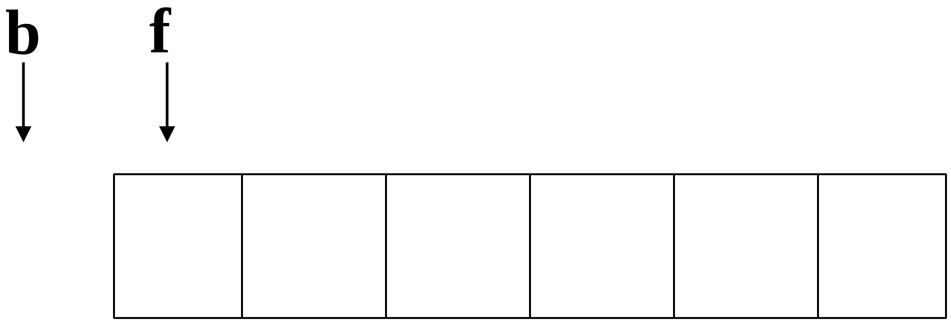
o3 = dequeue( )

o4 = dequeue( )

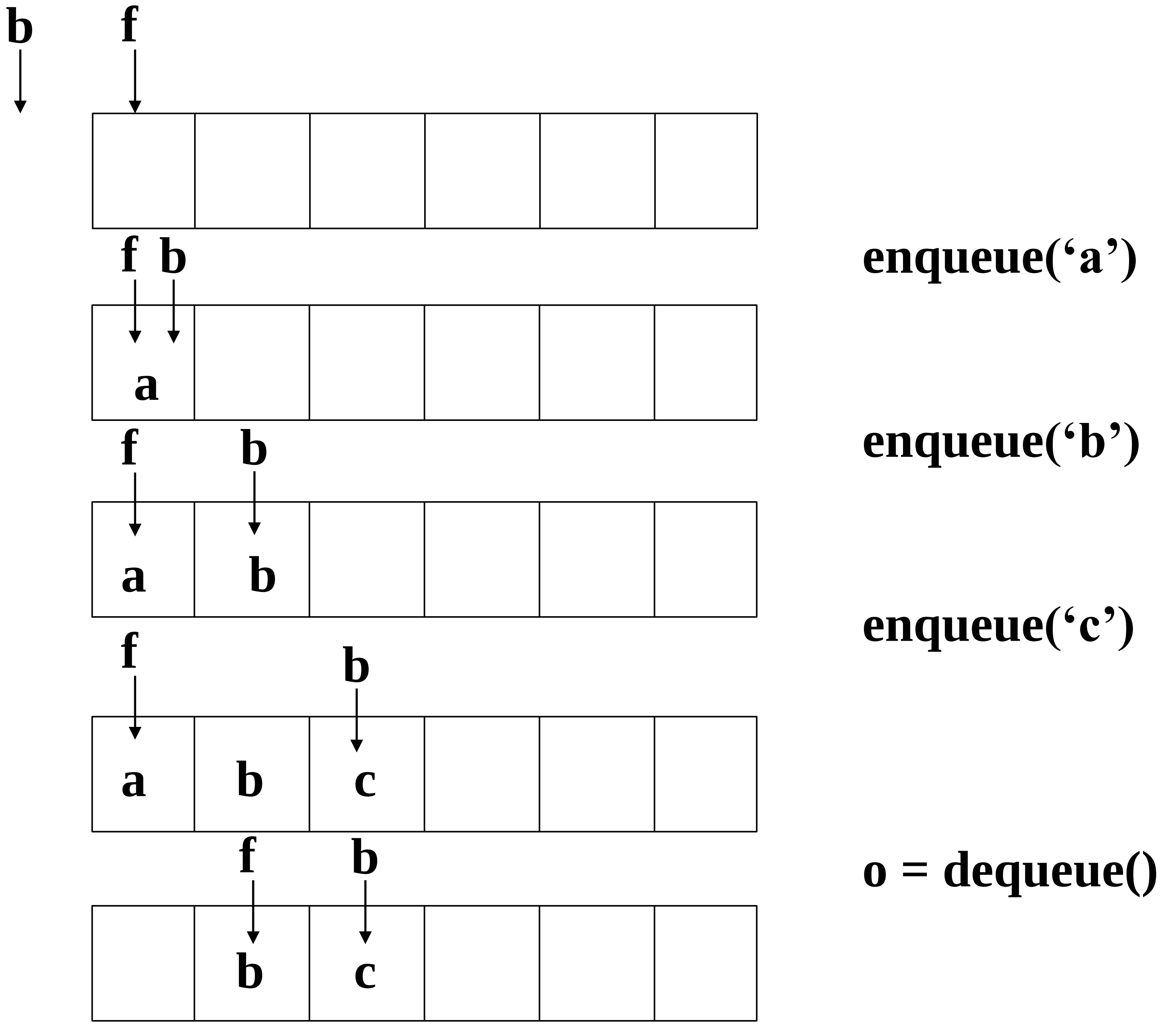
o5 = dequeue( )

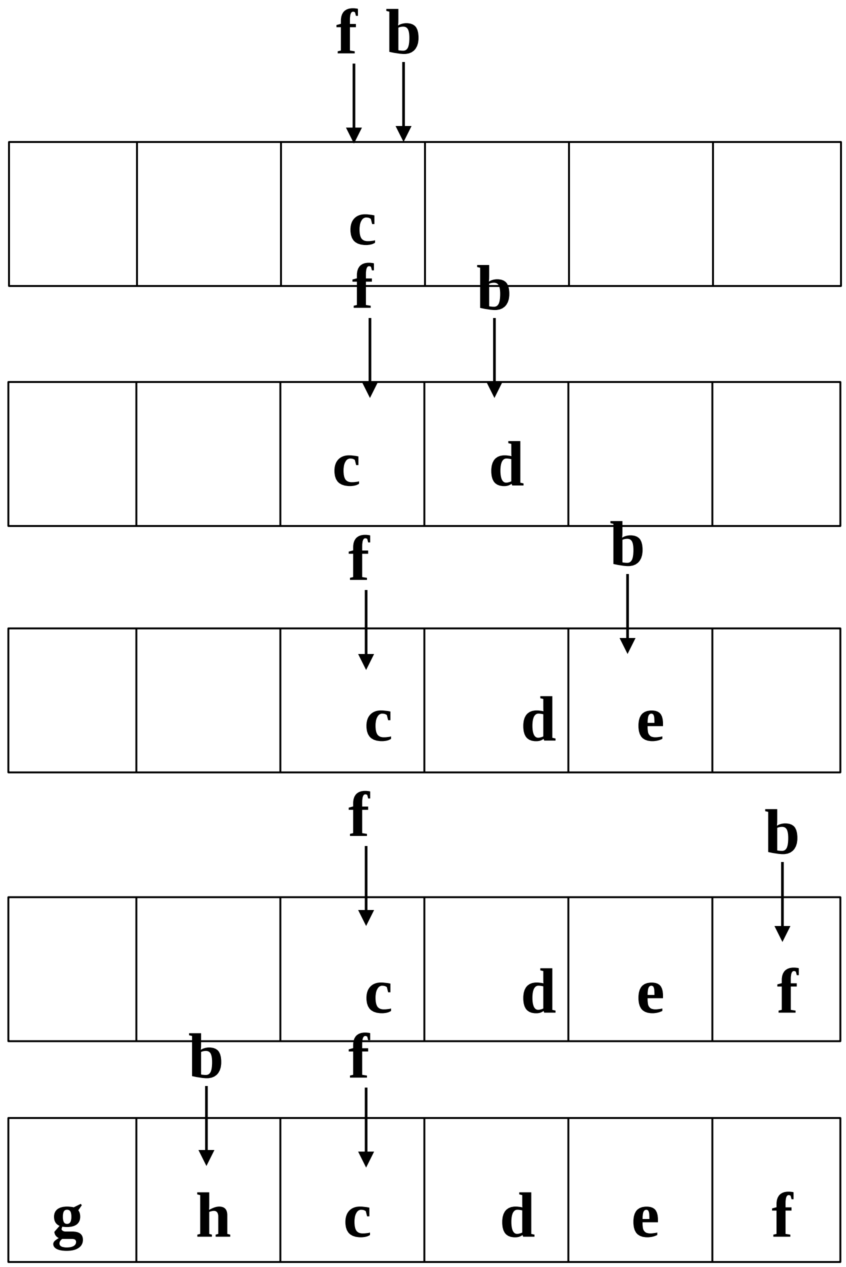
o6 = dequeue( )

In Class Practice



enqueue('a')
enqueue('b')
enqueue('c')
o = dequeue()
o = dequeue()
enqueue('d')
enqueue('e')
enqueue('f')
enqueue('g')
enqueue('h')
enqueue('i')


b
f
f b
a
f
b
a
b
f
b
a
b
c
f
b
b
c
enqueue(‘a’)
enqueue(‘b’)
enqueue(‘c’)
o = dequeue()



o = dequeue

enqueue('d')

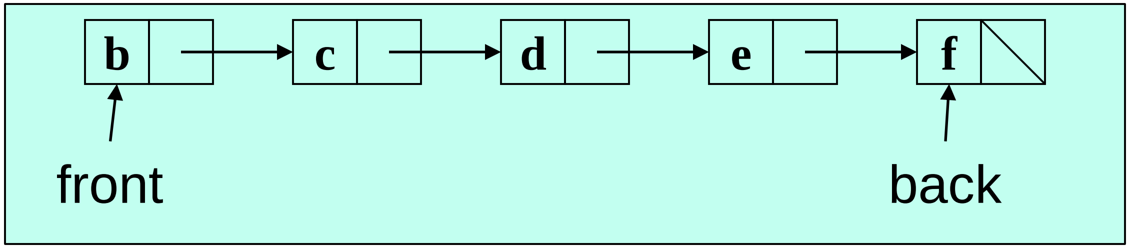
enqueue('e')

enqueue('f')

enqueue('g'), enqueue('h')

enqueue('i')

Linked List Queue Data Structure




```
// Basic idea only!
enqueue(x) {
  back.next = new Node(x);
  back = back.next;
}
```

```
// Basic idea only!
dequeue() {
  x = front.item;
  front = front.next;
  return x;
}
```

- What if ***queue*** is empty?
  - Enqueue?
  - Dequeue?
- Can ***list*** be full?
- How to *test* for empty?
- What is the *complexity* of the operations?
- Can you find the k^{th} element in the queue?

Circular Array vs. Linked List

Array:

- May waste unneeded space or run out of space
- Space per element excellent
- Operations very simple / fast
- Constant-time access to k^{th} element

- For operation insertAtPosition, must shift all later elements
  - Not in Queue ADT

List:

- Always just enough space
- But more space per element
- Operations very simple / fast
- No constant-time access to k^{th} element

- For operation insertAtPosition must traverse all earlier elements
  - Not in Queue ADT

This is stuff you should know after being awakened in the dark

Conclusion

- Abstract data structures allow us to define a new data type and its operations.
- Each abstraction will have one or more implementations.
- Which implementation to use depends on the application, the expected operations, the memory and time requirements.
- Both stacks and queues have array and linked implementations.
- We'll look at other ordered-queue implementations later.