Stacks and Queues

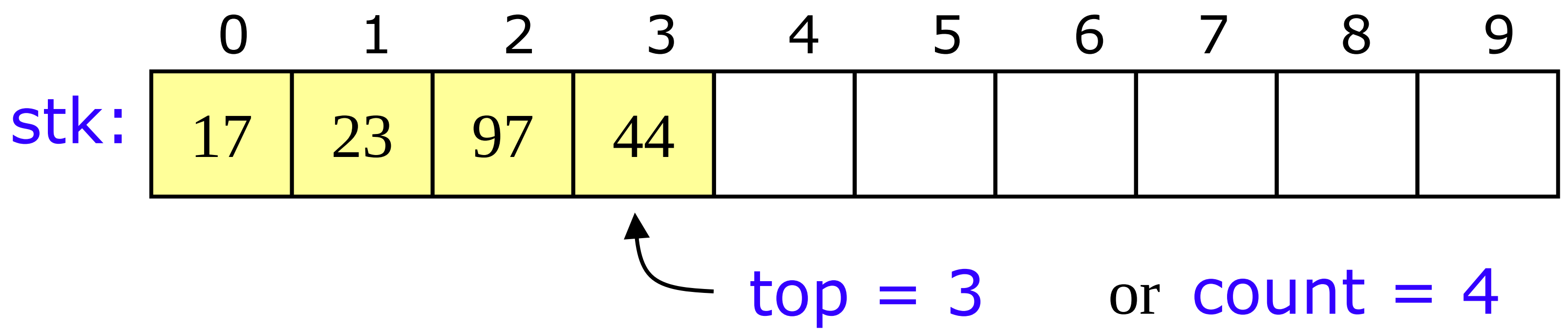
Stacks and Queues

- A stack is a last in, first out (LIFO) data structure
  - Items are removed from a stack in the reverse order from the way they were inserted
- A queue is a first in, first out (FIFO) data structure
  - Items are removed from a queue in the same order as they were inserted

Array implementation of stacks

- To implement a stack, items are inserted and removed at the same end (called the top)
- Efficient array implementation requires that the top of the stack be towards the center of the array, not fixed at one end
- To use an array to implement a stack, there is need of both the array itself and an integer
  - The integer tells:
    - Which location is currently the top of the stack, or
    - How many elements are in the stack

Pushing and popping



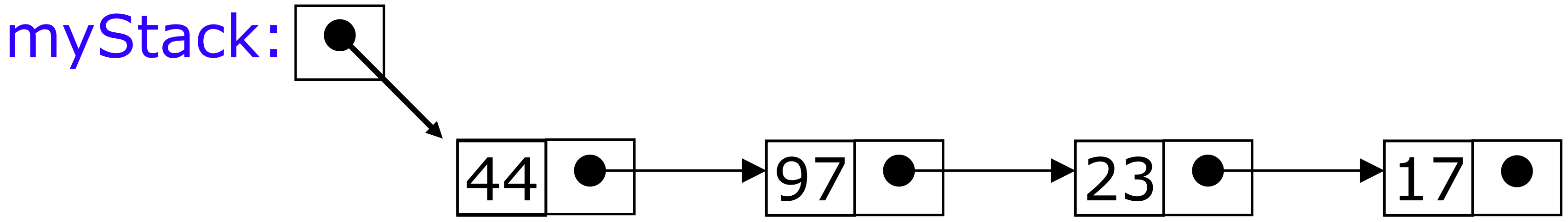
- If the bottom of the stack is at location 0, then an empty stack is represented by top = -1 or count = 0
- To add (push) an element, either:
  - Increment top and store the element in stk[top], or
  - Store the element in stk[count] and increment count
- To remove (pop) an element, either:
  - Get the element from stk[top] and decrement top, or
  - Decrement count and get the element in stk[count]

Error checking

- There are two stack errors that can occur:
  - Underflow: trying to pop (or peek at) an empty stack
  - Overflow: trying to push onto an already full stack
- For underflow, an exception is thrown
  - If the catch missed, Java will throw an ArrayIndexOutOfBounds exception
- For overflow, same things can be done
  - Or, user can check for the problem, and copy everything into a new, larger array

Linked-list implementation of stacks

- Since all the action happens at the top of a stack, a singly-linked list (SLL) is a fine way to implement it
- The header of the list points to the top of the stack



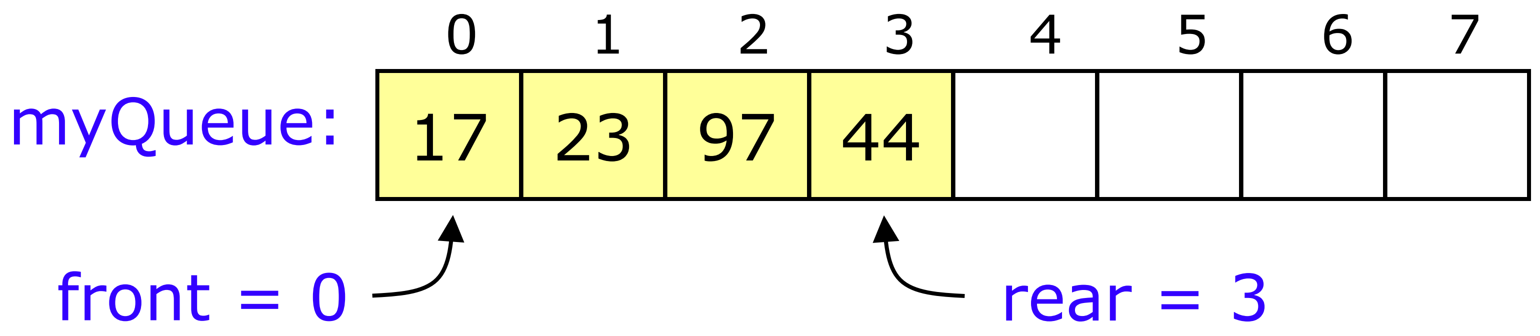
- Pushing is inserting an element at the front of the list
- Popping is removing an element from the front of the list

Linked-list implementation details

- With a linked-list representation, overflow will not happen (unless you exhaust memory, which is another kind of problem)
- Underflow can happen, and should be handled the same way as for an array implementation
- When a node is popped from a list, and the node references an object, the reference (the pointer in the node) does *not* need to be set to `null`

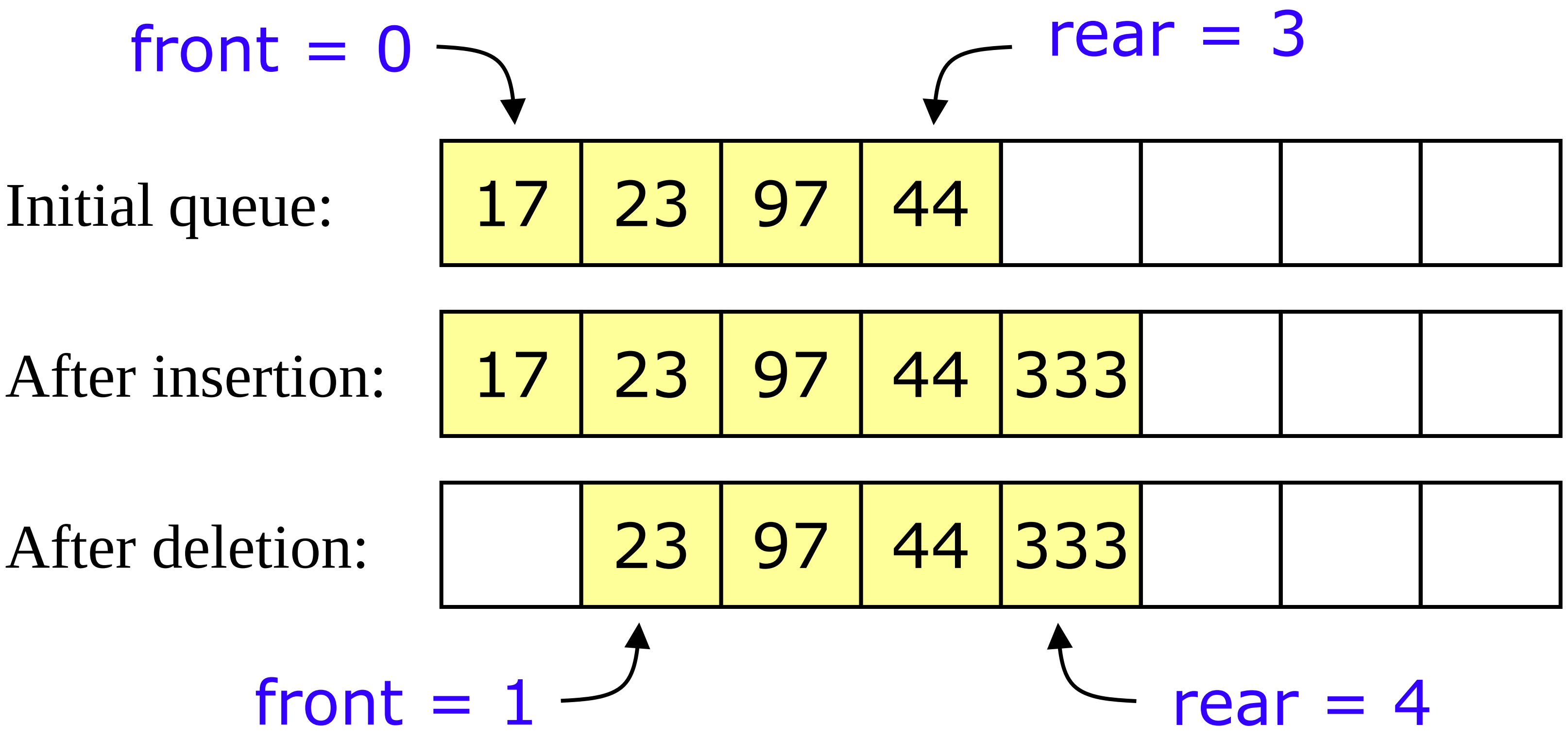
Array implementation of queues

- A queue is a first in, first out (FIFO) data structure
- This is accomplished by inserting at one end (the rear) and deleting from the other (the front)



- **To insert:** put new element in location 4, and set rear to 4
- **To delete:** take element from location 0, and set front to 1

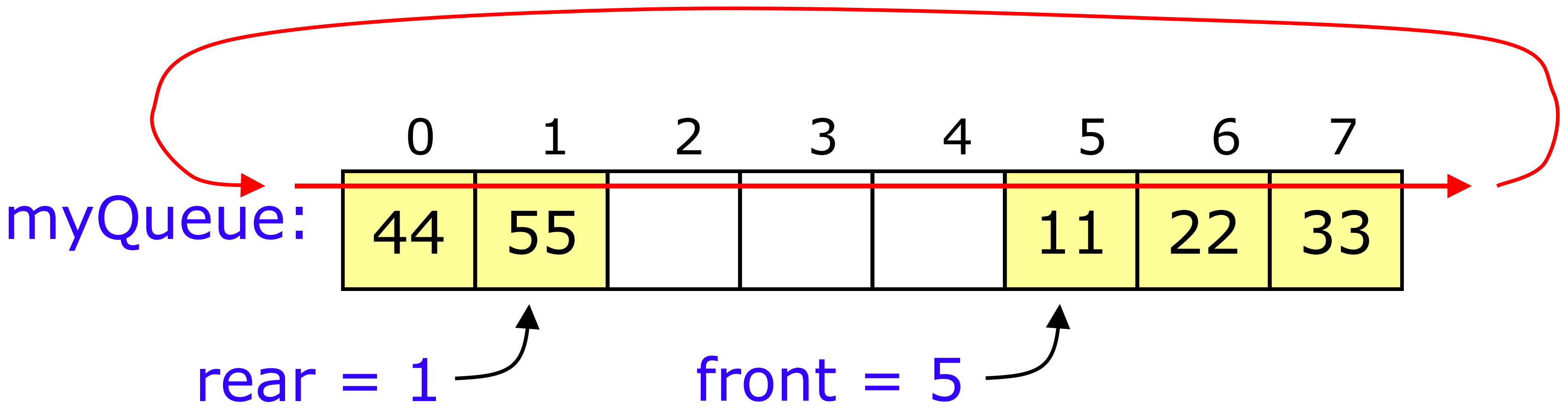
Array implementation of queues



- Now the array contents "crawl" to the right as elements are inserted and deleted
- This will be a problem after a while.

Circular arrays

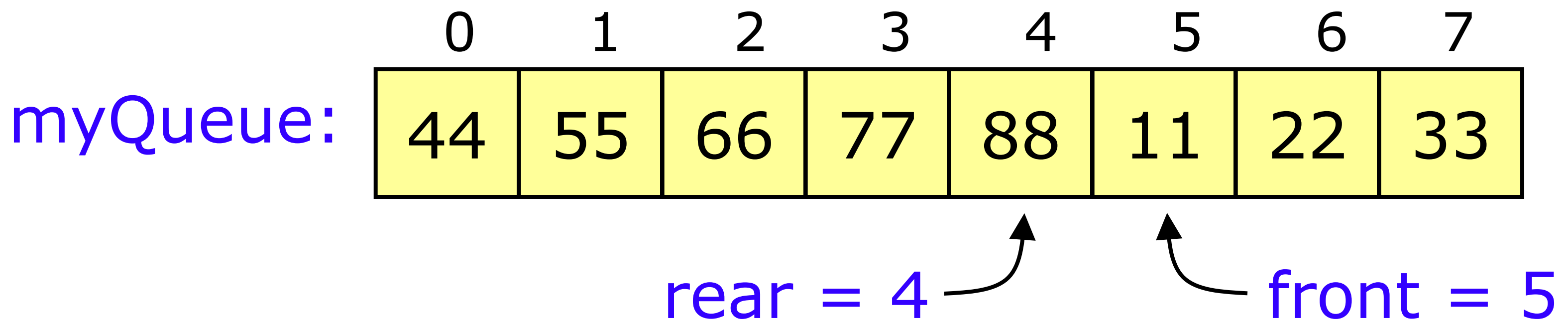
- We can treat the array holding the queue elements as circular (joined at the ends)



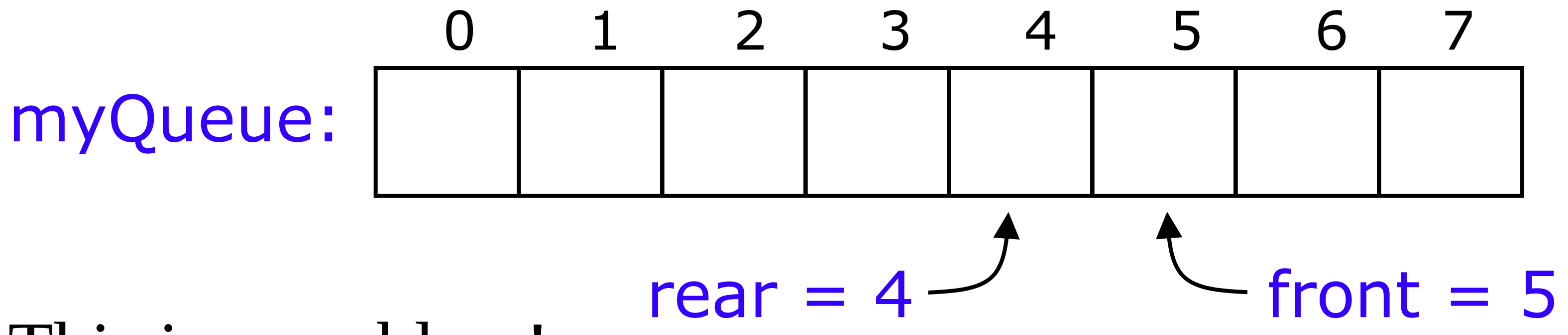
- Elements were added to this queue in the order 11, 22, 33, 44, 55, and will be removed in the same order
- Use: `front = (front + 1) % myQueue.length;` and: `rear = (rear + 1) % myQueue.length;`

Full and empty queues

- If the queue were to become completely full, it would look like this:



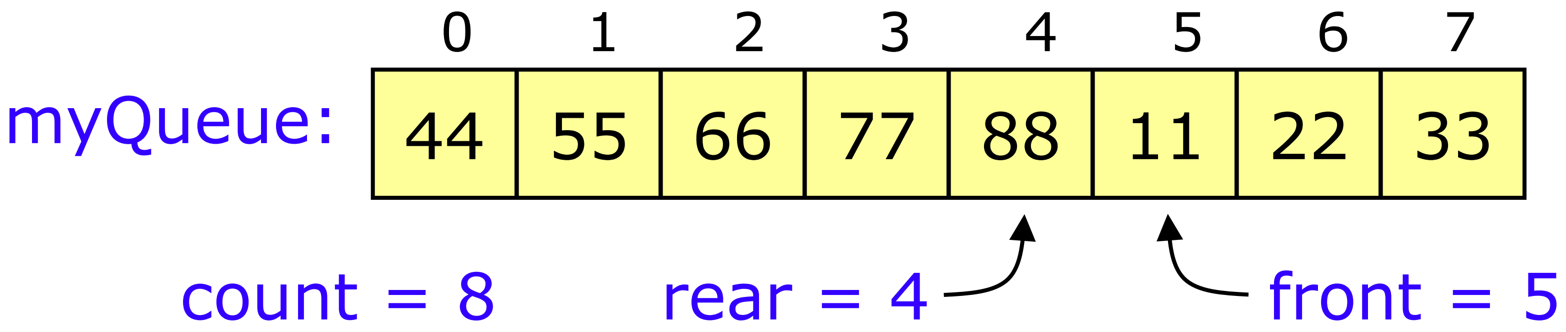
- If we were then to remove all eight elements, making the queue completely empty, it would look like this:



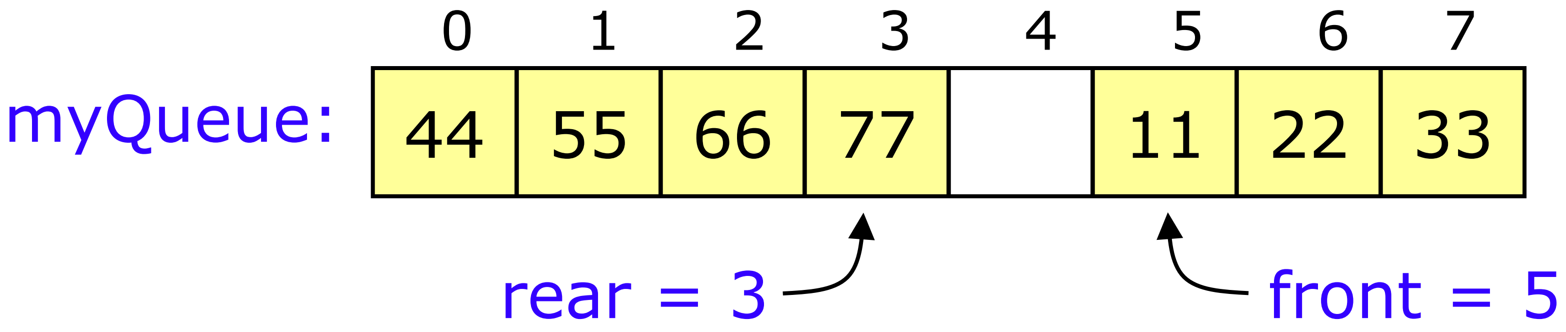
This is a problem!

Full and empty queues: solutions

- **Solution #1:** Keep an additional variable



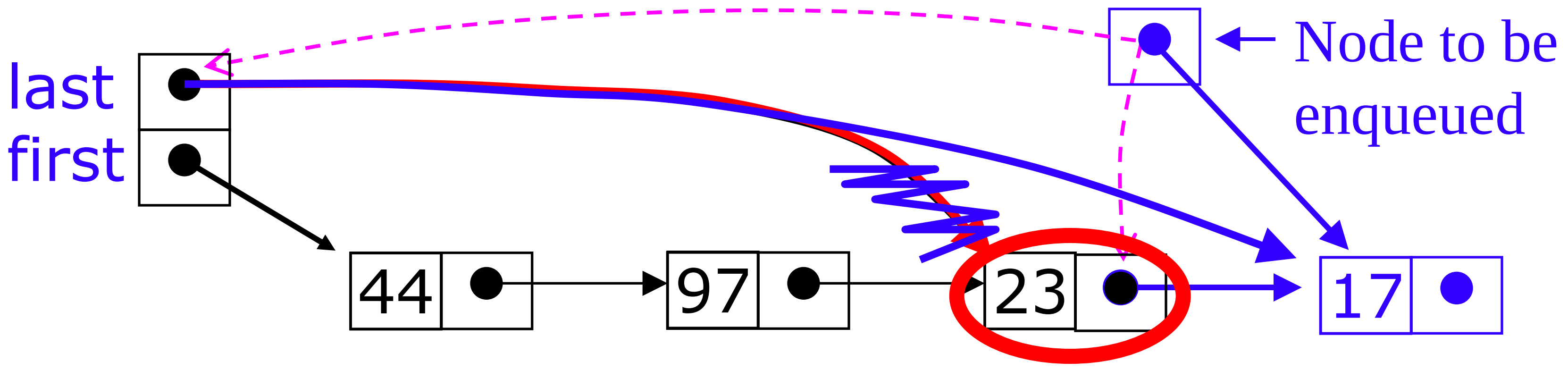
- **Solution #2:** (Slightly more efficient) Keep a gap between elements: consider the queue full when it has `n-1` elements



Linked-list implementation of queues

- In a queue, insertions occur at one end, deletions at the other end
- Operations at the front of a singly-linked list (SLL) are O(1), but at the other end they are O(n)
  - Because user have to find the last element each time
- BUT: there is a simple way to use a singly-linked list to implement both insertions and deletions in O(1) time
  - User always need a pointer to the first thing in the list
  - User can keep an additional pointer to the *last* thing in the list

Adding a node



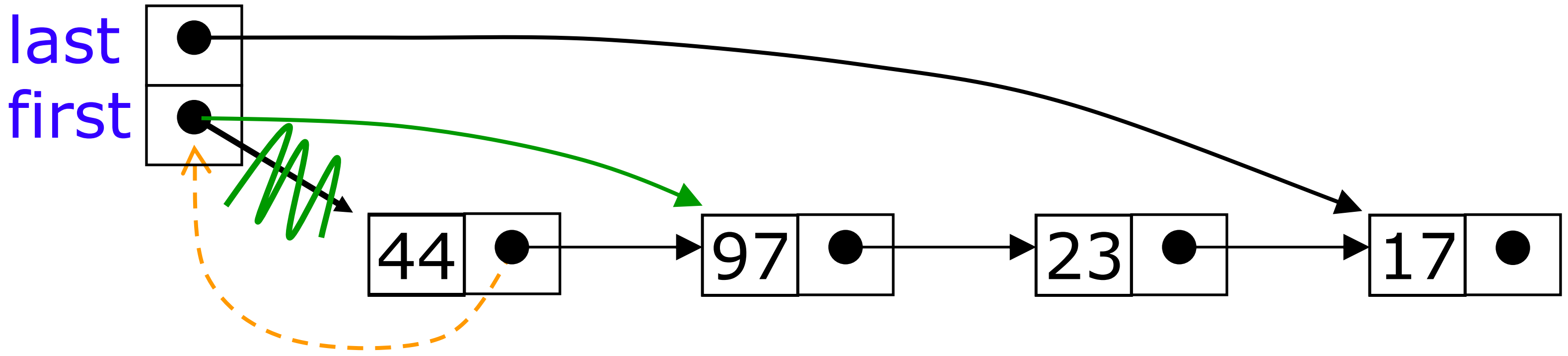
To enqueue (add) a node:

Find the current last node

Change it to point to the new last node

Change the last pointer in the list header

Removing a node



- To dequeue (remove) a node:
    - Copy the pointer from the first node into the header

Queue implementation details

- With an array implementation:
  - There are both overflow and underflow
  - Deleted elements should be set to `null`

- With a linked-list implementation:
  - only underflow
  - overflow is a global out-of-memory condition
  - there is no reason to set deleted elements to `null`