CS106B Final Review

Ashley Taylor
some slides adapted from Anton Apostolatos

Final Review Session Overview

- Logistics
- Sorting
- Linked Lists
- Hashing
- Binary Heap
- Trees
- Binary Search Trees
- Graphs
- Inheritance

Logistics

Final Logistics

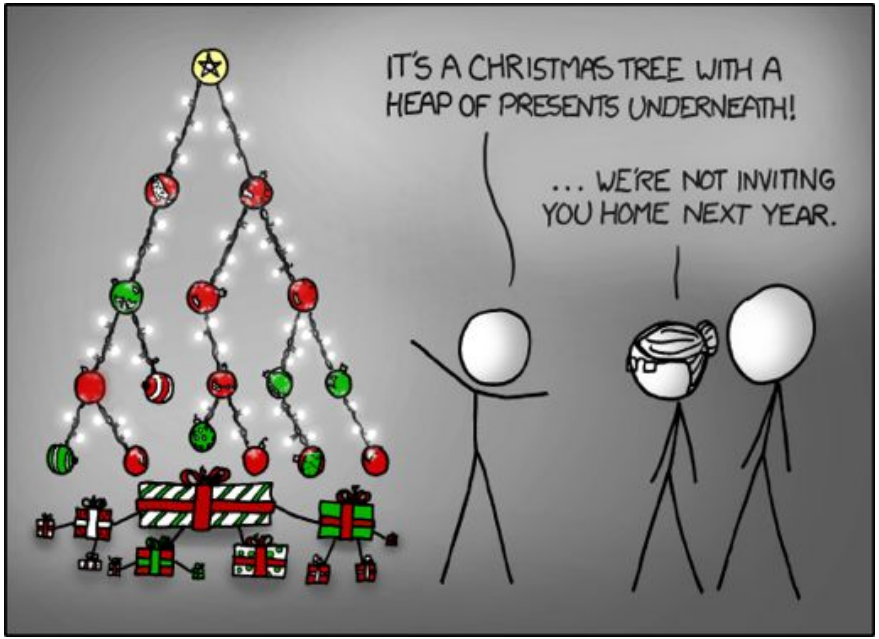
- Monday, December 11, 8:30-11:30am
- Memorial Auditorium
- Open books, one two-sided page of notes
- Pencils and pens accepted (please write darkly and clearly)

Basic exam tips

- Practice by **writing** answers to the practice exam/CSBS questions
- If your answer is outside the designated answer area, please indicate where to look (in the designated answer space) so we don’t miss it

What’s on the final

- Everything is fair game!
- Will be weighted to second half of the course



Sorting

Sorting: Tips

Make sure you understand the differences between the algorithms (especially in terms of run-time)

Make sure you can recognize the code when you see it

Practice tracing through how each algorithm will sort a list (when given the code)

Sorting: Insertion Sort

Works by inserting one element at a time into the sorted list

Sorted list starts as a list of size 1 with the first element in the list, then for all the other elements in the list, we insert each into its proper place in the sorted list

Runtime: O(N^2)

Sorting: Selection Sort

Find the smallest element in the list, and swap it with the leftmost element in the list

Continue by looking at the remaining (unsorted elements)

Runtime: O(N^2)

Sorting: Heap Sort

Load all the elements into a heap priority queue, then dequeue one-by-one

Runtime: O(N log N)

Sorting: Merge Sort

Split the array into two smaller arrays

Base case: an array of size 1 is trivially sorted

Recursive step: split into two arrays of size (N/2) that we call mergeSort on, then merge the two sorted arrays together

Runtime: O(N log N)

Sorting: QuickSort

Choose an element as a “pivot element”

For all the other elements in the array, split them to the left of the pivot (if they’re smaller than the pivot) or right (if they’re greater). The pivot is now in the correct spot

Recurse on the two arrays on either side of the pivot

Expected: O(N log N)
Worst case: (e.g. picking the smallest element each time) O(N^2)

LinkedLists

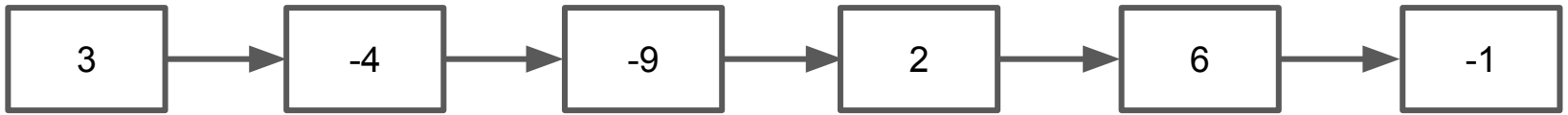
LinkedList Tips

- Draw lots of pictures! Make sure you know exactly where you want things to point, and draw out every step (you want to always have a pointer to everything you want to access)
- Make sure you delete a node when you don't need it anymore (but after you saved its `next`)
- Good test cases for your list: empty list, list of size 1, list of size 2, list of size 3; try adding/deleting from the beginning, middle, and end

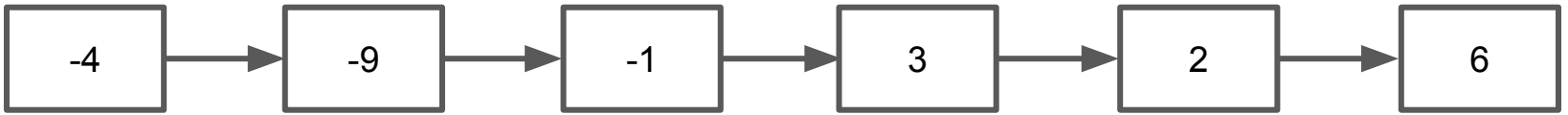
LinkedList - Split

Write a function that given a LinkedList of integers, reorders the list so that all the negative numbers are at the front, and all the positive numbers are at the end.

Before



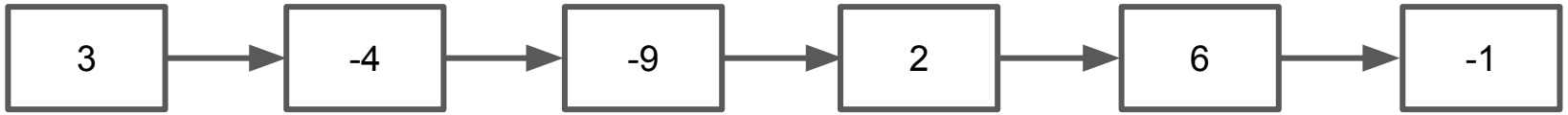
After



LinkedList - Split

Algorithm: Separate the list into a list of positive numbers and negative numbers

Before



After

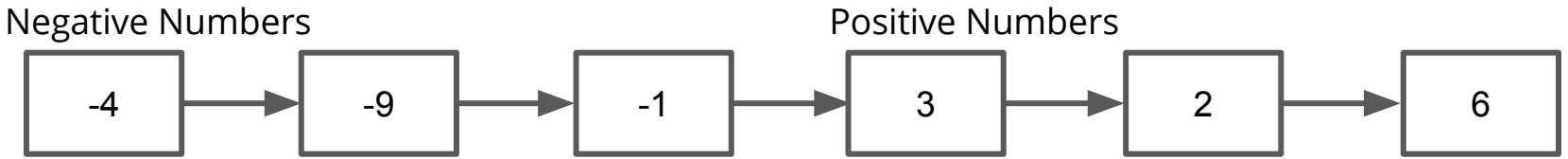
Negative Numbers

Positive Numbers

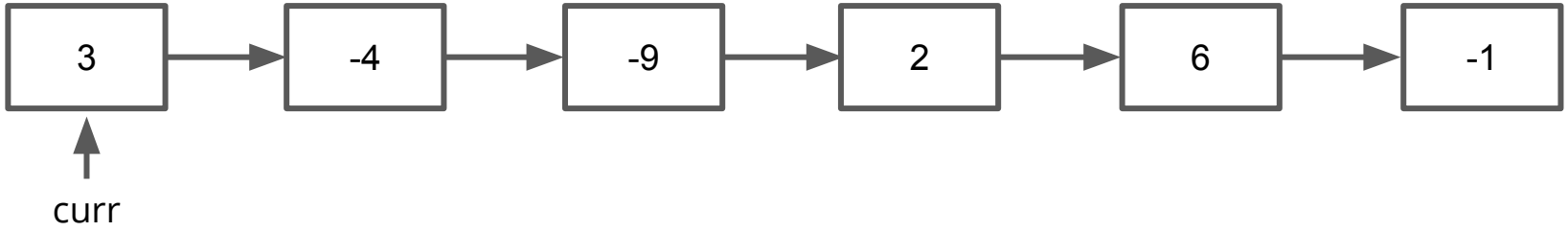
LinkedList - Split

Algorithm: Separate the list into a list of positive numbers and negative numbers

Add the positive numbers to the end of the negative numbers, and return the start of the negative numbers list



LinkedList - Split



Negative Numbers

negStart = NULL

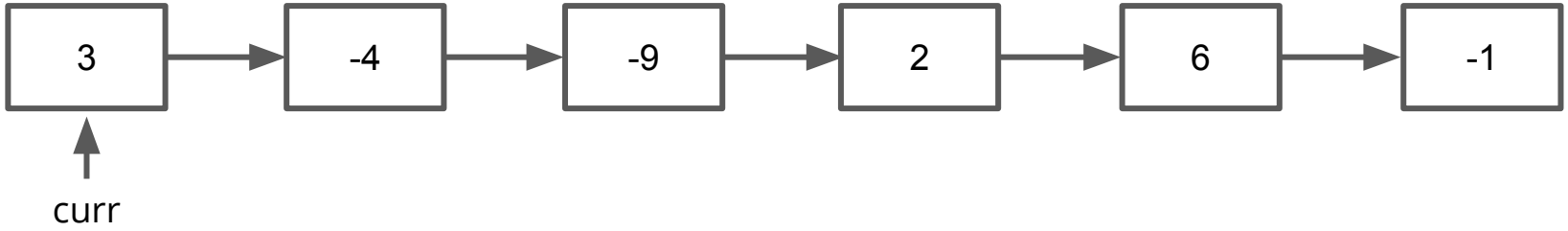
negEnd = NULL

Positive Numbers

posStart = NULL

posEnd = NULL

LinkedList - Split



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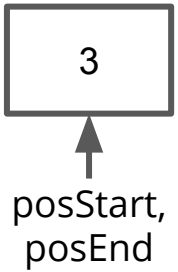
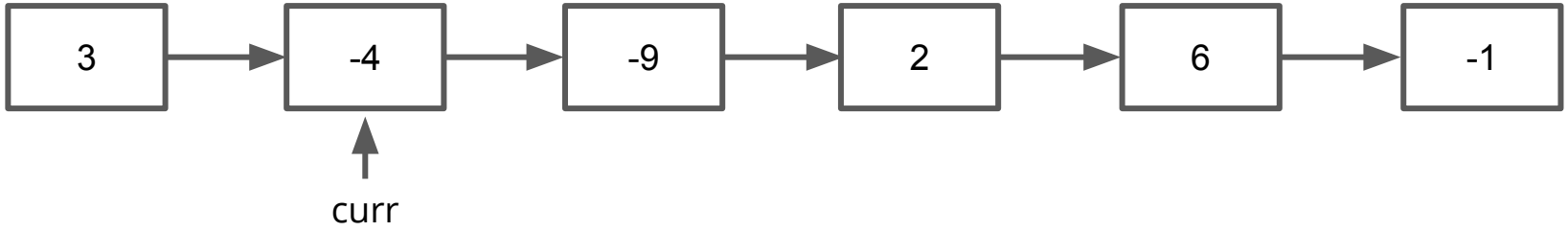
Positive Numbers



LinkedList - Split

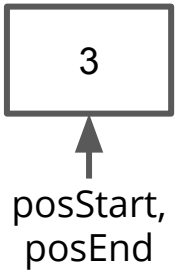


Negative Numbers

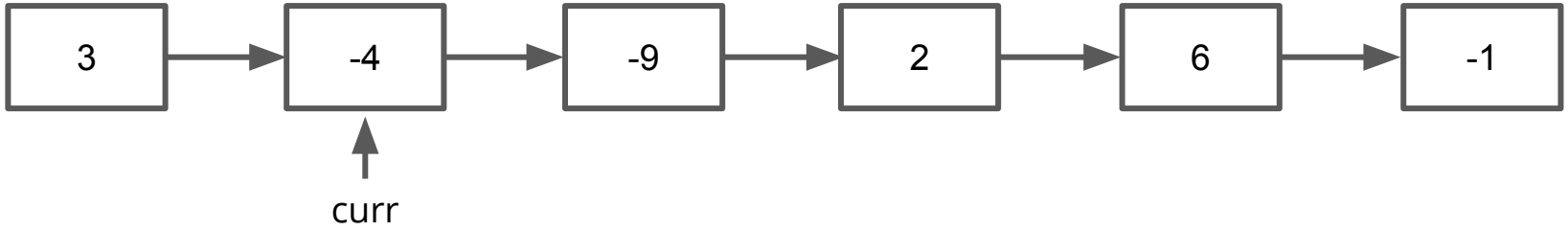
negStart = NULL

negEnd = NULL

Positive Numbers



LinkedList - Split



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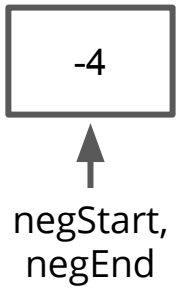
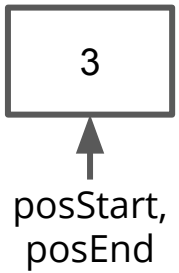


Positive Numbers



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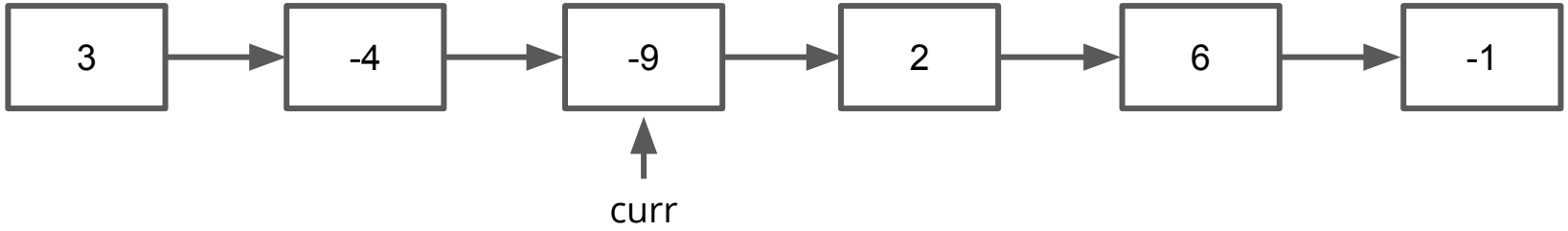

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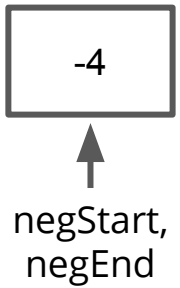

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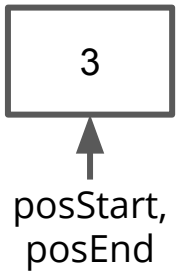

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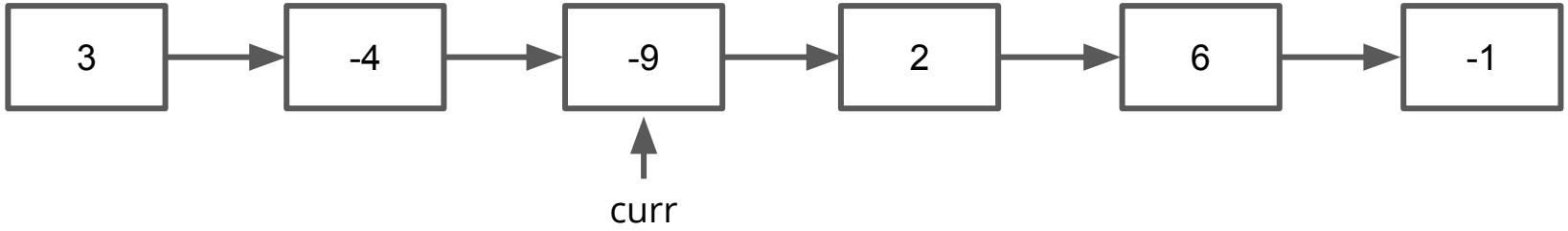

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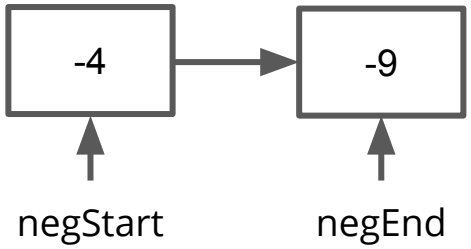

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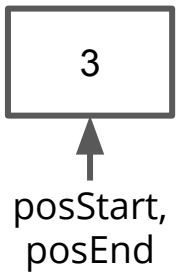

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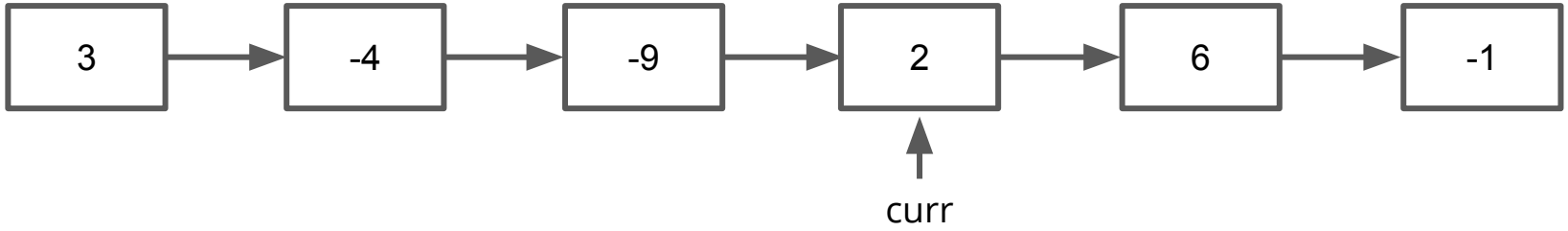

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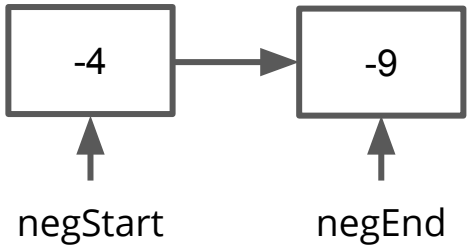

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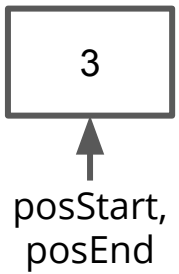

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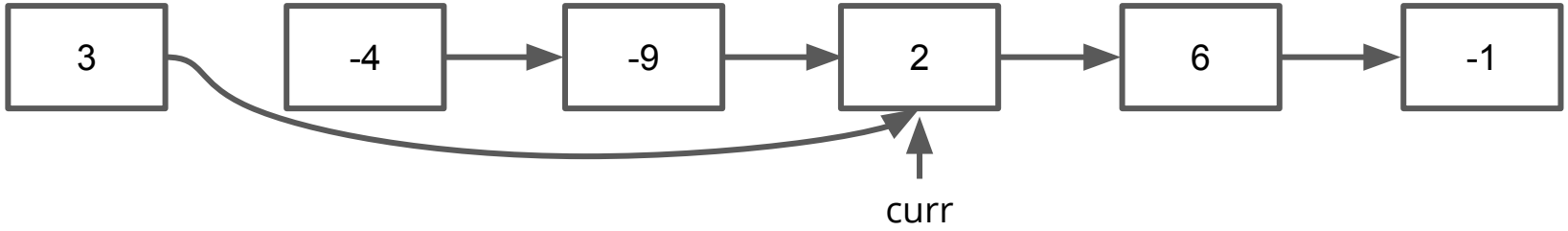

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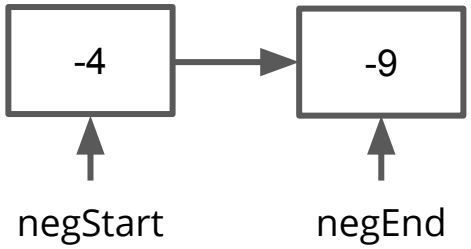

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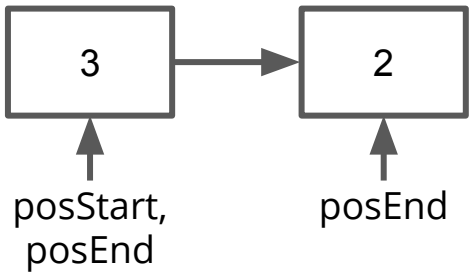

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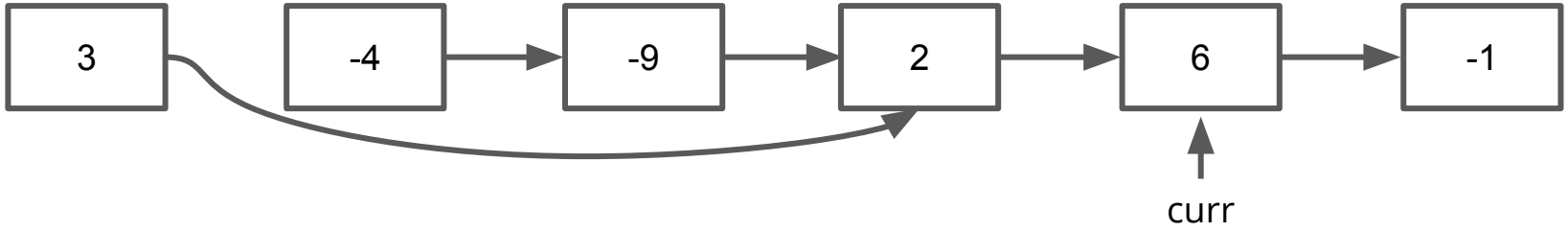

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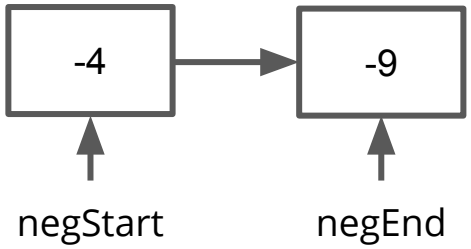

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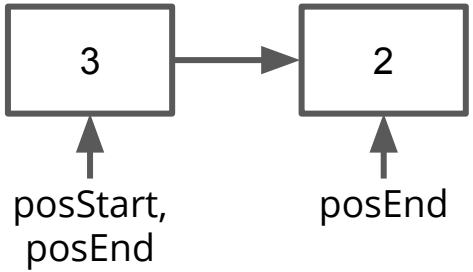

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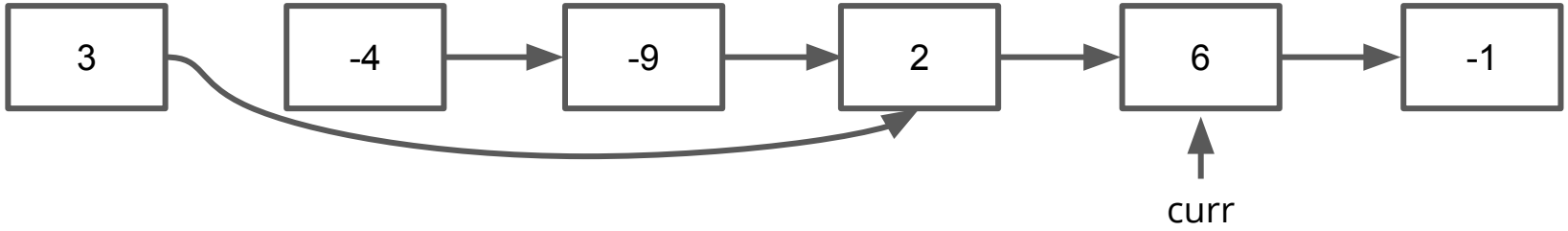

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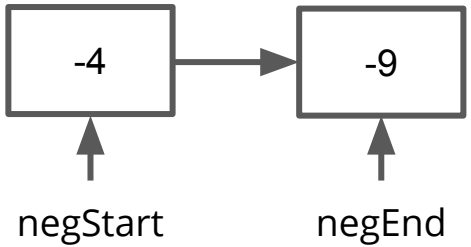

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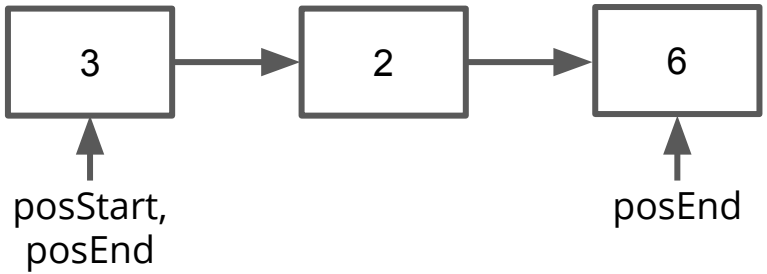

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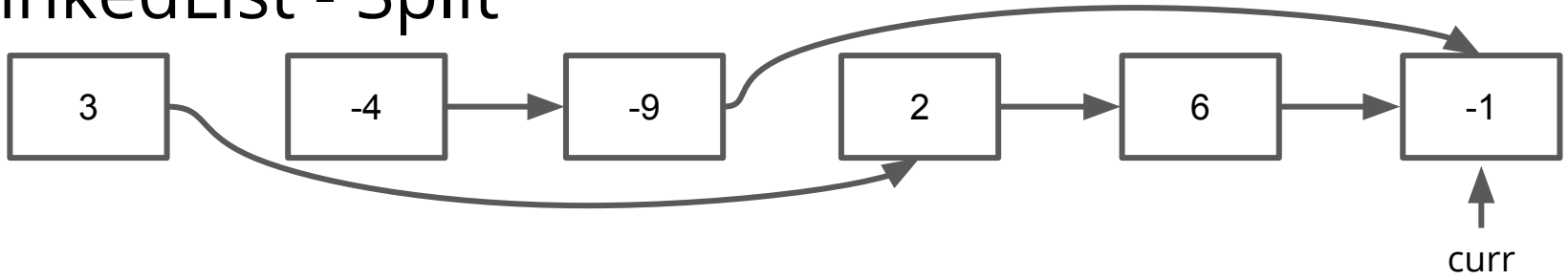

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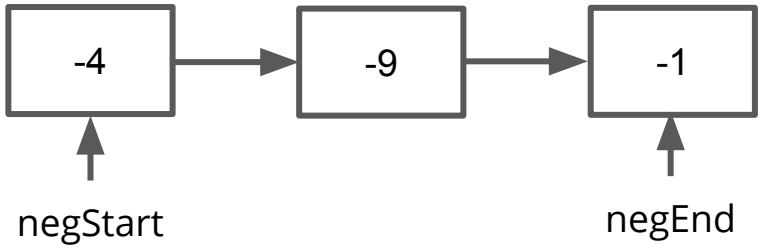

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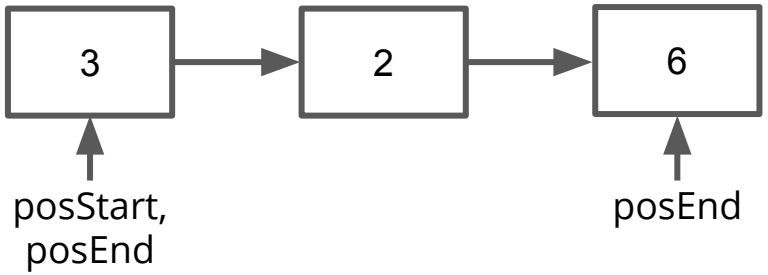

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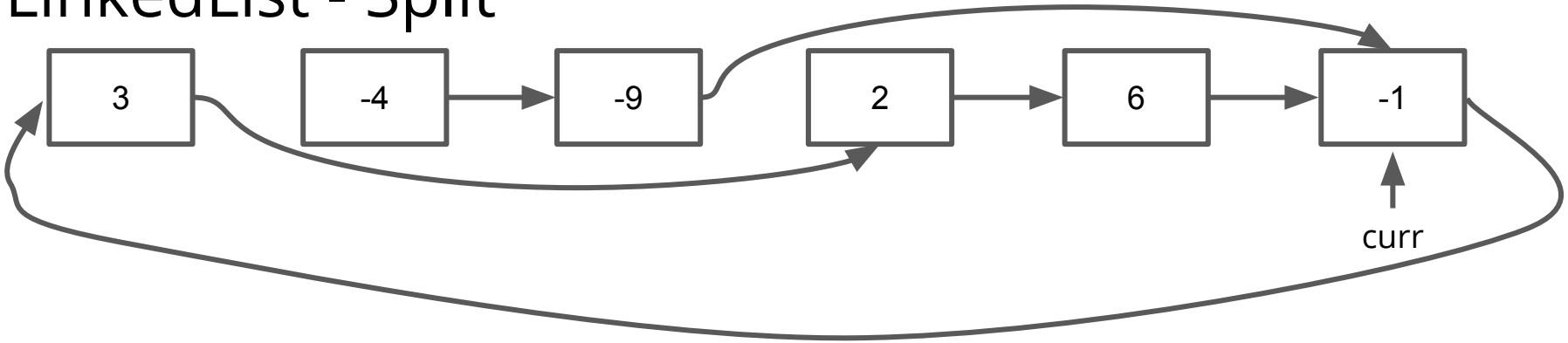

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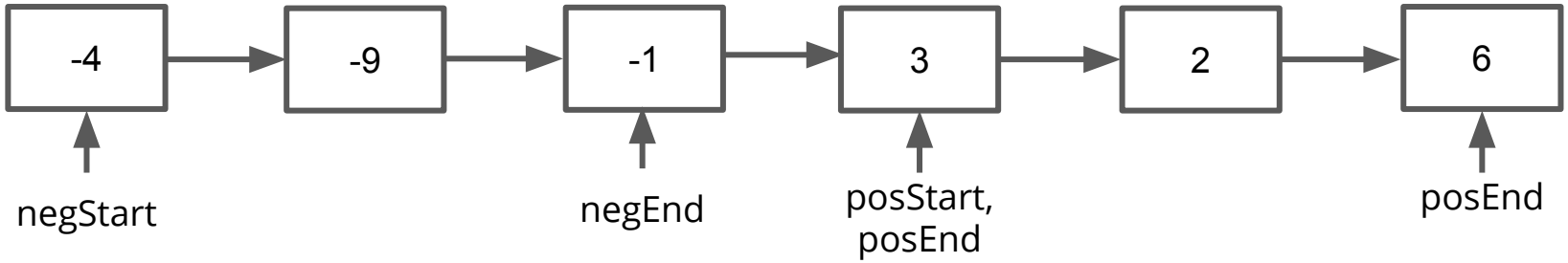

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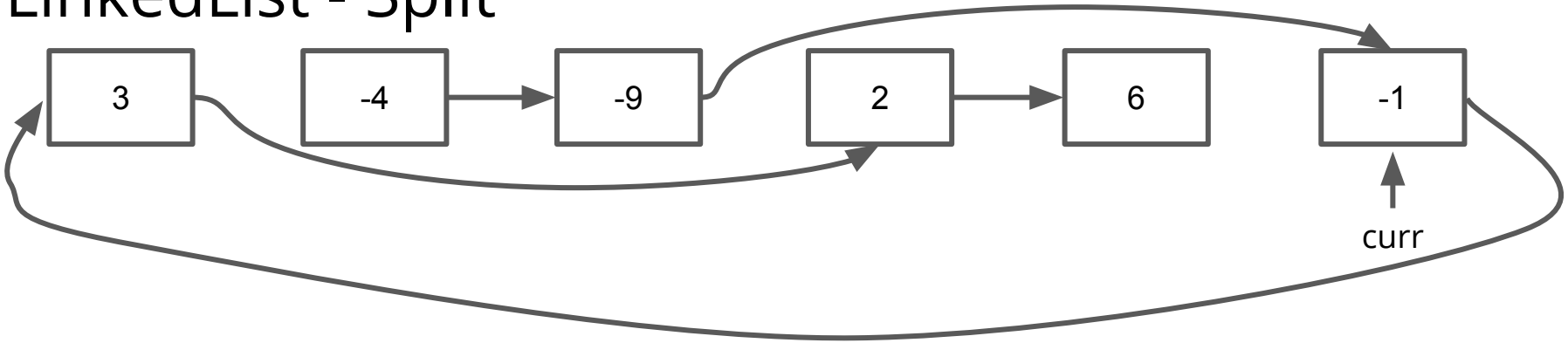
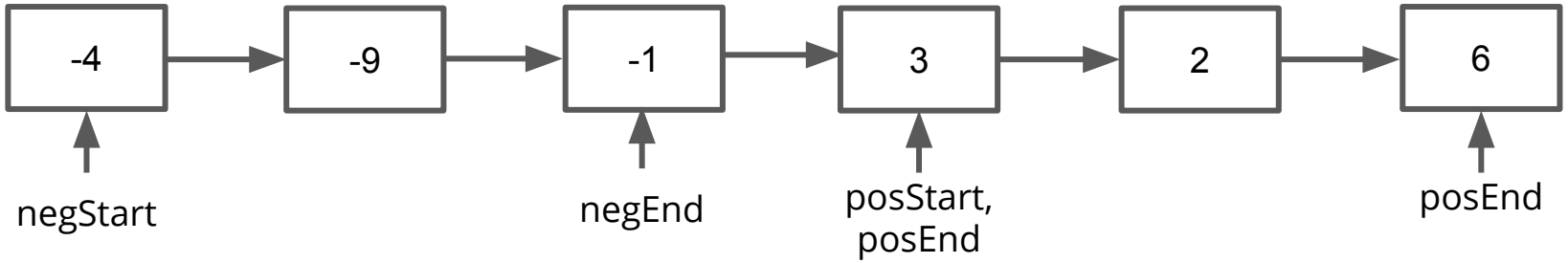


Make sure that posEnd points to NULL

Negative Numbers

Positive Numbers



LinkedList - Split Solution (Part 1)

```
ListNode *split(ListNode *head) {
   ListNode *curr = head, *negStart = NULL, *negEnd = NULL, *posStart = NULL, *posEnd = NULL;
   while (curr != NULL) {
       if (curr->data < 0) {
           if (negStart != NULL) {
               negEnd->next = curr;
               negEnd = curr;
           } else {
               negStart = negEnd = curr;
           }
       } else {
           if (posStart != NULL) {
               posEnd->next = curr;
               posEnd = curr;
           } else {
               posStart = posEnd = curr;
           }
       }
       curr = curr->next;
   }
```

LinkedList - Split Solution (Part 2)

```
    // if posEnd is NULL,
    // then the end of our list will already point to NULL
    if (posEnd != NULL) {
        posEnd->next = NULL;
    }

    // if there aren't any negative numbers,
    // just return the positive list
    if (negEnd != NULL) {
        negEnd->next = posStart;
        return negStart;
    } else {
        return posStart;
    }
}
```

Extra Practice

- Traverse (i.e. read every element in a LinkedList) without notes
- Add an element to a LinkedList (you can use the add function of your PQueue for reference)
- Delete an element from a LinkedList (use changePriority of PQueue for reference)
- Check out CSBS for lots of practice

Hashing

Hash Functions

Basic definition: a hash function maps something (like an int or string) to a number

A **valid** hash function will always return the same number given two inputs that are considered equal

A **good** hash function distributes the values uniformly over all the numbers

Hash Functions: Good or Bad

```
struct BankAccount {
  int routingNumber;
  int amount;
};
```

Two bank account objects are considered equal if they have the same routing number.

```
int hash(BankAccount account) {
  return randomInteger(0, 100);
}
```

Hash Functions: Good or Bad

```
struct BankAccount {
  int routingNumber;
  int amount;
};
```

INVALID - given the same bank account, might return any random number

Two bank account objects are considered equal if they have the same routing number.

```
int hash(BankAccount account) {
  return randomInteger(0, 100);
}
```

Hash Functions: Good or Bad

```
struct BankAccount {
  int routingNumber;
  int amount;
};
```

Two bank account objects are considered equal if they have the same routing number.

```
int hash(BankAccount account) {
  return account.routingNumber % 2;
}
```

Hash Functions: Good or Bad

```
struct BankAccount {
  int routingNumber;
  int amount;
};
```

VALID but Not Good - will generate the same result for two accounts that are considered the same, but not uniformly spread over all the integers

Two bank account objects are considered equal if they have the same routing number.

```
int hash(BankAccount account) {
  return account.routingNumber % 2;
}
```

Hash Functions: Good or Bad

```
struct BankAccount {
  int routingNumber;
  int amount;
};
```

Two bank account objects are considered equal if they have the same routing number.

```
int hash(BankAccount account) {
  return account.amount % 100;
}
```

Hash Functions: Good or Bad

```
struct BankAccount {
  int routingNumber;
  int amount;
};
```

INVALID - The bank account amount might change, leading to accounts with the same routing number being put in different buckets

Two bank account objects are considered equal if they have the same routing number.

```
int hash(BankAccount account) {
  return account.amount % 100;
}
```

Hash Functions: Good or Bad

```
struct BankAccount {
  int routingNumber;
  int amount;
};
```

Two bank account objects are considered equal if they have the same routing number.

```
int hash(BankAccount account) {
  return (account.routingNumber * 265443761L) %
INT_MAX;

}
```

Hash Functions: Good or Bad

VALID and GOOD - given the same routing number, this will always return the same number, and it's spread relatively evenly over all possible (positive) integers

*Taken from StackOverflow

```
struct BankAccount {
  int routingNumber;
  int amount;
};
```

Two bank account objects are considered equal if they have the same routing number.

```
int hash(BankAccount account) {
  return (account.routingNumber * 265443761L) %
INT_MAX;

}
```

Using Hash Functions

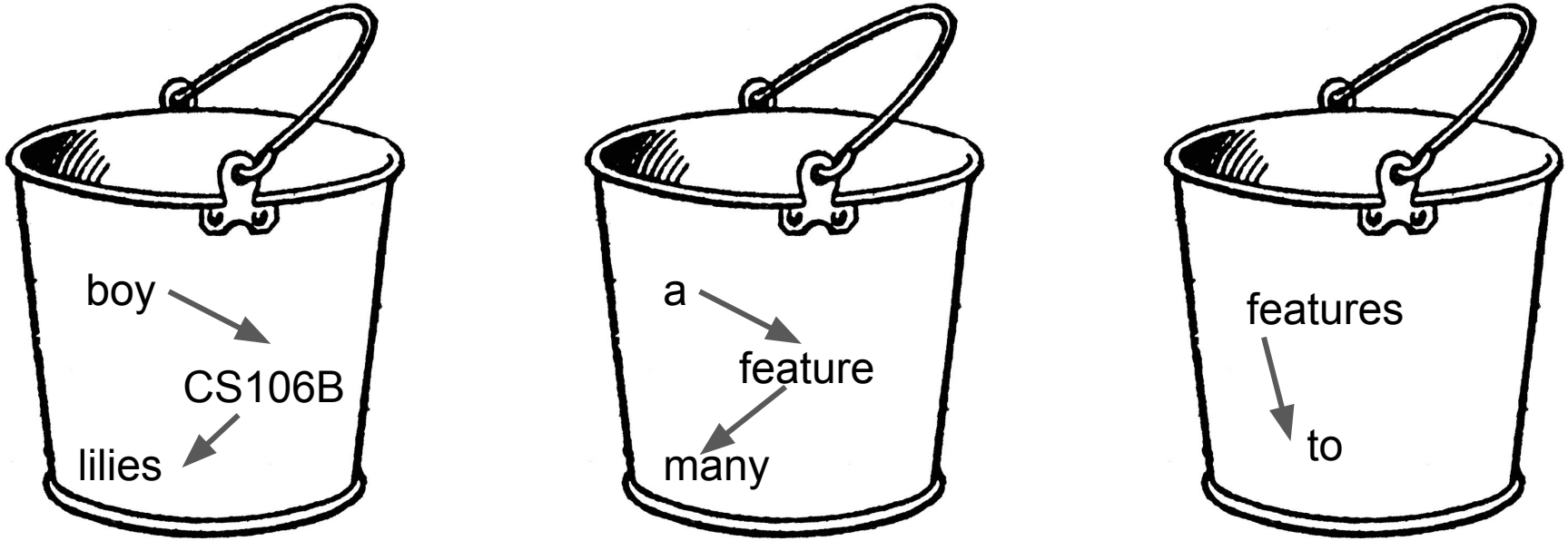
Hash Functions are used to assign elements to buckets for a HashSet or HashMap.

```
int bucket(elem) {
  return hash(elem) % numBuckets;
}
```

Using Hash Functions

Let's say our hash function returned the length of the string we're hashing and we have 3 buckets. Our buckets may look like:

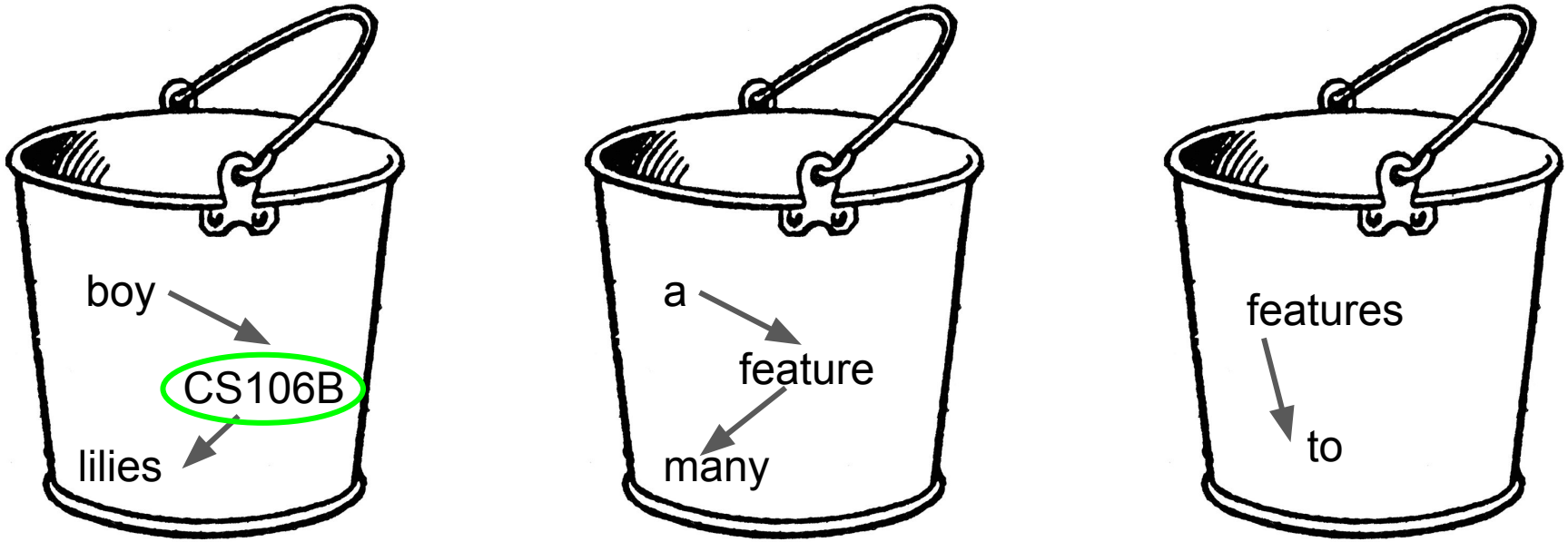
Inside each bucket, we have a LinkedList of elements



Using Hash Functions

When we search for an element, we look in it's bucket

Search CS106B: look in bucket 0 and look through the whole LinkedList



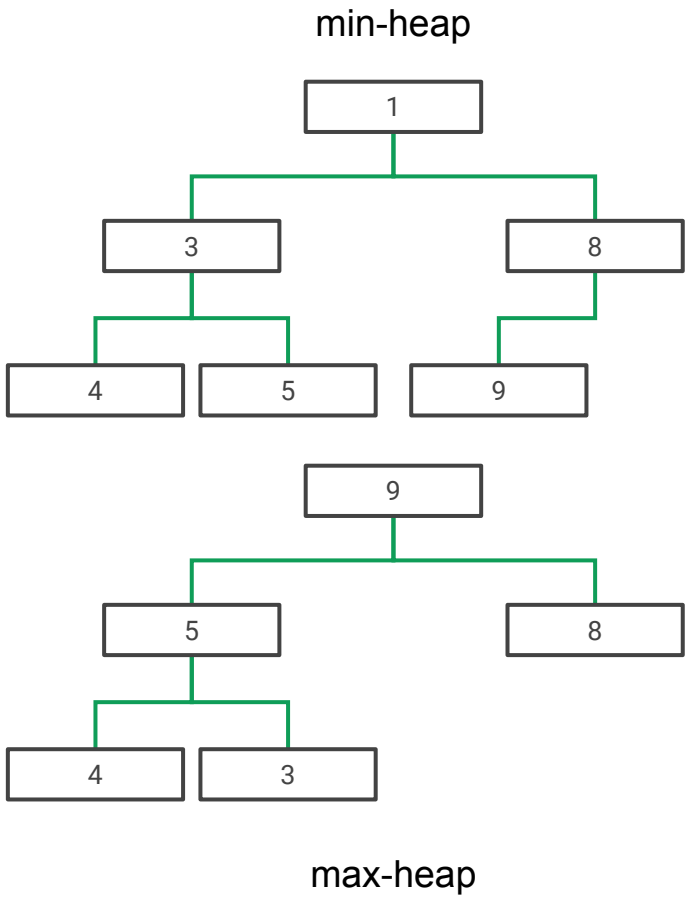
Heaps

Heaps: Overview

A heap is a type of **complete binary tree** that obeys some ordering property. (complete = each level is filled left to right before moving to the next level)

Min-heap: each parent is smaller than its children

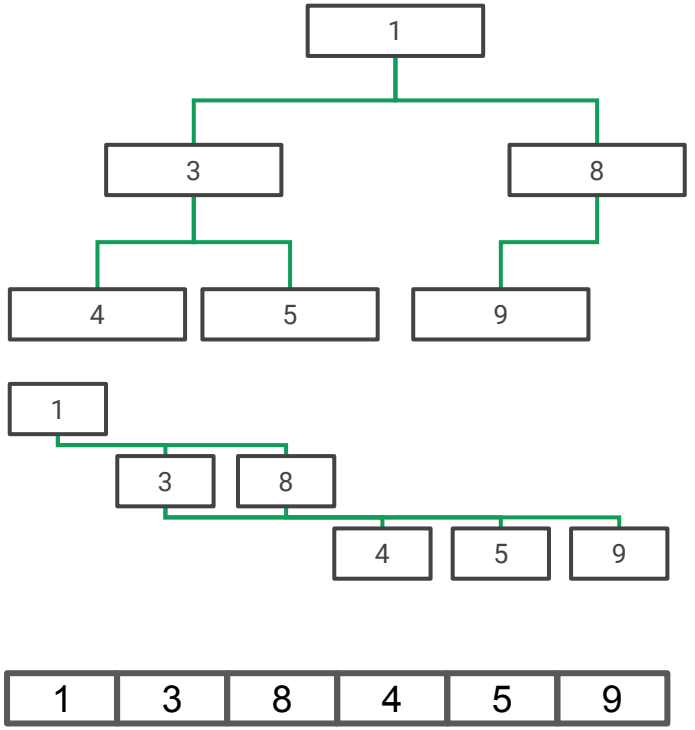
Max-heap: each parent is larger than its children



Heaps: Stored as an array

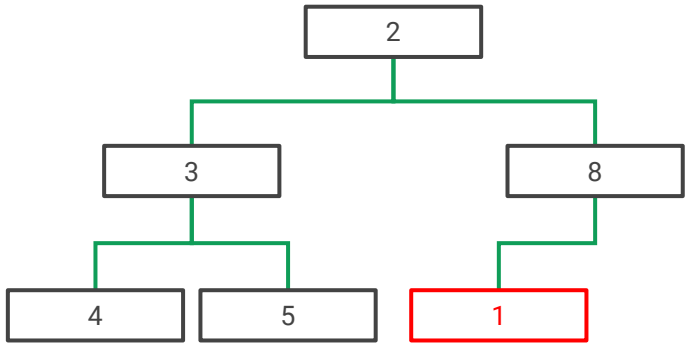
Usually stored in an array instead of as a tree

Written level by level (so that for a node at index n, its parent is at n/2 and its children are at 2n and 2n+1 if we one-index the array)



Inserting into a heap: bubble-up (inserting 1)

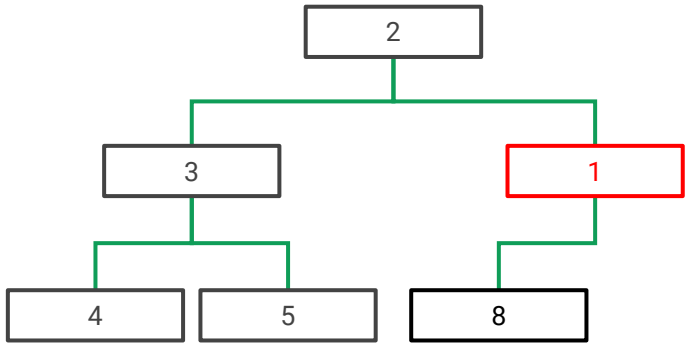
Add the element as a leaf node
to the heap



Inserting into a heap: bubble-up (inserting 1)

Add the element as a leaf node to the heap

If the element is less than its parent (if it’s a min-heap), swap it with it’s parent



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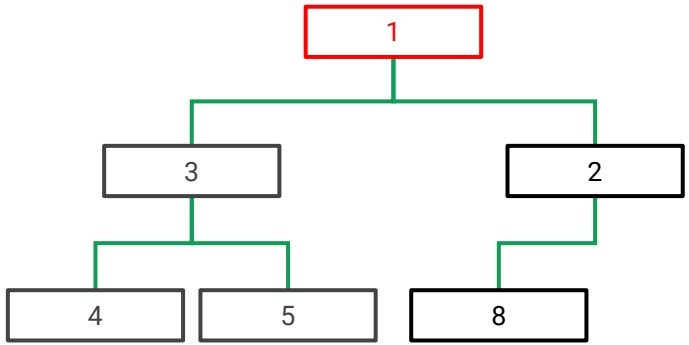

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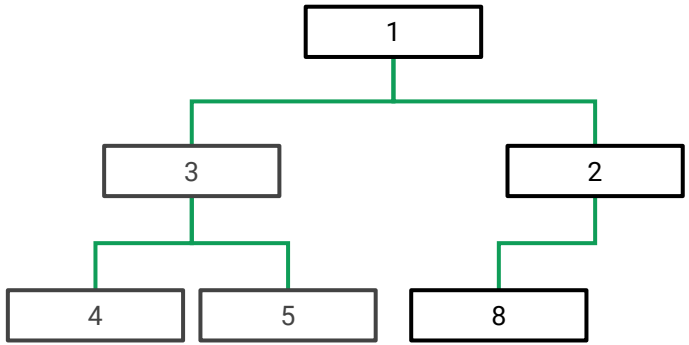
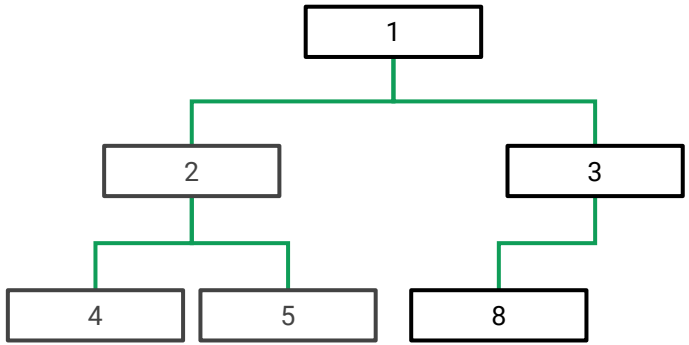


Deleting from the heap

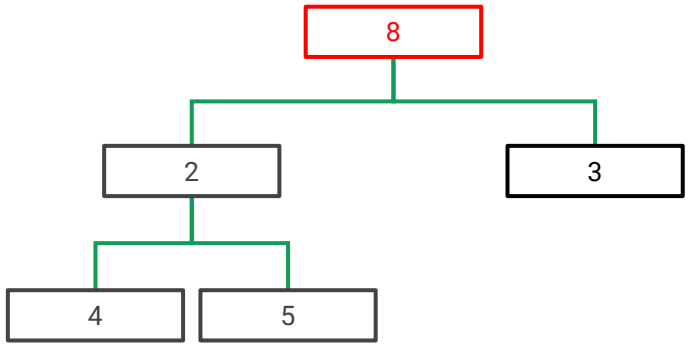
Remove the top element, and put the last leaf as the new root



Deleting from the heap

Remove the top element, and put the last leaf as the new root

While the node is larger than its children (min-heap), swap it with its **smaller** child



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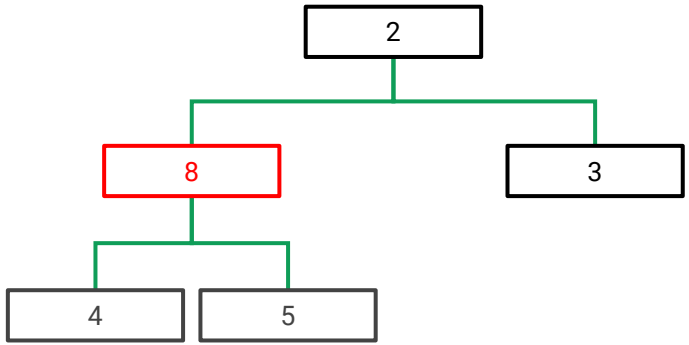

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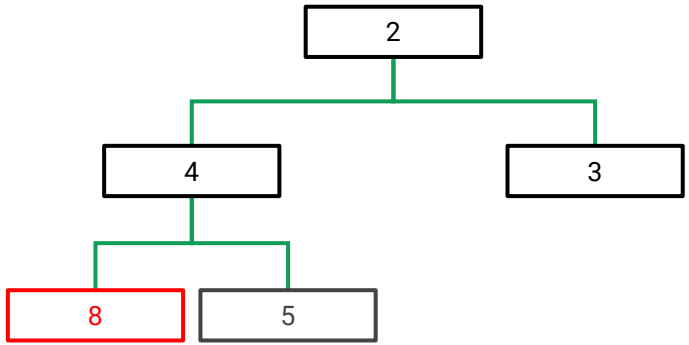

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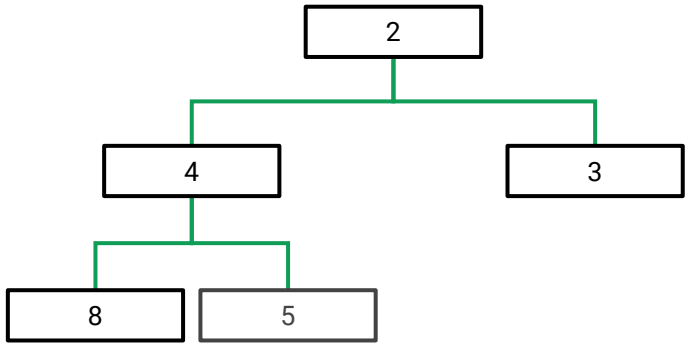

Binary Trees

Binary Trees

Binary trees always have two children, though other kinds of trees can have more (see: Trie)

Another way to think of trees: an acyclic graph

Trees - Traversals

General tree strategy: choose a traversal and implement the code that way

- Pre-order traversal: handle the root, then recurse to the two children
- In-order traversal: recurse to the left child, then handle the root, then recurse to the right child
- Post-order traversal: recurse to the children, then handle the root (e.g. deleting a tree)

Base case is usually that you've reached NULL

Trees - Is it a Heap?

Given a pointer to a tree, is the tree a valid min-heap?

Trees - Is it a Heap?

Given a pointer to a tree, is the tree a valid min-heap?

Recall: to be a min-heap, every parent must be smaller than both its children

Recall: every heap must be a **complete** binary tree

We can create two functions to check for these properties.

Trees - followsMinProperty

Want to determine whether each parent is larger than both its children

Let’s use preorder traversal (could write code with any traversal)

Trees - followsMinProperty

```
bool followsMinProperty(TreeNode *root) {
    if (root == NULL) {
        return true;
    }
    if (root->left != NULL && root->left->data < root->data) {
        return false;
    }
    if (root->right != NULL && root->right->data < root->data) {
        return false;
    }
    return followsMinProperty(root->left) && followsMinProperty(root->right);
}
```

Trees - isCompleteTree

We can use a modified version of height

Recall: height of a tree is the number of nodes from the root to the furthest away leaf

How could we created a modified definition of height to determine whether a tree is **complete** (fills each level of the tree from left to right completely before going to the next row)?

Trees - isCompleteTree

Idea: modified height is the number of nodes from the root to the **closest** leaf.

Idea: at each node, if the right subtree has height *h*, the left subtree can have either height *h* or *h + 1*

Trees - isCompleteTree

Idea: at each node, if the right subtree has modified height *h*, the left subtree can have either modified height *h* or *h + 1*

Need to keep track of a modified height parameter

Post-order traversal - only after finding the modified height of the left and right subtrees can we determine whether our current subtree is complete

Trees - isCompleteTree

```
bool isCompleteTree(TreeNode *head, int & minHeight, int & maxHeight) {
    if (head == NULL) {
        minHeight = 0;
        maxHeight = 0;
        return true;
    }
    int leftMinHeight, rightMinHeight, leftMaxHeight, rightMaxHeight;
    if (!isCompleteTree(head->left, leftMinHeight, leftMaxHeight) ||
        !isCompleteTree(head->right, rightMinHeight, rightMaxHeight)) {
        return false;
    }
    if (leftMinHeight < rightMaxHeight || leftMaxHeight > rightMinHeight + 1) {
        return false;
    }
    maxHeight = leftHeight + 1;
    minHeight = rightHeight + 1;
    return true;
}
```

Trees - isMinHeap

```
bool isMinHeap(TreeNode *root) {
   int modifiedHeight;
   return followsMinProperty(root) && isCompleteTree(root, modifiedHeight);
}
```